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Investigation of Relationship between Vegetation, Topography and Some Soil Physico-Chemical Characteristics in Nodoushan Rangelands of Yazd Province (Iran)

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Abstract The relationship between topography, soil factors, and distribution of ecological vegetation groups in the Nodoushan arid rangelands of Yazd province (Iran) was investigated. The present species were recorded in each vegetation group using a randomized-systematic sampling method. Plant cover and density were estimated quantitatively using the transect and quadrate methods, and the two-way indicator species analysis (TWINSPAN), after which vegetation was classified into different groups. Soil samples were taken from 0–30 cm in each quadrat. In each vegetation group, 20 environmental variables including altitude, slope, aspect, percentage of bare rock, grazing intensity, percentage of gravel, soluble ions (Na^+, K^+, Mg^{2+}, Ca^{2+}), total nitrogen, organic matter, lime, gypsum, EC, pH, and percentage of sand, silt and clay were measured. Multivariate techniques including detrended correspondence analysis (DCA) were used to analyze the collected data. The results showed that the vegetation distribution was related to elevation, slope, and soil characteristics such as texture, organic matter, gypsum, acidity, lime, and gravity percentage.

Key words: *Multivariate analysis, Nodoushan rangelands, Soil characteristics, Topography*

1 INTRODUCTION

Good soil environments can provide plants with sufficient nutrients and available water, and topographic characteristics are closely associated with local climate, which greatly impacts plants (Davies *et al.,* 2007). To better understand and manage rangeland ecosystems, it is important to study the relationship between environmental factors and plants in these ecosystems. The effects of environmental factors on plant Communities have been the subject of many ecological studies in recent years. In addition, soil–plant relationships have been studied (Abd El-Ghani, 2000; Folster *et al.,* 2001). Moustafa *et al.* (1996) found that the distribution of plants was largely affected by a moisture gradient that was controlled by elevation, slope, soil texture, sand, and the speed of winter and summer wind. The nature of the soil surface in the form of boulders, stones, cobbles and surface gravel is one of the most important factors controlling moisture availability and subsequently the

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distribution of plant communities in the mountains (Abd El-Ghani, 2000; Folster *et al.,* 2001). Slope aspect had significant effects on the composition, structure, and density of the plant communities (Kutiel and Lavee, 1999). Soil characteristics and topographical factors also have a significant effect on vegetation in the dry warm river valley in SW China (Xian *et al.*, 2008). The soil factors best correlated with the distribution of this vegetation are salinity, sand, sodium, potassium, magnesium and calcium in Failaka Island (Abbadi and El-Sheikh, 2002). Topography affects soil and climate in addition to affecting temperature and evapotranspiration (as elements of climate), makes deeper soil and higher content of organic matter, and results in intensive vegetation in the northern aspects in comparison to the southern ones (Jenny, 1980). Enright *et al.* (2005) showed that physical environmental factors likely to affect water availability were more important than soil chemicals, animal grazing and human impact factors for determining the distribution of major vegetation types and species richness patterns. Among different environmental factors, soil is of high importance in plant growth, and is a function of climate, organisms, topography, parent material and time (Hoveizeh, 1997). Determining which factors control the presence, number, variety, and relative abundance of plant species remains a central goal in ecology. The main purpose of this study was to investigate the relationship between topographic and soil factors with plant species to determine the strongest factors affecting the separation of vegetation groups.

2 MATERIALS AND METHODS

2.1 Study area

The study area is located in Nodoushan watershed of the Yazd province in the center of Iran (31°45" N and 53°28" E to 32°3" N and 53°47" E). The maximum and minimum elevations of this region are 3400 m and 1900 m, respectively. The climate is arid to semi-arid, and the average annual rainfall of the study area ranges from 124 to 247 mm. The average annual temperature is 8.7–14.6°C. Meteorological data was calculated for a 15-year period.

2.2 Data collection

Vegetation groups were identified based on field surveys. In each vegetation group, soil and vegetative attributes were described within quadrates located along transects. The sampling process was conducted during April and May of 2006, when most species were expected to be growing. Plant cover, density and importance of each plant species were estimated quantitatively using the transect and quadrate methods. In sites with crude bush communities, 30 quadrates of 2 m² were established, while six quadrates of 100 m² were established in communities of bushes with shrubs for each vegetation group (Johnson *et al.,* 2000). The sampling method was randomized systematic. In the area sampled, elevation, slope and aspect were recorded. Soil samples were taken from 0–30 cm in each quadrate. In each vegetation group, the percentage of bare rock, gravel, soluble ions (Na^+, K^+, Mg^{2+} and Ca^{2+}), total nitrogen, organic matter, lime, gypsum, EC, pH, and sand, silt and clay were measured. In each quadrate, the grazing intensity was estimated according to deformation of one class (palatable) of plant species and then transformed using a four-point scale (0=no grazing, 1=light grazing, 2=moderate grazing, 3=heavy grazing) (Woldewahid *et al.,* 2007).

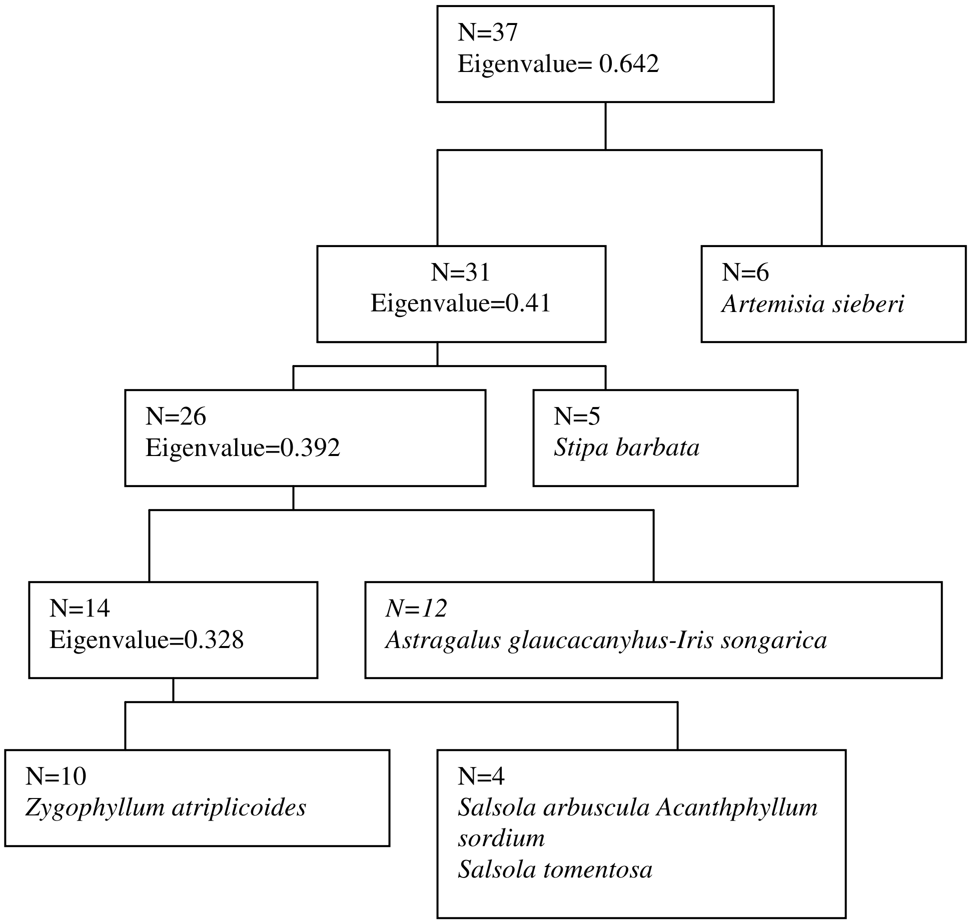
The Windows (Ver. 4.0) version of PC-ORD (McCune and Mefford, 1999) was used for classification and ordination of vegetation groups in the gradient of environmental factors**.** Data were analyzed by multivariate techniques. In the first step, vegetation of the study area was classified using the two-way indicator species analysis (TWINSPAN). To use this analysis, the importance value of the plant data were transformed using five-point scale (1=0–20, 2=20.1–40, 3= 40.1–60, 4=60.1–80, 5=80.1–100). After classification of the vegetation, relationships between environmental factors and vegetation were determined using detrended correspondence analysis (DCA).

3 RESULTS

3.1 TWINSPAN

The results of TWINSPAN classification are presented in Fig. 1. According to Fig. 1 and the eigenvalue of each division, vegetation was classified into five main groups. Each ecological vegetation group differs from the other in terms of its environmental needs. These ecological vegetation groups are as follows:

I. Artemisia sieberi - Salsola arbuscula
II. Artemisia sieberi - Zygophyllum atriplicoides
III. Artemisia sieberi - Astragalus glaucacanthus-Iris songarica
IV. Artemisia sieberi - Stipa barbata
V. Artemisia sieberi



N- Number of stands

Fig. 1 Dendrogram of TWINSPAN for vegetation in the study area.

3.2 Soil

The organic carbon content and nitrogen decreased in the vegetation group of *Artemisia sieberi-Salsola arbuscula*, while the levels of salinity and sodium ions in this group were high (Table 1). *Salsola arbuscula, Salsola tomentosa, Andrachne fruticulosa, Scariola orientalis* and *Peganum harmala* were found in the vegetation group. In the vegetation group of *Artemisia sieberi*, the organic carbon content and nitrogen were also high (Table 1), *Artemisia sieberi, Astragalus campylanthus, Astragalus myriacacanthus, Gymnocarpus decander, Thymus kotchyanus, Bromus tectorum* were found in the vegetation group.

Table 1 Mean of soil characteristics in five vegetation groups of TWINSPAN (at depths of 0–30 cm).

Soil characteristics		Vegetation groups				
		I	II	III	IV	V
OC	x	0.39	0.38	0.52	0.61	0.83
	v	0.04	0.04	0.05	0.10	0.07
Gravel	x	36.0	31.0	30.0	45.0	34.0
	v	1.00	1.00	1.00	3.00	3.00
N	x	0.02	0.02	0.02	0.03	0.06
	v	0.00	0.00	0.00	0.00	0.00
EC	x	0.15	0.20	0.12	0.12	0.11
	v	0.03	0.06	0.00	0.01	0.00
pH	x	8.51	8.55	8.28	8.56	7.93
	v	0.08	0.13	0.06	0.14	0.05
Li	x	25.8	28.2	23.5	32.8	21.2
	v	1.55	2.32	3.33	1.41	3.02
Clay	x	14.7	12.4	16.7	14.5	16.0
	v	1.48	2.26	1.61	1.61	0.72
Silt	x	29.8	23.0	25.6	31.0	30.8
	v	2.13	3.54	2.72	1.89	3.85
Sand	x	55.3	64.6	57.6	54.4	53.1
	v	3.10	5.29	3.20	3.23	4.51
Ca	x	36.7	46.5	36.3	44.3	40.7
	v	2.83	6.02	2.38	4.05	2.20
Na	x	88.1	173.9	48.8	33.6	103
	v	43.1	71.9	13.0	7.79	47.1
Mg	x	22.6	18.56	22.98	25.0	27.8
	v	2.41	4.92	2.97	2.90	1.98
K	x	114	90.2	124	93.57	132
	v	27.2	21.2	31.8	27.2	21

x=mean value and v=standard deviation.

[DOR: 20.1001.1.23222700.2011.0.2.1.2]

The abbreviation of vegetation groups and environmental factors is shown in Appendix A.

3.3 DCA and CCA

DCA and CCA were used to determine the most effective environmental factors in the separation of vegetation groups and relationships between vegetation and environmental factors.

3.3.1 DCA

The results of the DCA ordination are presented in Fig. 2 and Table 2.

The abbreviations of the vegetation groups are shown in appendix A.

The results of the DCA ordination are presented in Table 2. The eigenvalues for the data set indicate that the first DCA is by far the most important for representing the eigenvalue, variation, and coefficient of correlation of the environment-species of the five vegetation groups. As shown in Table 2, the first axis (eigenvalue=0.87) accounted for 24.1% of the variation in environmental factors.

The results of the DCA ordination of the TWINSPAN groups showed that, among all environmental factors, soil characteristics such as OC, Gips, pH, gravel percentage, $CaCO_3$ and topographical factors such as elevation and slope are the most effective for describing the distribution of vegetation groups in the study area (Fig. 3).

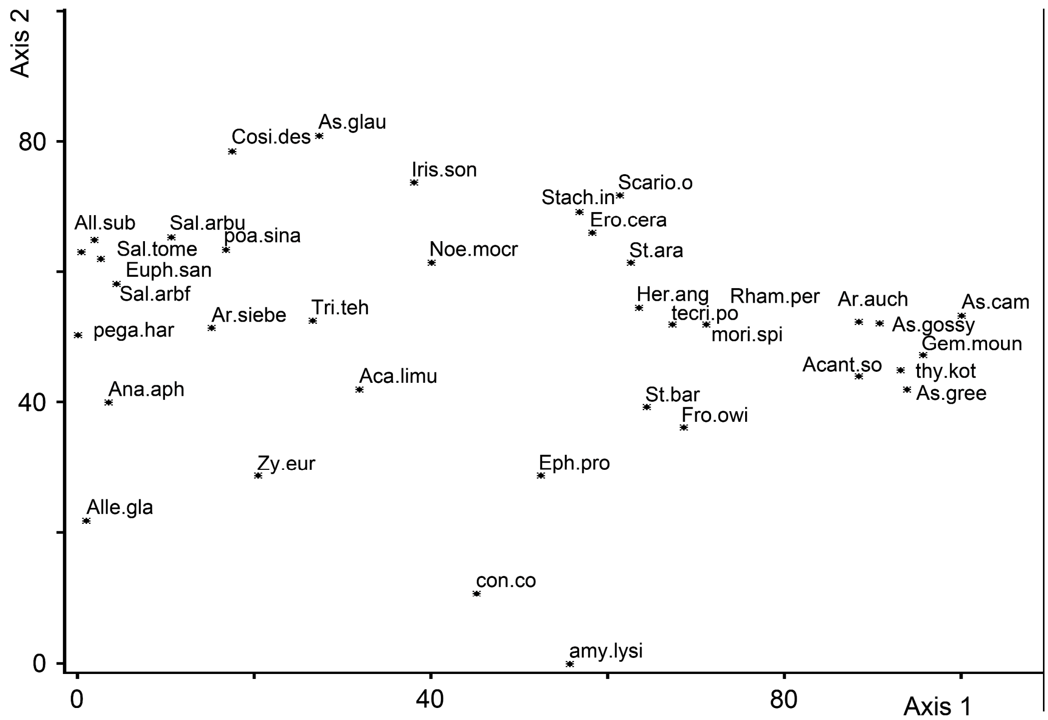


Fig. 2 DCA-ordination diagram of the plant species in the study area.

Table 2 DCA applied to the correlation matrix of environmental factors in the study area.

Percentage of variance explained	Coefficient correlation of plant species-environmental variables	Eigenvalue	Axis
24.1	0.930	0.87	1
6.9	0.925	0.214	2
5.7	0.840	0.168	3

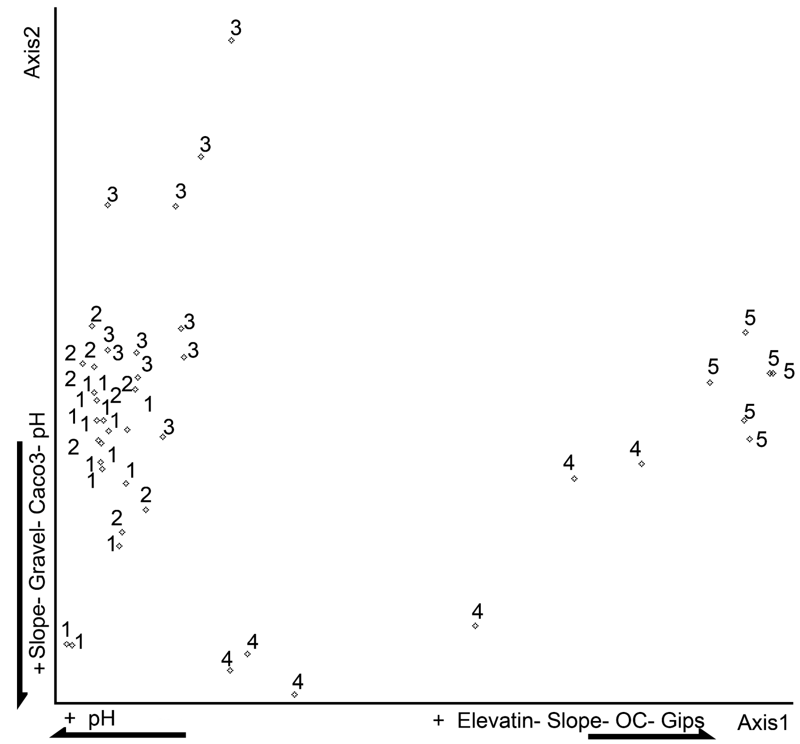


Fig. 3 DCA- ordination diagram of the TWINSPAN groups related to environmental factors in the study area.

As shown in Table 3, Axis 1 had a significant positive correlation with elevation (r=0.82), slope (r=0.61), OC (r=0.64) and gypsum (r=0.39) and a negative correlation with pH (r=–0.46). Axis 2 had a negative correlation with slope (r=–0.42), gravel percentage (r=–0.62), lime (r=–0.32) and pH (r=–0.33). Axis 3 was positively correlated with elevation (r=0.33) and gypsum (r=0.33) and negatively correlated with sand percentage (r=–0.46), lime (r=-0.31) and pH (r=–0.37).

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Table 3 DCA applied to the correlation matrix of environmental factors in the study area.

Environmental Factors	Axis 1 of DCA	Axis 2 of DCA	Axis 3 of DCA
Elevation	0.82**	-0.09	0.33*
Slope	0.61**	-0.42**	-0.19
Gr.	0.21	-0.62**	-0.08
Animal grazing	-0.20	0.27	0.22
Sand	-0.20	0.24	-0.36*
Li	-0.11	-0.32*	-0.31
Gips.	0.39**	0.18	0.33*
EC	-0.20	-0.24	0.24
pH	-0.46**	-0.33*	-0.37*
Ca	0.03	-0.26	-0.15
Na	-0.08	-0.18	0.16
Mg	0.18	-0.21	-0.05
OC	0.64**	0.04	-0.04
K	0.07	-0.08	-0.06

(*=P<0.05, **=P<0.01).
Abbreviations are defined in Appendix A.

4 DISCUSSION AND CONCLUSION

Overall, each plant species had a specific relationship with the environment. We proposed that combining several multivariate statistical approaches to discern the complicated relationships between vegetation, soil and topography would be a powerful tool for other areas. Soil is one of the most important components influencing vegetation. Vegetation and soil are influenced by topography. Topographic characteristics can also regulate moisture distribution pattern. Most studies that have been conducted to date have focused on the relationships between two components, but few have investigated the relationship between vegetation, soil and topography. Maestre *et al.* (2003) and Canton *et al.* (2004) considered whether the distribution of plants was affected by a moisture gradient controlled by elevation, slope, soil texture and sand. In many studies**,** soil salinity was considered to be the important factors that could affect vegetation type (Tuleninova and Globus, 2000) since soil salinization is widespread in alluvial plains in the study area. The results of the present study imply that topographical factors have a significant effect on vegetation groups in the study area. The results showed that, in the study area, the distribution of vegetation groups among different environmental factors was most strongly correlated with soil characteristics such as organic carbon, gypsum, lime, pH, and gravity, and with topographical factors such as elevation and slope. Huston, 1994, Zang *et al.,* 2008, Moustafa and Zaghloul, 1996, Kigeston and Walderson, 2003; Sebastia 2004; Davies *et al.,* 2007; and Enright *et al.,* 2005 showed that vegetation distribution was related to topographical factors. In the flat region of the study area, sodium ions (Na) and EC were found to be the effective factors in the distribution of ecological vegetation groups. For many of the vegetation groups dominated by halophyte species, sodium (Na) has a strong relationship with soil salinity and is an indicator of the separation of plant species in arid zones.

In the present study, sodium was identified as an indicator for some species such as *Artemisia sieberi, Zygophyllum atriplicoides* and *Halothamnus glaucus*. The results showed that

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the distribution of vegetation groups were not most strongly correlated with grazing intensity. Similar conclusions of the halophytic vegetation were reached by Wolderwahid *et al.* (2007). The results showed amount of organic carbon and gypsum affected the distribution of *Artemisia aucheri, Astragalus myriacacanthus, Acantophyllum sordium and Gymnocarpus decande*r. The vegetation groups of *Artemisia sieberi-Stipa barbata* and *Artemisia sieberi-Astragalus glaucacanthus-Iris songarica* are directly related to pH, gravel percentage, slope and lime percentage.

5 APPENDIX A

Abbreviations of the vegetation groups and environmental factors in the tables and figures.

As.glau = *Astragalus glaucacanthus*
Cosi.des = *Cousinia deserti*
Alle.sub = *Aellenia subaphylla*
Sal.arbu = *Salsola arbuscula*
Poa.sina = *Poa sinaica*
Sal.tome = *Salsola tomentosa*
Euph.san = *Ephedra intermedia*
Sal.arbf = *Salsola arbusculiformis*
Pe. ga. = *Peganum harmalla*
Ana.aph = *Anabasis Aphylla*
Alle.gla = *Aellenia glauca*
Zy.eur = *Zygophyllum atriplicoide*
Aca.liu = *Acantholimon flexuosum*
Ar.siebe = *Artemisi sieberi*
tri.tejh = *Trigonella elliptica*
Iris.son = *Iris songarica*
Noe.moc = *Noea mocronata*
Eph.pro = *Ephedra intermedia*
Con.co = *Convolvulus fruticosus*
amy.lysi = *Amygdalus lycioides*
Scario.o = *Scariola orientalis*
Stach.in = *Stachys inflate*
Ero.cera = *Erotia ceratoides*
St.ara = *Stipa arabica*
Her.ang = *Hertia angustifolia*
tecri.po = *Teucrium polium*
Rham.per = *Rhamnus persica*
Mori.spi = *Moriera spinosa*
St.ba = *Stipa barbata*
Fro.owi = *Frula ovina*
Ar.auch = *Artemisia aucheri*
Acant.soa = *Acanthophyllum sordium*
Gem.moun = *Gymnocarpus decander*
As.gree = *Astragalus myriacanthus*
thy.kots = *Thymus kotschyanus*
As.cam = *Astragalus campylanthus*
I = *Ar.si-Sa.ar = Artemisia sieberi-Salsola arbuscula*
II = *Ar.si-Zy.at = Artemisia sieberi-Zygophyllum atriplicoide*
III = *Ar.si-As.gl-Ir.so = Artemisia sieberi-Astragalus glaucacanthus- Iris songarica*
IV = *Ar.si-St.ba = Artemisia sieberi-Stipa barbata*
V = *Ar.au-As.my = Artemisia aucheri-Astragalus myriacanthus*
Organic Carbon (%) = OC
Eign = Eigenvalue
Gips = Gypsum (%)
Li = Lime (%)
Gr = Gravel (%)
pH= acidity
Elevation(m) = Elevation
SAR = Sodium absorption ratio
EC = Electrical conductivity

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بررسی رابطه بین پوشش گیاهی، توپوگرافی و برخی خصوصیات فیزیکی-شیمیایی خاک در مراتع ندوشن استان یزد (ایران)

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چکیده رابطه بین توپوگرافی، فاکتورهای خاکی و پراکنش گروه‌های اکولوژیک پوشش گیاهی در سرزمین‌های مرتعی خشک استان یزد بررسی شد. گونه‌هایی که در سطح مرتع حضور داشتند ثبت شدند و فاکتورهای پوشش گیاهی بر اساس روش نمونه‌برداری سیستماتیک- تصادفی مورد بررسی قرار گرفتند. برآورد تاج و پوشش و انبوهی به صورت کمی و با استفاده از ترانسکت و پلات انجام گردید و از طریق TWINSPAN گونه‌های گیاهی در گروه‌های مختلف طبقه‌بندی شدند. نمونه‌های خاک نیز از عمق ۳۰-۰ سانتیمتر در هر پلات برداشت شدند. در هر گروه گونه اکولوژیک پوشش گیاهی؛ بیست فاکتور محیطی از قبیل ارتفاع محل، شیب دامنه، جهت دامنه، درصد خاک لخت، چرای دام، درصد قلوه سنگ، یون‌های محلول (سدیم، پتاسیم، منیزیم و کلسیم)، ازت کل، مواد آلی، آهک، گچ، هدایت الکتریکی، اسیدیته خاک، درصد شن، سیلت و رس اندازه‌گیری شدند. از طریق آنالیز چندگانه DCA داده‌های بدست آمده آنالیز گردیدند. نتایج نشان داد که پراکنش پوشش گیاهی در ارتباط با ارتفاع شیب و خصوصیات خاک از قبیل بافت، مواد آلی، گچ، اسیدیته، آهک و درصد سنگریزه در منطقه مورد مطالعه بوده است.

کلمات کلیدی: آنالیزهای چندگانه، توپوگرافی، خصوصیات خاک، مراتع ندوشن