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Research and Full Length Article:

Use of Medicinal Species as an Ecological Indicator for Interpreting Changes in Rangeland Status (Case Study: Javaherdeh Rangelands of Ramsar)

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Abstract. The use of modern methods in the analysis of rangeland ecosystems has received much consideration. The study of the diversity of medicinal and sometimes toxic species in rangelands can be regarded as an indicator of ecological status changes in rangeland ecosystems. In the present study, Javaherdeh mountain rangelands in north of Iran were selected under three sites including long-term exclusion, medium-term exclusion, and grazing during 2018-2019. Sampling was performed in each plant type with 4 transects of 200 meters and a random point every 10 m. Identification of species was carried out using published methods. Shannon's diversity, Margalef's richness, dominance, and evenness indices were determined for each plot. The means comparisons were made for the three study sites using one-way ANOVA in SPSS v.22 software. According to the results, the highest values of diversity and richness indices for medicinal plants (1.817, 2.370) and total plants (2.062, 3.132) were calculated for the long-term exclosure. The evenness index for total species in the medium-term exclosure (0.588) and grazing area (0.620) was almost similar and higher than the amount of the long-term exclosure (0.058). However, the mentioned index for medicinal species in long term exclosure (0.739) was higher than two other sites. The dominance index for total plants in the grazing area (0.260) was higher than two other sites; however, this index of medicinal plants was higher in the grazing (0.355) and medium-term exclosure (0.393) sites as compared with the long-term exclosure (0.224). Overall, species diversity indices of medicinal plants could be a proper tool to interpret the ecological changes in range conditions. Therefore, ecological management of rangelands could be achieved through understanding and knowledge of these changes.

Key words: Species diversity, Species richness, Bioindicators, Rangeland, Javaherdeh Ramsar

Introduction

The disturbance of ecological balance in rangeland habitats causes changes in rage rangeland conditions (Stringer and Reed, 2006; Petz *et al.*, 2014) including negative impacts on ground cover, changes in rangeland species composition (Waters *et al.*, 2020) which native and palatable species are eliminated and unpalatable and invasive species (low palatable, medicinal and toxic species) such as *Malva neglecta, Stachys byzanthina, Phlomis olivieri* and *Hercleum persicum* increase in the habitats (Vallentine, 1990; Hoshino *et al.*, 2009). For instance, the results of Ji *et al.* (2020) show that heavy grazing significantly reduced total aboveground biomass, vegetation cover with increasing of livestock stocking rate, and the presence of palatable species so that the rangeland habitats will be occupied by invasive and toxic species (Khalatbari *et al.*, 2014; Karami *et al.*, 2019). According to the findings reported by Eldrige *et al.* (2018), exotic plant richness is also increased when livestock activity rises. Subsequently, invasive alien plants are estimated to reduce the value of livestock production (O'Connor and Van Wilgen, 2020).

Inventory of rangeland ecosystems is a step towards showing the deviations from the ecological balance. Nowadays, range managers are more interested in taking into account the ecological considerations for rangeland analysis (Jouri *et al.*, 2009) so that species diversity is among the indicators considered in assessing the changes in range ecological condition (Salarian *et al.*, 2015). Species diversity indicates the adaptability of species to the climate and geography of the region (Sahli and Conne, 2006). It is stated that ecosystem sustainability and health are dependent on species richness and diversity, which biological diversity and consequently, species richness decrease by the destruction of natural habitats (Yeylaghi *et al.*, 2012; Jafari *et al.*, 2017). Species diversity and richness were introduced as the basis of evaluating the range condition regarding the reports of Mesdaghi and Gholamibaghi (2008). In another study, similar results were reported through the effect of livestock grazing (Louhaichi *et al.*, 2009). Lyseng *et al.* (2018) studied the long-term grazing impacts on vegetation diversity and concluded while long-term grazing changed the composition and cover of certain functional groups, overall changes to plant diversity were limited. Furthermore, species diversity and related parameters such as species composition, dominance, evenness, and number of species are applied in assessing the ecological condition of ecosystems (Goodman, 1975). According to the researchers' findings, species diversity and richness have a direct relationship to range condition (Moridi *et al.*, 2007; Nikan *et al.*, 2012). Species diversity and richness have also been related to grazing intensity and traditional human activities; hence, the plant diversity and richness could be preserved by keeping human activities balanced in these ecosystems (Haynes *et al.*, 2013; Gafna *et al.*, 2017). Sometimes, abiotic factors affect vegetation diversity and composition as well (Lakey and Dorji, 2016).

The destruction of natural habitats due to living disturbances such as grazing and human activities, recreation and tourism can cause diminishing of the plant species diversity and richness (Mligo, 2006; Sokhanvar *et al.*, 2016). Some studies have compared the species diversity indices under three different conditions of the exclosure, moderate grazing, and overgrazing. The results revealed that the highest and lowest values of diversity indices (richness and evenness) were recorded by the exclosure and heavy grazing sites, respectively (Salami *et al.*, 2007; Jahantab *et al.*, 2010; Gholinejad, 2015; Karami *et al.*, 2019). Ejtehadi *et al.* (2002) have reversely shown lower values of species richness, evenness, and diversity in the exclosure site as compared with the grazing site in the Torogh Basin. Sokhanvar *et al.* (2016) have also reported the highest values of species diversity for the moderate grazing site.

Many studies have reported that the heavy grazing or long-term grazing on rangeland under different ecological conditions are causing the changes in vegetation structure and replacement of current species by toxic, medicinal, and low-value species. Occasionally, such disturbances could lead to the increased growth and propagation of medicinal and toxic species, which present low quality of the ecosystems (Wellstein *et al*., 2007; Saether *et al*., 2009; Cocca *et al*., 2012; Laliberté *et al.*, 2013; Rueda *et al.*, 2013). For example, the increase in the intensity of grazing in Iran's steppe Rangelands has led to the presence of low-value rangeland species so that the moderate-term grazing rest has been able to improve vegetation (Baghestani Maybodi *et al.*, 2020). On the other side, measuring the species diversity and its related parameters such as species composition, dominance, evenness, and the number of species can be done to determine the condition of terrestrial ecosystems such as a rangeland (Odum, 1960, 1964, 1977; Mesdaghi and Sadeghnejad, 2000; Reed *et al*., 2008). Therefore, the current research attempts to find out whether the medicinal herbs can be used as a keynote to analyse the rangeland condition.

Materials and Methods

Study area

The Javaherdeh mountain rangelands are located in North Alborz, between 50º 40´ E and 36º 54´ N with an approximate area of 9000 ha. The present study was conducted in three study sites including long-term exclosure (37 years) at an altitude between 1650-1950m, short-term exclosure (19 years) at 1950-2100m, and free-grazing site at 2100-3200 m on the same slope and edge (Table1). The average annual rainfall is about 750 mm (Climate information, 2018-2019), and according to the Emberger climate classification, the climate of the area is cold and semi-humid at altitudes between 1600-3200 m (Jouri, 2010). In terms of vegetation cover, the study area is located above the timberline with a dominant life form of grass-forbs. In addition, a spotted growth of shrubs is observed in some areas, replaced by cushion and thorny shrubs as the altitude increases. Sheep and goats are the dominant livestock in the study rangelands (Jouri, 1999).

Research Methods

In the current research, Due to the vegetation traits and environmental conditions in the region, the selection and sampling areas were random-systematically done (Mesdaghi and Sadeghnejad, 2000) in the stand area in three sites. Sampling was performed in each plant type with 4 transects of 200 m and a random point every 10 m (Arzani and Abedi, 2015).The plot size (1m^2) was determined by a minimal area method (Cain, 1932).

Table 1. Identification site case study

Site	Vegetation type	Altitude (m)
Long-term exclosure	*Bromus tomentulus- Dactylis glomerata- Stachys byzantina*	1650-1950
Mid-term exclosure	*Poa pratensis- Bromus tomentosus-Stachys byzantina*	1950-2100
Grazing area	*Poa pratensis- Stachys byzanthina- Onobrychis cornuta*	2100-3200

The identification of rangeland and medicinal plants was performed using the Colored Flora (Ghahraman and Atar, 1998; Mozafarian, 2015) and Flora Iranica (Rechinger, 1963-2005). The range condition and trend were determined by the four-factor modified method (Parker, 1950) and the trend balance method (Moghadam, 2005), respectively. The formulas presented in Table 2 were used to determine the diversity, richness, and other indices (Ejtehadi *et al.*, 2009). Presence and absence, percentage of plant species cover and plant density were considered as the most important criteria for measuring species diversity and richness indices.

Table 2. The formulas of diversity, richness, evenness, and dominance indices

Indices	Index abbreviation	Formula	Range	Reference
Diversity	Di	$H' = -\sum_{i=1}^{s} P_i \mathrm{Ln}\, P_i$	0- 4.5	Shannon-Wiener (1949)
Richness	Ri	$D_{mg} = \frac{S-1}{\mathrm{In}N}$	0-∞	Margalef (1957)
Evenness	Ev	$\hat{D}_{Max} = \frac{1}{s}$	0-1	Pielou (1975)
Dominance	Do	$C = \sum \left(ni/N \right)^2$	0-1	Simpson(1949)

In the table,
n is the number of species and
p_i is the relative abundance of each species, calculated as the ratio of individuals of species *i* to the total number of individuals of all species;
Ln is the logarithm at base *n*,
H' is the Shannon index as calculated with natural logarithms,
S is the number of species;
N number of individuals.

Statistical Analysis

Species diversity and richness indices were calculated using PAST v.2.1[1] software to determine the correlation between the rangeland condition and species life forms; correlation coefficient, and step-wised regression model (standard equation) were employed to determine and show the effective life form plants in the rangeland condition as well. It is stated (Nathans *et al.*, 2012) that the beta coefficient was used to determine the contribution of each independent variable to the distribution variance of the dependent variable (the range condition here). Duncan's test was used to compare the means of three sites.

Result

a) Floristic and range condition analysis

Several numbers of plant species (287 species), belonging to 43 families and 166 genera, were collected from the altitudes between 2000-3000 m a.s.l of which 61 were identified as medicinal species in Table 3 (25 families and 55 genera). The most important families in the study area were Poaceae (46 species), lamiaceae (29 species), Rosaceae (30 species), Apiaceae (22 species), Fabaceae (22 species), Brassicaceae (18 species), Asteraceae (19 species), and Scrophulariaceae (9 species). On the other hand, among the medicinal species studied, Asteraceae and lamiaceae, each with 8 species, and Brassicaceae 6 species and Fabaceae with 7 species were the most frequent plant families.

1-http://folk.uio.no/ohammer/past/index.html

Table 3. A selected list of species in the study area（Star sign *: Medicinal plants）

Scientific Name of Species	Family Name	Life form	Biological type	Altitude m
Acantholimon hohenackeri	Plumbaginaceae	P	Ch	3000
Agropyron caucasicum	Poaceae	P	He	2200
Aegilops sp.	Poaceae	A	Th	1700-2800
*Achillea millefolium**	Boraginaceae	P	He	1700-2000
*Alchemilla vulgaris**	Rosaceae	P	He	2000-3000
Allium akaka *	Alliaceae	P	Ge.b	2400
Allium aucheri	Alliaceae	P	He	2300-3200
*Alyssum minus**	Brassicaceae	A	Th	2300
Anagalis arvensis	Primulaceae	A	Ch	2100-2300
Anthemis mazandaranica	Asteraceae	A	Th	1000-2000
*Anthemis Triumfettii**	Asteraceae	P	He	2200-2800
Artemisia annua	Asteraceae	A	Th	1000-2300
Artemisia absinthium *	Asteraceae	P	He	2200-2600
*Astragalus sp.**	Fabaceae	P	He	2000-2900
Astragalus microcephalus *	Fabaceae	P	He	2200-3000
Atropa acuminata	Solanaceae	P	He	1800
Berberis integerrima *	Berberidaceae	P	Ph	2550
Brassica nigra *	Brassicaceae	A	He	1700-2000
Bromus briziformis	Poaceae	A	Th	1400
Bromus danthoniae	Poaceae	A	Th	2400
Bromus tectorum	Poaceae	A	Th	2200
Bromus tomentellus	Poaceae	P	He	2000-3000
Bromus tomentosus	Poaceae	P	He	2300-3000
Campanula glomerata	Campanulaceae	P	He	2500
*Capsela bursa-pastoris**	Brassicaceae	A	Th	2000-2200
Carum carvi *	Apiaceae	P	He	2500-2750
*Centaurea nigra**	Asteraceae	P	He	2000-2100
Chenopodium sp.	Chenopodiaceae	A	Th	1800
Cicaea Lutetiana	Onagraceae	P	He	1800
Convulvulus arvensis *	Convolvulaceae	A	Th	1900-2100
Coronilla varia	Fabaceae	P	He	2300
*Cirsium Vulgare**	Asteraceae	P	Ge	3000-3100
*Crambe orientalis**	Brassicaceae	P	He	2200-2600
Cuscuta Epithmum	Cuscataceae	A	Th	2400
Dactylis glomerata	Poaceae	P	He	2500
Draba Huetii	Brassicaceae	A	Th	2400
Echium amoenum *	Boraginaceae	A, B	He, Th	1450-2250
*Echinops ritrodes**	Asteraceae	P	He	2200
Erodium dimorphum	Geraniaceae	P	He	3000
Eryngium coeruleum *	Apiaceae	P	He	1100-1600
Epuhorbia aucheri	Euphorbiaceae	A	Th	200-2900
Euphrasia pectinatae	Scrophulariacea	P	He	2600-3000
Ferula orientalis	Apiaceae	P	He	1800
Festuca ovina	Poaceae	P	He	2700-3000
*Fumaria officinalis**	Fumariaceae	A	Th	2500-3200
Fragaria vesca *	Rosaceae	P	He	2000-2200
*Fraxinus excelsior**	Oleaceae	P	Ph	2000
*Galium verum**	Rubiaceae	P	Cr	2000-3200
Geranium collinum *	Geraniaceae	P	He	2500
Helianthemum nummularium	Cistaceae	P	He	1900
*Heracleum persicum**	Apiaceae	P	He	2100-3000
Hordeum violaceum	Poaceae	P	He	2000-3000
Hypericum performatum *	Hypericaceae	P	He	2000-2500
Hyssopus angustifolius	Lamiaceae	P	He	1950
Ilex Aquifolium	Aquifoliaceae	P	Ch	1600
Iris imbricata	Iridaceae	P	Ge.r	2000-3000
Juncus inflexus	Juncaceae	P	He	1800-2500
Juniperus communis	Cupressaceae	P	Ph	2000-3000
Lathyrus pratensis *	Fabaceae	P	He	1900-2200
*Lepidium sativum**	Brassicaceae	P	He	2000-2200
Linum nervosum	Linaceae	P	He	2400-2600
Lolium perenne	Poaceae	P	He	1100
Lotus corniculatus	Fabaceae	P	He	1900
Malus domestica *	Rosaceae	P	Ph	2000-2500

Scientific Name of Species	Family Name	Life form	Biological type	Altitude m
Malva neglecta *	Malvaceae	P	He	2500-2700
Marrubium vulgare	Lamiaceae	P	he	1400-1800
Medicago polymorpha	Fabaceae	A	Th	2000-3000
Melilotus albus	Fabaceae	A, B	He, Th	2100
*Mentha spicata**	Lamiaceae	P	He	2300-2800
*Nepeta racemosa**	Lamiaceae	P	He	2400-2800
Onobrychis cornuta *	Fabaceae	P	He	1900-2200
Onobrychis michauxii	Fabaceae	P	He	1800
Orobache alba	Orobanchaceae	A	Ge	2800
Papaver bractaetum	Papaveraceae	P	He	2800
Phalaris arundinacea	Poaceae	P	Ge.r	2800
Phleum iranicum	Poaceae	P	Ge.r	2400-2800
Phlomis olivieri	Lamiaceae	P	He	1800
Pimpinella anisum *	Apiaceae	P	He	2100-2500
Plantago ovata *	Plantaginaceae	P	He	2000-2500
*Plantago major**	Plantaginaceae	P	He	2950
Poa pratensis	Poaceae	P	He	2400-2600
Poa trivialis	Poaceae	P	He	1900
Polypogon semiverticillatus	Poaceae	A	Th	1650
Potentilla meyeri *	Rosaceae	P	He	2400-2600
*Primula auriculata**	Primulaceae	P	He	2100-2800
Prunus spinosa *	Rosaceae	P	Ph	2600
Pyrus boissieriana	Rosaceae	P	Ph	1550
Rhynchocorys maximae	Scrophulariacea	P	He	1400-2500
Rosa sp. *	Rosaceae	P	Ph	3200
Rumex elbursensis Boiss *	polygonaceae	P	He	2200
Ranunculus arvensis *	Ranunculaceae	P	He	2000
*Salvia staminea**	Lamiaceae	P	He	2000-3000
Sambucus ebulus *	Caprifoliaceae	P	He	2100-2400
Sanguisorba minor	Rosaceae	P	He	1600-2800
Secale cereale	Poaceae	P	He	2200-2600
Sedum album	Crassulaceae	P	He	2000-3000
*Senecio vulgaris**	Asteraceae	A	He	1500-2000
*Silene latifolia**	Caryophyllacea	P	Th	2000-2900
Sisymbrium Loeselii *	Brassicaceae	A	Th	1800-2000
Stachys byzantina	Lamiaceae	P	he	1200-2800
*Stachys lavandulifolia**	Lamiaceae	P	He	2200-2900
Tanacetum Parthenium *	Asteraceae	P	Ge.r	1900-3400
Teucrium polium *	Lamiaceae	P	he	2200
*Thymus kotschyanus**	Lamiaceae	P	Ch	2400-3000
*Tragopogon pratensis**	Asteraceae	A	Th	1900-2200
*Trifollium pratens**	Fabaceae	P	He	2200
*Trifollium repns**	Fabaceae	P	He	1900-3200
Urtica dioica *	Urticaceae	P	He	1000-3400
Valeriana clarkei	Valerianaceae	P	He	2900
*Verbascum speciosum**	Scrophulariacea	A, B	He, Th	2100-2900
Veronica argute-serrata *	Scrophulariacea	A, B	He, Th	2000-2200
Vicia cracca *	Fabaceae	P	He	2200
Vicia persica	Fabaceae	P	He	2500-3000
Viola arvensis *	Violaceae	A	Th	1900-2000

A: Annual, B: Biennial, P: Perennial, Th: Therophyte, He: Hemicryptophyte, Ch: Cryptophyte, Ge: Geophyte, Ph: Phanerophyte

According to the humid climate of the area, the range condition studied by the modified six-factor was determined to be good, fair, and poor for the long-term exclosure, medium-term exclosure, and free-grazing sites, respectively. Table 4 shows the results of the range condition and trend for the three study sites.

Table 4. Results of range condition and trend determination

Site	Range condition scores	Range condition quality	Range trend
Long-term exclosure	43.08	Good	Progressive
Mid-term exclosure	32.18	Fair	Progressive
Grazing area	28.93	Poor	Regressive

The significant levels ($P<0.05$) of the rangeland condition and other independent variables showed that except shrub forms of the total plants (TP) and medicinal plants (MP) and perennial grasses for the medicinal plants, other forms had significant correlations with range conditions (Table 5).

Table 5. Abstracted ANOVA results of the life forms and the range condition

life form	F stats	Sig.
Annual grass (TP)	4.179	0.017^{*}
Annual grass (MP)	6.333	0.002^{**}
Perennial grasses (TP)	201.431	0.000^{**}
Perennial grasses (MP)	1.028	0.359^{ns}
Annual forbs (TP)	53.125	0.00^{**}
Annual forbs (MP)	24.768	0.00^{**}
Perennial forbs (TP)	6.959	0.001^{**}
Perennial forbs (MP)	9.106	0.00^{**}
Shrubs (TP)	0.38	0.684^{ns}
Shrubs (MP)	0.38	0.684^{ns}
Bushy Trees (TP)	4.414	0.013^{*}
Bushy Trees (TP)	6.05	0.003^{**}

*: P<0.05, **: P<0.01, and ns: non-significant

The beta coefficient from the standard equation showed that the increase of annual forbs (total plants) such as *Senecio elbursensis*, *Alyssum minus*, *Echium amoenum*, and *Calendula persica* had a negative impact on the rangeland condition in the long-term exclosure. On the other hand, in the long-term exclosure, annual and perennial forbs (medicinal plants) such as *Convolvulus arvensis*, and *Polygonum persicaria* had a negative impact on rangeland condition (Table 6). Also, according to the following Table (6), the increasing of perennial grass species such as *Poa pratens*, *Dactylis glomerata*, *Bromus tomentellus* and annual and perennial forbs such as *Trefollium pratens*, *Sanguisorba minor* (perennial forbs) and *Plantago ovata* (annualal forbs) which are mostly native have positive effects, leading to the improvement of rangeland conditions.

Table 6. Abstracted equation coefficient Table for the sites of the area

Site	Standardized equation	R	R^2
Long-term exclosure (TP)	$Y = -0.352\,AF$	0.352	0.124
Long-term exclosure (MP)	$Y = -0.362\,AF - 0.447PF$	0.571	0.326
Mid-term exclosure (TP)	$Y = +0.352\,PF$	0.493	0.243
Mid-term exclosure (MP)	$Y = -0.208\,AF + 0.260PF$	0.304	0.093
Grazing area (TP)	$Y = +0.229\,PG + 0.219PF + 0.168AF$	0.323	0.104
Grazing area (MP)	$Y = +0.240\,PF + 0.1239PG$	0.273	0.074

AF: Annual Forbs, PF: Perennial Forbs, PG: Perennial Grass, TP: Total Plants, MP: Medicinal Plants

b) Bioindicators Indices Analysis

The analysis of the diversity and richness indices of the medicinal plants and the total plants in the long-term exclosure (LTE) area showed the highest levels while the evenness index of the medicinal plants was also the elevated rates in the same area (Table 7). The evenness index of the total plant and the dominance index of the medicinal plants were the exalted ratios in the medium-term exclosure (MTE) and the grazing areas (GA), respectively. Eventually, the dominance index of total plant was the highest rate in the grazing area.

According to Table 8, significant differences (*P<0.01*) were found among the three sites for all bioindicators indices of the medicinal and total plants. On the other hand, the indices are different from site to site.

Table 7. The average ± Standard Deviation of bioindicators indices in the area for medicinal plants (MP) and the total plants (TP)

Index	Species	Long-term exclosure	Mid-term exclosure	Grazing area
Diversity	Total Plants	2.062±0.046 [a]	1.806±0.042[b]	1.624±0.044[c]
	Medicinal Plants	1.817±0.048[a]	1.205±0.572[b]	1.299±0.045[b]
Richness	Total Plants	3.132±0.098[a]	2.673±0.111[b]	2.120±0.078[c]
	Medicinal Plants	2.370±0.092[a]	1.733±0.165[b]	1.462±0.058[c]
Evenness	Total Plants	0.058±0.017[b]	0.588±0.012[b]	0.620±0.094[a]
	Medicinal Plants	0.739±0.016[a]	0.681±0.018[b]	0.657±0.017[b]
Dominance	Total Plants	0.209±0.013[b]	0.229±0.010[ab]	0.260±0.014[a]
	Medicinal Plants	0.224±0.015[b]	0.393±0.024[a]	0.355±0.017[a]

Table 8. ANOVA analysis of bioindicators indices for three sites of the area for

Indices	Sources	df	MS	F	Sig.
Diversity (Total plants)	Between group	2	3.395	22.744	0.000**
	Within group	217	0.149		
	Total	219			
Diversity (Medicinal Plants)	Between group	2	8.239	44.266	0.000**
	Within group	217	0.186		
	Total	219			
Richness (Total plants)	Between group	2	19.44	28.243	0.000**
	Within group	217	0.688		
	Total	219			
Richness (Medicinal Plants)	Between group	2	16.99	18.822	0.000**
	Within group	217	0.903		
	Total	219			
Evenness (Total Plants)	Between group	2	0.123	6.626	0.002**
	Within group	217	0.022		
	Total	219			
Evenness (Medicinal Plants)	Between group	2	0.139	6.328	0.002**
	Within group	217	0.022		
	Total	219			
Dominance (Total plants)	Between group	2	0.05	4.012	0.019*
	Within group	217	0.013		
	Total	219			
Dominance (Medicinal Plants)	Between group	2	0.598	22.722	0.000**
	Within group	217	0.026		
	Total	219			

*: P<0.05, **: P<0.01

As it is seen in Fig. 1, the lower case letters *a* and *c* represent the largest and the lowest amount of bioindicators for three sites, respectively. For instance, the highest and lowest values of Shanon's diversity index were recorded in the long-term exclosure (LTE) and the grazing area (GA), respectively. Means of tratments for each index followed by the similar letter had no sig difference basd on Duncan.

Duncan test was employed to group the variables which were divided into three groups (Fig. 1). The grouping of variables was performed based on plant life forms.

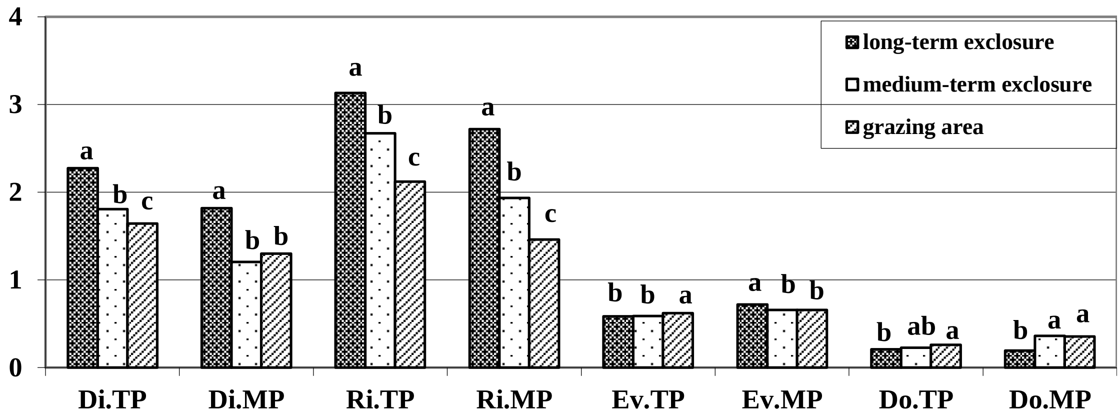

Fig. 1. Grouping of bioindicators for total plants and medicinal species in the three study sites
Code in Fig. 1: Diversity Total Plants (Di.TP), Diversity Medicinal Plants (Di.MP), Richness Total Plants (Ri.TP), Richness Medicinal Plants(Ri.MP), Evenness Total Plants(Ev.TP), Evenness Medicinal Plants (Ev.MP), Dominance Total Plants(Do.TP), Dominance Medicinal Plants(Do. MP)

The richness index, for both total plant and medicinal plants, was the highest in the

Discussion and Conclusion

The highest values of species diversity and richness indices for the medicinal plants and total plants were recorded in the long-term exclosure area. The reason is that after 30 years of exclusion in the area and the absence of any livestock and harvest of plant species, a variety of plant species has had enough time to stabilise their position in the region. Before the exclusion of the area, invasive species such as *Stachys byzantina* enterrd the area as a result of severe livestock grazing and remained. Soil climax has not been stabilised after more than 30 years of the exclosure in as much the species has occupied yet. Moreover, native species such as *Dactylis glomerata*, *Trifolium repense*, *Festuca ovina*, and *Bromus tomentosus* have had enough time to return to the main area. Because of well palatability and so close to the village (Javaherdeh), the species have been severely grazed before the exclosure. Hence, only a few communities of these species could be found in thorny shrubs as well as rocky and inaccessible areas. However, the exclosure has provided an opportunity for these species to reoccupy, propagate, and regenerate in the area. Consequently, due to the presence of before-and-after species in the exclosure area, the highest diversity and richness of

three sites and the dominance index was the lowst one in the same sites.

medicinal plants and total plants were observed in the area. The results of the present study are following the findings that are reported by Odum (1960, 1964), Ejtehadi *et al.* (2002), Salami *et al.* (2007), Wellstein *et al.* (2007), Saether *et al.* (2009), Jahantab *et al.* (2010), Yeylaghi *et al.* (2012), Gholinejad (2015), Salarian *et al.* (2015), and Abdelsalam *et al.* (2017). The current findings, however, sre conflict to Yao *et al.* (2019) who have reported that the long term non-grazed exclosures significantly decreased biodiversity indicators i.e., Species richness, Shannon diversity indices, and Evenness indices of vegetation. On the other hand, Sigcha *et al.* (2018) reported a clear influence of grazing exclusion on soil properties and plant community composition and structure; however, no influence was found in species diversity.

On the one hand, the results presented in Table 7 showed that the evenness index in the short-term exclosure area and grazing area was almost similar and higher than the long-term exclosure area. Due to the presence of livestock on the grazing site and resting of grazing in the short-term exclosure area, the palatable species were grazed and hence have headed to reduce, and consequently, the invasive species have gradually increased in the area that the evenness index was increased. In other words, the number of each species in the occupied area has risen. This result is in agreement with the findings of Nikan *et al.* (2012), Khalatbari *et al.* (2014), Karami *et al.* (2019), Rotich *et al.* (2018) as well. The evenness index values of the medicinal plants were higher in the long-term exclosure site as compared with the two other sites. It can be interpreted in such a way that if the presence of all species in the study area (three sites) is assumed to be zero and only the medicinal plants are considered in the three sites, the long-term exclosure area shows the largest number of species per unit area (Table 7). The presence of these species (medicinal and invasive species) in the area was high in the long-term exclosure area (site) that has demonstrated the lack of soil climax. Such a presence of the medicinal and invasive species could be considered as an alarm since the regressive components and elements of rangeland are still observed in the long-term exclosure area (such as *Stachys byzantina*). Therefore, if intensive grazing restarts in the exclosure area, the rangeland condition will be returned to a poor condition and regressive state due to the presence of the mentioned species so that the evenness index emphasizes this important point. The findings of the studies reported by Mligo (2006), Louhaichi *et al.* (2009), Cocca *et al.* (2012), Rueda *et al.* (2013), Haynes *et al.* (2013), Lyseng *et al.* (2018) and Baghestani Maybodi *et al.* (2020) point out the changes in rangeland condition and thus, the increased number of unwanted species. Moderate human activities are a guarantee to the balanced rangeland condition (Zohdi *et al.*, 2018); therefore, in the study area, the warning signs should be taken into consideration.

The richness index of total species had higher values in the grazing area as compared with the two other study sites (Table 7). This result could be associated with the removal of palatable species and the presence of a small number of species in a wide area. For instance, higher altitudes of the study area are occupied with *Astragalus* and *Onobrichys* as well as a few numbers of *Thymus* and *Juniperus* genera. Approximately, the same results are reported by Ranyard *et al.* (2018).

As a result, the dominance of the total species in the grazing area is higher than the other two sites (short-term exclosure and long-term exclosure). The dominance index in the grazing and short-term exclosure areas was higher than the long-term exclosure area. Although the number of species per unit area is lower in the short-term exclosure, a large area is occupied by invasive and medicinal plants. As a result, the dominance of medicinal plants increased in the grazing area and the short-term exclosure as compared with the long-term exclosure. Increasing of unpalatable and invasive species in the grazing land or disturbed rangelands is reported by researchers such as Goodman (1975), Stringer and Reed (2006), Laliberté *et al.* (2013) and Petz *et al.* (2014). In general, the presence and diversity of medicinal and invasive species have increased with increasing of disturbances from livestock grazing (Eldrige *et al.*, 2018).

Regarding the results, the use of biological indices can provide a clear picture of changes in the rangeland ecosystem. In particular, a comparison between the diversity, richness, and dominance indices of medicinal plants and total species in the region could provide a more realistic interpretation of ecological areas. The results of the present study emphasize the researcher's remarks on assessing the condition of terrestrial ecosystems by studying the diversity index and its components (Odum, 1960, 1964, 1977; Reed et al., 2008; Jouri *et al.*, 2009; Khalatbari *et al.*, 2014). Overall, the rangeland ecological condition and its changes trend could be evaluated and interpreted by the medicinal plants in a given area. Therefore, this parameter as one of the evaluation parameters in rangeland research could be recommended to be taken into consideration by other researchers.

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استفاده از گونه‌های دارویی به عنوان یک شاخص اکولوژیک برای تفسیر تغییرات وضعیت مرتع (مطالعه موردی: مراتع جواهرده رامسر)

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چکیده. تمایل ارزیابان مراتع به استفاده از شیوه‌های نوین در تجزیه و تحلیل اکوسیستم پیچیده مرتع رو به سمت ملاحظات اکولوژیک گذاشته است. بررسی تنوع گونه‌های دارویی (و گاها سمی) در عرصه‌های مختلف مرتع، می‌تواند به عنوان شاخصی از تغییرات وضعیت اکولوژیک اکوسیستم‌های مرتعی تلقی شود. بدین منظور، مراتع کوهستانی جواهرده رامسر تحت سه سایت مطالعاتی (قرق بلندمدت، میان مدت و چرا) در سال ۱۳۹۸-۱۳۹۷ انتخاب شد. نمونه‌برداری در هر تیپ گیاهی با ۴ ترانسکت ۲۰۰ متری و به فاصله هر ۱۰ متر یک نقطه تصادفی انجام شد. شناسایی گونه‌ها توسط منابع معتبر صورت گرفت. شاخص‌های تنوع شانون، غنای مارگالف، چیرگی و یکنواختی برای هر پلات تعیین شد. با استفاده از روش آنالیز واریانس یک طرفه در محیط نرم افزاری SPSSv.22، مقایسه میانگین‌های سه منطقه انجام شد. نتایج نشان داد که شاخص تنوع و غنای گونه‌ای برای گونه‌های دارویی به ترتیب (۱/۸۱۷، ۲/۳۷۰) و کل (۲/۰۶۲، ۳/۱۳۲) در منطقه قرق بلند مدت بیشترین مقدار بوده است. شاخص یکنواختی برای کل گونه‌ها در قرق میان مدت (۰/۵۸۸) و منطقه چرا (۰/۶۲۰) تقریبا مشابه و بیشتر از منطقه قرق بلند مدت (۰/۰۵۸) بوده است. اما شاخص یاد شده برای گونه‌های دارویی در قرق بلند مدت (۰/۷۳۹) بیشتر از دو منطقه دیگر است. همچنین شاخص چیرگی برای کل گونه‌ها در منطقه چرایی (۰/۲۶۰) بیشتر از دو منطقه دیگر بوده اما در ارتباط با گیاهان دارویی شاخص چیرگی در منطقه چرایی (۰/۳۵۵) و قرق میان مدت (۰/۳۹۳) بیشتر از منطقه قرق بلندمدت (۰/۲۲۴) است. بنابراین شاخص‌های تنوع زیستی گونه‌های دارویی به خوبی توانسته‌اند مفسر خوبی برای تغییرات اکولوژیکی وضعیت مرتع باشند که با شناخت و آگاهی از این تغییرات دستیابی به مدیریت اکولوژیک مراتع نیز میسر خواهد شد.

واژگان کلیدی: تنوع گونه، غنای گونه‌ای، شاخص زیستی، مرتع، جواهرده رامسر