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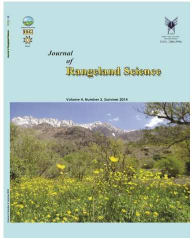

Full Length Article:

Comparison of Ecological Patches' Potentials and Functions in Rangeland Ecosystems (Case Study: Qahavand Rangelands, Hamedan Province, Iran)

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Abstract. Interrupting the processes which control ecosystem resources has dramatic impacts on the rangeland conditions. To protect ecosystems and landscape, it needs to understand the ecosystem processes which regulate the ecosystem resources. As main components of ecosystems, patches and inter-patches play important roles in energy and materials cascade. Ecologically, functional parameters such as stability, infiltration and nutrient cycling serve as key factors determining the movement of sediments, nutrients and organic matter as well. The present research aims to evaluate and compare the ecological patches of grasses, shrubs and mixed grasses- shrub using indices of stability, infiltration and nutrient cycling. Therefore, sampling was carried out in Qahavand rangelands located in the south east of Hamadan province, Iran on three patches of grass (*Cynodon dactylon*), shrub (*Camphorosma monspeliaca* L. and *Astragalus microcephalus*) and mixed grasses-shrub (*Camphorosma monspeliaca* + *Cynodon dactylon*) to evaluate the aforementioned parameters. Samples were taken along three 50 m transects using LFA (Landscape Function Analysis) method. Three indices of stability, infiltration and nutrient cycling and their individual contributions on the whole ecosystems' functions were determined. Results showed that all three patches vary significantly in function so that the mixed patch (*Camphorosma monspeliaca* + *Cynodon dactylon*) may be accounted for the highest values among the others. The study area had a good level of stability and nutrient cycling while infiltration rate was moderate mainly due to much proportion of clay in soil texture. Somehow, results of soil profile study in the area imply good stability and moderate infiltration.

Key words: Ecological patches, Stability, Infiltration, Nutrient cycling

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Introduction

Wise protection of ecosystems needs to understand the ecosystem pathways controlling resources. Patches and inter-patches are integral parts of ecosystems affecting the transportation and storage materials (Tongway and Ludwig, 2002). Patches may be found as single plant, stone or any other object conserving the resources (Whitford, 2002). Pattern and dynamics of patches represent the main characteristics of vegetation. Most researchers have emphasized on the importance of patch structure as a determinant of ecosystem functions (Fahrig and Paloheimo, 1988; Pickett and White, 1985).

Patched structure in vegetation communities frequently leads to some differences in survival, reproduction and migration of single species, life forms, etc. (Fowler, 1984; Gibson, 1988 a, b). Such heterogeneity not only is resulted from changes occurred in the abiotic components of environment, but also may be due to biotic components (passive and active). Getting aware of surface soil conditions seems to be essential. This helps us to conceive rangeland potentials and soil properties among many others. Nearly, all erosion types occur as a result of low soil infiltration and its instability (Rezaei *et al.*, 2006).

Wide varieties of vegetation are affected by environmental factors including climate, soil and topography. Establishment of different vegetation types due to vegetation ecological nature and distribution is based on the adaptation of various species to soil conditions and environmental agents (Heshmati *et al.*, 2007). The relationship between vegetation and environmental vegetation is found to be an important point promising the sustainable utilization, conservation and evaluation of rangelands. As an indispensable part, soil has a considerable importance for vegetation and others components. According to soil science literatures, some soil surface properties are closely tied to soil stability. In respect to empirical data and theoretical predictions within most landscapes, some resources including water, organic matter and nutrient cycle are characterized by patched distribution (Noy-Meir, 1973; Tongway, 1995). This pattern in turn improves productivity (Montana *et al.*, 2001; Noy- Meir, 1973) emerging as spatially heterogeneous vegetation along with perennial species surrounded by fertile soil matrix. Vegetation and soil parameters as the main ecological indices (Pyke *et al.*, 2002) are known as quantifiable measures showing dynamical state of a given habitat or landscape (Pellanet *et al.*, 2000).

To shed lights on the changes occurred in rangeland by LFA method facilitates understanding the natural processes, providing data transformation potential in the form of useful information to be used directly by users, managers and practitioners of rangelands. Vegetation or ecological patches are distributed in terms of magnitude and ecological nature of resources. However, vegetation associations are arranged according to the tolerance of different species to varying environmental resources (Heshmati, 2003). Patchiness in vegetation and soil varies in spatial scales from rangeland to basin scales (Li *et al.*, 2008) as well as individual plant species (Fahrig and Paloheimo, 1988; Fowler, 1984). Distribution of resources controlled by vegetation and soil in turn results in accurate regulating landscape functions and subsequently production and diversity (Rahbar, 2006; Tongway, 1995). It is worthy to note that discrete nature of vegetation is resulted from various erosion and deposition processes as well as complicated interactions between individual plants and surrounding soil matrix (Fowler, 1984; Tongway and Ludwig, 2002). Large vegetation patches play enormous

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ecological roles while providing many advantages for rangeland landscapes (Forman and Colling, 1995). As a result, a given landscape will lose major parts of it without big patches. At the same time, those landscapes characterized by large patches would not have some benefits and advantages. On the other hand, those small vegetation patches act as a corridor or springboard to vegetation colonization, harbor rare species and small habitats while improving diversity and heterogeneity in the habitat for those species restricted to small patches. Hence, small patches are of more advantages than the bigger ones. They may serve as the supplement of large patches instead of their substitution. Increased shrubs within a landscape exert some spatial changes in soils (Schlesinger *et al.*, 1996), change resource flow among shrub batches and inter-patches (Li *et al.*, 2008) and finally, strengthen shrubs consistency and durability (D'Odorico *et al.*, 2007).

Air and windburn nutrients, litters, decomposed materials and seeds are accumulated under shrubs' canopy cover while increasing the infiltration capability (Bhark and Small, 2003). Nonetheless, those bare inter-patches are exposed to high temperature and evapotranspiration. Subsequently, their organic nitrogen decomposition, denitrification and ammonium volatilization are lessened with the erosion emergence and low landscape function (Schlesinger *et al.*, 1990). The combined effects (outcomes) of such processes strengthen fertile islands around shrubs by which shrubs get more tolerant against environmental adverse impacts (Schlesinger *et al.*, 1996; Whitford, 2002).

Simultaneously, underground organs of grass have high contributions in forming aggregations both chemically and physically and improving soil stability and integrity as well. One of the most unique characteristics of grass patches is to form and colonize underground parts like complex and strong rhizomes, branched stolon and roots penetrating to soils deeper than 30 cm (Rahbar *et al.*, 2001).

Given above discussion, evaluating the contribution of grass and shrub patches to the rangelands' landscape has been done frequently. To understand this subject seems to be crucial to predict how arid and semiarid systems respond to the anthropogenic and environmental sharp changes (Tausch *et al.*, 1993).

Hence, to satisfy this end, the varying functions and structures related to rangeland patches as well as their implications in the whole ecosystem components should be evaluated. The present research aims to shed lights on functional and structural changes of ecological patches and its contribution in the whole ecosystem stability using three indices of infiltration, stability and nutrient cycling.

Materials and Methods

Study area

The study was conducted in Qahavand rangeland (Shara district) located in south eastern Hamadan province at 33°58´ to 35°44´ N and 48°49´ to 33°28´ E.

It is nestled in 1574 m above sea level. Study area is characterized by shallow saline gravels and some calcareous materials' accumulation. According to soil taxonomy, this is fall into American classes, Fine loamy, Sodic, Thermic Type and Haplo Calcides and pH ranged from 7.3 to 8.8 poor in organic matter that is less than 1% (Ahmadian *et al.*, 2010).

As it can be seen from high EC value, these soils are mostly saline. Soils have poor drainage consisting of clays in the absence of enough organic matter.

Within vegetation community dominated in the area, shrubs are encircled by some grass species. Such general structure can be distinguished as follows: grass (*Cynodon dactylon*), shrub (*Camphorosma monspeliaca* and *Astragalus microcephalus*) and grass-shrub mixture (*Camphorosma*

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monspeliaca + *Cynodon dactylon*). *Camphorosma monspeliaca* belonging to Chenopodiaceae family is a perennial shrub characterized by woody stems or a cushioned shape in the diameter of 20 cm covered by white fuzzes or mixed brown prostrate with 7 cm stems or flowery stems up to 100 cm. Leaves are 3-9 m long (Asadi, 2001). This species is distributed in different aspects all over the world (Turkey, Caucus, Iran, Central Asia, Afghanistan, Pakistan and North Africa) (Asadi, 2001). In Iran, it is identified as one species and two subspecies. Subsp. *monspeliaca* is found in the north and northwest (Mazandaran, Azerbayjan, Semnan, Zanjan and Tehran) and subsp. *lessingii* may be found in the northwest, west and center of Iran (Azerbayjan, Hamadan, Markazy, Chaharmahal Bakhtiari, etc.). *Cynodon dactylon* belonging to Graminae family is native to northern and eastern Africa, Asia, Australia and southern Europe. Its lamina is colored in grayish green in the length of 30 cm. Complex and deep root system enabled it to penetrate to about 2 m depth. It is mostly colonized in a creeping manner with stolon, rhizomes and seeds (Walker *et al.*, 2001). *Astragalus microcephalus*, a shrub species from Leguminosae family is native to eastern, Mediterranean and Middle East growing to 0.5 m (1ft 8in). The flowers are hermaphrodite (having both male and female organs) and suitable for light (sandy) and medium (loamy) soils and prefers well-drained soil with a suitable pH for acidic, neutral and basic (alkaline) soils. It cannot grow in the shade (Kotrebai *et al.*, 1999). All three species differ in morphology and architecture. *Camphorosma monspeliaca* has a spherical shape surrounded by its stems in circled manner, whereas Astragalus shrub grows as semi-prostrate or cone shaped. *Cynodon* spp. while dispersing in a creeping or prostrate manner called a rosette one. In addition, former species keeps its initial shape and during the year, it seems green while two latters lose their leaves and get into dormancy period (Aellen, 1967).

Sampling methods and data analysis

To evaluate functional characteristics of the desired rangeland, sampling was carried out in a landscape scale. For this, functional traits for the ecological patches were considered. The ecological patches were segregated as follows: grass (*Cynodon dactylon*), shrub (*Camphorosma monspeliaca* and *Astragalus microcephalus*) and grass-shrub mixture (*Camphorosma monspeliaca* + *Cynodon dactylon*). All patches were studied with respect to functional parameters including stability, infiltration and nutrient cycling (Tongway, 1995). Three 50 m transects were established as the function of area topography so that all transects were set from upslope to downslope. Then, the vegetated patches to bare inter-patches were selected. Each transect had five replications along which width and length of patches as well as inter-patches were taken down. Then, landscape function analysis model (Tongway and Hindley, 2004) was used to determine soil stability using soil cover, litter cover, cryptogam cover, crust brokenness, soil erosion type and severity, deposited materials, surface nature (resistance to disturbance), stability to wetting and infiltration by perennial grasses' basal area and shrubs and trees cover, litter, Soil surface roughness, resistance to disturbance, litter (origin and degree of decomposition), stability to wetting and texture and finally nutrient cycling was measured by perennial grasses' basal area and shrubs and trees cover, litter (origin and degree of decomposition), cryptogam cover and soil roughness (Table 1). Data statistical analysis was performed using Landscape Function Analysis (LFA) software in Excel developed by Tongway and Ludwig (2002). In addition to ecological patches' comparison, one-way analysis of

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variance (ANOVA) in a randomized manner by software $SPSS_{17}$ was done.

Patches were individually measured for eleven indices shown in Table 1; then, each index was calculated by summing the indices' scores and expressed in percent.

Table 1. Indices and its association with functional parameters

Index	Class Number	Functional Parameters		
		Nutrient Cycling	Infiltration	Stability
Crust brokenness	4			*
Soil erosion type and severity	4			*
Deposited material	4	*	*	*
Cryptogam cover	4	*		*
Rain splash protection	5			*
Litter	10			*
Origin and degree of decomposition	4	*	*	
Grass basal area	4	*	*	
Soil surface roughness	5	*	*	
Stability to wetting	5		*	
Soil resistance to disturbance	5		*	
Texture	4		*	

(*: Relation to interested functional trait)

Results

The ecological patches were segregated as follows: grass (*Cynodon dactylon*), shrub (*Camphorosma monspeliaca* and *Astragalus microcephalus*) and mixed grass-shrub (*Camphorosma monspeliaca* + *Cynodon dactylon*). Also, one inter-patch (bare soil) involved frequent identified inter-patches. According to variance analysis, all treatments were differed significantly in three indices such as stability, infiltration and nutrient cycling at probability level of 1% (Table 2).

Table 2. Results of variance analysis of landscape function indices in case study

Source of Variation	DF	MS		
		Stability	Infiltration	Nutrition
Between groups	4	92.110**	133.113**	210.909**
Within groups	10	1.592	6.053	4.382

**= Significance at probability level of 1 %, MS= Means square

Results of means comparisons using Duncan test for the stability implied that the mixed patch (grass+ shrub) was accounted for the highest stability rate (51.8%) among the others (Fig. 1). At the same time, the lowest stability rate was attributed to bare soil. The mixed and *Camphorosma* spp. had no significant differences. Other patches however were differed significantly to each other (P<0.5) (Fig. 1).

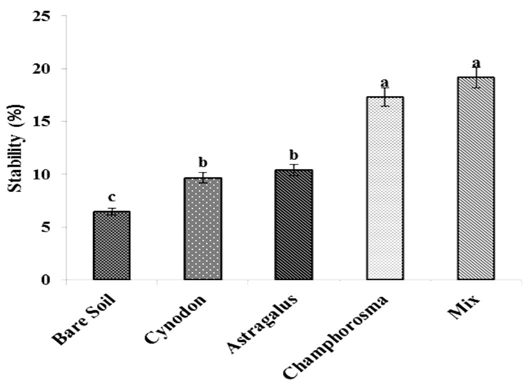

Fig. 1. Means comparison of stability among the studied patches (column followed by the same letters had no significant differences at 5% probability level of Duncan method)

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Means comparison analysis for stability index showed that soil cover in the mixed patch had the highest stability whereas the lowest percent was assigned to cryptogam cover in *Astragalus* patches (Fig. 2). According to means comparison analysis, *Astragalus* spp. and *Camphorosma* spp. patches did not differed significantly in terms of infiltration. Additionally, *Astragalus* spp. and *Cynodon* spp. patches were not varied at probability level of 5%. The highest and lowest infiltration rates were assigned to the mixed and bare soil patches, respectively (Fig. 3).

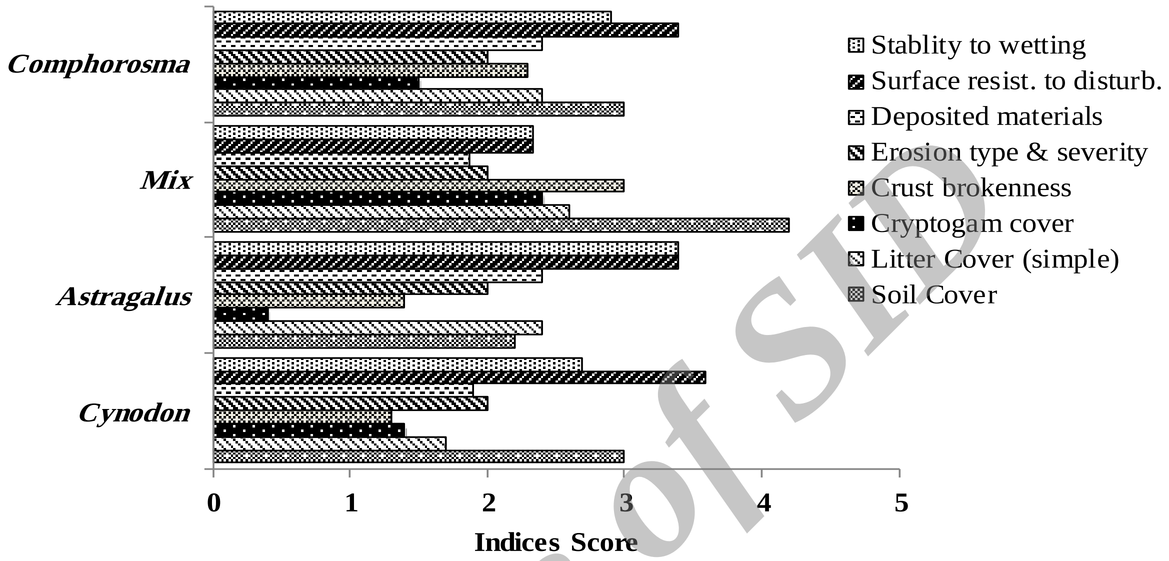

Fig. 2. Means of patches stability based on indices

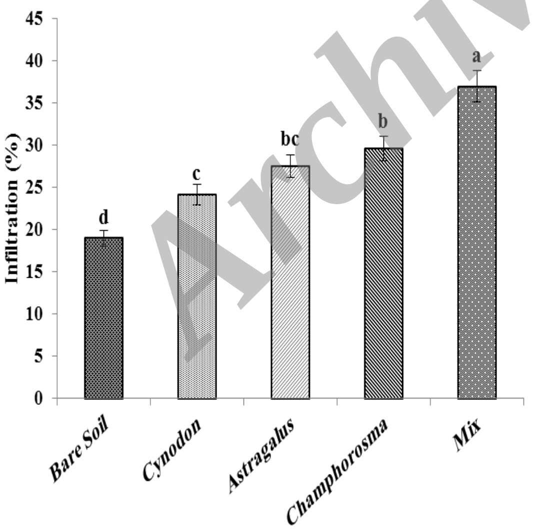

Fig. 3. Means comparison of infiltration among the studied patches (column followed by the same letters had no significant differences at 5% probability level of Duncan method)

Mean separation for the patches' infiltration in terms of the related indices showed that litter cover (original and incorporated) was accounted for the highest and lowest values for the mixed and *Camphorosma* spp., respectively (Fig.4).

The mixed and *Cynodon* spp. patches showed no significant difference for nutrient cycling. Similarly, both *Camphorosma* spp. and *Astragalus* spp. patches did not varied significantly ($P<0.5$). The lowest and highest nutrient cycling scores were attributed to the bare soil and mixed patches respectively among the studied treatments (Fig. 5).

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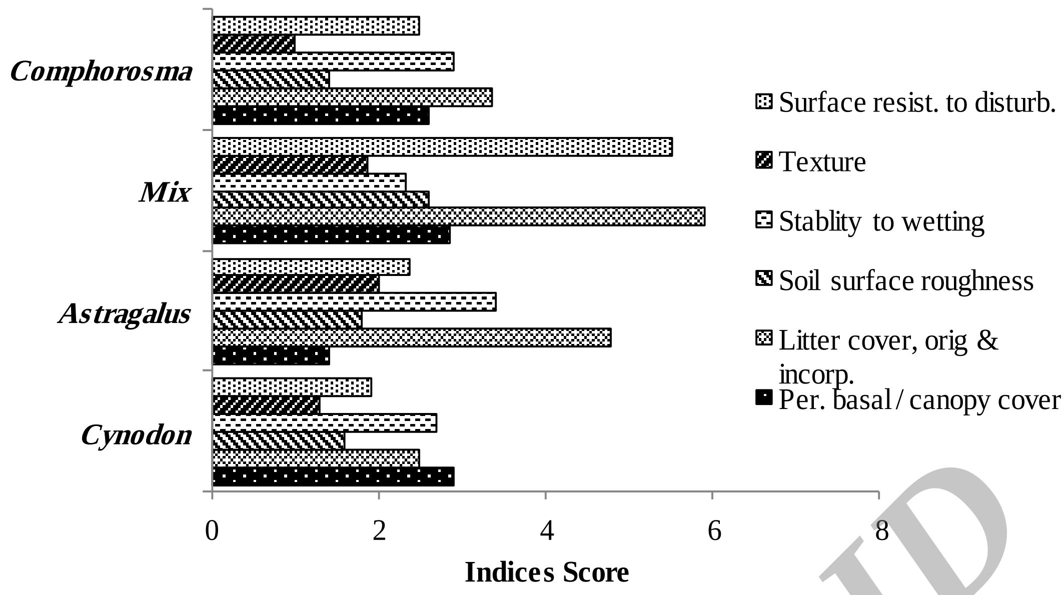

Fig. 4. Comparison of patches' infiltration based on the related indices

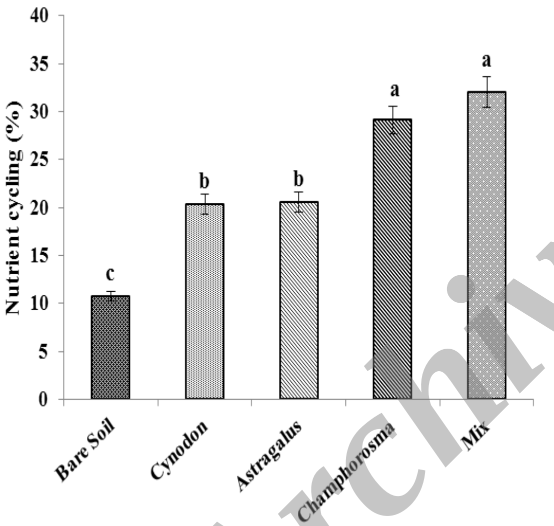

Fig. 5. Means comparison of nutrient cycling among the studied patches (column followed by the same letters had no significant differences at 5% probability level of Duncan method)

Also, means comparison for nutrient cycling in patches through the related indices revealed that soil surface roughness in the mixed patches showed the highest values among the others. In addition, cryptogam cover in *Astragalus* spp. patches had the lowest value for nutrient cycling (Fig. 6).

As for the contribution of individual patches in the whole ecosystem stability, mean separation analysis indicated that two patches of mixed and *Camphorosma* spp. were accounted for the highest contribution in the ecosystem stability showing no significant difference. The lowest contribution was attributed to bare soil which is not significantly different from *Astragalus* spp. and *Cynodon* spp. (Fig. 7).

As with the contribution of each patch in whole ecosystem infiltration, the mixed one showed the highest contribution in ecosystem infiltrating capability followed by *Camphorosma* spp. and finally, bare soil and Astragalus. The mixed one and *Camphorosma* spp. are not significantly different in terms of infiltration rate. Similarly, *Camphorosma* spp. and *Cynodon* spp. are not significantly different in terms of infiltration (Fig. 8).

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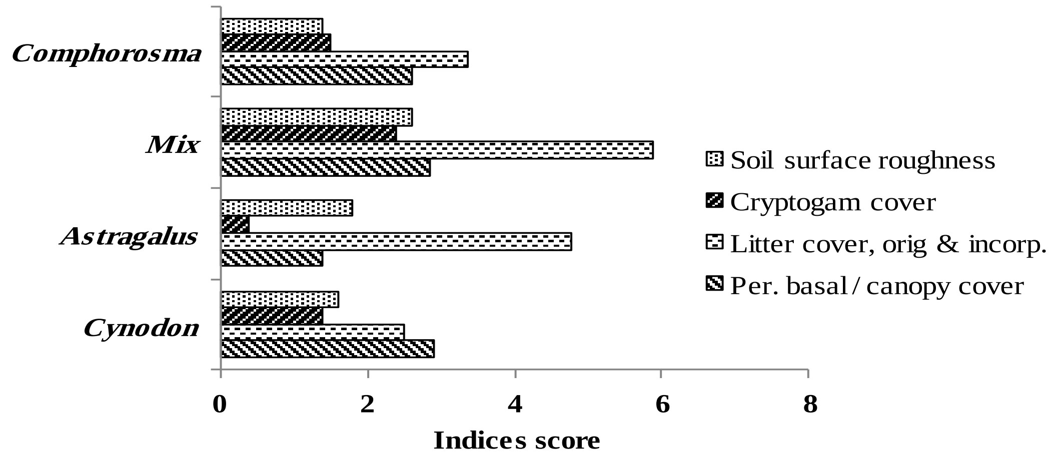

Fig. 6. Means Comparison of patches' nutrient cycling based on related indices

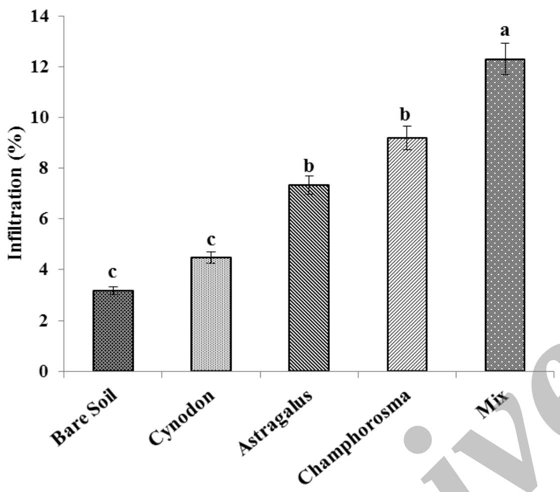

Fig. 7. Means comparison of individual patches' contribution in ecosystem stability (column followed with the same letters are not significant at 5% probability level of Duncan method)

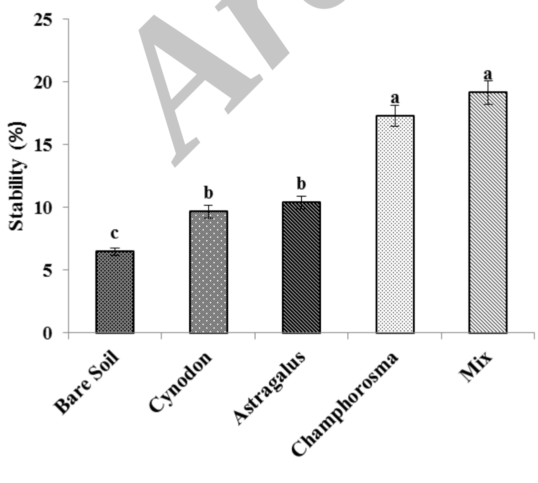

Fig. 8. Means comparison of individual patches' contribution in ecosystem infiltration (column followed by the same letters had no significant differences at 5% probability level of Duncan method)

In terms of nutrient cycling, Duncan test showed that the mixed patch has been accounted for the highest contribution in nutrient cycling of ecosystem. This was significantly differed from the others (P<0.5). Bare soil and *Astragalus* spp. had the lowest nutrient cycling in case study with no significant differences (Fig. 9).

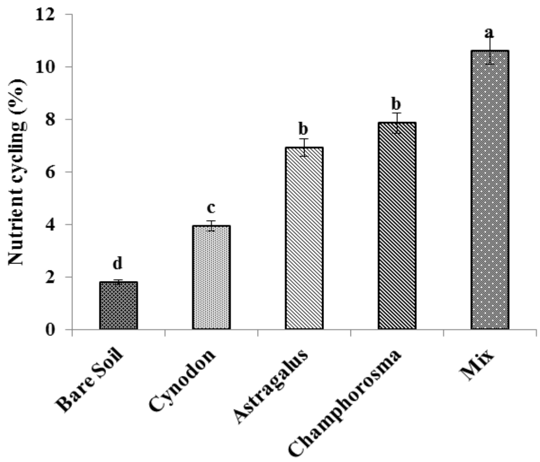

Fig. 9. Means comparison of individual patches' contribution in nutrient cycling (column followed by the same letters had no significant differences at 5% probability level of Duncan method)

Discussion and Conclusion

Presumably, the main reasons for high percent of triple indices (infiltration, stability and nutrient cycling) in mixed patch (grass+ shrub) as well as their remarkable contribution in landscape stability are the withstanding against wind, accumulation of organic matter,

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silt, sand and litter and all together improving grass or shrub establishment. This is because those patches regulate water dynamics and heat transference (Charley and West, 1975; Charley and West, 1977; Aguiar and Sala, 1994). Presence of big patches of shrub and grass in saline soils of case study may be resulted from grass seed dispersion while trapping them by *Camphorosma* spp. acting as a nurse species and providing germination conditions for grasses. This is confirmed by the findings in Patagonia desert where shrubs are encircled by a loop of grasses (Soriano *et al.,* 1994). Such mosaic pattern in the arid and semiarid conditions might be resulted from a mutual or one-way symbiosis (Asadi, 2001).

Low infiltration rate in some patches including bare soil may be attributed to the following reasons: 1) during rainfall and subsequently runoff, the suspended materials fill the soil pores through forming a seal that may be blockage micro-pores, 2) upon absorbing water dissolved cations and due to the expansion properties of clays, clays are swelled while lowering soil particles' pores; in other words, this occurs when water contained organic matter and some exchangeable ions such as Na^+ and K^+ and 3) algae and bacteria lead to blockage and less infiltration, especially when water is enriched by nutrients (Rahbar *et al.,* 2001).

Shrubs and shrub+ grass patches scored high infiltration as compared to the others. This may be attributed to the extended root system which in turn paved the suitable way to water to be infiltrated to soil. High nutrient cycle rate in the mixed patches is resulted from the increased organic matter and nitrogen die to rapid litter decomposition in grasses and secondary litters (Rahbar *et al.*, 2001). Increased level of organic carbon stems from the sedimentation and deposition processes containing litters from upslope as well as increased soil saturation percent in turn regulating soil temperature and soil microbial activity. Another important reason for high stability and nutrient cycling is found to be close canopy cover and two heterogeneous root systems for taking up nutrient absorption and cycling which is in line with the results reported by Tongway and Hindely (2004).

Any weaknesses and losses in such system impose negative nutrient dynamics and cycle. A study conducted in Australia (Tongway, 1995) confirmed such idea where vegetation disturbance and losses led to the degradation of side plants and the lowering of soil conservation. According to Soriano *et al.* (1994), mixed patches of shrub + grass in Patagonian desert were only accounted for 18% of vegetation community; however, it was responsible for 44% of total ecosystem production (Soriano *et al.*, 1994). These reports suggest high importance of mixed patches for the arid and semiarid ecosystem functions. As a whole, landscape function in terms of infiltration, nutrient cycling and stability was high thanks to much shrub density as well as mixed patches. This results in better moisture conditions, higher infiltration due to much biomass and nutrient cycle for rapid annual biomass decomposition in previous years. Higher stability might be attributed to the increased species diversity within mixed patches. The last, but not the least, ecosystem function may be undertaken as the evaluation of material cycle and energy flow resulted from fauna and flora interactions with their ambient environment. Indeed, arid regions and saline soils made by anthropogenic activities have some complicated functions arising too many questions for the researchers to be responded. For instance, sine N decomposition and mineralization just occur in upper horizons, so how do grasses and shrubs respond to such variations? Whether does the grazing change the relative

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importance of competition or symbiosis and then the shrubs: grass ratio or not? Can patches studied in the present research be considered as an aspect of biodiversity while playing important roles in the production and diversity association?

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مقایسه پتانسیل و عملکرد لکه‌های اکولوژیک در اکوسیستم‌های مرتعی (مطالعه موردی: مراتع قهاوند، استان همدان، ایران)

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چکیده. حفاظت اکوسیستم‌ها و چشم اندازها مستلزم درک فرایندهای اکوسیستم که منابع اکوسیستم را کنترل و تنظیم می‌کنند می‌باشد. لکه‌ها و میان لکه‌ها، اجزای اکوسیستم‌ها می‌باشند که بر چرخه انرژی و گردش مواد در اکوسیستم کمک شایانی می‌کنند. خصوصیات عملکردی لکه‌های اکولوژیکی نظیر پایداری، نفوذپذیری و چرخه عناصر مغذی از عوامل کلیدی تعیین کننده سرانجام و حرکت رسوبات و مواد آلی می‌باشند. هدف این مطالعه ارزیابی و مقایسه نقش لکه‌های اکولوژیکی گراس‌ها، بوته و مخلوط گراس-بوته در عملکرد با استفاده از شاخص‌های پایداری، نفوذپذیری و چرخه عناصر مغذی می‌باشد. بدین منظور در منطقه جنوب شرق استان همدان، شهر قهاوند نمونه‌برداری در سطح چشم‌انداز که شامل سه لکه گراس (***Cynodon dactylon***)، بوته(***Camphorosma monspeliaca* L.**) و ***Astragalus microcephalus***) و مخلوط گراس-بوته (***Cynodon dactylon* + *Camphorosma monspeliaca***) انجام و ویژگی‌های عملکردی مرتع مورد بررسی، مطالعه شد. نمونه‌برداری در سه ترانسکت ۵۰ متری انجام شد و با استفاده از مدل LFA سه ویژگی پایداری، نفوذپذیری و چرخه مواد غذایی و نقش لکه‌ها در پایداری نفوذپذیری و چرخه مواد مغذی کل اکوسیستم تعیین گردید. نتایج نشان داد که سه لکه مورد بررسی دارای عملکرد متفاوت بوده و از نظر آماری اختلاف معنی‌داری داشتند، به طوری که لکه مخلوط (***Cynodon dactylon* + *Camphorosma monspeliaca***) دارای بیشترین مقادیر در همه شاخص‌های عملکردی بود. منطقه مورد مطالعه از نظر پایداری و چرخه عناصر غذایی در حد خوبی قرار داشت در حالی که از نظر ویژگی‌های نفوذپذیری در سطح متوسطی بود که به دلیل وجود مقدار فراوان رس و شوری خاک بود. در عین حال نتایج پروفیل خاک در منطقه حاکی از پایداری خوب و چرخه عناصر و نفوذپذیری متوسط در منطقه مطالعاتی بود.

کلمات کلیدی: لکه‌های اکولوژیک، پایداری، نفوذپذیری، چرخه عناصر مغذی

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