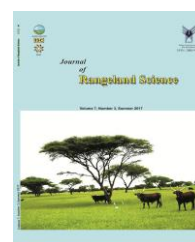


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**Research and Full Length Article:**

## **Determining Range Suitability Using Fuzzy and Hierarchical Method (Case Study: Bagheran Birjand Watershed, South Khorasan Province, Iran)**

Einollah Rouhi-Moghaddam<sup>A\*</sup>, Halimeh Joloro<sup>B</sup>, Hadi Memarian<sup>C</sup>

<sup>A</sup>Associate Professor, Faculty of Water and Soil, University of Zabol, Zabol, Iran, \*(Corresponding Author),  
Email: erouhimm@uoz.ac.ir

<sup>B</sup>Former M.Sc. Student of Range Management, University of Zabol, Zabol, Iran

<sup>C</sup>Assistant Professor, Faculty of Natural Resources, University of Birjand, Birjand, Iran

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**Abstract.** Evaluating rangelands means to identify and create potential and actual rangelands in order to utilize this valuable natural resource properly. Hence, one of the important factors in rangeland management is to determine range suitability and recognize factors affecting it. Weighted Linear Combination Method (WLC) is one of the most common methods used for locating and Analytic Hierarchy Process (AHP) method is one of the most used methods of criteria prioritization and weighting. The purpose of this study was to evaluate range suitability of Bagheran Birjand watershed area in Southern Khorasan Province, Iran using AHP-Fuzzy method in a region with an area of 11879 ha in 2014. For this propose, in the environment of Geographical Information System (GIS), the maps of factors affecting the suitability (slope, production, erosion, quality of water resources, water need estimation percent and distance from water sources) were prepared. Data were standardized using fuzzy method and for weighting the criteria, the Analytic Hierarchy Process method was used. The results of AHP-Fuzzy model based on the weighted linear combination showed that 55.43% of rangelands were in suitability class of moderate suitability (S2), 9.55% of the lands were in suitability class of low suitability (S3) 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.

**Key words:** Range suitability, Weighted linear combination method, AHP and fuzzy method, Bagheran Birjand watershed

## Introduction

Range ecosystems are considered as one of the most complex ecosystems and precise relationships are found between the components. This requires that available range resources in each region should be evaluated properly for a variety of utilizations and lands' suitability should be specified for each user type. Correct programming for suitable utilization from those not only decreases rangeland degradation but also causes the conservation and improvement of those. Thus, one of the most important and also difficult factors in the analysis and evaluation of rangelands is the utilization based on those potentials and abilities. Recognition of factors affects those, and has a special importance to desirable use and suitable management of rangeland (Ariapour *et al.*, 2013).

Historical evidence has shown that rangelands were manipulated in the past and this trend has continued to the present time that it resulted in the destruction of ranges. Nowadays, rangelands have been utilized regardless of the capabilities and talents; now, many rangelands have been widely destroyed regardless of other available capabilities and resources relying on single-use (Mohtashamnia, 2000).

In the past, rangelands were used for livestock grazing, but with the increased people knowledge, various aspects of ranges' usefulness have been considered. Hence, contrary to range public record with the aim of informing on how to have a stable harvest and ranges' good yield by livestock, four issues have been raised including the maintenance and protection of basic resources, multi-purpose use, the importance of social and economic processes in the management of resources and interactions (Fadaie *et al.*, 2014).

Range suitability is a case that rangeland can be used for livestock grazing for many years without destructing its vegetation and soil as well as the adjacent areas and this does not

limit the range use in the coming years (Moghadam, 2009). The definition of range suitability should be revised because rangelands are not used only for livestock grazing and also other aspects of range use should be considered (Arzani *et al.*, 2014).

Noting that all factors of ecosystem have a role in the animal grazing and there is no possibility to recognize all of them; so, the recognition of the most important factors and selection of them to use by the abilities of GIS to decrease time and increase the accuracy for the preparation of information layers and integration of them are necessary. The kind of animals which uses the rangeland can be different according to physical factors such as slope, dimension of range, natural barriers, water resource spreading, soil properties, soil sustainability, soil sensitivity to erosion, percent of plant coverage, soil coverage and forage production (Moghadam, 2009).

Presently, a portion of methods is applied to analyze environmental vulnerability (Chen *et al.*, 2015). The Land Suitability Index (LSI) assessment tool (Marull *et al.*, 2007) presented the integrity and hierarchy of the land suitability assessment system; yet, it may simplify questions and be unable to express the non-linear characteristics of land suitability (Shao *et al.*, 2016). GIS application to analyze the grazing capability at a landscape scale is not a new concept (Mehrabi *et al.*, 2012). Amiri (2009) utilized GIS to portray rangelands suitable for sheep grazing in the semi-arid landscapes of Iran. In order to classify the goat grazing suitability using GIS, a study was conducted in middle Taleghan rangelands (Sour *et al.*, 2013). The findings indicated that no vegetation type was classified in S1 (High suitability) and N (Non suitability) classes and most of the studied types were grouped into the class S2 (Moderate

suitability). In examining water resources' suitability for sheep grazing in Sarab Sefid area, it was found that slope is the main and important factor limiting range suitability of Sarab Sefid area (Ariapour *et al.*, 2013). Rostami *et al.* (2014) determined the rangeland suitability for sheep grazing in the watershed of Sadegh Abad, Kermanshah Province, Iran. Three sub-models namely forage production model, water suitability model (quantity, quality and distance of water resources) and erosion sensibility which formed the components of the final studied model. The findings indicated two separate classes including low suitability (S3) and non-suitability (N) with the contributions of 68.65 and 31.34% rangeland area, respectively. The purpose of this study is to evaluate range suitability of Bagheran Birjand watershed area in South Khorasan Province, Iran using AHP-Fuzzy method.

## Materials and Methods

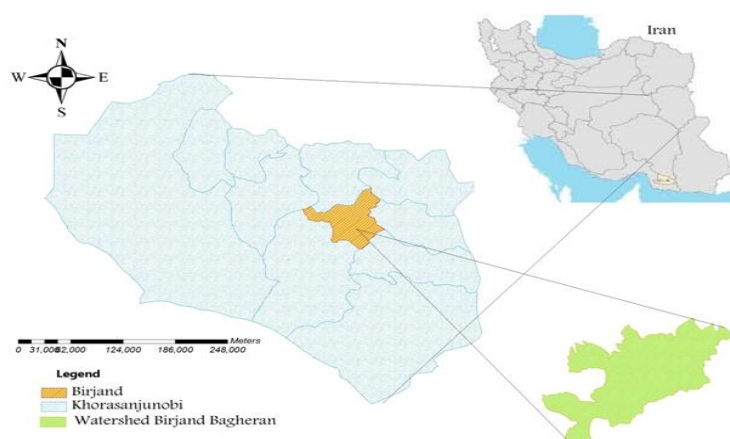
### Study area

Geographical characteristic of studied area: Bagheran mountain region with an area of 11879 ha and in geographical location of 58°5'48" to 59°11'02" longitude and 32°43'14" to 32°51'31" latitude is located in the southwest of Birjand in Southern Khorasan Province, Iran (Fig. 1). The mean annual rainfall of area is 188 mm and the mean annual

temperature is 13.5°C. According to a survey of studies conducted within the scope of Bagheran Birjand area on vegetation generally in the studied area, 138 species from 31 plant families were identified.

### Research method

In this study, first initial map of 6 influential criteria was raster on suitability in GIS environment. Fuzzy-AHP model was used for preparing suitability map in software Idrisi after converting the studied raster maps (slope, erosion, distance from water resources, quality, percent, and creation) in the environment of GIS in ASCII format of the files in Idrisi software. Then, the given map was interpreted. Fuzzy membership function is for the studied linear criteria and the state is incremental for some criteria and for others, it is decreasing (Table 1). Using fuzzy membership functions, maps were standardized. Then, using Weighted Linear Combination (WLC) method, factors' weight was obtained (Table 2). Finally, because each of used parameters (slope, distance from water resources, water quality, percent, erosion, and creation) had a different effect on range suitability, it required each element that was valued based on the degree of importance (Table 3). For this purpose, Analytical Hierarchy Process (AHP) was used.



**Fig. 1.** The region geographical location, South Khorasan Province, Iran

**Multi-criteria evaluation using WLC**

Weighted Linear Combination (WLC) technique is one of the most common and simplest methods in multi-criteria decision-making (Karam, 2005). The technique that is also called scoring method is on the basis of the weighted average concept. An analyst or decision maker directly gives weights to criteria based on relative importance of each studied criterion. Then, through multiplying the relative weight by the feature value, a final value was obtained for each option. Then, final values of each option was determined, options with the highest values would be considered as the most suitable option for the given objective (Shahabi and Niyazi, 2009).

In water resources' quality map, three factors of Mg, Total Dissolved Solids (TDS), and EC were examined; three factors according to the opinion of experts of Natural Resources Organization were scored in software Idrisi through WLC method so that the sum of these three factors' scores were 1. Based on the degree of importance, TDS was scored 0.5, Mg was scored 0.3 and EC was scored 0.2.

**Evaluation and standardization of criteria by Fuzzy method**

In multi-criteria evaluation, in order to achieve a certain objective, some indices

should be defined and specified that based on them, the given objective can be achieved. In the present study, range suitability criteria include 6 criteria of land slope, erosion, creation, quality of water resources, distance from water resources and water percent. Mentioned criteria become criterion maps in GIS environment. In order to synchronize the measurement scales and convert them to comparable units, criteria standardization process was used.

In this study, fuzzy method was used to normalize the data. Standardization of data converts all values of map layers to the same domain for example between zero and one or zero to 255. Standardization process in fuzzy method is done through reforming values in the form of a membership set. In this case, the maximum value namely 1 belongs to maximum membership and minimum value; namely, zero belongs to minimum membership (Sui, 1999). In fuzzy normalization method, values' reforming usually uses different functions such as S-shaped, J-shaped and linear. In the present study, criterion maps were standardized using fuzzy linear functions in software environment Idrisi (Table 1) and their values were converted to comparable units from zero to one.

**Table 1.** Threshold limit and fuzzy function type to standardize criterion maps in fuzzy logic

No.	Criterion	Control points (threshold values)		Fuzzy function type	Fuzzy function name
		a	b		
1	Vegetation	50	200	Increasing	Linear
2	Percent	20	100	Increasing	Linear
3	Distance	0.0	4100	Decreasing	Linear
4	Erosion	0.28	1.00	Decreasing	Linear
5	Slope	10	60	Decreasing	Linear
6	TDS	0.0	12900	Decreasing	Linear
7	Mg	0.0	235	Decreasing	Linear
8	EC	0.0	16000	Decreasing	Linear

**Weighting method**

After converting the evaluation criteria to comparable and standard scales, each weight and relative importance should be

determined in relation to the given objective. In this study, Analytic Hierarchy Process (AHP) method has been used to determine the relative weight of each specific criteria (Satty, 1980). AHP is a mathematical method to

determine the importance and priority of criteria in the process of analysis and evaluation. Mentioned method has three main stages as follows.

1. Criteria definition and organization in a hierarchy (forming matrix of criteria)
2. Evaluation and pairwise comparison of relative importance of elements in each hierarchical level
3. Institutionalization and synthesis using pairwise comparison results' solving algorithm at all levels of hierarchy

In this method, a series of pairwise comparisons was obtained from criteria relative importance for the given evaluation. The pairwise comparisons are analyzed to create a series of weights (the sum is 1) (Taghvaei and Ghafarri, 2006).

Criteria and relative weights obtained for each criterion are the main input data for the analysis of multi-criteria evaluation in GIS environment. In order to determine the degree of accuracy of weighting, consistency index is used (Satty, 1980) if consistency index equals to 0.1 or less weighting is correct; otherwise, relative weights given to the criteria should be changed and weighting should be done again. According to the above method, weighting for each criterion was done and the results are listed in Table 2; consistency index obtained for weighting 6 criteria is also equivalent to 0.03 and represents the consistency acceptance. After determining each criterion weight, final map of Bagheran range suitability was prepared.

**Table 2.** Weight obtained from hierarchical method for each criterion

Vegetation	Distance from water resources (%)	Slope (%)	Erosion (%)	Percent (%)	Quality (%)
0.4183	0.0771	0.0547	0.0426	0.0203	0.0203

**Table 3.** Criteria pair wise comparison matrix

	Vegetation	Distance	Erosion	Slope	Percent	Quality
Vegetation	1	-	-	-	-	-
Distance	1.5	1	-	-	-	-
Erosion	1.7	1.3	1	-	-	-
Slope	1.5	1	1	1	-	-
Percent	1.3	3	5	5	1	-
Quality	1.3	3	5	5	1	1

## Results

Output Map obtained from the weighted linear combination method and hierarchical method for evaluating suitability in Birjand watershed area is a combined map with raster format and a combination of slope (Fig. 2), vegetation (Fig. 3), water resources percent (Fig. 4), distance from water resources (Fig. 5), erosion (Fig. 6) and water resources quality (Fig. 7) maps. Values are between zero and 255. Higher values (to 255) in the map indicate greater suitability for sheep grazing and lower values (to zero) indicate less grazing suitability. After drawing the output map (Fig. 8), the mentioned map was

transferred to GIS environment and a classified map was prepared according to Fig.9 that the area is classified in three classes of S2, S3, and N. The results of this map given in Table 4 show that 55.43% equaling to 6585 ha was considered as moderate suitability (S2) class, 9.55% (1135 ha) was considered as low suitability (S3) class and 6.21% (736 ha) was considered as non-suitability (N) class. Of course, some parts of that area that are not rangelands were considered as non- rangelands.

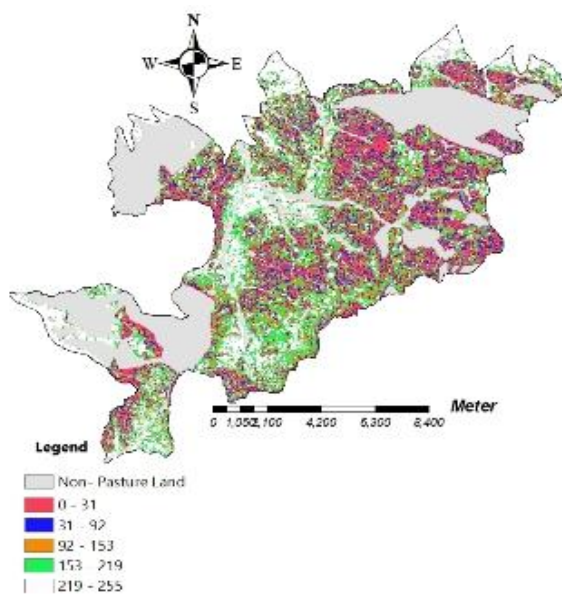
Class N that is the lack of suitability is mostly on the parts of the area with high steep and erosion as well as low water resources and access to it. Also, the

regional coverage in some parts of given area was partly considered as Bagheran watershed area limit. Using the weighting method (Table 2), it was found that slope and erosion had minimum weight and score and creation had the highest score

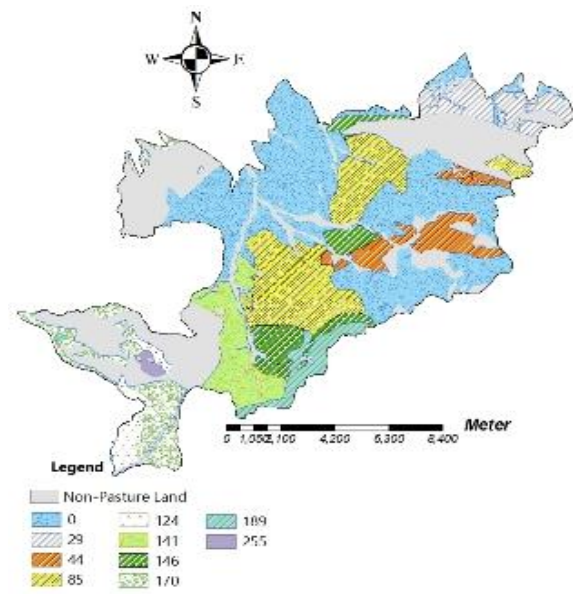
that is considered the most important factor in range suitability. So, it can be concluded that this model limit for sheep grazing in Birjand Bagheran watershed area is related to the area water resources and high slope as well as vegetation.

**Table 4.** Area and percent of final suitability classes of AHP- Fuzzy model

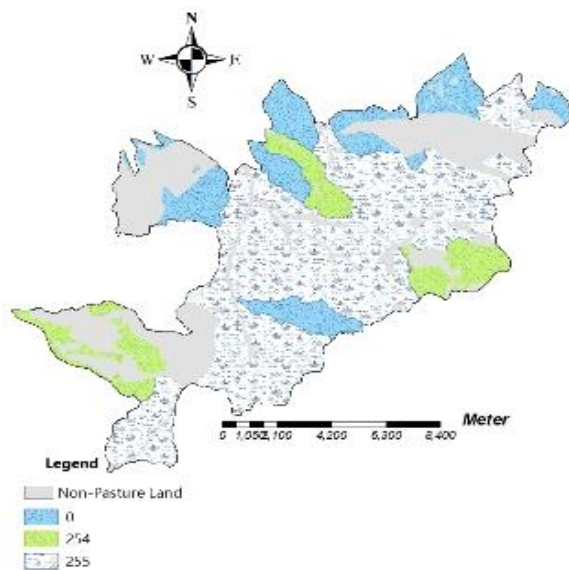
Suitability class	Area (ha)	Area (%)
High suitability (S1)	0	0
Moderate suitability (S2)	6585	55.43
Low suitability (S3)	1135	9.55
Non-suitability (N)	736	6.21
Non- range lands	3421	28.81
Total	11879	100



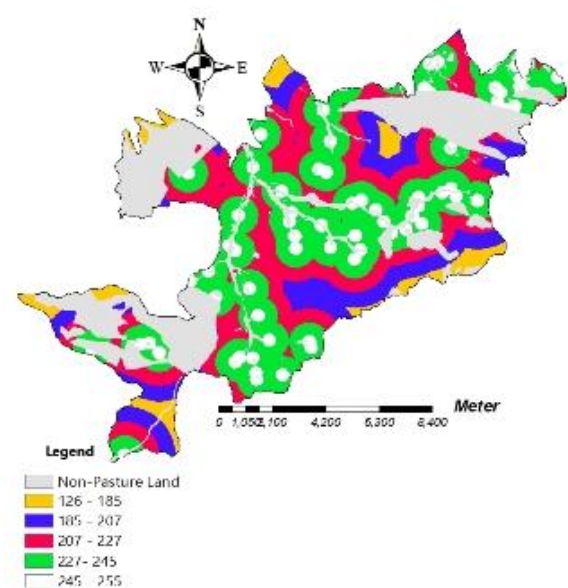
**Fig. 2.** Bagheran range slop map



**Fig. 3.** Bagheran range vegetation map



**Fig. 4.** Bagheran range water resources percent map



**Fig. 5.** Bagheran range distance from water resources

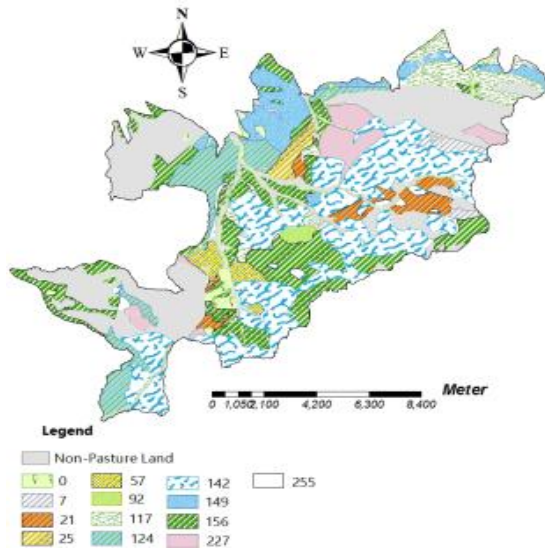


Fig. 6. Bagheran range erosion map

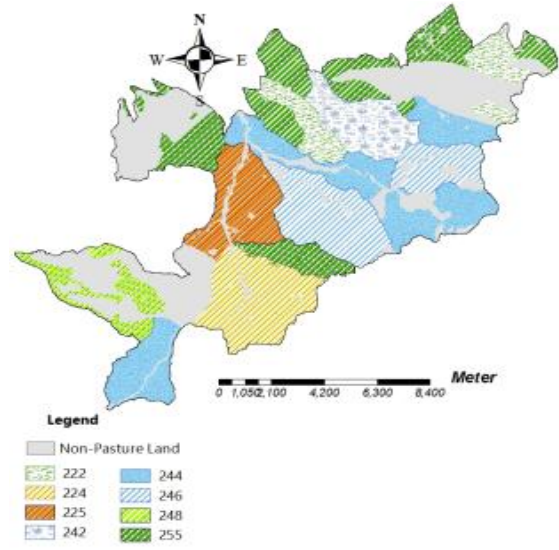


Fig. 7. Bagheran range water resources quality map

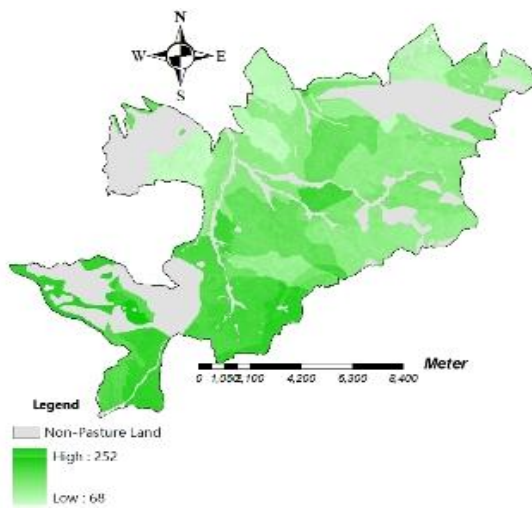


Fig. 8. Bagheran range suitability final map

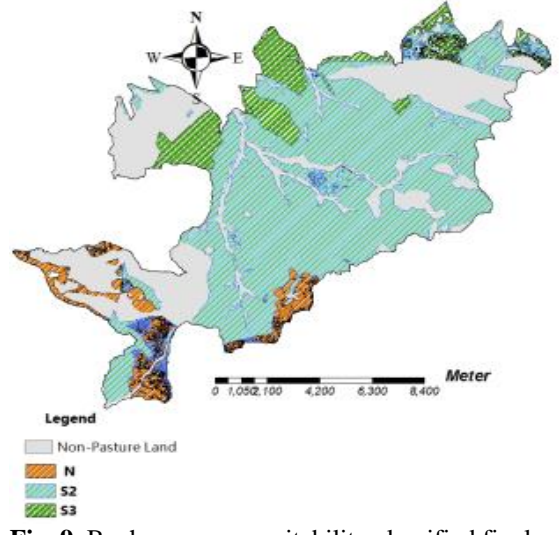


Fig. 9. Bagheran range suitability classified final map

## Discussion

Range suitability classification and rangelands evaluation to understand their potential properly, particularly for the exploitation of arid and semi-arid rangelands where rangeland ecosystems are very fragile are essential and sustainable development factors. In the field of rangelands' suitability using multi-criteria decision-making methods in the world, few studies have been conducted. According to the results of the model of sensitivity to erosion, the most important factors reducing range suitability of studied area (Bagheran Birjand) included the area with high slope and grazing that had caused loss of vegetation in some parts of studied area.

Holechek (1998) considered high slopes up to 60% as unusable for livestock. Arzani *et al.* (2006) in studying Taleghan ranges' suitability in Iran considered high slope, range conversion to dry land, early grazing, the presence of stones sensitive to erosion and low vegetation as important factors limiting the rangelands. Amiri and Arzani (2012) in prioritizing proper locations for beekeeping using AHP found that the importance degree of vegetation index value (weight of 0.687) is higher than that of environmental and physical factors (weight of 0.244) and access to water resources (weight of 0.069). Similarly, in Iran, Mohtashamia (2000), Tahmasbi (2001), Aghamohseni Fashami (2002), Yousefi (2005), Rafaei

(2006) and Ariapour *et al.* (2013) in their studied areas considered slope as the most important factor reducing range suitability. According to Mohtashamnia (2002) in Dasht-e-Bakan, slope, elevation, distribution of water resources and natural obstacles were introduced as factors limiting and reducing the range suitability for sheep grazing. According to Tahmasbi (2001) in Sabzkouh area, steep and sensitive to erosion were introduced as factors limiting and reducing the range suitability for sheep grazing and Aghamohseni Fashami (2002) in Lar area introduced high slope, cliff, stone and soil sensitivity to erosion and land utilization pattern as factors limiting and reducing the range suitability for grazing sheep. Yousefi (2005) in their studies considered the following factors as the most important factors reducing the range suitability in Taleghan area in order of importance: range conversion to dry land, early grazing, the presence of erosion-sensitive stones and available erosion in the area while proper coverage of rocks and pebbles, proper rainfall, the presence of perennial plants were factors affecting reducing sensitivity to erosion, and as a result increasing final suitability. Rostami *et al.* (2014) illustrated that low suitability for sheep grazing in the watershed of Sadegh Abad, Kermanshah Province was due to soil erosion sensitivity and limited standard exploitation of forage.

Final map of rangelands' suitability in some parts had no needed conditions for sheep grazing and shows the priority for protective measures' implementation that sheep grazing should be avoided. Such a map can be considered as one of bases of determining future range suitability in programs of range management of local office of Natural Resources Office in Southern Khorasan Province and is used by the related organizations. Traditional methods of combining maps and multi-criteria evaluations often due to large number of

variables, vast areas, traditional cartography problems, several errors, large amount of information and etc. have high costs and prolonged research lack necessary accuracy. In this study, in order to determine range suitability, AHP and GIS combination methods were used. AHP method advantages are the use of experts' opinions in evaluation process, flexibility and several criteria and sub-criteria. Although GIS and Multi-Criteria Decision-Making methods (MCDM) are two distinct areas of research and study, they can easily benefit from the advantages and capabilities of each other because on one hand, GIS has a great ability in decision-making data and spatial information creation, storage, retrieval, modification, manipulation and evaluation and as a result, the analysis of problems based on MCDM and on the other hand MCDM methods including AHP can be combined with spatial data, preferences and experiences of decision-makers and experts in the form of decision options and provide a valuable set of criteria to show priorities of decision-makers and their combination with GIS (Malczewski, 1999 and Nekhay *et al.*, 2009). Finally, considering the grazing capacity and applying the correction programs in rangelands can affect the increase of range suitability for grazing sheep.

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## تعیین شایستگی مرتع حوزه آبخیز باقران بیرجند به روش فازی و سلسله مراتبی

عین اله روحی مقدم الف<sup>\*</sup>، حلیمه جلورو<sup>ب</sup>، هادی معاریان<sup>ج</sup>  
الفدانشیار، دانشکده آب و خاک، دانشگاه زابل، زابل، \* (نگارنده مسئول). پست الکترونیک: erouhimm@uoz.ac.ir  
ب دانش آموخته کارشناسی ارشد رشته مرتعداری، دانشکده آب و خاک، دانشگاه زابل، زابل  
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**چکیده.** ارزیابی اراضی مرتعی به معنی شناسایی و تولید بالفعل و بالقوه مراتع به منظور بهره‌برداری صحیح از این منبع با ارزش طبیعی است. از این رو یکی از عوامل مهمی که در مدیریت مراتع اهمیت دارد، تعیین شایستگی مرتع و شناخت عوامل موثر بر آن می‌باشد. روش ترکیب خطی وزن‌دهی شده (WLC) یکی از معمول‌ترین روش‌های مورد استفاده برای مکان‌یابی و روش تحلیل سلسله مراتبی (AHP) از پرکاربردترین روش‌های اولویت‌بندی و وزن‌دهی معیارها است. هدف از این تحقیق ارزیابی شایستگی مرتع حوزه آبخیز باقران بیرجند در منطقه‌ای با وسعت ۱۱۸۷۹ هکتار با روش AHP-Fuzzy می‌باشد که در سال ۱۳۹۳ در منطقه‌ای با وسعت ۱۱۸۷۹ هکتار انجام گرفته است. بدین منظور در این تحقیق در محیط سیستم اطلاعات جغرافیایی نقشه فاکتورهای تاثیرگذار شایستگی (شیب، تولید، فرسایش، کیفیت منابع آب، درصد برآورد نیاز آبی و فاصله از منابع آبی) تهیه گردید. برای استانداردسازی داده‌ها از روش فازی و برای وزن‌دهی به معیارها از روش تحلیل سلسله مراتبی استفاده شد. نتایج حاصل از مدل AHP-Fuzzy به کمک ترکیب خطی وزنی نشان داد که ۵۵/۴۳ درصد اراضی مرتعی در کلاس شایستگی متوسط S2، ۹/۵۵ درصد اراضی در کلاس شایستگی کم S3 و ۶/۲۱ درصد اراضی در طبقه غیرشایسته قرار گرفتند. بنابراین عامل محدودیت در این مدل برای چرای گوسفند در منطقه مورد مطالعه مربوط به منابع آب و شیب زیاد حوزه و همچنین پوشش گیاهی می‌باشد.

**کلمات کلیدی:** شایستگی مرتع، روش ترکیب خطی وزن‌دهی شده، روش سلسله مراتبی و فازی، حوزه آبخیز باقران