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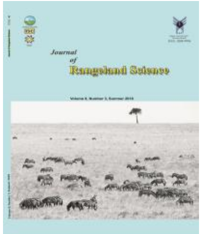

Research and Full Length Article:

Indicator Species for Rangeland Management by ANP-DEMATEL Method (Case Study: Nahavand Rangeland)

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Abstract. The wide ecological area consists of a rangeland with special vegetation and one of the key factors in rangeland management is to select Management Indicator Species (MIS). Management indicator species based on a new method such as Analytical Network Process-Decision Making Trial and Evaluation (ANP-DEMATEL) is one of the most important stages in the successful Range management as choosing a suitable species for the site can be the key to success. This paper provides research contribution on selecting management indicator species using ANP-DEMATEL for the Range management of Nahavand rangeland in Hamedan, Iran in 2016. This research as a guide to determine the best Management Indicator Species (MIS) was interested in how to use ANP-DEMATEL approach using Super Decisions software version 2.8. The criteria of species selection were grazing pressure, soil conservation, palatability, and beekeeping value and a set of species for criteria included *Acanthophyllum microcephalum*, *Thymus kotschyanus*, *Hypericum perforatum*, *Bromus tomentellus*, *Tragopogon graminifolius*, *Malabaila secacul*, *Festuca ovina*, *Poa bulbosum*, *Hordeum bulbosum* and *Medicago sativa*. Criteria were identified as the most preferable options. Results showed that grazing pressure and soil conservation with the values of 2.001 and 1.125 were the best criteria for the range management. Among species, *Medicago sativa*, *Thymus kotschyanus*, *Hypericum perforatum* and *Acanthophyllum microcephalum* (0.1454, 0.1387, 0.1247 and 0.1155) contributed to rangeland management objectives. The result of this study showed that the multi-criteria decision making and ANP-DEMATEL can provide accurate results and help rangeland managers to overcome knowledge gaps under complex ecological conditions.

Key word: DEMATEL Method, ANP, Rangeland, Species selection, Multi-criteria

Introduction

In Iran, the semi-arid rangelands cover the majority of the terrestrial areas. It was estimated that 90 million hectares or 55% of the Iranian land is occupied by rangelands (Badripour *et al.*, 2006). The rangelands in Iran have a great economic importance; 6% of the gross national products such as meat, medical plants, herbs, and honey are provided from rangelands. The survey of vegetation will enable us to solve the management problems and evaluate the plant information and trend prediction. The plant species composition should be considered for the study of vegetation. Preservation of valuable natural ecosystems requires the protection of vegetation and plant communities (Moslemi, 1997).

Considering the important roles of plants in ecosystems balance led us to understand the relationships between plants and their environment. Moreover, the rangelands fulfill important ecological functions such as the provision of biodiversity and the maintenance and preservation of biotic cycles (Gauch, 1982).

Due to degradation of the rangelands, the rangeland management plan and MIS selection as the rehabilitating plan in rangeland are important. Because complex ecological regions such as Nahavand Mountain rangeland, decision making methods that allow rangeland managers to overcome knowledge gaps with expert judgments could provide a more robust MIS selection process.

Multiple Criteria Decision-Making (MCDM) problem, which requires the consideration of a large number of complex criteria. A robust MCDM method should consider the interactions among these criteria. The analytic network process (ANP) is a relatively new MCDM method which can deal with all kinds of interactions systematically. The Decision Making Trial and Evaluation Laboratory (DEMATEL) not only can convert the relations between cause and effect of criteria into a structural model, but also can be used as a way to handle the inner dependences within a set of criteria (Tseng, 2009).

Multiple criteria decision making (MCDM) techniques allow rangeland managers to incorporate available ecological information and expert judgments within an organized framework to determine the best alternatives (Ariapour *et al.,* 2014; Mendoza and Martins, 2006; Moffett and Sarkar, 2006; Schmoldt *et al.,* 2001). Also Multi Criteria Decision Making Method and the Integrated ANP-DEMATEL Model is used for Agricultural Land Suitability Analysis (Pourkhabbaz *et al.,* 2013 and 2015).

To identify the interactions among evaluation criteria of alternative systems, DEMATEL approach (Fontela and Gabus, 1976) was used to construct a network structure with interdependent relationships. In recent years, DEMATEL technique has been widely applied to evaluate interrelationships between criteria. (Tseng, 2009; Yang *et al.*, 2008; Liou *et al.*, 2007; Wu *et al.*, 2008) DEMATEL was also used to evaluate interrelationship between influential factors in assessing knowledge management strategies in Taiwan country (Wu *et al.*, 2008). As Multiple Criteria Decision Making (MCDM) method, ANP has been widely applied to the complexities of many real worlds (Tsai *et al.*, 2014; Yeh *et al.*, 2014; Hsu and Hu, 2009). These two models were proposed by Saaty (Saaty, 1996 and 2001). In recent years, there is an increase in the use of ANP for a variety of issues such as municipal solid waste, investment and technology (Aragonés-Beltrán *et al.*, 2010; Lee *et al.*, 2009).

ANP that uses DEMATEL techniques has been used in several studies for municipal solid waste management (Tseng, 2009), the healthcare sector, management, education and brand marketing (Lee *et al*., 2009; Wang and Tzeng, 2012), evaluation of desertification strategies (Sadeghi Ravesh and Khosravi, 2015), environmental issues and sustainable development (Zakerian *et al*., 2014), Environmental impact assessment of asphalt roads (Amini *et al*., 2016), development of an optimized forage harvest machinery system (Lu *et al*., 2013).

ANP and DEMATEL were used to solve dependence and feedback problems to suit the real world (Yang *et al*., 2008). They used ANP to overcome interdependence and feedback between criteria and alternatives in MCDM methods; also, they adopted DEMATEL to determine the degree of influence of criteria. Their study provides a numerical example to illustrate the proposed method. Although ANP has been used to overcome interdependence and feedback criteria or alternatives, it could not determine the strength of relationships between criteria. DEMATEL was used to address this inadequacy. Widely used in many fields, DEMATEL can quantify relevant degrees and relationships between various elements in order to understand the relationship structure to solve the mentioned problems (Tsai and Chou, 2009; Chen *et al*., 2012). Because of the inherent complexity of ecological variables, decision making approaches such as ANP-DEMATEL could provide a more robust MIS selection process. The present study applied ANP-DEMATEL to MIS selection. Accordingly, we used the ANP-DEMATEL to determine the best MIS among a set of alternative species for Nahavand Hamedan rangeland management in Iran.

Materials and Methods

Study Area

The study area is located between longitudes of 47º53′44″ E and 48º00′51″ E, latitudes of 34º18′43″ N and 34º13′24″ N in Hamedan Province, Iran (Fig. 1). The elevation varies from 1600 to 2800 m above sea level and the average elevation is 2641 m. The average annual rainfall of the zone is 593 mm. The average maximum and minimum annual temperatures are 15.9 and -1.1ºC, respectively. The study area is dry about 4 to 5 months (June, July, August, and September).

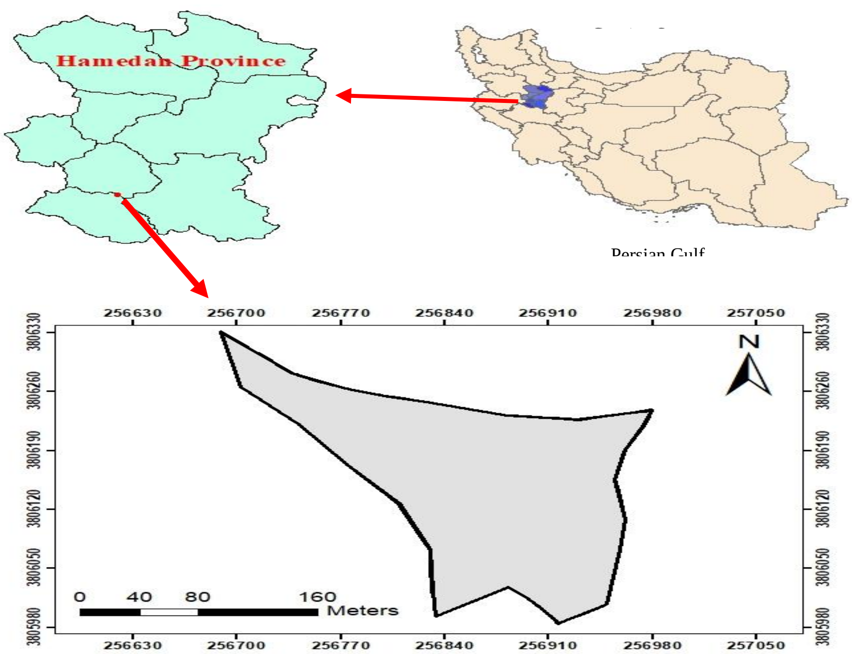


Fig. 1. Geographic location of Nahavand in Hamedan province, Iran

Research Methodology

This study sought to develop an approach of MCDM which might be useful for rangeland managers to prioritize plant species and describe the ANP-DEMATEL method for the identification of priority of plant species in the rangeland of western Iran. Based on expert opinions, 10 plant species *(Acanthophyllum microcephalum, Thymus kotschyanus, Hypericum perforatum, Bromus tomentellus, Tragopogon graminifolius, Malabaila secacul, Festuca ovina, Poa bulbosum, Hordeum bulbosum, Medicago sativa*) and 4 criteria were selected as a basis for rangeland management. We used the ANP-DEMATEL as a multiple criteria decision-making tool to prioritization. The criteria identified for the prioritization of rangeland species were resilient to grazing pressure, soil conservation, palatability, beekeeping value and 6 plant species were identified as priority plants in the western rangelands of Iran. *Medicago sativa*, *Thymus kotschyanus* and *Hypericum perforatum* emerged as the most important species in the western rangeland (Fig. 2).

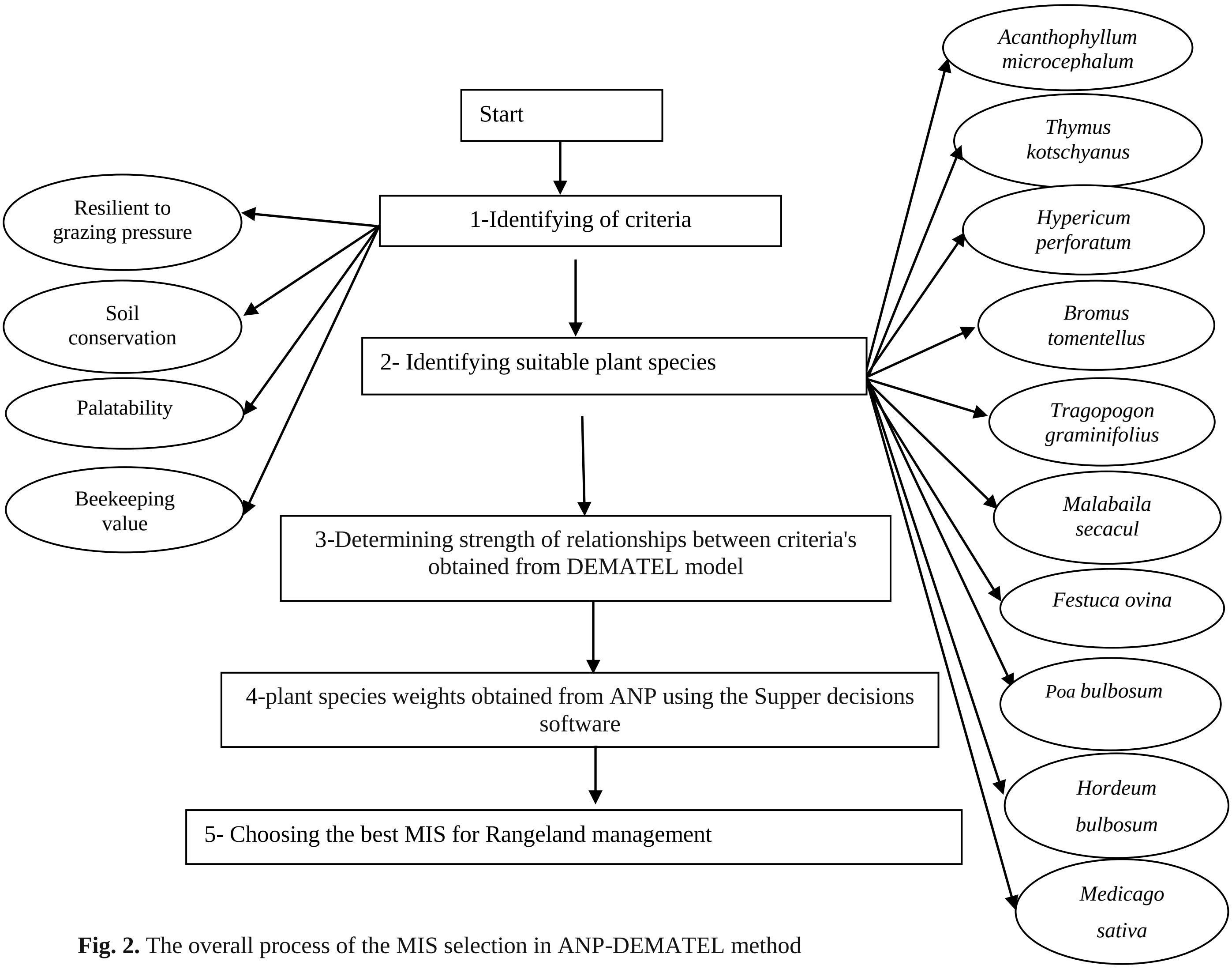


Fig. 2. The overall process of the MIS selection in ANP-DEMATEL method

ANP

ANP is an extension of the AHP; indeed, it is the general form of the AHP. These two models are proposed by Saaty (Saaty, 1996 and 2001). AHP is a well-known technique that breaks down a decision-making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels but ANP is a nonlinear structure with bilateral relationships (Fig. 3) (Aragonés-Beltrán *et al.*, 2010). So, the main innovation of the ANP is its network structure which enables the interactions between elements situated in different clusters and dependencies between the elements in the same cluster to be taken into account (Tseng, 2009; Nekhay *et al.*, 2009). In this paper, ANP is used to obtain the weight of the criteria. The application steps of ANP can be described in the following steps.

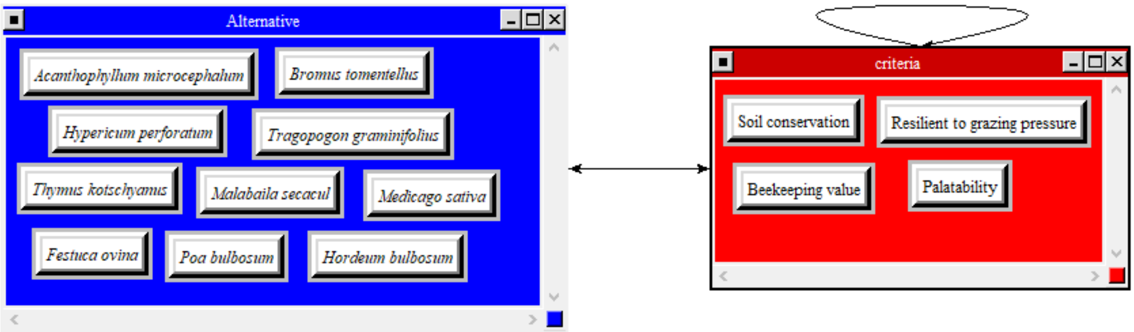


Fig. 3. A schematic example of designing conceptual model in ANP

Step 1: As mentioned above, the first step is to construct a conceptual model and to determine relationships between/among clusters and nodes. The conceptual model (Fig. 2) is constructed and the relationships (shown by arrows in the conceptual model) between/among clusters, and nodes are determined.
Step 2: Criteria are compared using Super Decisions software in the whole network in order to form an un-weighted super matrix by pairwise comparisons (the same as the AHP). In this phase, decision makers compare two elements. Pairwise comparisons are made with the grades ranging from 1–9 (Vasiljević *et al.*, 2012). A reciprocal value of each number is used to express the inverse comparison. The values of pairwise comparisons are allocated in the comparison matrix and local priority vector is derived from eigenvector. The consistency of pairwise matrix like the AHP must be less than 0.1 (Sener *et al.*, 2011).
Step 3: The weights obtained from the previous steps are introduced into the super matrix that includes the entire network components and represents their inter relationships. In this step, super matrix is called the initial super matrix. Equation (1) shows the general form of the super matrix.

$$W = \begin{array}{c} \\ C_1 \\ C_2 \\ C_n \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_n \end{array} \\ \begin{bmatrix} W_{11} & W_{12} & W_{1n} \\ W_{12} & W_{22} & W_{2n} \\ W_{n1} & W_{n2} & W_{nn} \end{bmatrix} \end{array} \qquad \text{(Equation 1)}$$

Where
W is the weight and C_k is the kth cluster (k =1, 2,…, N) which has n_k elements denoted as e_{k1}, e_{k2}, …, e_{kn_k}. A matrix segment, W_{ij}, represents a relationship between the *i*th clusters and the *j*th cluster.

Each column of W_{ij} is a local priority vector obtained from the corresponding pairwise comparison representing the importance of the elements in the ith cluster on an element i n the *j*th cluster (Lee *et al.*, 2009).

Step 4: The cluster weights should be calculated in this step in order to weigh the initial super matrix. When the cluster weight matrix has been obtained, the initial super matrix can be weighted by multiplying the cluster weights matrix by an initial super matrix (Nekhay *et al.*, 2009). The newly obtained matrix is known as the weighted super matrix.

Step 5: The final step consists of multiplying the weighted super matrix n times by itself until the limit super matrix is reached. Some super matrices may have a cyclicity effect. As a result, two or more final limit super matrixes may be obtained. The main property of the limit super matrix is that its columns are equal and represent the global priority vectors (Nekhay *et al.*, 2009).

DEMATEL Method

In order to solve the complicated global problems, DEMATEL method had been applied at the end of 1971 by Gabus and Fontela (Gabus and Fontela, 1972).

In this paper, DEMATEL is prepared in the six following steps:

Step 1: In order to pairwise comparisons, the five point scale regarding the level of impacts of particular dimensions was used. The measurement criteria of 0, 1, 2, 3, and 4 are used to illustrate no influence, very low influence, low influence, high influence and very high influence, respectively (Tseng, 2009).

Step 2: The direct-influence matrix was constructed based on the degrees of relative impacts derived from the pair comparisons in Equation (2). An n×n direct influence matrix A with the directly observed relations was obtained (Taghizadeh Herat *et al.*, 2012).

$$A=\begin{bmatrix} a_{11} \ . \ . \ . & a_{1j} \ . \ . \ . & a_{1n} \\ a_{i1} \ . \ . \ . & a_{ij} \ . \ . \ . & a_{in} \\ a_{n1} \ . \ . \ . & a_{nj} \ . \ . \ . & a_{nn} \end{bmatrix} \quad \text{(Equation 2)}$$

Where

A= average matrix, a_{ij} denotes the degree of impacts of the i factor on the j factor

Step 3: The normalized matrix obtains from Equations (3) and (4):

$$X= s.A \quad \text{(Equation 3)}$$

$$s = min\left[\frac{1}{max_i \sum_{j=1}^{n}|a_{ij}|}, \frac{1}{max_j \sum_{i=1}^{n}|a_{ij}|}\right] \quad \text{(Eq. 4)}$$

Where the all matrix diagonals are equal to zero and the sum of each row and column does not exceed 1.

Step 4: Deriving the full relationship matrix T from the Equation (5):

$$T= X + X^2+\dots X^K=T=X(1-X)^{-1} \quad \text{(Eq. 5)}$$

Step 5: Summing each column and row to obtain D and R (Equations 6 and 7):

$$D = \left(\sum_{j=1}^{n} T_{ij}\right) = [d_i]_{nx1} \quad \text{(Equation 6)}$$

$$R = \left(\sum_{i=1}^{n} T_{ij}\right) = [r_j]_{1xn} \quad \text{(Equation 7)}$$

Where,

d_i is the sum of each row in T and the rows show the degrees of direct and indirect impacts over the other criteria, and r_j is the sum of each column in T where columns indicate the degrees of influence from other criteria. Numeric a logarithm variable, i represents the factors that influence others, r_j represents factors that are influenced by others, d_i+ r_j represents the strength of relationships between factors, and d_i-r_j represents the strength of influences among factors (Lee *et al.*, 2011).

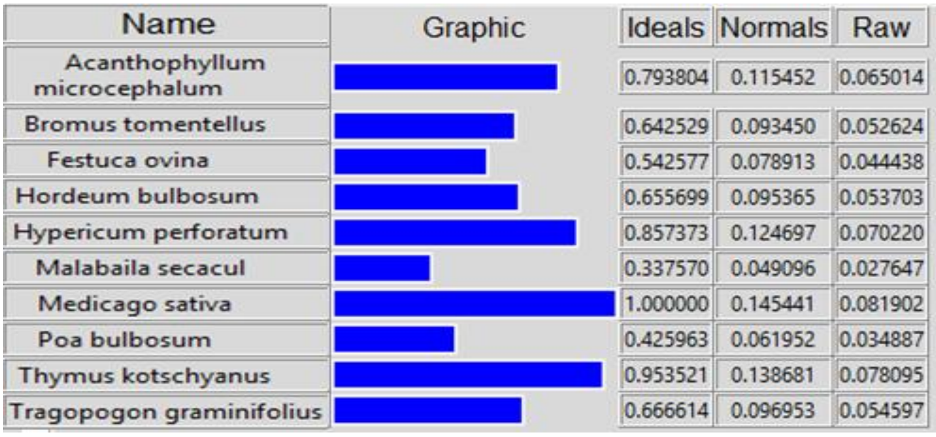
Step 6: Determining a threshold value in order to ignore the minor effects is necessary to isolate the relationship structure of the factors and finally obtain NRM (Yang and Tzeng, 2011) (Tables 1 & 2).

Results and Discussion

In this research, the best species for rangeland management were prioritized using ANP-DEMATEL method based on resilient to grazing pressure, soil conservation, palatability and beekeeping value criteria at a western rangeland of Iran.

MIS selection criteria for rangeland management objectives include resilient to grazing pressure as the highest important criteria followed by soil conservation and palatability (Table 2).

As a result of the ANP-DEMATEL ranking of MIS in rangeland management, *Medicago sativa* plant species was the most preferred whereas the *Malabaila secacul* plant species is the least important in rangeland improvement (Fig. 4) (Table 1). This study has shown how an integration of different expert's preference can be conducted using ANP-DEMATEL method. Also, this study has shown that the integration of ANP and DEMATEL for MIS selection in rangeland management is the best option according to different points of view.



Name	Graphic	Ideals	Normals	Raw
Acanthophyllum microcephalum		0.793804	0.115452	0.065014
Bromus tomentellus		0.642529	0.093450	0.052624
Festuca ovina		0.542577	0.078913	0.044438
Hordeum bulbosum		0.655699	0.095365	0.053703
Hypericum perforatum		0.857373	0.124697	0.070220
Malabaila secacul		0.337570	0.049096	0.027647
Medicago sativa		1.000000	0.145441	0.081902
Poa bulbosum		0.425963	0.061952	0.034887
Thymus kotschyanus		0.953521	0.138681	0.078095
Tragopogon graminifolius		0.666614	0.096953	0.054597

Fig. 4. ANP ranking in supper decisions software

Table 1. The final weights for species based on ANP method in Nahavand rangeland, Hamadan Province

Species	Weight	Rank
Medicago sativa	0.145441	1
Thymus kotschyanus	0.138681	2
Hypericum perforatum	0.124697	3
Acanthophyllum microcephalum	0.115452	4
Tragopogon graminifolius	0.096953	5
Hordeum bulbosum	0.095365	6
Bromus tomentellus	0.093450	7
Festuca ovina	0.078913	8
Poa bulbosum	0.061952	9
Malabaila secacul	0.049096	10

Table 2. The final weights for criteria based on DEMATEL method in Nahavand rangeland, Hamadan Province

Criteria	Weight	Rank
Resilient to grazing pressure	2.001	1
Soil conservation	1.125	2
Palatability	0.011	3
Beekeeping value	-3.137	4

This study was meant to support the practical implementation of management indicator species selection on the Nahavand rangeland, Hamadan, Iran by utilizing the ANP-DEMATEL technique for increasing awareness of natural resources management and experts. This approach considered experts opinion and local understanding to identify MIS selection and reflect an attitude towards Rangeland management improvement. Resilience to grazing pressure was assessed as the most criteria and *Thymus kotschyanus, Hypericum perforatum, Acanthophyllum microcephalum,* and *Hordeum bulbosum* species to be more resilient to grazing pressure. The consequence of increased grazing pressure on plant diversity is of great interest; therefore, to introduce high resistance species to grazing is very important for the conservation of the ecosystems. Our study reveals the importance of considering *Medicago sativa, Thymus kotschyanus, Hypericum perforatum* and *Acanthophyllum microcephalum* plant species adaptation to grazing when operational planning rehabilitates rangeland. The results of this study showed that *Medicago sativa* and *Acanthophyllum microcephalum* had the highest impact on erosion control and soil conservation according to soil conservation criterion. Mousavi *et al.* (2014) found in their study that plant types with the highest percentage of cover such as *Artemisia aucheri, Astragalus gossypinus* and *Bromus tomentellus* are with the highest rates of erosion control. However, given the relative low cover rates, low variation of cover between pasture types, the interaction of effective environmental factors such as geology and topography, and the involvement of other environmental factors, especially the geological and topographical diversity within each vegetation type, a linear relationship between cover rate and erosion control could not be expected. The result showed that *Bromus tomentellus* had a high palatability in the study area which is in agreement with the results of Ariapour *et al.* (2014) that chose *Bromus tomentellus* as the best species in terms of palatability and frequency to manage pastures of Sarab Sefid, Borujerd, Iran. According to the subject of beekeeping value based on the obtained results, *Thymus kotschyanus, Hypericum perforatum* and *Medicago sativa* which are species of Labiatae, Hypericaceae and Gramineae family, respectively were identified as the most important species in the study pastures. The results of Amiri *et al.* (2013) indicated that the most important plant families used by Apiaceae, Cruciferae, Gramineae, Liliaceae and Caryophyllaceae in Ghare Aghach, Isfahan province (10 km from Semirom) were Compositae, Labiatae, knowledge of plants and their distribution as well as phenology (especially flowering time) are important planning tools in order to protect and prevent the destruction of pastures and to develop beekeeping in the area.

Conclusion

In this study, ANP-DEMATEL was used to determine the best MIS using managerial and environmental criteria in a part of Nahavand rangeland, Iran. This research targeted MIS selection that has the greatest suitability in Range management and improvement. Decision analysis at the MIS selection needs more detailed knowledge; therefore, ANP-DEMATEL was used to extract values for criteria and species in rangeland management. It can be concluded that the use of ANP-DEMATEL is more effective in the prioritization of criteria and MIS selection for rangeland management. Analysis has shown that resilient to grazing pressure is the most important criterion and *Medicago sativa* plant is the most suitable species in the study area for rangeland management. The criteria identified here by the different experts are consolidated so that the approach could be applied at different scales appropriate to different levels of western Rangelands of Iran.

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انتخاب گونه‌های شاخص برای مدیریت مراتع با استفاده از فرآیند Anp-Dematel (مطالعه موردی: مراتع نهاوند)

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چکیده. منطقه وسیع از هر منطقه اکولوژیکی شامل مراتع با پوشش گیاهی خاصی می‌باشد و یکی از عوامل کلیدی در مدیریت مراتع کشور، انتخاب گونه‌های شاخص مدیریت است. گونه‌های شاخص مدیریت بر اساس یک روش جدید مانند روش ANP-DEMATEL که یکی از عوامل مهم در برنامه‌ریزی مدیریت جامع پوشش گیاهی است می‌تواند به عنوان گونه گیاهی مناسب، کلید موفقیت باشد. در این پژوهش، انتخاب گونه‌های شاخص با استفاده از فرآیند تحلیل شبکه و دیمتل با هدف مدیریت مراتع منطقه نهاوند همدان در سال ۱۳۹۵ انجام شد و به عنوان راهنمای انتخاب گونه‌های شاخص مدیریت و آشنایی با روش تحلیل شبکه و دیمتل است که با استفاده از نرم افزار Super Decisions ورژن ۲/۸ استفاده شده است. معیارهای در نظر گرفته شده در این مطالعه، فشار چرا، حفاظت خاک، خوشخوراکی گونه‌ها و ارزش زنبورداری بوده و گونه‌های در نظر گرفته شده شامل *Acanthophyllum microcephalum*, *Thymus kotschyanus*, *Hypericum perforatum*, *Bromus tomentellus*, *Tragopogon graminifolius*, *Malabaila secacul*, *Festuca ovina*, *Poa bulbosum*, *Hordeum bulbosum* and *Medicago sativa* بوده است. بر اساس نتایج بدست آمده، فشار چرا و حفاظت خاک با وزن‌های ۲/۰۰۱ و ۱/۱۲۵ بهترین معیار برای مدیریت مراتع بوده است. از میان گونه‌های در نظر گرفته شده، گونه‌های *Medicago sativa*، *Thymus kotschyanus*، *Hypericum perforatum* و *Acanthophyllum microcephalum* به ترتیب (با وزن ۰/۱۱۵۴ و ۰/۱۲۴۷، ۰/۱۳۸۷، ۰/۱۴۵۴) مهمترین گونه‌های شاخص مدیریت مرتع بودند. نتایج این پژوهش نشان داد روش‌های ارزیابی چند معیاره و به خصوص روش تحلیل شبکه-دیمتل، می‌تواند به مدیران مراتع کشور کمک کرده و از سویی پیچیدگی شرایط بوم شناختی منطقه را کاهش داده و از سوی دیگر انتخاب گونه‌های شاخص مدیریتی را راحت‌تر کند.

کلمات کلیدی: روش DEMATEL، فرآیند تحلیل شبکه‌ای (ANP)، مدیریت مراتع، انتخاب گونه، چند معیاره