ISSN: 2538-2152; ECOPERSIA 2023;11(2):141-151.

Elements Describing the Distribution of Plant Functional Groups in Mountainous Rangelands

[DOR: 20.1001.1.23222700.2023.11.2.3.5]

[DOI: 10.22034/ecopersia.11.2.141]

ARTICLE INFO

Article Type
Original Research

Author
Esfandiar Jahantab, *P.hD.*[1*]
Reza Yari, *P.hD.*[2]
Esmaeil Sheidai-Karkaj, *P.hD.*[3]
Maedeh Yousefian, *P.hD.*[4]

How to cite this article
Jahantab E., Yari R., Sheidai-Karkaj E., Yousefian M. Elements Describing the Distribution of Plant Functional Groups in Mountainous Rangelands. ECOPERSIA 2023;11(2): 141-151

DOR:
20.1001.1.23222700.2023.11.2.3.5

[1]Department of range and Watershed Management, Faculty of Agriculture, Fasa University, Fasa, Iran.
[2]Assistant Professor, Khorasan-e-Razavi Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Mashhad. Iran.
[3] Associate Prof., Department of Range and Watershed Management, Faculty of Natural Resources, Urmia University, Urmia, Iran.
[4]Research Assistant Professor, Forest and Rangelands Research Department, Mazandaran Agricultural and Natural Resources Research and Education Center, Agricultural Research, Education and Extension Organization (AREEO), Sari, Iran.

*** Correspondence***
Address: Department of Range and Watershed Management, Faculty of Agriculture, Fasa University, Fasa, Iran.
Postal Code: 7461686131
Tel: +98 (71) 53150071
Fax Number: +98 (71) 53151000
Email: e.jahantab@fasau.ac.ir

Article History
Received: February 12, 2023
Accepted: March 27, 2023
Published: February 15, 2023

ABSTRACT

Aims: Plant functional groups are categories of species that exhibit similar responses to environmental parameters. The current research was carried out to evaluate factors that describe the distribution of plant functional groups in the mountainous rangelands of Chaharbagh, Golestan.

Materials & Methods: Three transects of 300 meters were considered in the representative area of each plant type. Ten plots were considered in dimensions of 2 x 2 meters along each transect. The names of species, the percentage of vegetation, and the number of species were determined. Six soil samples were collected for each plant type. The biological form of each plant species was determined. Plants were classified based on edibility, vegetative form, biological form, and life span. To evaluate the relationship between environmental factors and plant functional groups, Redundancy Detrended Analysis (RDA) was applied.

Findings: The results showed that the occurrence of phanerophytes was affected by electrical conductivity and lime. With an increase in Potassium, the frequency of Camophytes increases. Palatability values of the first class were affected by direction, saturated moisture content, and organic Carbon. Values of tree-type growth were affected by electrical conductivity and lime. Forb vegetation increased in correlation with clay content. Grass and pseudo-grass vegetative forms were affected by direction factors, soil-saturated moisture content, and organic Carbon.

Conclusion: Overall, a precise study of differences in plant functional groups can be a fundamental approach for monitoring changes in rangeland under management strategies which require further attention in future research.

Keywords: Environmental Factors; Palatability Classes; Plant Type; Summer Rangelands.

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[DOR: 20.1001.1.23222700.2023.11.2.3.5]

[DOI: 10.22034/ecopersia.11.2.141]

Introduction

Suitable management of ecosystems requires sufficient knowledge of the relationship between ecological parameters in natural habitats, such as altitude, topography, climate, soil, vegetation, and living organisms. Environmental factors cause plants of similar ecological needs to be seen together in the same area and form plant communities. Plant functional groups are species with similar ecological behaviors that respond similarly to environmental factors and biological stimuli while having similar effects on most ecosystem processes [1]. These groups outline the relationships between the response of vegetation to environmental changes and the effects of these changes on the characteristics of the ecosystem [2]. Every community includes a set of plant species with similar nature and ecological needs, which are dependent on a specific habitat for themselves under the influence of complex environmental conditions. There is usually a deep correlation between vegetative elements and environmental conditions [3]. Examining the relationship between environmental factors and plant functional groups in different ecosystems is necessary. So far, several studies have considered the relationship between environmental factors and plant functional groups. Low and high altitudes in mountainous areas are reportedly among the most important factors in vegetative distributions [4]. According to previous findings, Sheidai Karkaj et al. (2015) [5] reported that 90.48 % of species' ecological distribution depended on the soil's physical and chemical characteristics. Zare Chahoki (2007) [6], in a study of relationships between the presence of plant species and environmental factors in the rangelands of Poshtkoh of Yazd province, used the logistic regression method and stated that the most important soil characteristics that affect the distinctness of vegetation types were lime, gravel, soil saturated moisture, and electrical conductivity. Moradi and Ahmadpour (2007) [7] identified the most effective soil factors affecting the parameters of plant species as electrical conductivity, acidity, Nitrogen, and clay. Mohtshamnia et al. (2007) [8] studied the slopes and heights; the direction and amount of precipitation were the most important environmental factors affecting the establishment and distribution of plant ecological groups. He et al. (2007) [9] studied the effect of environmental factors (i.e., climate, topography, and soil) on the composition of vegetation in China using classification methods. Among their 20 environmental factors, the most influential variables in the distribution of vegetation were organic matter, total Nitrogen, and the amounts of clay, silt, altitude, relative humidity, Calcium ion, and electrical conductivity. According to Yibing (2004) [10] in China, the application of Principal Component Analysis (PCA) and Correlation analysis (CA) methods showed that the physical and chemical properties of soil, such as nutrients, moisture, salinity, and acidity, affected habitat homogeneity. These factors reportedly controlled the distribution pattern of plant communities in these areas. Jafari et al. (2009) [11] examined the relationship between vegetative cover and some soil properties in the Nodushan rangelands of Yazd. They reported that the most critical soil properties in distinguishing the vegetation types of plants were soil texture, Gypsum, salts, Potassium, lime, and electrical properties. Shahriari et al. (2020) [12] evaluated the relationship of plant functional groups with environmental factors in the mountainous forests of South Zagros, thereby stating that all plant functional groups have a highly significant correlation with altitude, electrical conductivity, available Potassium, and soil acidity. Sadeghirad et al.

[DOR: 20.1001.1.23222700.2023.11.2.3.5]

[DOI: 10.22034/ecopersia.11.2.141]

(2021) [13] reported that the most important factors of soil affecting the distribution of vegetation are salinity and sodium. Altitude and slope were effective topographical factors that shaped the composition of plant communities in a region. Mofidi and Sheidai Karkaj (2022) [14] stated that the characteristics of plant functional groups differed per grazing intensity. Sheidai-Karkaj et al. (2012) [15] reported that plant community zones were characterized by species cover dominance using cluster analyses.

Considering the vital role of plants in the balance of the ecosystem and the various uses that humans make of it directly or indirectly, knowledge of the relationships between plants and environmental factors is necessary for maintaining ecological stability. While aware of the existing relationships, researchers can determine the causes of distribution and changes in vegetation cover, the capacity of habitats [16], the habitat conditions, and the places of plant growth per plant type or ecological group. Such classifications are important for adopting correct management measures following ecological principles in reconstructing and managing rangelands and their ecosystems [17]. Therefore, a sufficient understanding of the changes in the relationship and distribution of plant functional groups with environmental factors is necessary for the proper management of rangelands. Accordingly, the current research aimed at determining the most influential factors among soil physicochemical properties and topography in the distribution of ecological functional groups of plants. It also considered the differences in plant cover under various environmental conditions in Chaharbagh rangelands. The findings can assist in protecting natural habitats, biodiversity, water, and soil sustainability while identifying vulnerable areas of mountainous rangelands and their ecosystems.

Materials & Methods

Study Area

Chaharbagh Golestan was considered in its summer meadows with an area of about 9 thousand hectares, located 45 km southeast of Gorgan City and on the southern slopes of the Alborz Mountain range. The geographical coordinates of the region are 28’35’36’ to 36’28’40’ north latitude and 54’36’24’ to 54’36’36’ east longitude. The region is an important summer rangeland in the Golestan province, located in the transition between the Hirkani vegetation zone and the semi-steppe vegetation zone. The average rainfall was 348 mm, most of which occurs in the form of snow in winter. The annual average temperature is 6.5 °C. The minimum altitude of the region is 2000 meters, and the maximum is 3218 meters. Also, the average altitude is 2609 meters above sea level. Most of the mountainous area is characterized by small and big hills. Geologically, the area’s bedrock consists of the Cretaceous to Quaternary dark-colored limestone. The region’s climate is cold and Mediterranean based on the De Martonne classification method. Vegetation is comprised chiefly of *Poa* species with scattered junipers. Chaharbagh rangelands have a variety of plants, such as *Achillea millefolium*, *Astragalus gossypinus*, *Berberis vulgaris*, *Onobrychis cornuta*, *Rhamnus pallasii*, *Stachys inflata*, *Agropyrum trichophorum* (Link), *Acanthophyllum microcephalum*, *Festuca ovina* L., *Cousinia commutate* Bunge., *Cirsium arvense* L., *Galium verum* L., *Thymus kotschyanus* and *Centaura echvaldii*.

Selection of Plant Types and Sampling of Vegetation and Soil

The vegetation typology of the region was determined by a topographical map 1/50000 and Google Earth. It was also used for recognizing the ecological regions of the country and based on the specified floristic-physiognomic classification method. Accordingly, six plant types were identified in the study area, and a necessary evaluation of vegetation and soil sampling was done (Table 1). Sampling in the representative area of each type of plant was done randomly and systematically. For sampling and measurement in each plant type, depending on the topographical conditions and the size of each type, three transects of 300 meters were established in the representative area of each type. There were ten plots along each transect with dimensions of 2 * 2 meters and 30 plots. In each established plot, the name of each species, the percentage of coverage, and the number of species were calculated and estimated. Also, in each transect, soil samples were taken from the first and last plot according to the rooting depth of the dominant plants in the area (generally six soil samples for each plant type and a total of 36 soil samples). After sieving, the soil samples were taken to the laboratory to determine the physical and chemical properties of the soil, including soil texture, electrical conductivity, acidity, Potassium, Phosphorus, lime, saturated moisture, and the amount of organic matter. Also, the slope, direction, and altitude were measured at each soil sampling point. The average slope, modified direction, and average altitude were measured for each plant type. To examine the flora of the area during the survey of the study area, all plants in the study area were sampled. After drying the samples, they were identified using reliable sources [18-20]. The biological form of plant species was determined based on Raunkiaer's classification method [21]. The plants were classified according to their edibility, vegetative form, biological form, and lifespan [22].

Data Analysis

Classification methods were used to evaluate the relationship between environmental factors and plant functional groups. According to the length of the gradient, regarding the variables, Detrended Correspondence Analysis was used, which was less than 3 in value, and the RDA was used as a linear method to classify the plant functional groups with environmental factors [23]. All statistical calculations for classification were done using Canoco software (version 5).

Findings

Descriptive features of the plant functional

Table 1) Characteristics of plant types in the study area.

Row	Plant Type (Abbreviation)	Area (Hectares)	Average Vegetation (%) Cover	Medium Altitude
1	*St ba- On co*	1255.81	33.6	2698
2	*As go- On co-St ba*	1414.37	26.62	2749
3	*Ju po- On co- St ba*	3059.09	25.5	2795
4	*Ar au- St ba*	1462.7	27.23	2598
5	*Ar au- On co- St ba*	1396.3	25.07	2601
6	*Ho vi- Cr ko- Ag in*	17.9	83.4	2508

*** St ba- On co: (Stipa barbata-Onobrychis cornuta); As go- On co- St ba: (Astragalus gossipinus-Onobrychis cornuta- Stipa barbata); Ju po- On co- St ba : (Juniperus polycarpus-Onobrychis cornuta- Stipa barbata); Ar au- St ba : (Artemisia aucheri-Stipa barbata); Ar au- On co- St ba: (Artemisia aucheri-Onobrychis cornuta- Stipa barbata); Ho vi- Cr ko- Ag in: (Hordeum violaceum-Crepis kotschyana-Agropyron intermedium)*

[DOR: 20.1001.1.23222700.2023.11.2.3.5]
[DOI: 10.22034/ecopersia.11.2.141]

groups in each type are presented in Table 2. Since the current research aimed at evaluating the relationship between environmental factors and plant functional groups, Detrended Correspondence Analysis (DCA) was implemented on the vegetation data (i.e., response data) to record the slope length and to select suitable linear and non-linear statistical methods. The results (Table 3) showed that the av-

Table 2) Descriptive features of functional groups of different plant types.

Type/PFT	*Ar au- St ba*	*Ju po- On co- St ba*	*Ar au- On co- St ba*	*As go- On co- St ba*	*St ba- On co*	*Ho vi- Cr ko- Ag in*
B	0.02	1.38	1	1	0	0.2
A	2.02	2.38	29	0.42	1.4	1.42
P	24.64	20.91	53.4	22.6	23.33	28.63
ES	0.2	0.47	9.1	0	0.1	0
ES, IT	0.23	0.52	0.7	0.03	0.2	2.27
IT	23.1	22.4	33.2	22.3	23.25	24.3
IT, ES, M	0.02	0.38	11.6	0.12	0.1	1.44
IT, M	0.7	0.63	1.2	0.2	0.42	0.73
IT, M, ES, SS	0.31	0.25	11.6	1.1	0.27	0.33
PL	0.1	0.02	16	0.27	0.4	1.18
Ch	9.3	14.68	0.8	15.05	14.22	9.71
He	4.4	6.78	63.2	6.28	7.4	14.4
Ph	9.08	0.73	0	0.33	0.38	1.5
TH	1.88	2.48	19.4	2.36	2.43	4.64
Shrub	8.77	18.8	0	14.73	13.27	8.45
Tree	8.83	0.07	0	0.33	0.43	1.5
Forb	2.4	2.35	54.9	1.43	2.6	5.88
Grass	4.66	2.91	23.2	7.52	8.43	14.42
Grass-liked	0	0.54	5.36	0	0	0
I	4.53	7.87	19.3	7.43	7.67	13.95
II	1.83	1.18	29	8.68	12.52	1.46
III	18.3	15.62	35.1	7.9	4.54	14.84

**PFT: Plant Functional Types; B: Biennial; P: Perennial; A: Annual; ES: European-Siberian; ES, IT: European-Siberian, Irano-Turanian; IT: Irano-Turanian; IT, ES, M: Irano-Turanian, European-Siberian, Mediterranean; IT, M: Mediterranean, Mediterranean; IT, M, ES, SS: Mediterranean, Mediterranean, European-Siberian, Sahara-Sindian; PL: Polar; Ch: Camophytes; He: Hemicryptophyte; Ph: Phanerophytes; TH: Trophytes; I: First Palatability Class; II: Second Palatability Class; III: Third Palatability Class

Table 3) Detrended Correspondence Analysis (DCA) results according to the two axes.

Axes	Gradient Length	Specific Value	Cumulative Variance Percentage
1	0.52	0.168	63.99
2	0.41	0.023	72.86

[DOR: 20.1001.1.23222700.2023.11.2.3.5]

[DOI: 10.22034/ecopersia.11.2.141]

erage gradient length is less than three, so a relevant assessment of the relationship between environmental factors and plant functional groups was involved using the RDA as a linear method. The DCA results showed the axes' importance based on the specific value, which decreased from the first to the second axis. Thus, a significant contribution to the changes in the functional groups was related to the first axis. The results showed that the first two components explained about 72 % of the changes.

The results of RDA (Table 4) indicated the relationships between environmental factors and plant functional groups, as described in Figure 1. More than half of the variance in data differences (Table 4), i.e., about 90 %, can be explained by the two main components, first and second. Thus, the analyses of classifications in the two-dimensional space of the image can provide acceptable generalizations of relationships between the variables. Meanwhile, the analysis of the results in the two-dimensional space can be done easily and added to other spaces or dimensions.

Table 4) Results of Redundancy Detrended Analysis (RDA) on environmental data and species diversity.

Axes	Specific Value	Justified Variance	Cumulative Variance Explanation Percentage
1	0.77	77/95	77/95
2	0.118	11/87	89/82
3	0.052	5/26	95.08
4	0.04	4.01	99.09

The biological form values of phanerophytes were influenced by electrical conductivity and lime. Higher values of electrical conductivity and lime caused an increase in the vegetative form of phanerophyte. Also, higher Potassium levels in the soil correlated with more Camophytes in the area. Direction factors, saturated moisture content, and organic Carbon influenced Trophytes and Hemicryptophyte biological forms. Steeper slopes correlated with a greater prevalence of Trophytes and Hemicryptophyte biological forms (Figure 1).

Regarding the Palatability classes, values of the first class were influenced by direction, saturated moisture content, and organic Carbon. In other words, with increased direction factors, saturated moisture, and organic Carbon, more species of the first Palatability class existed. According to the results, the second Palatability class increased parallel to higher amounts of silt, saturated moisture, slope direction, organic Carbon, and contents of sand and gravel. Also, the results showed that the slope values and clay content influenced the third Palatability class. With the increase of these factors, the percentage of the third palatability class increased (Figure 1).

The values of tree growth were influenced by electrical conductivity and lime, meaning that the vegetative form of a tree was more evident with the increase in electrical conductivity and lime factors. Accordingly, the shrub's vegetative form was affected by the amount of Potassium, and with the increase in the amount of Potassium, the values of the shrub's vegetative form increased. The vegetative form of forbs increased with more clay content, and the vegetative forms of grass and pseudo-grass were influenced by slope direction, saturated moisture, and organic Carbon (Figure 1).

The results of the geographic distribution of plant species showed that the percentage of species belonging to the regions of Irano-Turanian, European-Siberian, Irano-Turanian-Mediterranean, and Irano-Turanian-European-Siberian and Mediterranean increased parallel to an increase in the slope degree and clay content (Figure 1).

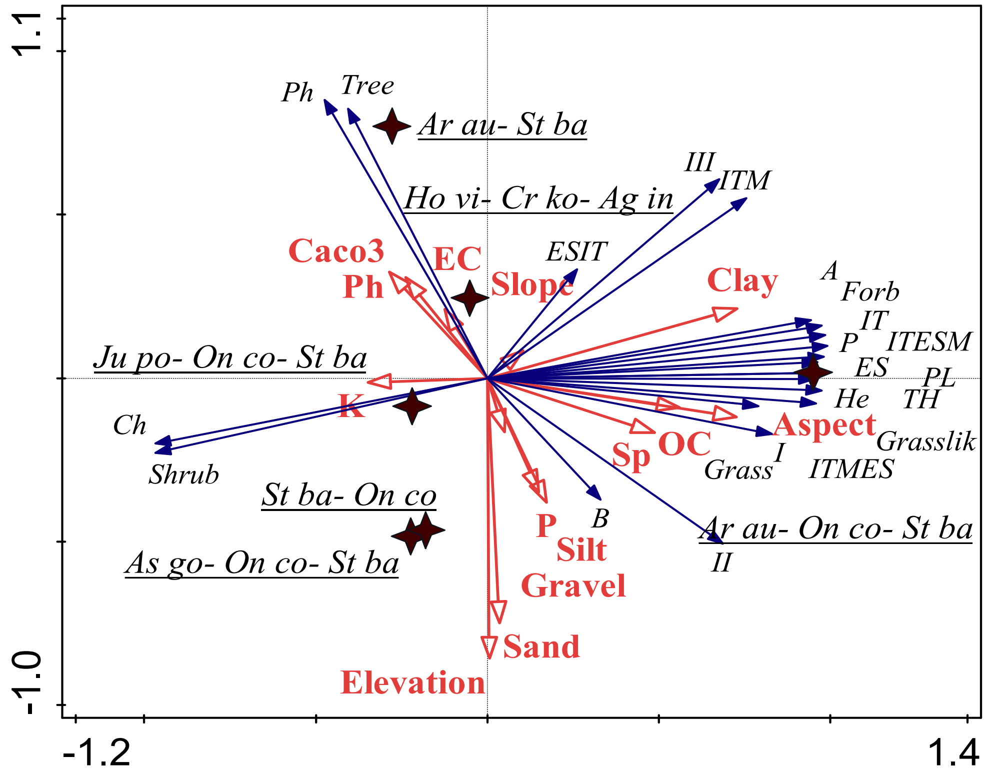

Figure 1) Relationship between plant functional groups and environmental factors
Vegetative period: P, A, B. Chorotype: PL, (IT, M, ES, SS), (IT, M), IT, (ES, IT), ES. Biological form: TH, Ph, He, Ch. Vegetative form: GL, G, F, B, Sh. Palatability: 1, 2, 3.

Discussion

Acquiring a proper amount of understanding regarding the differences in the relationship and distribution of plant groups with environmental factors is necessary for correct management strategies on rangelands, primarily to assess the structure and function of an ecosystem. Thus, assessing the composition and diversity of plants, the fodder value, and the vegetation cover of an area is required. Plant composition is widely used in rangeland studies and is considered one of rangeland's most important ecological and management indicators [24].

Accordingly, the current research aimed to assess the factors that explain the distribution of plant functional groups in the mountainous rangelands of Chaharbagh, Golestan. The results showed that the vegetative form of phanerophytes increased with higher electrical conductivity and lime. By increasing the amount of Potassium, the biological form of charophytes increased. Direction, saturated moisture, and organic Carbon factors influenced Trophytes and Hemicryptophytes. The increase in slope degree increased the number of Trophytes and hemi-cryptophytes. The percentage of species in the first Palatability class increased by increasing the direction factors, saturated moisture, and organic Carbon. The second Palatability class became more prevalent parallel to an increase in silt, saturated moisture, slope direction, organic Carbon, contents of sand, and gravel. The third palatability class was influenced by slope and clay content. With higher values of these factors, the percentage of the third Palatability class increased.

Tree growth values were affected by electrical conductivity and lime. In other words, the tree's vegetative form increased parallel to

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[DOI: 10.22034/ecopersia.11.2.141]

higher electrical conductivity and lime. The amount of Potassium affected the shrub's vegetative form, and with the increase in Potassium content, the amount of the shrub's vegetative form increased. The vegetative form of forbs increased parallel to the higher clay content. Grass and pseudo-grass vegetative forms were affected by slope direction, saturated soil moisture, and organic Carbon. Relevantly, Zare Chahoki (2007) [6] stated that the most important soil properties that were effective in causing differences among vegetation types were lime, gravel, saturated moisture, chalk, and electrical conductivity. Also, Moradi and Ahmadpour (2006) [7] indicated that the type of plant species was affected most variably by electrical conductivity, acidity, Nitrogen, and clay. Mohtshamnia et al. (2007) [8] evaluated the vegetation cover of the Fars steppe in Iran. They reported that the soil texture, acidity, soil moisture, Phosphorus, Gypsum, Potassium, lime, slope degree, altitude, slope direction, and amount of rainfall were important environmental factors in establishing and distributing plant functional groups per ecological conditions. Jafari et al. (2009) [11] revealed that the most important soil characteristics in distinguishing the vegetative types of plants were soil texture, chalk, salts, Potassium, lime, and electrical conductivity. Research by Shahriari et al. (2020) [12] indicated that all plant functional groups had a highly significant correlation with altitude, electrical conductivity, available Potassium, and soil acidity. Research on the diversity and composition of plant functional groups, including trees, shrubs, grasses, and tree seedlings, in mountainous forests of Lishan Nature Reserve in North China indicated that all plant functional groups had significant correlations with altitude and soil copper content [25]. In another study on Mexican forests, altitude was reported as the main factor that affected all plant functional groups [26]. In some conditions, differences in the functional groups were not caused by the direct relationship of environmental factors but indirectly related to factors such as slope direction and degree, the intensity of livestock grazing, the accessibility of rangelands, and grazing intensity, all of which affected community composition and plant functional groups. Relevantly, previous research showed that a change in grazing management of rangelands could cause differences in the composition of plant communities, thereby transforming them in the long run [27-29]. Guevara et al. (2009) [30] reported an increase in the percentage of woody shrub species and a decrease in edible species affected by livestock grazing. Gunderson (2000) [31] stated that livestock grazing and disturbance in rangelands are indicators of the first group of species to be affected. Thus, the findings herein are consistent with the results of previous research. The behavior and differences in the index species among the plant community can indicate whether rangeland ecosystems are under pressure. Hickman and Hartnett (2002) [32] reported that animal grazing causes the harvesting of plants, the movement of food and their redistribution through waste, and, thus, pressure on rangelands through the mechanical disturbance of soil and plant materials. With the disturbance of livestock grazing in rangeland ecosystems, especially by high-intensity grazing, the accumulation of soil particles and plant materials around the plant base (vegetable spots) can become problematic and reduce the resilience of the ecosystem [33]. Livestock grazing affects prominent species among plant species in the first stage since prominent species occupy a significant part of the animal diet. The pressure on rangelands puts pressure on the most prominent species, allowing other species to emerge. When this replacement by other plant species continues, the plant community may eventually lack *Poa* species and become covered with non-edible, annual, herbaceous, or perennial non-edible woody species [34]. Usually, increasing livestock grazing pressure reduces the dominance of native species, and thus, invasive species replace them. The percentage of species belonging to the regions of Irano-Turanian, European-Siberian, Irano-Turanian-Mediterranean, Irano-Turanian-European-Siberian, and the Mediterranean increased in correlation with higher clay percentage and higher slope degree.

Based on the classification results, most of the trees were distributed in limestone areas, and the presence of mountainous juniper species was the most important in the tree population of plant communities. From an ecological viewpoint, juniper has a high resistance to lime. Meanwhile, the prevalence of grass species is directly related to the amount of organic Carbon in the soil and the amount of soil moisture. The presence of grass species is a characteristic feature of the area under study. Rangelands are a unique environment in which the required water is partly obtained from the melting snow of the surrounding mountains, which can support the occurrence of more first-class plants. With the increase in altitude, the number of trees decreased because the dormant buds were less resistant to the harsh cold of winter temperatures at high altitudes. Since the ambient air is colder at high altitudes, trees are usually observed in fewer numbers.

The biological forms of plants show their adaptations to the climatic, soil, and biological factors and, ultimately, ecological conditions of an environment [35]. Hemicryptophytes are usually more abundant than other biological forms because of their mountainous nature and cold temperatures, compared to the moderate climate of the Fandoghlu region, according to [36]. Also, according to general climate conditions, Trophytes form the second most abundant vegetation in terms of density in the region, which reflects the adaptation of this group of plants to the region's cold and relatively humid climate conditions. Akbarzadeh (2007) [37] studied the life form of plants in rangelands from Mazandaran and found that Hemicryptophytes are dominant because of the mountainous, cold climate of the region. The second group of life forms was Trophytes, which agreed with the current results. More than half of the identified species had bi-regional distributions. The distribution pattern of plants is mainly under the influence of two factors, temperature, and humidity. In turn, temperature and humidity correlate with altitude. Thus, altitude predominantly affects the distribution patterns of plant community structure and diversity [38]. North-facing slopes have higher soil moisture content because of receiving less solar energy. Thus, they provide better-growing conditions. In the southern and western slopes, however, these variables reach the lowest values [39]. Ultimately, differences in plant functional groups can be essential for analyzing and monitoring rangeland land in specific management strategies. These subjects deserve more attention in future studies. Dwyer et al. (1984) [40] reported that the biomass of forage, soil density, and compaction, as well as the percentage of total vegetative cover and each type of vegetation, is suitable for studying the resilience of rangeland lands and their ecosystems.

Conclusion

The results showed that the occurrence of phanerophytes was affected by electrical conductivity and lime. With an increase in Potassium, the frequency of Camophytes increases. Trophyte and Hemicryptophyte biological forms were affected by direction, saturated soil moisture content, and organic Carbon. Palatability values of the first class were affected by direction, saturated moisture content, and organic Carbon. The second Palatability class became more prevalent with increased silt, saturated moisture, direction, organic Carbon, contents of sand, and gravel. The third Palatability class was affected by slope and the clay content, the increase in which correlated with more of the third Palatability class of species. Values of tree-type growth were affected by electrical conductivity and lime. The prevalence of shrub vegetative form depended on the amount of Potassium, the increase in which correlated with more of the shrub vegetative form. Forb vegetation increased in correlation with clay content. Grass and pseudo-grass vegetative forms were affected by direction factors, soil-saturated moisture content, and organic Carbon. With more slopes and higher percentages of clay, the geographic distribution of plant species showed a greater prevalence of species belonging to the regions of Irano-Turanian, European-Siberian, Irano-Turanian Mediterranean, Irano-Turanian-European-Siberian, and Mediterranean. Overall, a precise study of differences in plant functional groups can be an important approach for monitoring changes in rangeland under management strategies which require further attention in future research.

Acknowledgment

The authors would like to thank the soil laboratory of Gorgan University of Agricultural Sciences and Natural Resources for guidance and for providing facilities during the research period.

Ethical Permissions: None declared.

Authors' Contributions: Jahantab E. (First author), Introduction author/Methodologist/Original researcher (25%); Yari R. (Second author), Methodologist/Original researcher/Statistical analyst (25%); Sheidai-Karkaj E. (Third author), Methodologist/Original researcher/Discussion author/ Statistical analyst (25%); Yousefian M. (Fourth author), Methodologist/Original researcher/Discussion author/ Assistant researcher (25%).

Conflict of Interests: Authors declare they have no conflict of interest.

Funding: None declared.

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[DOR: 20.1001.1.23222700.2023.11.2.3.5]

[DOI: 10.22034/ecopersia.11.2.141]

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