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Modeling Land Suitability Analysis to Livestock Grazing Planning Based on GIS Application

[1]*Fazel Amiri,* [2]*Abdul Rashid, Mohamed Shariff and* [3]*Amir Saadatfar*

[1]Department of Engineering, Islamic Azad University,
Bushehr Branch, Group of Natural Resources, Iran
[2]University Putra Malaysia, Institute of Advance Technology, Malaysia
[3]Department of Natural Resources,
Gorgan Agriculture and Natural Resource University, Gorgan, Iran

Abstract: The evaluation of rangelands means recognition and evaluation of the potential and actual production with the aim of effective exploitation of this natural valuable recourse. In this research study, the suitability model of common graze of sheep and goats on rangeland of Ghara-Aghch Watershed in the Isfahan province, through FAO [1] suggested method in geographic information system software, regarding the effective factors on suitability of common use was determined. In this research, the sampling in the region plant types (as the management units of the vegetation) was done randomly via application of three 200-meter transects and measuring the data on the vegetation percentile and the production of the vegetation in one-square-meter plots. Through the combination of three measures of the available forage, water recourses and the sensitivity of the soil to erosion, the final suitability model of the pasture regarding the livestock graze was determined. The results of final suitability model of the common graze revealed that no level was put in the S_1 suitability category (unlimited), 694.36 hectares (9.7%) in the S_2 suitability category (with minor limitation), 5439.35 hectares (75.9%) in the S_3 suitability category (major limitation) and 1025.81 hectares (14.3%) were placed in N suitability category (unsuitable). The most important reducing factors in the suitability model of the sensitivity of the soil to erosion were found to be: the land use and the vegetation cover and in the forage production suitability model were: the amount of the available forage in comparison with the total production and the existence of the less palatability plants among the pasture plants. In general, regarding the water resources, no serious difficulty was observed for the livestock's drink, only in some areas the far distance from the water resources and the precipitous slope caused the decrease or limitation in the graze suitability. Among the entire particulars of the studied lands, the specifications of the vegetation and the forage production were determined as the most significant factors in reducing the suitability of the rangeland for common graze of the sheep and goats.

Key words: Range suitability model · Common use · FAO · Livestock grazing · Geographic Information System (GIS)

INTRODUCTION

The assessment of rangelands is an activity that frequently challenges those involved in the livestock industry, in environmental protection and in land and rangelands management. The main objectives of an integrated land forage and livestock resources suitability assessments are to quantify the resource endowment, understand interrelationships between resource components, predict environmental impact, estimate livestock support capacity and to evaluate development options.

Geographic Information System field has experienced rapid growth in recent the years. GIS is a technology that applied on earth as the inverse problem. The GIS is a computer programme can be used to aid managerial,

Corresponding Author: Fazel Amiri, Institute of Advance Technology, Malaysia, P.O. Box: 43400 UPM Serdang, Selangor, Malaysia, Kuala Lumpur - Malaysia, E-mail: famiri@putra.upm.edu.my or amiri_fazel@yahoo.com.

policy and development decisions, primarily by modeling land and forage resources for their suitability analysis to livestock grazing planning, taking system complexity into account.

Definition of the term common use first was used in use of rangeland forage for grazing the livestock by Cook [2] and Smith [3]. They defined the term common use as the use of a pasture's forage for more than one variety of livestock (cattle, sheep, goats and wildlife) with the aim of reaching the maximum production. Ospina [4] alleged that common graze is very important in rangeland management and conservation of the rangelands. Holechck *et al.* [5] explained the rationales for improvement of the stability of the rangeland against the common use as follows: better distribution of the livestock in the pasture, harvesting more than one plant species and using pasture lands more uniform. Regarding the economy of the rangeland, the common use can be studied in two aspects: firstly, in common use due to increase in livestock products, the income will increase; secondly, the risk hazard will decrease; thirdly, the invading species will be controlled, on the other hand, in common use the preservation costs will increase and the rangeland management will become more difficult [6]. Heady [7] said that in common use, the efficiency of forage use will increase due to combined use of the grasses, forbs and shrubs. Cook [2] and Smith [3] explained that regarding the livestock grazing, topography, reaching the water resources and priority of management goals are among the effective factors in the success or failure of the management of common use in rangeland. Coffey [8] said that considering the preference of grazing the species by the livestock in common use is very important. The cattle preferred the grasses to the forbs and shrubs, while the sheep prefer the forbs to the grasses and the goats prefer the shrubs and small branches to the grasses and forbs. Therefore, the common graze of the cattle, sheep and the goats on the rangeland causes that all the vegetations be grazed and as a result the woody plants and the shrubs which form a large part of the rangeland, be grazed in a large quantity in the common graze. Luginbuhl [9] by adding goats to a pasture being grazed by the cattle showed that the goats by grazing the shrubs and decreasing them will provide the necessary time for growing the grasses. In fact, by adding the goats to the pasture grazed by the cattle without influencing the cattle's grazing preference, via controlling the woody plants, the grazing capacity will increase and in addition to the rise in income the rangeland are also rectified. Adding the sheep in a pasture which is being grazed by the cattle show the same result but differing in that the sheep in comparison with the goats consume fewer woody species; however, the sheep also, by controlling the woody species in a suitable grazing pressure will cause improvement of the rangeland. A few studies have been carried out in the field of presenting suitability model of the rangeland for livestock grazing [10-14]. No research has been carried out on common use of the sheep and goats. Therefore, the objectives of this study, while recognizing the most important factors affecting the suitability model for the common use of the rangeland, also determine the kind and rate of the limitations and the factors reducing the suitability with the aim of gaining an adequate plan for grazing.

MATERIAL AND METHODS

Study Area: The study area is located in the Ghara-Aghch catchments in the Isfahan province (10 kilometers northeast of Semirom), in the Central of Iran. The area under the study (51°, 34′, 54½ to 51°, 45′, 53½ E and 31°, 26′, 19½ to 31°, 03′, 28½ N) is a 8962.25-hectare plain % 79.9 of which are rangeland (Fig. 1).

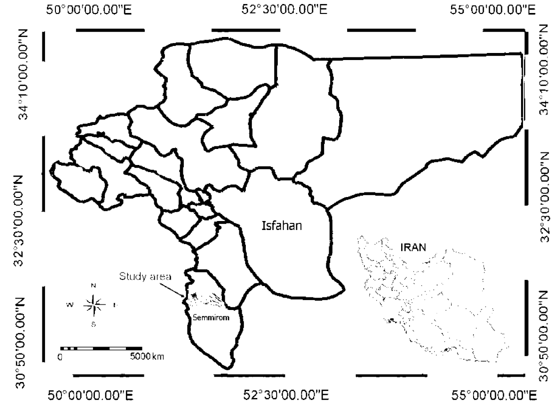

Fig. 1: Location of study area

The climate is semi-arid with an average annual rainfall of 358 mm yr $^{-1}$, falling mainly in the autumn and winter. The average minimum and maximum temperatures are 3.1°C and 16.7°C (Mean annual temperature is about 10 degrees Celsius) and the climate thereof based on the climate classification via the Dumbarton method is semi- arid. Sheep and goats were the two main sources of animal production. In Ghara-Aghch, the rangeland area is negatively affected by inappropriate land management practices, e.g. over utilization. Uncontrolled utilization of the vegetation of the rangelands affects on the forage quality because of the transition from a plant community with a higher nutritive value to one with lower nutritional value.

Vegetation Type: Site studying and data collection has been carried out during the spring until autumn of the 2010. Vegetation segments, pasture boundaries, agricultural lands, fruit gardens, urban settlements, bare soils, out cropped rocks and stony areas have been mapped with field studies using 1:50,000 scale map and aerial photographs [15, 16]. Preliminary vegetation types were distinguished with the physiognomic-floristic-ecologic method. Mean while with determination of the pasture type, its boundaries were checked on the map according to the vegetation entities features and dominant species [15]. In this study, a visual scoring method of the available dominant species to report the vegetation cover map, botanical composition and forage production in 17 vegetation types (Fig. 2; Table 1). Overstocking and extended grazing periods are current characteristics o f inappropriate management practices in the study area. In this study, 182 plant species in ten major vegetation types were identified in highland rangeland in Ghara-Aghch in negative and poor trend and condition.

The Factors of Common Use Model: The suitability model of common use is comprised of three measures of the capacity and production of forage, the soil sensitivity to erosion and physical factors (water resources and slope). The components of suitability model of common use have been illustrated in figure 3.

The method introduced by FAO [1] for the range suitability classification used ERDAS version 8.5 as GIS Software. Land evaluation normally requires a comparison between the inputs required and the outputs obtained when each relevant land utilization type is applied to each land unit.

Two orders of range suitability for livestock grazing were considered: suitable (S) and unsuitable (N). Three classes of suitability were determined including high suitable (S1), moderately suitable (S2) and marginally suitable (S3) [1].

The Soil Sensitivity to Erosion Criterion: The soil sensitivity to erosion model was determined by the Erosion Potential Model (EPM). This model is based on the evaluation of four factors of land use, slope, erosion potential, soil characteristics and geology, that depending on the strength and weakness of each factor. It is graded [17, 18]. The figure four shows the suggested factors in this model and the manner of the connection thereof [19]. For creating erosion sensitivity classes, the slope map and EPM model were used to calculate erosion potential. According to this model;

Table 1: Vegetation communities in Ghara-Aghch rangelands

Number		Vegetation type	Area (ha)
1	Ag.tr	Agropyron trichophoum	122.77
2	Ag.tr-As.pa	Agropyron trichophoum-Astragalus parroaianus	305.59
3	Ag.tr-As.ca-Da.mu	Agropyron trichophoum- Astragalus canesens- Daphne macronata	898.36
4	As.ad-Ag.tr-Da.mu	Astragalus adsendence-Agropyron trichophoum-Daphne macronata	385.59
5	As.pa-Ag.tr	Astragalus parroaianus-Agropyron trichophoum	162.77
6	As.ly-Ag.tr-Da.mu	Astragalus lycioides-Agropyron trichophoum-Daphne macronata	237.51
7	As.ca-Br.to-Co.cyl	Astragalus canesens-Bromus tomentellus-Cousinia cylianderica	2029.68
8	As.br-Br.to-Da.mu	Astragalus brachycalyx-Bromus tomentellus-Daphne macronata	116.2
9	As.go-Co.cyl	Astragalus gossipianus-Cousinia cylanderica	362.66
10	As.pa-Co.cyl-Da.mu	Astragalus parroaianus-Cousinia cylanderica-Daphne macronata	-
11	As.cy-Fe.ov	Astragalus cyclophylus-Ferula ovina	105.7
12	Br.to-As.pa	Bromus tomentellus-Astragalus parroaianus	373.11
13	Co.ba-As.go	Cousinia bachtiarica-Astragalus gossipianus	188.52
14	Co.ba-Sc.or	Cousinia bachtiarica-Scariola orientalis	499.07
15	Fe.ov-Br.to-As.za	Ferula ovina-Bromus tomentellus-Astragalus zagrosicus	212.33
16	Ho.vi-Po.bu	Hordeum bulbosum-Poa bulbosa	36.76
17	Br.to-Sc.or	Bromus tomentellus-Scariola orientalis	153.58
Total rangeland area			7158.81

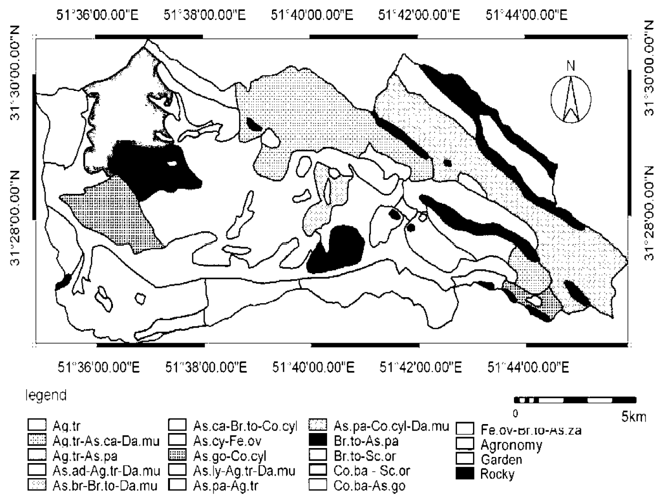

Fig. 2: Vegetation type (VT)

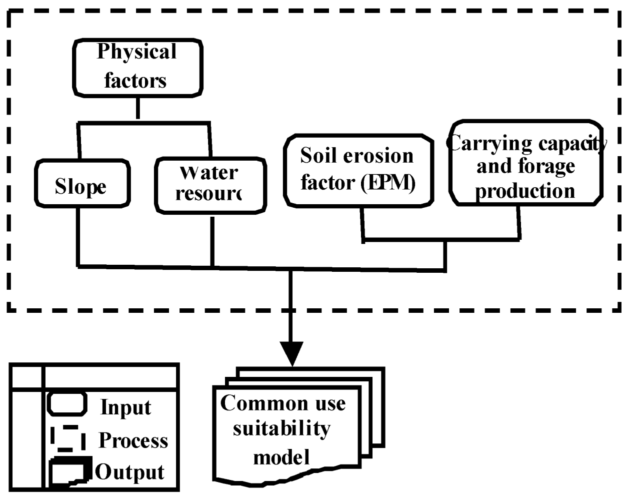

Fig. 3: The components of common use suitability model

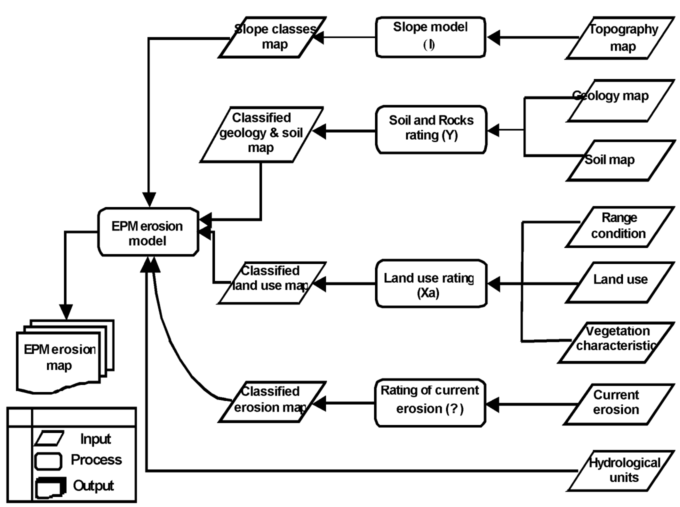

Fig. 4: EPM Model for Soil Erosion

$$Z = Y.Xa\,(\Psi + I^{0.5}) \quad (1)$$

Where; Z is the erosion severity index, Y is the sensitivity of soil and bedrock to erosion, Xa Is the land use index, Y is the erosion index of the watershed and I is the average gradient of the slope [19]. Soil depth, type, texture, gravels, structure, rocky outcrops and groundwater were the characteristics used to categorize each group (Fig.4). Sensitivity to the erosion sub-model for each vegetation type was created by integrating range condition, land use, slope, erosion potential, soil characteristics and geology. Sensitivity to erosion was then classified as shown in Table 2. The little erosion class was placed in suitability category S_1, low and medium erosion class in S_2 suitability category and high and very high erosion classes were placed in the suitability categories of S_3 and N respectively. Sensitivity to erosion was then classified as shown in Table 2.

The Capacity and Forage Production Factors: Regarding the data relevant to the conditions of livestock breeding, the percentile of herd combination in each Samman unit[1] was determined and for determining the common graze capacity [14] (Fig. 5), first the plan of the Samman unit was adopted with the vegetation's type of the region so that the percentile of the herd combination in the vegetation types located in the boundaries of each Samman unit must be determined. The vegetation's parameters in April-May and May-June 2009 and April-May and May-June 2010 were taken. In order to find out the grazing capacity and the suitability of the forage production in vegetation types, first the existing plant species in region vegetation types were listed and the percentage of canopy cover of each variety separately and based on the percentage from the total plot was sampled and the amount of production of the entire plant varieties edible for the sheep and goats separately via cut and weighing in each plot at the end of active growth period the varieties suitable for sheep and goats grazing [20] via random sampling in 10 vegetation types (determined via floristic-physiognomic method) in one-square-meter plots with three 200-meter transect in length [21]. Through field visit and interview with the experts of Natural Resources Institute (NRI) the palatability class of the species separately for sheep and goats were classified in one of the three palatability classes of (I, II and III) and the proper use factors (PUF) in vegetation types were determined based on the soil sensitivity to erosion suitability class adapted from the EPM model and regarding the range condition, range trend in vegetation types (Table 3).

Then the available forage of the existing varieties in the vegetation types for sheep and goats in common use was calculated from the product multiplying each variety available forage production in palatability or Proper Use Factor (PUF) (each one, which is lesser) and herd combination percentage (sheep and goats) and by adding up the available forage product of the all varieties of a type, the usable product in common use was concluded [3]. In figure 6 the components of the determination of capacity and suitability of forage production in common use is demonstrated. The diagram derived from the common grazing capacity model will be applied in the next stage as he inputs for the water resource's model.

Table 2: Classes of sensitivity to erosion [14]

Symbol	Range of Z	Classes	Suitability classes
1	< 0.2	Low	S1
2	0.2-0.7	Medium	S2
3	0.7-1	High	S3
4	>1	Very High	N

Table 3: Coefficient rates of palatability and proper use factor for calculation of available forage

Proper Use Factor (PUF)	Range trend (RT)	Range condition (RC)	Soil Erosion sensitivity (SE)
50	Up or Static	Good or Excellent	Low and Medium (S_1 or S_2)
40	Down	Good or Excellent	Low and Medium (S_1 or S_2)
40	Up or Static	Fair	Low (S_1)
35	Up or Static	Fair	Medium (S_2)
30	Down	Fair	Medium (S_2)
30	Up or Static	Fair	High (S_3)
25	Down	Fair	High (S_3)
30	Up or Static	Poor	Medium (S_2)
25	Down	Poor	Medium (S_2)
25	Up or Static	Poor	High (S_3)
20	Down	Poor	High (S_3)

*When the erosion suitability class is S_3 and the pasture is in a poor condition and the tendency is negative, the allowed exploitation limit for goats is considered zero and the production suitability class is considered N (not suitable)

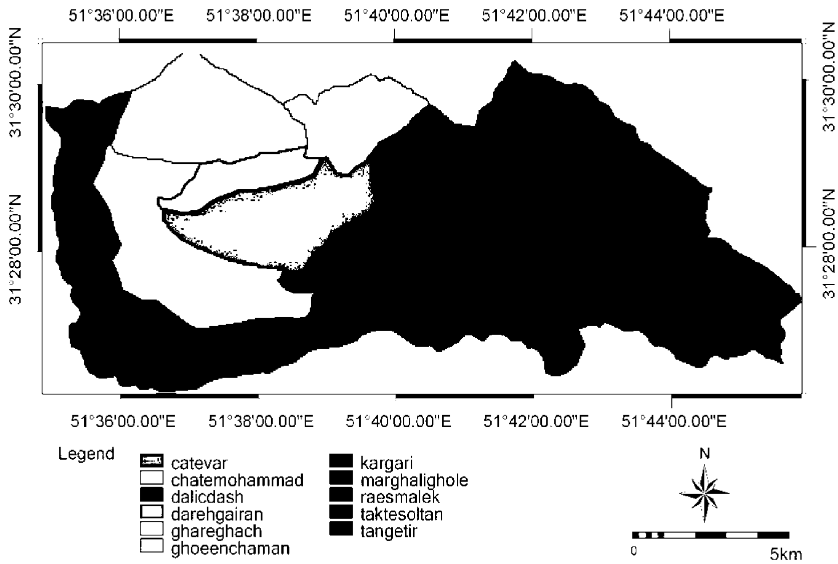

Fig. 5: Erosion class properties

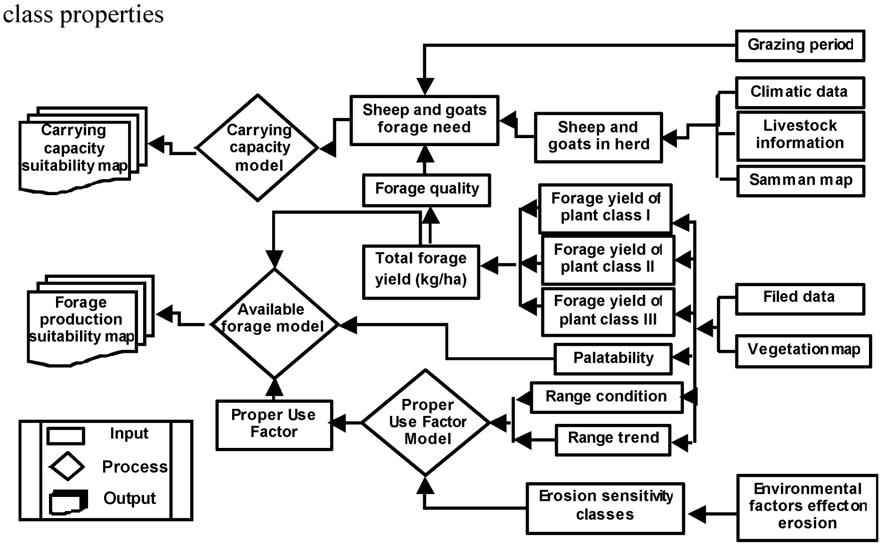

Fig. 6: The components of carrying capacity and suitability forage production in common use model

As you can see in the figure 6 the components of the common grazing capacity model are comprised of four sub-models as the amount of available forage for the sheep and goats, gazing period, forage need for common use and the area of the vegetation types (ha) and in order to create the available forage, relevant information based on equation 2 was integrated for each vegetation type:

$$DLNN = GP + T + FQ \qquad (2)$$

where DLNN = Daily Livestock Nutrition Need, GP = Grazing Period, T = Topography and FQ = Forage Quality [19].

The average daily requirement of a 50 kg sheep and 37 kg goats consuming quality forage was determined as 1.35 kg dry matter. Available forage (AF, kg/day) for livestock was calculated as:

$$AF = \Sigma(Y + (P/PUF)) \qquad (3)$$

Where; Y= yield (kg/ha), P = palatability and PUF = proper use factor [22]. PUF was determined by combining information on range condition trend and erosion sensitivity [23].

The common grazing capacity model are comprised of four sub-models as the amount of available forage for the sheep and goats, gazing period, forage need for sheep and goats and the area of the vegetation types and will be calculated based on the formula 4 [22].

$$GC = \frac{AF}{\text{DLNN}} \tag{4}$$

At this formula; GC for grazing capacity, AF for available forage (Kg/ha) at the area of the type (ha) and DLNN for Daily Livestock Nutrition Need [50]. To determine the number of goats, the Animal Unit (A.U) for the goats was divided to 0.8 (since each goat in the study area is 0.8 Animal Unit). Furthermore, to find out the forage production suitability class, the ratio of the available forage production to the total products of that type based on the Table 4.

Physical Factors: The suitability class of this model was determined via the combination of two measures of slope and water resources.

Slope: To determine the slope suitability categories in the common use of slope suitability classes Table 5 was used.

Water Resources: The suitability categories of this model were determined via the combination of three sub-models of quality, quantity and distance from water sources (Fig.7). To determine the distance from water sources suitability classes in common use, the suitability categories illustrated in Table 6 were applied.

Khan and Ghosh [25] in a research study compared the goat's and sheep's tolerance to saltiness under difficult environmental conditions in the Rajasthan deserts and explained that the tolerance of the goats is more than the sheep's. The water suitability precincts of the region were classified based on the Total Dissoluble Salts in water (TDS) as per the Table 7.

The Quantity of the Water Sources: Many factors affect the amount of water used by the livestock among which are the kind of the livestock, the livestock's age and breed, the region topography, the available forage and the quality of the forage, the grazing season, the quantity, quality and the distance from the water resources. King [26] developed formula 5 for the amount of needed water for African goats with average weight of 37 kilograms:

$$a\ \text{l/kg}^{0.82}\text{/day} = ?\ \text{lit /day} \tag{5}$$

In this formula (a) is the coefficient which will be calculated via local investigations. The (?) is the amount of needed water for the livestock and (kg) is the alive weight of the livestock on the kilogram basis. Ferreira *et al.* [28] calculated the amount of the needed water for the sheep of Merino breed with the average weight of 50 kilograms via the formula (6):

$$37\ \text{ml/kg}^{0.82} \tag{6}$$

Therefore, in the study area and regarding the total factors involved in the calculation of the needed water in each Samman unit in addition to asking the local pastoral-farmers also regarding the formulas 5 and 6, the water need for a mature sheep (Ghashghaei Turkish breed) was calculated five liters per day and for a mature goats (Ghashghaei Turkish breed) four liters per day [14].

In order to determine the quantity of the water resources, the grazing capacity map of each vegetation type was overlaid with the map of the Samman unit afterwards via weight averaging based on the area of each Samman unit, the number of permitted livestock

Table 4: Suitability forage production classes

Production classes	*Available forage production (AF)	State
S_1	40% (of total production)	1
S_2	30-40% (of total production)	2
S_3	20-30% (of total production)	3
N	< 20% (of total production)	4

* Minimum production lower then 100 (kg/h)

Table 5: Suitability slope classes [24]

60<	30-60	10-30	0-10	Slope (%)
N	S_3	S_2	S_1	Suitability classes

Table 6: Water resource distance (meter) and its suitability classes

	Slope class (%)			
Suitability 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 7: Water quality for sheep, goats and its suitable classes [26].

Total Dissolved Salts (TDS; ppm)				
N	S_3	S_2	S_1	Suitability class
>10000	6000-10000	3000-6000	<3000	Sheep
>10000	7000-10000	5000-7000	<3000	goats

Table 8: Suitability water resource quantity classes

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

(sheep and goats) was calculated in each Samman unit. Then the suitability categories were determined via comparison of the available water in each Samman unit with the water need of livestock of each Samman unit according to Table 8.

RESULTS

The Sensitivity to Erosion Model: The soil sensitivity to erosion model in vegetation types shows that 3.5% of the region rangeland surface (254.25 hectares) were classified in the erosion class (II) low sedimentation intensity, 64% (4585.98 hectares) (III) medium sedimentation intensity and 32.4% (2318.95 hectares) were classified in erosion class (IV) high sedimentation intensity. Furthermore, the results of suitability categories of the soil sensitivity to erosion revealed that 4585.98 hectares (64%) of the rangeland surface were classified in the S_2 suitability category and 2572.84 hectares (36%) were placed in S_3 suitability category. The map of suitability categories of EPM model are shown in Figure 8.

The Forage Production and Common Grazing Capacity: The results of the suitability model of forage production in vegetation types of the study area under investigation are illustrated in Table 9. According to the forage production model, none of the vegetation types fall into the S_1 suitability category. About 1352.46 hectares equaling 18.89% of the rangeland fell into the S_2 suitability category, around 4837.74 hectares equaling 67.57% of the rangeland fell into the S_3 suitability category regarding the forage production and finally 968.61 hectares equaling 10.8% of the area of the region rangeland fell into the N suitability category regarding the forage production (Figure 9). The results of the common grazing capacity in the study area are shown in the Table 10.

The Suitability Model of the Water Resources Quality: The water resources quality sub-model will be settled on via examination of effective factors on the water quality and the comparison thereof with the specific standards. Based on the water resources quality sub-model and considering the water quality, there is no limitation in the region in question and the whole region fell into the S_1 suitability category (Table 11).

The Suitability Model of the Water Resources Quantity: The results achieved from the water resource's quantity sub-model are illustrated in Table 12. Based on the water resources quantity suitability sub-model, it was revealed that there is no limitation considering the water amount in the Samman uint region in question and all fell into the S_1 suitability category regarding the water resource's quantity suitability.

Distance from Water Resources Suitability: Based on the distance from water resources suitability sub-model, 6385.17 hectares of the rangeland area (89.2%) fell into the

S_1 suitability category, 530.04 hectares (7.4%) of the rangeland of the region in question fell into the S_2 suitability category and only 243.6 hectares (3.4%) of the region rangeland fell into the unsuitability (N) categories; in addition, no area of the rangeland area fell into the S_3 suitability category. The outcomes of the final model of the water resources are demonstrated in the Table 13. The region in question has no problem regarding the quantity and quality of the water resources; it is only the distance from the resources that mainly determines the suitability of the rangeland, regarding the water resources.

Final Common Grazing Use: The outcome of the final suitability model of the common grazing, which is derived from the combination of three suitability sub-models of the soil sensitivity to erosion, forage production suitability and the suitability of the water resources, is demonstrated in Table 14.

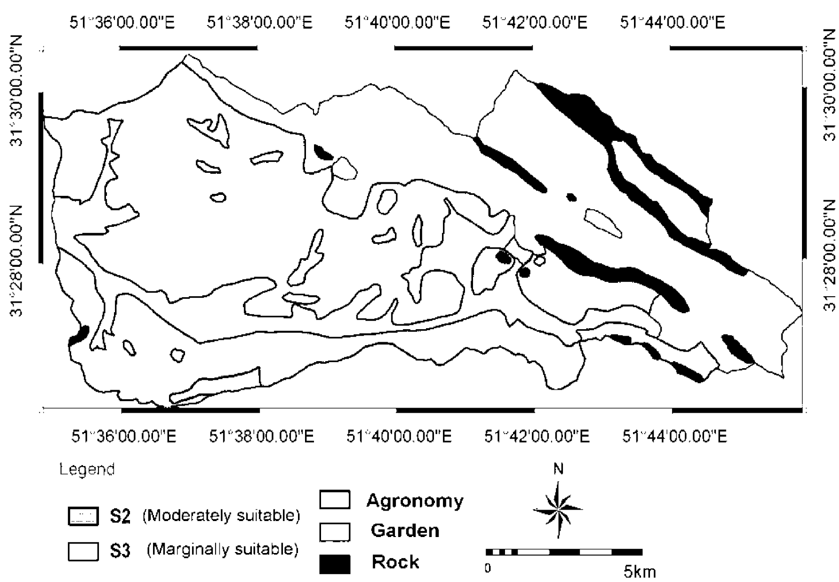

Fig. 8: Erosion class properties in study area

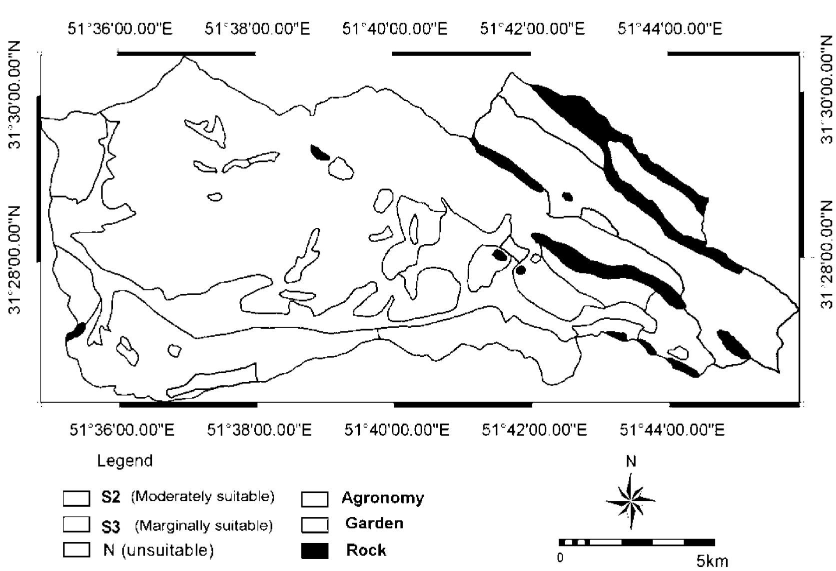

Fig. 9: Suitability map of forage production of study area

Table 9: Suitability based on forage production and available forage of vegetation type in Ghareh Aghach

Number	Vegetation type	Available forage based on herd composition (kg/h) Sheep	Goats	Ratio of available forage to total production	Forage suitability classes
1	Ag.tr	88.9	31.8	31.7	S_2
2	Ag.tr-As.pa	60.7	34.3	27.6	S_3
3	Ag.tr-As.ca-Da.mu	66.6	23	27.7	S_3
4	As.ad-Ag.tr-Da.mu	66.7	24.2	30.8	S_2
5	As.pa-Ag.tr	58.2	22.4	25.8	S_3
6	As.ly-Ag.tr-Da.mu	60	20.8	28.2	S_3
7	As.ca-Br.to-Co.cyl	42.1	16.8	25.1	S_3
8	As.br-Br.to-Da.mu	67.8	23.2	32.3	S_2
9	As.go-Co.cyl	35.2	24.2	23.1	S_3
10	As.pa-Co.cyl-Da.mu [1]	-	-	-	N
11	As.cy-Fe.ov	56.1	31.2	30.01	S_2
12	Br.to-As.pa	58.5	19.8	30.2	S_2
13	Co.ba-As.go	44.2	23.8	27.5	S_3
14	Co.ba-Sc.or	33.9	19.5	23.3	S_3
15	Fe.ov-Br.to-As.za	81.3	30.2	33.4	S_2
16	Ho.vi-Po.bu	152	53.8	31.8	S_2
17	Br.to-Sc.or	53.6	29.8	28.4	S_3

[1]Since this type is classified in the S_3 erosion suitability class and has a poor condition and downward trend is not suitable for common grazing.

Table 10: The common grazing capacity of vegetation type

Number	Vegetation type	Available forage (kg/h) Sheep	Goats	Area (h)	Daily forage need (kg) Sheep	Goats	Common Gazing period (day)	Common use grazing capacity (on AUM)	(number of head) Sheep	Goats
1	Ag.tr	88.9	31.8	122.77	1.36	1.165	120	95	67	35
2	Ag.tr-As.pa	60.7	34.3	305.59	1.38	1.179	120	186	112	93
3	Ag.tr-As.ca-Da.mu	66.6	23	898.36	1.4	1.19	120	500	356	180
4	As.ad-Ag.tr-Da.mu	66.7	24.2	385.59	1.41	1.2	120	217	152	81
5	As.pa-Ag.tr	58.2	22.4	162.77	1.44	1.234	120	79	55	30
6	As.ly-Ag.tr-Da.mu	60	20.8	237.51	1.4	1.194	120	119	85	42
7	As.ca-Br.to-Co.cyl	42.1	16.8	2029.68	1.49	1.272	120	700	477	279
8	As.br-Br.to-Da.mu	67.8	23.2	116.2	1.42	1.217	120	64	46	23
9	As.go-Co.cyl	35.2	24.2	362.66	1.54	1.315	120	125	69	70
10	[1]As.pa-Co.cyl-Da.mu	-	-	-	-	-	120	-	-	-
11	As.cy-Fe.ov	56.1	31.2	105.7	1.43	1.222	120	57	34	29
12	Br.to-As.pa	58.5	19.8	373.11	1.55	1.322	120	158	113	56
13	Co.ba-As.go	44.2	23.8	188.52	1.52	1.3	120	75	46	36
14	Co.ba-Sc.or	33.9	19.5	499.07	1.63	1.397	120	145	87	73
15	Fe.ov-Br.to-As.za	81.3	30.2	212.33	1.37	1.168	120	151	105	57
16	Ho.vi-Po.bu	152	53.8	36.76	1.52	1.3	120	44	31	16
17	Br.to-Sc.or	53.6	29.8	153.58	1.39	1.19	120	82	50	40

[1]This type is not suitable for common graze.

[2] The weight of the sheep (a livestock unit) is 50 kilograms and the average weight of the goat is 37 kilograms, 50/37 = 0.8 as a result the ratio of each sheep to goat in the region is 0.8.

Table 11: Water resources quality and quantity

	Water		Water yeild (lit/s)							The results of water quality								Suitability cass of
No	code	Samman name	Q Min	Q Max	Q Men	pH	$\frac{Ec / 25^{\circ}C \; \text{min mihos}}{\text{Cm}}$	T.D.S mgL^{-1}	% Na	Cl^{-} meL^{-1}	CO_3^{2-} meL^{-1}	HCO_3^{3} meL^{-1}	SO_4^{2} meL^{-1}	Ca^{2+} meL^{-1}	Mg^{2+} meL^{-1}	K^{+} meL^{-1}	S.A.R	water quality
1	A	Takhte soltan	3.48	4.1	3.79	7.8	315	203	3.00	3.51	0.00	193.5	5.25	62.25	2.59	0.38	0.07	S1
2	B	Tange tir	5.8	13.38	9.59	7.2	366	238	2.00	3.54	0.00	244.04	0.48	70.14	6.08	0.39	0.07	S1
3	C	Tange tir	0.35	1.8	1.08	7.2	366	238	2.00	3.54	0.00	244.04	0.48	70.14	6.08	0.39	0.07	S1
4	D	Tange tir	0.18	1.41	0.79	7.2	366	238	2.00	3.54	0.00	244.04	0.48	70.14	6.08	0.39	0.07	S1
5	E	Reismelek	0.2	0.35	0.27	7.8	230	150	12.00	3.54	0.00	134.22	10.08	34.06	6.08	0.39	0.28	S1
6	F	Takhte soltan	0.1	3.54	1.82	7.8	314	204	3.00	3.54	0.00	195.23	5.28	62.12	2.43	0.39	0.07	S1
7	G	Chat mohammad	0.32	1.1	0.71	7.6	387	252	6.9	7.09	0.00	189.12	43.6	54.2	14.6	0.39	0.21	S1
8	H	Chat mohammad	0.7	1.2	0.95	7.6	387	252	6.9	7.09	0.00	189.12	43.6	54.2	14.6	0.39	0.21	S1
9	I	Ghoen chaman	0.94	1.31	1.12	7.3	388	252	7.00	7.09	0.00	189.12	43.7	54.1	14.59	0.39	0.21	S1
10	J	ketivar	0.15	1.3	0.72	7.9	374	343	4.9	7.08	0.00	225.6	10.0	60.12	10.94	4.6	0.39	S1
11	K	ketivar	0.5	1.5	0.71	374	343	4.9	7.08	0.00	0.00	225.6	10.0	60.12	10.94	4.6	0.39	S1
12	L	Reis malek	0.52	1.2	0.86	7.8	230	150	12.00	3.54	0.00	134.21	10.0	34.0	6.02	0.38	0.28	S1
13	M	ketivar	0.65	1.12	0.88	7.9	373	343	4.9	7.08	0.00	225.7	10.08	60.12	10.94	4.6	0.39	S_1
14	N	Takhte soltan	0.12	0.65	0.38	7.8	313	204	2.9	3.51	0.00	194.8	5.35	61.8	2.52	0.37	0.08	S_1
15	O	Delig dash	0.94	1.12	1.03	7.3	387	353	7.00	7.0	0.00	188.9	43.5	54.3	14.7	0.36	0.22	S_1
16	P	Ghoyein chaman	0.2	0.35	0.27	7.26	386	251	7.01	7.03	0.00	189.12	43.2	53.8	14.49	0.33	0.2	S_1
17	Q	Ghoyein chaman	1.0	1.3	1.15	7.31	387	253	7.00	7.00	0.00	188.9	43.5	54.3	14.7	0.36	0.22	S_1
18	R	Mergh aligholi	0.3	1.5	0.75	7.8	315	204	3.00	3.54	0.00	195.2	5.28	62.12	3.43	0.39	0.21	S_1
19	S	Mergh aligholi	0.86	2.2	1.53	7.8	315	204	3.00	3.54	0.00	195.2	5.28	62.12	3.43	0.39	0.21	S_1
20	T	Ghoyein chaman	0.6	2.4	1.5	7.2	386	251	7.01	7.03	0.00	189.12	43.2	53.8	14.49	0.33	0.22	S_1
21	U	Ghoyein chaman	0.18	1.4	0.79	7.2	386	251	7.01	7.03	0.00	189.12	43.2	53.8	14.49	0.33	0.22	S_1
22	V	Ghare aghach	0.12	0.68	0.4	8.00	374	343	5.00	7.09	0.00	225.7	10.08	60.12	10.94	4.6	0.39	S_1
23	W	Khar gari	0.14	0.91	0.52	7.3	387	353	7.00	7.00	0.00	188.9	43.5	54.3	14.7	0.36	0.22	S_1
24	X	Dareh jeiran	0.11	0.85	0.48	7.9	373	343	4.9	7.08	0.00	225.7	10.08	60.12	10.94	4.6	0.39	S_1

Table 12: Quantity suitability of water resource based on water content and carrying capacity in each Samman unit

Samman unit	Water content (lit/day)	Carrying capacity in each Samman unit (A head of livestock in 120 day)		Water need (lit/day)		Suitability classes of water quantity	
		Sheep	Goats	Sheep	Goats	Sheep	Goats
Catevar	224640	389	122	1945	488	S_1	S_1
Chatemohammad	143424	328	166	1640	664	S_1	S_1
Dalicdash	88992	99	55	495	220	S_1	S_1
Darehgairan	41472	249	143	1245	572	S_1	S_1
Ghare-aghach	34560	125	84	625	336	S_1	S_1
Ghoeenchaman	417312	107	81	535	324	S_1	S_1
Kargari	44927	27	24	135	96	S_1	S_1
Marghalighole	196992	326	192	1630	768	S_1	S_1
Raesmalek	97632	258	152	1290	608	S_1	S_1
Taktesoltan	517536	91	50	455	200	S_1	S_1
Tangetir	990144	166	94	830	376	S_1	S_1
Total	2797632	2165	1163	10825	4652	S_1	S_1

Table 13: Water resources model-based categorization of land area (ha; %) into suitability classes

Suitability classes	Common use Area (ha)
S_1	6,385.17 (89.2%)
S_2	530.04 (7.4%)
S_3	-
N	243.6 (3.4%)
Total land area in study	7,159 ha

Table 14: Model-based categorization of land area (ha; %) into suitability classes

Sub-model	S1	S2	S3	N
Erosion	0	4,078 (57.0%)	386 (5.4%)	2,696 (37.6%)
Water Resources	0	4,519 (77.1%)	859 (12.0%)	478 (6.7%)
Forage production	0	979 (13.7%)	5,211 (72.8%)	969 (13.5%)
Integrated model	0	1,126 (15.7%)	4,918 (68.7%)	1,116 (15.6%)
Total land area in study = 7,159 ha				

DISCUSSION

Although Iran is the second largest country in the Middle East, it has limited rangelands such as fertile soil and water, resulting in limited opportunities to expand and/or intensify arable farming [29]. Extensive animal husbandry, on the other hand, including nomadic, transhumant and sedentary forms, is widespread over the rangelands of the country. Rangelands and animal husbandry have been important in Iran for a very long time, as witnessed by the teachings of Zoroaster [30, 31]. The degree of importance attached to a specific rangeland area reflects its productivity, land scarcity and the availability of alternative sources of income. In Iran, as in other parts of the world, animal husbandry is the most productive use of the semi-arid zones bordering the desert [32, 33]. As Niknam and Kyne [34] have calculated, 80 to 90% of the livestock production of Iran, equal to 168,000 to 180,000 ton y^{-1} of meat [36], is associated with the rangelands. Annual dry matter production of rangelands is estimated at more than ten million tons per hectare. In addition to forage production, mining, fuel wood collection, industrial use of rangeland by-production, e.g. medicinal plants and recreation are other rural enterprises in the rangelands of Iran [36].

Many of the researchers explained in their studies that the common use, via increasing the grazing evenness [37], will in the long term cause to increase the grazing capacity and livestock productions [38-40], as well as increasing the plant diversity and income of the livestock-farmers; also in common use via eating the poisonous and invade plants by the livestock, which are not sensitive to these species, the rangeland will improve and the livestock productions will increase. For example, the leaves of the plants Spurge and Larkspur are poisonous for the cattle but safe for the sheep. Therefore, the sheep grazing will protect the cattle on the rangeland [41]. In the common use model adapted for the study no area fell into the S_1 suitability category (limitless) and the main part of the rangeland area (75.9%) fell into S_3 suitability category (with high limitation). Among the entire particulars of lands surveyed, the particulars related to the vegetation and forage production were the most significant factors in decreasing the region's rangeland common use suitability.

In adapting the grazing suitability model for the rangeland we shall consider that in each region regarding the climatic condition, vegetation, soil, the status of the current utilization and topography, the factors effective in the suitability will be different. Therefore, recognizing the factors effective in the model and determining the amount of limitations they impose, are among the major factors in analyzing and assessing the rangeland. In the studies carried out for determining the rangeland suitability for the sheep grazing by Arzani *et al.* [11] and Amiri [13, 14] three measures of forage production, water resources and the soil sensitivity to the erosion comprised the components of the livestock grazing model. Consequently, in this model via application of the FAO method [1] the said three measures were employed to determine the rangeland final grazing suitability model as well.

The Soil Sensitivity O the Erosion Model: The most important erosion reducing factors in the study area are the land and vegetations use. The results obtained from this study on the factors affecting the erosion are in compliance with many other studies carried out in this regard. In a way that, the factors of land use, surface cover, run off and the current erosions on the region area are among the most important factors influencing the erosion of the Ghara Aghach region. Hedayatizadeh *et al.* [42] stated that the most important factors in increasing the erosion are the soil sensitive to the erosion, the high speed and long duration of the wind blowing, unsuitable vegetation cover and the low rate of moisture on the soil surface and the lack of a proper management in land use. Bani Neameh *et al.* [24] mentioned the unsuitable land use (plowing the rangeland and changing them into the farmlands) as the main factor in reducing the suitability of the rangeland of Roozeh Chay in Uromieh. The negative effects of the over grazing and early grazing on the reduction of infiltration and increasing the run off (and consequently, the increase of the erosion) are clearly specified.

Water Resources Model: In the study area regarding the climatic condition, quantity (the number of the permanent water resources), quality and the distance from the water resources, the water resource's factor did not impose such a considerable limitation on the region's rangeland suitability for grazing the livestock. However, the high slope of the livestock path to the water resources has caused the formation of the unsuitability category for the livestock. Valentine [43] on importance of the slope factor in reaching the water resources declared that by increasing the slope the livestock ability to graze decreases and using the livestock demands to expend lots of energy. On the cases of steep slops it recommended not to use them for grazing, instead they must be applied for other purposes (such as wild life and tourism). The quality and quantity of the water resources in the region did not impose any limitations. This study declared that the slope factor in the rangeland of Semirom region is the major factor in decreasing and limiting the rangeland suitability regarding the distance from the water resources. The outcome of the researches stated the slope as the reducing and sometimes limiting factor in the range suitability. As a result the slope factor considerable importance in determining the suitability of the pasture for grazing. As the slope rises the time in which the water stands on ground decreases and the rate penetration decreases and the amount of the running water increases. On the other hand, the possibility of placing the mature soils on the steep slopes reduces. The grazing on thee steep slopes will cause the movement of the soil and consequently, will make difficult for plants to remain stable. Furthermore, the livestock will spend lots of energy to walk on the steep slopes (for grazing and reaching the water sources) as a result their function will decrease. Cook [2] explained that on the slopes more than 60 degrees the forage is grazed at little. Kekem [44] defined the slopes with more than 50 percents as the useless for all kinds of the livestock, also Holechek *et al.* [45] the slopes with more than 60 percents and Zhou [46] defined the slopes with more than 75 percents as useless for livestock grazing and pointed out that on the steep slopes the wild animals would graze better than the livestock.

Forage Production Model: The major factor in reducing the suitability of the rangeland of the study area, regarding the forage production was the lowness of the proper use exploitation limit and secondly, the existence of the plants in the II and III classes of suitable for livestock grazing in the forage combination and the decrease of the available forage for the livestock. It must be noted that the factors which will cause the reduction of the proper use factor exploitation limit in the region, they themselves are deemed as the reducing factors of the suitability of the rangeland. The effects of the previous use (changing the rangeland into farmlands and leaving them, over grazing) the low vegetation cover, the existence of the plant in the low palatability class among in the vegetation (perennial forbs and annual grasses) are among the factors in reducing the suitability of the forage production in the study rangeland. Plowing the rangeland with the aim developing the un-irrigated cultivation in the regions, which the annual raining rate allows the rain-watered cultivation, is one of the factors in destruction of the rangeland. This rangeland while having deep and good soil are among the best rangeland in the country [47]. The climatic condition of the study area facilitates the un-irrigated cultivation. In the past, wherever the soil depth and the slope degree were not the limiting factors. The region's rangeland has been plowed and cultivated. During the early years of leaving the un-irrigated- farms, the invader plants (most of the annual grasses and forbs) have grown in the region. The annual forbs and grasses to make a temporary vegetative ground cover (during the growth period), therefore in most of the year the ground has no vegetative cover and is defend-less against the erosion. This study showed that the changing the rangeland to rain-watered farms and leaving them over after a while, over grazing, early grazing, low vegetations cover and presence of fewer palatable species as the most important factors in reducing the suitability of the forage production in the study Rangeland. Hedayatizadeh *et al.* [42] stated that low vegetative cover is among the most important factors in reducing the production suitability in the region under investigation.

Regarding the results of the final range suitability model, it was revealed that the most important factors in reducing the rangeland suitability of study area is the low amount of the available forage in comparison to the total forage production. It must be noted that other factors in reducing the suitability of the region's rangeland such as low vegetations cover, lack of proper vegetative ground cover to protect the surface soil, presence of surface run off, slope, the sensitivity of the stone and soil to an erosion, climatic condition, plant combination, the condition and trend of the vegetation types, over grazing and finally, some invasions to the rangeland areas and malfunction, in some way altogether determine the suitability of the region's rangeland. Furthermore, the slope factor in limiting the grazing is the steep slope of the region (more than 60 degree).

Farahpour and Van Köln [10] in on the survey on the effects of the grazing on the suitability of the rangeland of Shadegan in Esfahan, mentioned the early and over grazing as the main cause of the reduction of the suitability of the rangeland, but in the Ghara Aghach district due to the limitations that the Institute of the Natural Resources (I.N.R.) of Esfahan Province and Semirom City impose on the early grazing, the early grazing is not the suitability limiting factor in the region's rangeland. Kiet [48] on determining the suitability of a region in Australia considered two factors of the slope and water resources as the suitability limiting factors of this rangeland for grazing the cattle. Whereas due to the existence of numerous permanent water resources in the Ghara Aghach rangeland, the water resources factor does not impose much limitation on the suitability of the rangeland of the region; only the slope factor in reaching the water resources just in a limited area of the region's rangeland is the suitability limiting factor. Fitomokiza [49] on determining the suitability of the rangeland of the Gaza Province in Mozambique for grazing the cattle, regarding such parameters as raining and growing season, soil characteristics, vegetative cover, the needed and available forage, reaching the water resources and slope, expressed the major suitability limiting factors in the region's rangeland as: firstly, the lack of accessibility to the water resources; then, low palatability of the plant species and low production of the forage and slope. It must be noted that the results of the Kiet studies [48] and Fitomokiza's [49] are in compliance with that of ours. Arzani *et al.* [11] research which was carried out on sheep grazing in four regions of Siahrood and Lar in the Alborz mountain range, Ardsetan in central area and Dasht-e Bakan in Zagros region, revealed that in Siahrood region, the variety of the poisonous plants, steep slope, temporary water resource and the components sensitive to the erosion were the factors limiting the suitability. The factors limiting the suitability of the rangeland in Lar Region in order of their importance are: the steep slope, the sensitivity of the stone and soil to the erosion and the manner of exploiting the lands; among the factors limiting the suitability of the rangeland in Ardedstan region are: low productivity, the existence of the invading plants, far distance from the water resources, the manner of exploiting the lands and the current erosions; in Dasht-e Bakan, the slope, distribution of the water resources and lack of permanent water resources were the factors limiting the suitability of the rangeland for grazing the sheep.

The outcome of this research study showed that due to low productivity of palatable forage as a result of constant utilization of the rangeland in the semi-arid regions also the shortage or lack of palatable plants in one hand and the existence of numerous un palatable and thorny plants in the vegetation composition, on the other hand, the effective grazing the livestock in the rangeland will be limited.

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