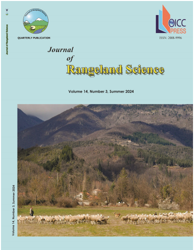

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Changes in species diversity and functional diversity of vegetation under different grazing intensities in Changizchal Rangelands, Mazandaran Province, Iran

Mansoureh Kargar[1,*], Majid Sadeghinia[2], Sara Farazmand[3]

[1]*Watershed and Natural Resources Administration of Alborz Province, Karaj, Iran.*
[2]*Department of Nature Engineering,Factually of Agriculture and Natural Resources, Ardakan University, Iran.*
[3]*Department of Rangeland and Watershed Management, Faculty of Natural Resources, Behbahan Khatam Alanbia University of Technology, Iran.*

*****Corresponding author:** kargar_sahar@yahoo.com

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Abstract:

Different indices of functional diversity such as Functional Richness (FRic), Functional Evenness (FEve) and Functional Divergence (FDiv) could help to understand the relationship between plant diversity and ecosystem function. Therefore, this study was aimed to evaluate changes in species diversity and functional diversity of vegetation under different grazing intensities in relation to soil physic-chemical properties in Changizchal rangelands, Mazandaran province, Iran. During the spring and summer of 2014, three functional traits including Specific Leaf Area (SLA), Vegetation Height (VH), and Leaf Dry Matter Content (LDMC) were measured in three grazing intensities (low, moderate and high). Taxonomic diversity was quantified using several indices including Species richness (S), Shannon (H), Evenness (E) and Simpson (D). In addition, functional diversity was quantified using single trait-based (FDvar) and multi trait-based indices (functional richness (FRic), functional divergence (FDiv), and functional evenness (FEve)). The result showed that functional richness and species richness increased at moderate grazing. Similarly, the higher values of FDvar of the SLA were observed in a moderate grazing. Whereas the FDvar of VH values significantly increased in light grazing. The low grazing induced the increase in the FDive and FEve coupled with decreasing soil organic carbon ($P < 0.05$). The FDvar for SLA had a positive relationship with soil N and P in low grazing. Stable grazing on Changizchal rangelands tends to increase competition for soil N and P, resulting in an increase in the functional richness in the grazed plant communities. The present study highlights the potential importance of low to moderate grazing intensities in mediating and reducing competition between plants for nutrient resources.

Keywords: Biodiversity; Rangeland stability; Grazing management; Leaf functional traits; Rangeland ecosystem

1. Introduction

Rangeland ecosystems are among the main territorial ecosystems which support several functioning and services for human society (Omidipour et al., 2021). The impact of biotic stress, particularly grazing pressure on plant diversity is quite controversial. On one hand, grazing is considered as a key factor to promote diversity and grazing can reduce plant diversity and lead to the homogenization of rangeland (Teague and Barnes, 2017). But most of graze able rangelands of the world are under a continuous or relatively unmanaged grazing intensity which is in excess of carrying capacity. This mismanagement has resulted in degraded vegetation and soils as well as loss of soil productivity and biodiversity (Tahmasebi et al., 2017).

In Iran, rangelands occupy about 90 million ha, accounted for 54.6 % of the total area of the country and 65 % of the natural resources with more than 8,000 species exposed to

this disturbance (Jafarian et al., 2019). In particular, the 378,000 ha of Caspian rangelands in Mazandaran province, Iran are characterized by high plant diversity and a good condition because of climate conditions (Jafarian et al., 2019). But due to mismanagement and high sheep and cattle density, biodiversity has been seriously reduced (Jafarian et al., 2019). In addition, overgrazing by livestock is a major driver of rangeland degradation, mainly through the reduction of productivity and resilience (Jafarian et al., 2018). Overgrazing is among the main causes of vegetation degradation because it diminishes vegetation cover and disrupts important ecological processes such as grass recruitment and nutrient cycling (Chillo et al., 2017).
Plant functional characteristics play an important role in predicting patterns of species composition, community structure and their response to livestock grazing, land use changes, vegetation succession, and abandoned fields that have led to significant ecological uptake (Ricotta and Moretti, 2011; Spasojevic and Siding, 2012; Karadimou et al., 2014; Chillo et al., 2017; Rahmanian et al., 2019; Jäschke et al., 2020). In order to understand the response of plant communities to livestock grazing and its effect on ecosystem functioning, it is necessary to focus on more than just individual species and their identity (Dubuis, 2013; Jafarian et al., 2018). The plants in a community should be partitioned into different groups based on their functional traits. Plant functional characteristics play an important role in predicting patterns of species composition, community structure and their response to environmental changes that have led to significant ecological uptake (Casanoves et al., 2011). For example, an increase in the diversity of a trait such as Specific Leaf Area (SLA) is associated with the increased niche differentiation in response to the competition for limiting resources such as light and nutrients (Kraft et al., 2008; Dwyer et al., 2014). The analysis of functional diversity can clarify the effects of increasing livestock grazing on ecosystem functioning. Many studies have been carried out on the comparison of indigenous varieties and species richness within the country. Previous studies in Iran have indicated that intraspecific variation of individual traits can also play an important role in plant response to changes in environmental factors (Heidari and Saeedi Garaghani, 2013; Mansoori et al., 2013; Jafarian et al., 2018).
In this regard, we hypothesized that: i) Functional richness in areas with moderate grazing is higher than those with low intensity of grazing. ii) The response of plant communities to graze in mountain rangeland may depend on the water availability and soil fertility. Therefore, we assessed that the functional basis of changes in the plant species and functional diversity of mountain rangeland in the north of Iran are under different grazing intensities. This research was aimed to determine the effects of grazing intensity on functional diversity through single trait and multiple-traits indices, and the effect of such changes on soil properties.

2. Materials and methods

2.1 Study site

The study area, Changizchal rangelands, is located in the Northern part of Iran (52°11′-52°49′ N; 35°15′-35°49′ E). It covers ca. 2415 ha, with the elevation ranging from 2500 to 3100 m (Figure 1). It has a semi-arid cold climate with the mean annual temperature of 12.79 °C; and the mean anual precipitation of 652 mm. The soil type is sandy-loamy and silty.
The experiment was carried out in low, moderate and heavy grazing sites, which were adjacent to each other in our study area. Grazed rangelands at all sites are dominated by *Heracleum persicum* Desf (Apiaceae), *Astragalus aegobromus* Boiss. & Hohen (Fabaceae) and species *Phlomis cancellata* Boiss. & Hohen (Lamiacea), *Achillea millefolium* L and *Erigeron uniflorus* L and *Tragopogon graminifolius* DC (Asteraceae), *Bromus tomentellus* Boiss and *Poa pratensis* (Poaceae) (Jafarian et al., 2019).

2.2 Sampling design

Three different grazing sites including low, moderate, and heavy grazing intensities were established in the area. Vegetation was grazed by sheep. From mid spring and summer of 2014, sampling was done using 1 × 1 m plot. In total, 150 sampling plots were randomly selected in each grazing

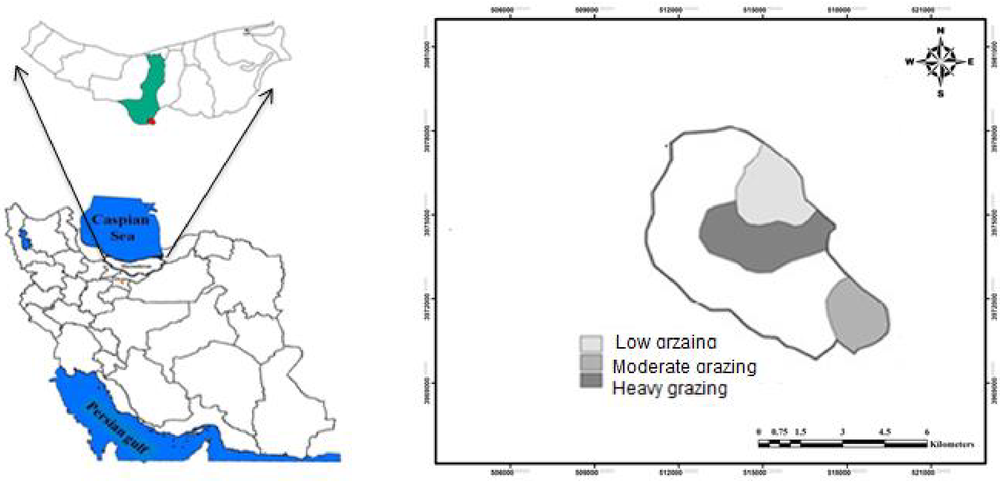

Figure 1. The Changizchal rangelands located in Mazandaran province, Northern Iran.

intensity. The plots were separated by 100 m at each site.

2.3 Functional traits measurement

The leaves were weighed, scanned and analyzed in the laboratory using the Leaf area matter software to measure their surface. We also measured the leaf dry mass after drying and weighing the leaves. The vegetation height was measured in the field as the distance between the top of the photosynthetic tissue and the ground (Dubuis, 2013). Specific leaf area (SLA) was calculated as the ratio of the leaf surface to its dry mass, expressed in $mm^2\,mg^{-1}$ (Dubuis, 2013). Leaf dry matter content (LDMC) is the ratio of the leaf dry mass to its saturated fresh mass (in $mg\,g^{-1}$) (Rossier, 2011).

2.4 Soil measurements

The soil data were recorded within 50 plots at 0–30 cm depth throughout the study area. The soil samples were air-dried and passed through a 2 mm sieve to prepare them for experiments. The soil analysis used methods as follows: the Bouyoucos hydrometer method for soil texture, the Kjeldahl method for total nitrogen and the modified Walkley-Black wet oxidation procedure for organic carbon content (Baize, 2000). Potassium was determined after extraction with 1N ammonium acetate adjusted to pH 7, total phosphorus was determined calorimetrically from wet digestion with H_2SO_4 + $HClO_4$, $CaCO_3$ was measured following the procedure outlined in moisture saturation which was the difference between the weight of saturated and oven-dried (105 °C during 24 h) soils. Soil pH was determined in a soil/water solution with a volume ratio of 1:1 (Pellissier et al., 2010).

2.5 Functional and species diversity indices

To measure species diversity in each quadrat, we calculated species richness, Shannon entropy of true species diversity, and the Simpson index of species evenness based on species number and relative abundance (Jost, 2006). As a single trait index, we calculated functional divergence (FDvar) considering individually SLA, LDMC, and VH for each grazing area, using the FD package in R (Laliberte and Shipley, 2010). The functional divergence index is essentially the variance in the values of the characteristics of the species present in a site, and the squared residuals due to the abundance of used species (Mason et al., 2012). It is defined as:

$$FDvar = \frac{2}{\pi}\arctan(5V)$$

where:
5 is a scaling factor used to define the index over a range of 0–1;
V is the weighted variance of trait x, expressed as:

$$V = \sum_{i=1}^{s} w_i \left(\ln x_i - \overline{\ln x}\right)^2$$

This index takes one of the traits at a time and uses the relative abundance of any species (w_i) to load its contribution to diversity in a community.
The mean of $\ln x_i$ is weighted by the abundance as:

$$\overline{\ln x} = \sum_{i=1}^{s} w_i \ln x_i$$

where:
Multi-traits diversity indices including functional Richness (FRic), Functional Evenness (FEve) and Functional Divergence (FDiv) were used to evaluate the functional diversity for leaf traits (Villeger et al., 2008; Mouchet et al., 2010). These indices are based on the frequency of species in each plot, and Gower distances matrices from five traits in grazed plots (Laliberte and Shipley, 2010).

2.6 Data analysis

To investigate the effect of grazing on species diversity, single-trait and multi-trait functional diversity in three study sites, we used a linear-mixed model with residual maximum likelihood (REML): response ~ Site/Grazing. Here, the diversity indices were included as response variables along with ‘Grazing’ as nested fixed factors within each site; individual quadrats were taken as a random factor to account for any spatial autocorrelation. The Ime4 package in R was used to perform mixed models (Bates et al., 2011). We used generalized canonical discriminant analyses (gCCA) with a nested linear model to examine and visualize linkages among the FD of individual traits and soil nutrient availability in grazed plots across the three study sites. The gCCA was performed using the Candisc package (Friendly and Fox, 2013).

3. Results and discussion

3.1 The effects of grazing on the functional diversity of single-traits (FDvar)

The FDvar for leaf matter dry content (LDMC) significantly decreased in heavy grazing but increased at moderate grazing (Table 1). The FDvar of vegetation height (VH) significantly increased in moderate grazing and FDvar of SLA significantly increased in heavy grazing. The relationships between FDvar for SLA, VH and LDMC and soil properties in three grazing system were assessed using a scatter plot two main canonical functions CAN1 and CAN2. The FDvar for SLA and VH had a positive relationship with soil N and P content. The increase in FDvar from LDMC was associated with the reduction of organic carbon and increase in soil total nitrogen (Figure 2).
FDvar of VH significantly increased at moderate grazing site but decreased at low grazing site. The mean value of single-traits (FDvar) such as leaf dry matter content, SLA and vegetative height at each treatment tended to decrease at moderate and high grazing. LDMC is more influenced by soil factors than SLA and VH because it is related to the storage of plant resources, which is itself linked to the quality of nutrients present in the soil and indirectly linked with the pH that influence nutrient availability (Figure 2). These results, with recent observations, suggest that the response of functional diversity to environmental change does not only relate to species diversity (Simova et al., 2014) as the response of the community to grazing pressure may be complex (Karadimou et al., 2014). A community with high SLA and consequently low LDMC may have reduced

Table 1. Results of linear-mixed modelling for effect of grazing on functional diversity (FDvar) of single traits, functional diversity of multi-trait and species diversity.

Diversity indices	AIC/BIC	Heavy grazing	Moderate grazing	Low grazing
Functional diversity of single traits				
Leaf Matter Dry Content	193/125	**−0.04 ± 0.01***	**0.12 ± 0.01***	0.34 ± 0.05
Species Leaf Area	−214/−167	**−0.17 ± 0.008***	0.15 ± 0.01	**0.21 ± 0.03***
Vegetation Height	−182/−173	0.11 ± 0.02	**0.16 ± 0.005**	**−0.12 ± 0.08***
Functional diversity for multi-trait				
Functional Richness (FRic)	235/259	3.21 ± 1.1	**4.11 ± 1.01***	**2.98 ± 0.09***
Functional Divergence (FDiv)	−178/−192	0.003 ± 0.008	−0.004 ± 0.06	**0.01 ± 0.04**
Functional Evenness (FEve)	76.4/−32.1	−0.02 ± 0.077	−0.001 ± 0.004	**0.08±0.02**
Species diversity				
Species richness	374/421	−1.4 ± 0.87	**1.12 ± 1.14***	**0.92 ± 1.11***
Shannon diversity	48.6/32.7	**1.1 ± 1.23***	1.9 ± 1.2	**1.77 ± 0.23**
Simpson evenness	422/369	32.1 ± 22.76	**7.43 ± 1.88**	−7.90 ± 3.67
Simpson diversity	−279/−261	−1.67 ± 0.05	**−3.45 ± 1.77***	−3.15 ± 2.19

AIC: Akaike information criterion, BIC: the Schwarz's Bayesian Information Criteria. Value = slope value + standard error with bold entries indicating ($P < 0.05$), * indicating ($P < 0.01$). The values with positive and negative signs indicate increased and decreased diversity indices.

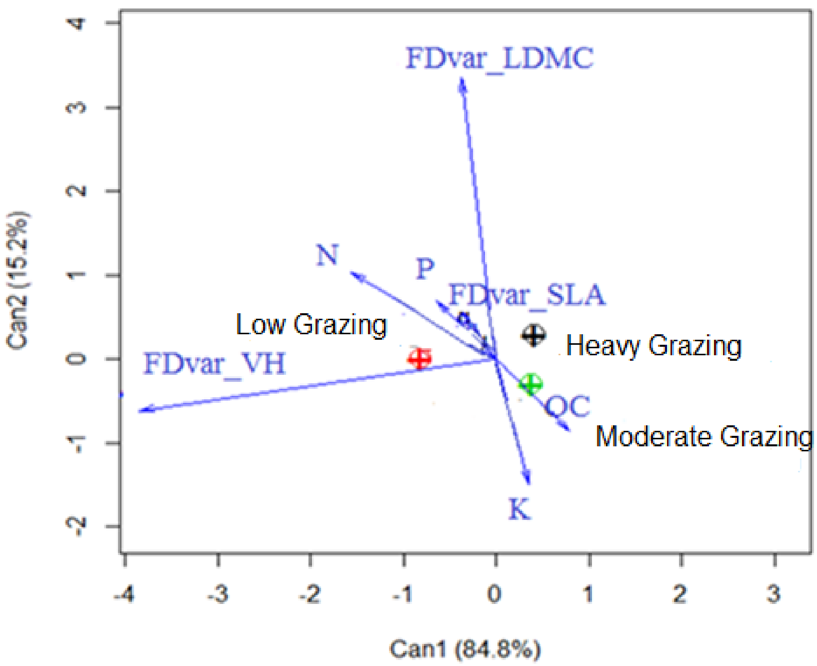

Figure 2. Generalized canonical discriminant analysis showing the links among functional diversity (FDVar) of individual leaf traits, specific leaf area (SLA), leaf dry matter content (LDMC), vegetation height (VH), and soil N, P, K.

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amounts of litter. Also, plants with lower LDMC may have higher plant component digestibility, but lower leaf proportion (Cornelissen et al., 2003). Low SLA and VH, and high LDMC are traits related to a species that may grow slowly and grow on soils with poor nutrients and acid soils (Dubuis, 2013).

3.2 The effect of grazing on the functional diversity of multi-traits and species diversity

Functional richness (FRic) significantly increased in moderate and low grazing. Functional divergence (FDiv) significantly increased in moderate grazing (Table 1). The low grazing induced increase in the FDiv and FEve coupled with decreasing soil organic carbon ($P < 0.05$) (Figure 3).
Functional evenness did not change in the moderately grazed site, and it increased in low grazed site (Table 1; Figure 3). Functional richness (FRic) in moderate grazing had significantly changed due to an intermediate disturbance type of response, as found in other rangelands for species diversity. The results showed that functional richness significantly increased in moderate grazing and low grazing. The low grazing increases plant productivity by increasing the amount of plant litter in functional groups, which may increase the C and N dynamics by increasing root production. This may be due to the fact that in the study area, with increasing intensity of grazing, shrubs increase and as a result, the richness of functional richness. The higher the functional richness, the more different the species is in terms of function, i.e. the range of nutrient source occupied by the ecological nests of the species. Functional divergence index (FDiv) indicates the nesting differences of species on the vector of nutrient resources. High divergence in function indicates that the species has large nesting differences over food resources, resulting in less competition (Cingolani et al., 2005). The results showed that the highest amount of FDiv is related to low grazing intensity. This research confirms that the variability of this trait was low and it has less tolerance against physical hazards such as animal grazing and wind. This idea has been used for the differences in the performance of ecological systems (Jafarian et al., 2018). Communities with high divergence increase the performance of the ecosystem as a result of the proper use of nutrient sources, which is consistent with the findings of other researchers i.e. (De Bello et al., 2012; Zhang and Linfeng, 2015).

3.3 The effect of grazing on the species diversity

The species richness significantly increased in low and moderate grazing but Shannon diversity increased at heavy grazing. The results showed that Simpson diversity significantly decreases in moderate grazing (Table 1). Shannon diversity in high grazing rates is due to the inability of plants to grow again after disturbance and the emergence of dominant non-palatable species (Cingolani et al., 2005; Petchey and Gaston, 2006). In addition, a significant change in the between different functional groups may be due to the complementary role; species regeneration, and species pool size (Niu et al., 2015).
The low grazing induced increase in the Species richness, Shannon diversity and Simpson evenness coupled with increased soil organic carbon ($P < 0.05$) (Figure 3). Some studies have shown that increasing light availability and low grazing can lead to excessive complications of bed in herbaceous ecosystems (Mansoori et al., 2013). It is expected that moderate grazing promotes diversity of plant communities by reducing opportunities for an exclusion of competition

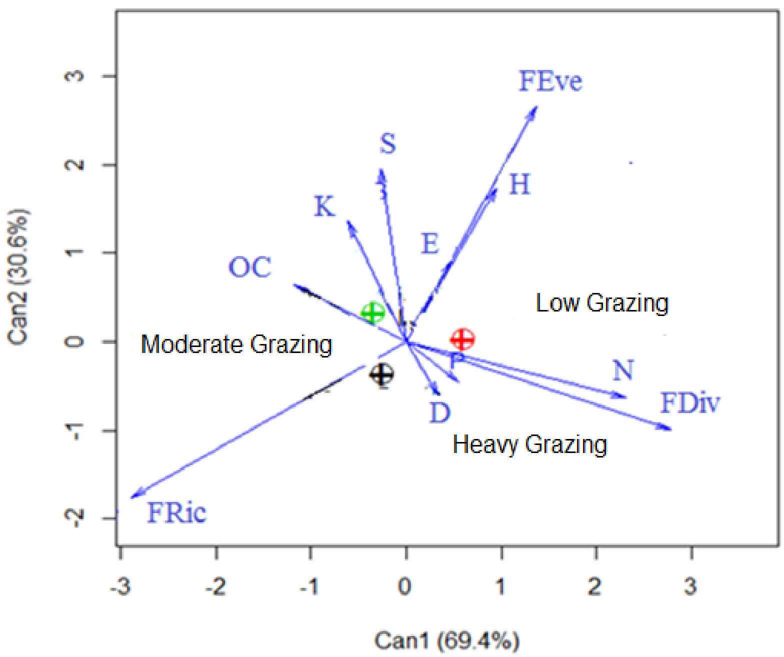

Figure 3. Generalized canonical discriminant analysis showing the influence of species and functional diversity in the suite of multi-traits at each of the three study sites (FRic: Functional Richness; FDiv: Functional Divergence; FEve: Functional Evenness; S: Species richness; H: Shannon species diversity; E: Simpson species evenness; D: Simpson species diversity).

between the subdominant species (Olff and Ritchie, 1998). Trapping by livestock can lead to congestion and changes in levels of infiltration, bulk density and reduced destructive activities (Yu and Jia, 2014). Moreover, under long-term pressure of grazing, some energy and nutrients are transmitted to the diet (Lu et al., 2015; Zuo et al., 2016), while shrublands can collect a large amount of soil organic matter due to the increase of litter on the soil surface by the lowering of bed decomposition (Nieder and Benbi, 2008).

4. Conclusion

The results of this study indicate that functional diversity is higher in moderate and low grazing intensities probably due to the competition of plants with each other and the existence of good reproduction in these two sites. We observed that the species diversity and evenness diversity were increased by increasing grazing intensity. Also, the functional divergence and evenness in response to the grazing were less responsive. Stable rangelands can be achieved through interventions such as soil fertility, but this study dealts with only a better understanding of the total functional characteristics of rangeland species. Our results showed that soils from low grazing have higher nutrient concentration than other intensities. This could be the consequence of the reduction, segregation of the nutrient concentration among habitats.

Authors Contributions
All authors have contributed equally to prepare the paper.

Availability of Data and Materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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