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Research and Full Length Article:

Role of Plant Species and Ecological Patches in Conserving and Fixing Natural Lands′ Soil Using Landscape Functional Analysis (LFA) (Case Study: Dehbar Rangeland, Torghabeh, Mashhad, Iran)

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Abstract. Degradation of plant patches is considered as one of the indices for rangeland degrading health condition. Investigating the accuracy of triple indices (infiltration, stability and soil nutrient cycle) presented by LFA method seems necessary to determine its efficiency in semi-arid areas with the least cost. This study aims to investigate the role of vegetative species and growing forms on soil surface characteristics in Dehbar semi-steppe rangelands, Iran in 2014. So, eleven soil surface characteristics in different vegetative types each of 3 replicates were measured using landscape functional analysis (LFA). Then, the measured parameters were classified based on their sustainability, permeability and food chain continuum for each plant species. According to the results obtained from various analytical investigations, the ecological patches consisting of *Artemisia aucheri* (46.83%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (with the amount of 41.7%) were higher than other forms of vegetative growth for soil sustainability. The complex of *Acantholimon sp., Artemisia aucheri* and *Astragalus commixtus* had the lowest amount in terms of soil sustainability (38%). The comparison of soil permeability indices for different types of plant covers showed that the percentage of *Artemisia aucheri* (32.06%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (33.5%) had the highest amount while all other patches were equal and had the lowest amount. In terms of food chain, the ecological patches such as *Artemisia aucheri* (25.63%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (27.66%) had the highest amount. The complex of *Artemisia aucheri* and *Astragalus commixtus* (16.36%), the complex of *Acantholimon sp.*, *Artemisia aucheri* and *Astragalus commixtus* (13.63%) and the complex of *Acantholimon sp.* and *Agropyron intermedium* (15.36%) had the lowest values ($p \leq 0.01$). Therefore, *Artemisia aucheri* (shrub) and a complex of *Artemisia aucheri* and *Agropyron intermedium* (grass) patches, introduced as ecological indicators for the study area, are suggested for rangelands restoration.

Key words: Ecological patch, Land functional analysis (LFA), Growth form, Semi-steppe rangelands

Introduction

Landscape is seen as a whole its single components. The components in a landscape are related to the structure of landscape (Ahmadpour *et al.*, 2017) and can be identified by analysis of several items like land cover, morphology, presence of settlements and etc (Tagliafierro *et al.*, 2013). Assessing the landscape as a whole is an important step to understand the landscape functionality and finally to identify areas with different levels of ecosystem function and services (Tavora and Turetta, 2016). The effects of the landscape pattern organization on ecosystem functions and services are central issues in academic research (Simone *et al.*, 2016; Bautista *et al.*, 2016; Berdugo *et al.*, 2017; Rolando *et al.*, 2017).

In Iran 90% of rangelands are located at arid and semi- arid regions mainly characterized by low in amount rainfall events and extensive oscillations. Evaluation of variations of rangeland functional characteristics based on primary ecosystem processes such as water circulation, food chain and energy flow is extensively expensive and time consuming (Pellant *et al.,* 2002). Therefore, because of the necessity of investigating these features in rangelands we have to use ecological indices instead. Such indices are considered as members of ecosystems characteristics and measured easily and fast. These indices are closely related with rangelands functional features (Whitford, 2002; Pellant *et al.,* 2002; Mesdaghi and Ghorbani, 2009). Methods like landscape functional analysis (LFA) have been yet used to evaluate vegetative cover in Australia (Tongway, 1994). LFA is a monitoring procedure that uses rapidly acquired field-assessed indicators to assess the biogeochemical functioning of landscapes at the hill slope scale. This method considers rangelands as landscape systems (Saedi *et al.*, 2017).

The use of modern ecosystem monitoring methods such as LFA is regarded as one the major issues in ecological studies. The main concepts of the method were first established in Australia to evaluate soil surface characteristics that is relatively in concordance with Australia's ecological conditions (Tongway, 1994; Tongway and Hindley, 1995; Ludwig and Tongway, 1997). In Iran, this method was used to investigate soil quality (Rezaei *et al.,* 2006 (b)), rangelands potential (Rezaei and Arzani, 2007) and the effects of management activities on rangelands and soil characteristics (Arzani *et al.,* 2007). There are several studies to monitor and investigate rangeland ecosystems in different climate and different uses using LFA method (Rezaei *et al.,* 2006a; Jafari *et al.,* 2008; LotfiAnari and Heshmati, 2009; Ghodsi *et al.,* 2010; Mesdaghi and Ghorbani, 2010; Forouzeh and Sharafatmand, 2012; Mayor and Bautista, 2012; Motamedi *et al.,* 2013; Ebrahimi and Arab, 2014). Ghodsi *et al.* (2011) investigated the effect of different growth forms on soil surface features in semi-steppe rangeland in Golestan province using LFA method and found that shrub form increases soil surface stability higher than other forms and the soil surface of wheat grasses had higher percentage of nutrient cycle.

Mahdavi *et al.* (2013) tested the Rangeland Health Model to interpret the function of semi-steppic area in Iran and found that all three attributes of the rangeland ecosystem were below the threshold line of integrity at the extreme. Their results showed that this model had produced different assessments in the sites with the equal ecologic conditions but unequal management practices. Moreover, the descriptive categories of indicators as well as the attributes had the ability to identify the differences in the evaluation area. Ebrahimi and Arab (2014) surveyed the effects of contour furrow on ecological indices of Jiroft rangeland health in Iran, using landscape function analysis. Their results indicated that three health indicators were higher in the contour furrow compared to control treatment. In addition, some parameters like litter movement, soil surface resistance to erosion, soil surface roughness and erosion in contour furrow had the biggest share among the rangeland health indicators. Poutra *et al.* (2017) performed LFA method to investigate the impact of tin mining on the environment of Bangka in Indonesia. They assayed three locations: un-reclaimed tin-mining, reclaimed tin-mining and natural forest (as reference site). The results showed that all three indicators of LFA were high in natural forest compare to other areas.

Among various affected parameters, the plant species, growth form and vegetative cover intensity were important (Sabeti, 1975; Mabbuttand Fanning, 1987). Different growth forms have different influences on soil sustainability that is related to structural variations (Bestelmeyer *et al.*, 2006; Shaker, 2016; Khosravi *et al.*, 2017). Tongway and Hindley (2004) suggested that the responses of ecological patches to rainfall events are completely various that is in dryer seasons they reduce their dimensions' size because of more mortality events in fresh tissues of plants. However, nobody can ignore the effects of various plant species and their growth forms on topsoil characteristics in order to better management on different types of rangelands. Since rangeland ecosystems are divided into various patches, LFA is comparing each patches characteristics. Thus, based on the obtained results we can manage range ecosystem in a more efficient trend. As it has been yet proved, soil superficial characteristics affect rangelands features directly. According to the fact that using LFA method is developing in Iran, investigating the accuracy of triple indices (infiltration, stability and soil nutrient cycle) is necessary to determine this method efficiency in these areas or the regions with similar ecological conditions. Therefore, this study aims to investigate different plant species and their various growth forms on superficial soil characteristics (i.e. sustainability, permeability and soil nutrient cycle) using land functional analysis (LFA) method in Dehbar semi-steppe region in Mashhad, Iran.

Materials and Methods

This study was conducted on Dehbar rangelands located at Torghabeh town, 22 km far from South West Mashhad city on the way of Mashhad-Torghabeh road. The study site is located at 36˚11'12″ to 36˚19'30″ north latitude and 59˚10'25″ to 59˚22'25″ east longitude (Fig.1). The average altitude is 1973 m above sea level and the average of maximum and minimum altitude are 2700-1483 m. The amount of annual precipitation is 361.8 mm. The dominant species in the study area is *Artemisia aucheri*.

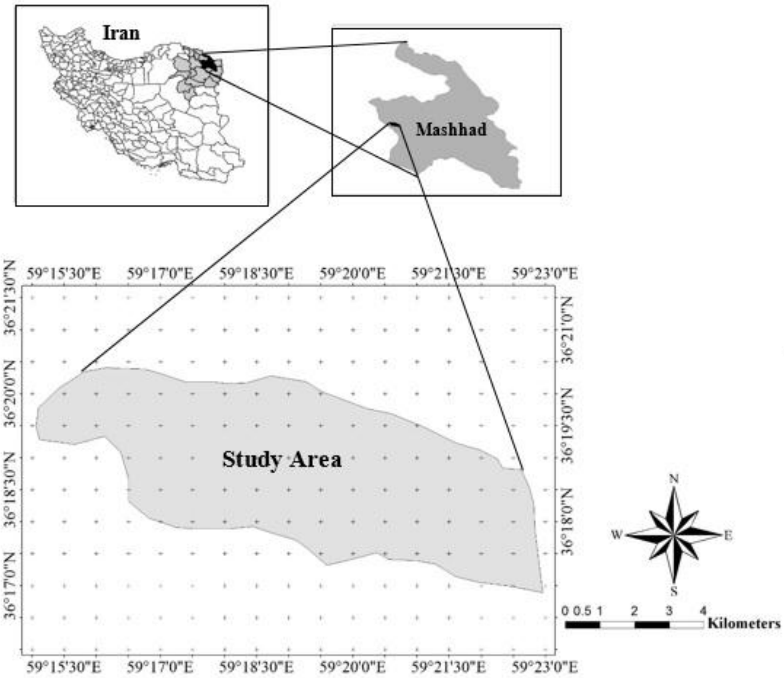

Fig. 1. Location of Dehbar region in Iran

Sampling was conducted along four 50 m transects which were placed on predominant slope of the region. Measurements were done based on randomly- systematic sampling method. Different types of patches were defined based on various plant species and their growth form (i.e. brush, brush-grass complex and pulvinus). Patches sizes were measured by their vegetation cover and soil bare size. The length and width of patches were measured and averaged along transects. Then, 11 soil indices were ranked according to the method guideline for each patch and inter-patch spaces along an "evaluation territory". This territory constitutes of transects length in which patches and inter-patches spaces were located (Tongway and Hindley, 2004). According to the measured indices, three functional characteristics were calculated by LFA software package. Nominal indices for rangeland functions along transects were assessed based on (Tongway and Hindley, 1995). The indices and their classes include:

1- Soil surface cover that prevent rain drops forces to degrade soil particles (6 classes)
2- Soil conservation coefficient (6 classes)
3- Soil surface crust frangibility (4 classes)
4- Cryptogams cover percent (4 classes)
5- Soil erosion and intensity (4 classes)
6- Eroded materials (4 classes)
7- Litter cover percent (5 classes)
8- Small topographic features (5 classes)
9- Soil surface resistance to erosion (5 classes)
10- Soil structural sustainability (4 replicates)
11- Soil texture (4 classes)

In the next step, soil superficial condition was defined using three main criteria including sustainability, permeability and food chain which are indicators for soil characteristics in every rangeland. Secondary features are sub-members of these three main criteria. Eight (numbers 1, 3, 4, 5, 6, 7, 9 and 10) of 11 aforementioned indices were relate to sustainability, 6 (numbers 2, 7, 8, 9, 11 and 10) relate to permeability and 3 (numbers 4, 7 and 8) relate to food chain. As it is implied, this study was designed based on completely randomized statistical design. Analysis of Variance (ANOVA) and Duncan mean comparison test (α=0.05) were conducted to compare mean differences between various indices measured for every patches. SPSS statistical software package version 18 was applied for statistical analysis.

Results

Different plant species in every patch, was identified by a taxonomist in Botanical Research Center located at Ferdowsi University of Mashhad, Iran. Plant species was divided into seven groups. The following vegetation types were identified based on field assays:

1- A complex of *Artemisia aucheri* and *Agropyron intermedium*
2- A complex of *Artemisia aucheri* and *Astragalus commixtus*
3- *Artemisia aucheri*
4- A complex of *Acantholimon* sp. and *Artemisia aucheri+ Astragalus commixtus*
5- A complex of *Acantholimon* sp. and *Artemisia aucheri*
6- *Astragalus commixtus*
7- A complex of *Acantholimon* sp. and *Agropyron intermedium*

The ANOVA was conducted among seven ecological patches (vegetation types) for soil sustainability, permeability and food chain. The Results showed significant difference between patches for sustainability, permeability and food chain (Table 1).

Table 1. Analysis of Variance (ANOVA) among ecological patches for sustainability, permeability and food chain.

Source of variation	DF	Sustainability (%)	Permeability (%)	Food chain (%)
Ecological patches	6	100.53**	37.59**	14.72**
Error	14	0.32	0.16	0.15

** means significance at α=0.01

According to the means comparisons among the ecological patches, the percentage of *Artemisia aucheri* (46.83%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (with the amount of 41.7%) were higher than other forms of vegetative growth for soil sustainability (Table 2). The complex of *Acantholimon sp.*, *Artemisia aucheri* and *Astragalus commixtus* had the lowest amount in terms of soil sustainability (38%). The comparison of soil permeability indices for different types of plant covers showed that the percentage of *Artemisia aucheri* (32.06%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (33.5%) had the highest amount. Comparing soil permeability of ecological patches indicated that patches with a complex of *Artemisia aucheri* and *Astragalus commixtus* (27.76%), the complex of *Acantholimon sp.*, *Artemisia aucheri* and *Astragalus commixtus* (23.9%) and the complex of *Acantholimon sp.* and *Agropyron intermedium* (25.06%) were equal statistically and had the lowest values ($p \leq 0.01$) (Table 2). In terms of food chain, the ecological patches such as *Artemisia aucheri* (25.63%) and complex of *Artemisia aucheri* and *Agropyron intermedium* (27.66%) had the highest amount and they were in the first level. The second level is for *Astragalus commixtus* and *Acantholimon sp.*, *Artemisia aucheri*. The complex of *Artemisia aucheri* and *Astragalus commixtus* (16.36%), the complex of *Acantholimon sp.*, *Artemisia aucheri* and *Astragalus commixtus* (13.63%) and the complex of *Acantholimon sp.* and *Agropyron intermedium* (15.36%) were in the third level and had the lowest values ($p \leq 0.01$) (Table 2).

According to results, different types of plant species and as a consequence various ecological patches play a significant role in preventing soil particles to be eroded against erosive processes resulting in conserving soil resources in natural lands.

Table 2. Means of ecological patches (vegetation types) for sustainability, permeability and food chain.

Eecological patches (vegetation types)	Soil sustainability(%)	Soil permeability(%)	Soil food chain cycle(%)
Artemisia aucheri and *Astragalus commixtus*	41.7 a	25.76 c	16.36 c
Artemisia aucheri and *Agropyron intermedium*	48.13 cd	33.5 a	27.66 a
Artemisia aucheri	46.83 ab	32.06 a	25.63 a
Acantholimon sp. and *Artemisia aucheri* + *Astragalus commixtus*	38 e	23.9 c	13.63 c
Acantholimon sp. and *Artemisia aucheri*	44.06 bc	28.8 b	20.83 b
Astragalus commixtus	43.9 bc	29.23 b	21.43 b
Acantholimon sp. and *Agropyron intermedium*	40.56 cde	25.06 c	15.36 c

Means of column with the same letters are not significantly different based on Duncan method (α=0.05)

Discussion

Means comparisons of ecological patches were significantly different for soil sustainability permeability and food chain indices (P<0.01). According to various plant types and growth forms in the study area, result showed that the complex of *Artemisia aucheri* (shrub) and *Agropyron intermedium* (grass) resulted in the highest soil sustainability with a significant difference compared to other types of vegetation (p≤0.01) followed by patches consisting of the shrub *Artemisia aucheri* (Table 2). Large cover form and lying on the floor and strong and deep root system of this shrub species can be the reason. Low height of covering and a lot of density in the plant base are caused maximum soil conservation and stability. Abedi and Arzani (2004), Jafari *et al.* (2008) and Ghodsi *et al.* (2011) confirmed this subject in their research. It deserves mentioning that *Artemisia aucheri* and the complex of *Artemisia aucheri* and *Agropyron intermedium* showed the highest coefficient in conserving soil surface particles against high precipitation. Such an influence is argued to be the consequence of their growth forms that is in consistent with Abedi and Arzani (2006) research.

Soil texture did not differ for each patch type. Vegetation intensity also increased for perennial shrub species as well as for complexes consisting of shrubs and grasses. Such a complex is of a strong capacity to absorb degraded materials, hence, received a high score in this respect. Therefore, soil surface resistance to degrading forces (high precipitation and wind erosion) increases. Such an issue does not show a significant difference respecting to other complexes. *Artemisia aucheri* is one of the most predominant species in Dehbar rangelands. This species has low height but a high intensity of stems in lower and basal parts of the plant complex (patch) that leads to maximum soil conservation and soil sustainability (Ghodsi *et al.*, 2011; Jafari *et al.*, 2008).

A comparison of soil permeability index between different groups of plant types showed that patches with a complex of *Artemisia aucheri* and *Agropyron intermedium* could get the highest values followed by *Artemisia aucheri* with a statistically significant difference relative to other groups of plant types (p≤0.01) (Table 2). Lotfi and Heshmati (2010) proved that shrub species increase soil permeability that make them probable for being applied in restoring operations for rangeland ecosystems. Mayor and Bautista (2012) investigated amount and processes of runoff and water caused sediments at South West Spain rangelands. They compared sustainability and permeability indices of bared and vegetated soils using LFA approach. The results obtained from their study declared that amount of runoff is closely correlated to soil permeability that is vegetative cover increased permeability that in consequence resulted into reduced run off. This study revealed that *Artemisia aucheri* and the complex of *Artemisia aucheri* and *Agropyron intermedium* are ecological indicators for Dehbar region because of their outstanding role in conservation and sequestration of soil in the study area.

The comparison of food chain index for different types of plant covers declared that patches with a complex of *Artemisia aucheri* and *Agropyron intermedium* could get the highest values followed by *Artemisia aucheri* with a statistically significant difference relative to other groups of plant types (p≤0.01) (Table 2). Holm *et al.* (2002) in their study on wetlands and shrub lands of Western Australia resulted in that there was a strong correlation between soil permeability and sustainability indices with concentrations of soil organic matters so that increasing these organic matters will increase plant growth, soil stability and infiltration. Furthermore, they observed a faster rate of litter and organic matter degradation in patches consisting of *Artemisia aucheri* and *Agropyron intermedium*. Grass (herbal) species are degraded in a short time and returned to the soil organic sink because of their thin stems and tenuous leaves (Ghodsi *et al.*, 2011). Short-term lived and momentary roots of grasses substantially increase organic matters and humus in the surrounding soil (Sabeti, 1975). Shrubs, because of their wide spread root systems play an important role in taking up the minerals including K, Ca and Mn (Tongway and Ludwig, 1990). Grasses increase soil water holding capacity and enhance nutritional cycling system in natural ecosystems (Palmer *et al.*, 2001). In a study by Li *et al*. (2007), it was observed that shrubs significantly affect nutrition distribution mode and decrease run off and soil erosion. Woody plants and their litters cause more soil fertility because of increasing P and N levels in the soil as consequence of improved organic matters (Butterfield and Briggs, 2008).

Conclusion

In this study, some soil parameters were investigated such as soil sustainability, permeability and food chain cycling indices for Dehbar semi-steppe region, Iran using landscape functional analysis (LFA) approach. Results showed that patches consisting of the shrub *Artemisia aucheri* and the grass *Agropyron intermedium* as well as patches consisting of the Shrub *Artemisia aucheri*, solely, achieved the highest suitability for increasing the estimated indices with significant differences compared to other types of vegetation patches mainly because of their growth form. Thus, these two species play important roles in conserving and sequestrating soil particles in semi-steppe regions. Therefore, these two types of patches are considered as ecological indicators for the study area to be applied for restoration and rangeland management operations in the study area.

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نقش گونه‌های گیاهی و لکه‌های اکولوژیک در حفظ و تثبیت خاک اراضی طبیعی با استفاده از تجزیه و تحلیل کارکرد چشم‌انداز (مطالعه موردی: مراتع دهبار طرقبه، مشهد، ایران)

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چکیده. تخریب لکه‌های گیاهی می‌تواند شاخصی برای تشخیص نزول وضعیت مرتع باشد. لکه اکولوژیک سطحی از چشم‌انداز است، که باعث تجمع منابع در اکوسیستم می‌شود. ارزیابی صحت شاخص‌های سه گانه (نفوذپذیری، پایداری و چرخه عناصر غذایی خاک) ارائه شده توسط روش LFA، برای تعیین میزان کارایی و صحت این روش در مناطق نیمه خشک با حداقل هزینه ضروری به نظر می‌رسد. بنابراین تحقیق با هدف بررسی اثر گونه‌های گیاهی و فرم‌های متفاوت رویشی بر ویژگی‌های سطح خاک، در مراتع نیمه استپی دهبار طرقبه مشهد در سال ۱۳۹۳ انجام شد. بدین منظور، ۱۱ ویژگی سطح خاک در گونه‌های مختلف گیاهی در سه تکرار اندازه‌گیری شد و سپس فاکتورهای اندازه‌گیری شده در قالب سه مشخصه پایداری، نفوذپذیری و چرخه عناصر غذایی برای هر گونه گیاهی طبقه‌بندی گردید. نتایج نشان داد، که لکه بوته‌ای *Artemisia aucheri* (۴۶/۸۳٪) و لکه مخلوط بوته و علف گندمی *Artemisia aucheri* و *Agropyron intermedium* (۴۱/۷٪) نسبت به گونه‌ها و فرم‌های رویشی دیگر، پایداری را افزایش می‌دهند. ترکیب *.Acantholimon sp*، *Artemisia aucheri* و *Astragalus commixtus* کمترین مقدار را در ارتباط با پایداری خاک داشت (۳۸٪). مقایسه شاخص‌های نفوذپذیری خاک در رابطه با انواع پوشش های گیاهی نشان داد، که درصد *Artemisia aucheri* (۳۲/۰۶٪) و ترکیب *Artemisia aucheri* و *Agropyron intermedium* (۳۳/۵٪) بیشترین مقدار را داشت، در حالی که پچ‌های دیگر از لحاظ آماری با یکدیگر برابر بوده و کمترین مقدار را داشتند. در ارتباط با چرخه عناصر غذایی، پچ‌های اکولوژیکی از قبیل *Artemisia aucheri* (۲۵/۶۳٪) و ترکیب *Artemisia aucheri* و *Agropyron intermedium* (۲۷/۶۶٪)، دارای بیشترین مقدار بود. ترکیب *Artemisia aucheri* و *Astragalus commixtus* (۱۶/۳۶٪)، ترکیب *.Acantholimon sp*، *Artemisia aucheri* و *Astragalus commixtus* (۱۳/۶۳٪) و ترکیب *.Acantholimon sp* و *Agropyron intermedium* (۱۵/۳۶٪)، دارای کمترین مقدار بود ($p \leq 0.01$). در این تحقیق *گونه‌های Artemisia aucheri* و *Agropyron intermedium*، به عنوان معرف‌های اکولوژیکی منطقه مورد مطالعه قلمداد شده و می‌توانند برای انجام عملیات احیای مرتع پیشنهاد شوند.

کلمات کلیدی: لکه اکولوژیک، تجزیه و تحلیل عملکرد چشم‌انداز، فرم رویشی، مراتع نیمه خشک