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Ecotones and forest communities along an elevation gradient in Hyrcanian forests, north of Iran

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ABSTRACT

A comprehensive understanding of plant associations, especially in transition areas can be achieved by identification of vegetation and study of relationships between plant species and environment. Borders of ecotones and forest communities (Tiremrud basin in the southern part of Tonekabon, Iran) were found based on environmental factors such as elevation, slope and changes in floristic patterns. Totally, 44 plots (20 × 20 m) were collected by the transect method with at least one sample plot per contour line and 50 m interval. A total number of tree species was recorded separately in each sample plot. Herbaceous species were sampled based on the Brown-Blanket cover percentage and frequency of vegetative elements by 5 × 2 m^2 micro plots in four corners and centre of each main plot. Four ecological groups were identified on altitudes 2070, 1236, 924, and 375 m above sea level with mean slopes of 43, 50, 40, and 59%, respectively. The first and fourth ecological groups were at the highest and the lowest elevations, respectively, while the second and third ones in the middle of the two groups. A comparison of ecological groups in terms of plant biodiversity indicated significant differences altogether. In terms of species diversity indices, Shannon-Wiener and Simpson-Pilo revealed that the first, fourth, and second ecological groups had maximum, minimum, and average values, respectively. According to findings of this study, ecological groups had significant differences in terms of altitude factor.

Keywords: Shannon-Wiener and Simpson species diversity, biodiversity.

INTRODUCTION

Conservation, maintenance, and management of natural resources require a comprehensive understanding of these issues. It is therefore, essential to utilize plant ecology and sociology to determine and identify endogenous environments, environmental uniformity, sequences and stages, as well as plant communities. Noteworthy, understanding the plant communities encompasses identification of habitats and prediction of floristic evolution in a given environment, since the emergence of vegetation is a result of the interaction between vegetative elements and physical environmental factors. Given the number of effective factors, if these factors are all equivalent and independent of each other, the variety of possible combinations would be very significant. Climate and topography are among the most fundamental drivers of plant diversity (Zhang *et al*. 2017). It is essential to identify and study vegetation in applied studies for solving ecological issues related to the management and conservation of natural ecosystems (De Bello *et al.* 2005, Díaz *et al*. 2007).

Plants reflect a set of environmental conditions including climate, humidity, and soil variables (Muller- Dombois & Ellenberg 1974, Guilemette & Desrochers 2008, Kaufmann *et al.* 2017) and changes in vegetation results from the dominance of environmental factors (Awasthi *et al*. 2015). Species and species diversity are distributed along differing environmental gradients (Hortal *et al*. 2013, Slaton 2015). Development and distribution of plant species in nature are not by accident, but those with similar nature and ecological needs in nature are brought together to form plant communities. The correlation of these factors with plant communities could be determined by the study of plant communities and the analysis of different environmental gradients. The identification of plant

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communities in an area facilitates the identification of soil properties and other environmental variables. The Hyrcanian forests in north of Iran exhibit complex biodiversity and structure that can optimally be managed in the future only by full recognition of this ecosystem. These forests are integrated, and there was no disconnection from lowland to high altitudes in the early years of the last century. During the recent decades, a significant percentage of these forests have lost and only a few small patches remained in lowlands due to changing the land use for crop production, residential, and industrial purposes. Due to the specific physiographic conditions of the mountainous regions in the high altitudes of Hyrcanian forests, there are different climatic and edaphic conditions in each region. These forests span from the coastal plain and continue to be at high elevations in different areas and elevation bands. The ecosystem changes from forest to range in high altitudes (Tenzin & Hasenauer 2016). Somehow the most obvious ecotone between the forest and rangeland ecosystems is visible at the high elevations of Hyrcanian forests. The width of these ecotones varies in various regions with different environmental conditions. The forest communities change due to elevation changes and consequently, climate change. Since plant species have different ecological niches, they are located in different elevation profiles of the Hyrcanian forests (Marvi Mohajer 2002, Borah *et al*, 2014). Different studies focused on plant diversity of ecotones along raising elevations (Arekhi *et al.* 2010, Nogué *et al.* 2013 Irl *et al.* 2015, Singh *et al.* 2019, Sharma *et al.* 2019). Ecotones are significant areas of landscape heterogeneity that contain elements, patterns, and processes at different spatial scales. Depending on the scale, climate, topographic characteristics, soil, and species interactions, physiological and genetic population parameters are essential considerations in ecotonal areas. Ecotones can be sensitive areas for detecting the effects of climate change. The study of ecotones enables us to gain a better understanding of the cause-and-effect relationships between certain landscapes (Sabzeghabaee *et al*. 2012). This study seeks to find the width of ecotone communities and to identify dominant conditions in these crucial areas because the type of management in these ecosystems depends on the conditions of the two communities, and the attitude on the management of these areas should be different.

MATERIALS AND METHODS

The study area

The study area is located in basin No. 32 of Mazandaran-Noshahr Provincial office of Natural Resources, and Tonekabon district office of Natural Resources, between latitude 36° 36´ to 36° 45´ N and longitude 50° 46´ to 50° 50´ E. Minimum and maximum elevations are 111 and 3520 m above sea level (masl), respectively. The total area of the Tiremrud basin is 20287 ha, based on the Master Plan of the northern forests of Iran.
According to the general climatic conditions, this area has a temperate and humid climate with average annual rainfall and temperature of 1111 mm and 12.3 °C. The average maximum and minimum temperatures are 23.8 °C (August) and 1.6°C (February), respectively.

Study method

In the present study, a suitable area in which the objectives of the study could be achieved was selected by literature review, collecting experts' opinions, and visiting forests. Given the plant communities of the study area and using the forest management plan, borders of ecotones and forest communities of the area were identified and considered as the main sampling classes. Other environmental factors such as elevation, slope, alterations in floristic pattern and differences were considered for sampling. The transect method was used to collect the required data. A transect is a straight line or strip used in the study of the layering and analysis of community structure in places where some habitat features are evident on steep slopes (Goldsmith & Harrison 1976, Gopal & Bhardawaj 1979).
Transects are commonly used along an area characterized by rapid vegetation changes and marked environmental gradients. Specimen plots were identified and studied along a transect at specified intervals (50 m) perpendicular to the counter line from the coastal plain (low elevation) to the forest and pasture ecotone (high elevation). In total, 44 sample plots were collected in this study. The total number of tree species was recorded separately in each sample plot. Micro plots (5×2 m^2) in quadrate and centre of plots were taken for sampling grassland. The percentage of crown cover and frequency of floristic elements were determined and recorded based on Braun-Blanquette method.

Analysis method

To easily understanding the concept of the continuum vegetation composition changes and to help better understanding of relationships between species and environmental factors, relevé (survey) with similar species

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composition were classified into ecological groups. PC-ORD Ver. 5 for Win software (Ajbilou & Maranon 2006) was used to classify and analyse ecological species groups. Excel spreadsheet format was used to introduce data to this software. The numerical classification of two-way index species (TWINSPAN) was used to reduce the subjective factor in disaggregating groups and determining ecological groups.

The TWINSPAN method was based on ground vegetation information (composition of the total crown cover of all species and the composition of herbaceous species based on basal area of (100-75-50-25-12.5-5-2-1-0). The fourth cut-off level was experimentally selected (Gilliam 2007, Flynn *et al.* 2009) as the stopping point for group formation. After classifying the habitat and identifying plant ecological groups of the area, the value indicator index of species was calculated to determine indicator species of each community using the index value (IV) or Durfrene & Legendre methods (Dufrene & Legendre 1997). The biodiversity in plant ecological groups was compared using species richness index (S) (Magurran 1988), Shannon-Wiener species diversity (Peet 1974), Simpson (Hill 1973) and Pilo uniformity (Peet 1974) (Table 1).

Table 1. Richness, Uniformity and species biodiversity indices.

Index	Reference	Formula
Species richness (S)	Magurran, 1988	$R = S$
Pilo uniformity	Peet, 1974	$p_i = \frac{n_i}{N}$ $\quad J' = \left[-\sum p_i \ln(p_i)\right] / \ln S$
Shannon-Wiener species diversity	Peet, 1974	$H' = -\sum_i p_i \ln(p_i)$
Simpson diversity	Hill، 1973	$\lambda = 1 - \sum_i p_i^2$

S= No. species P_i= Crown cover percent of species (i) (n_i) total percentage of crown cover of species (N).

RESULTS AND DISCUSSION

Based on indicator species analysis (TWINSPAN) method and group formation cut-off level (Fig. 1), the ecological groups had mean altitudes of 2070, 1236, 924, and 375 m and mean slopes of 43, 50, 40, and 59%, respectively.

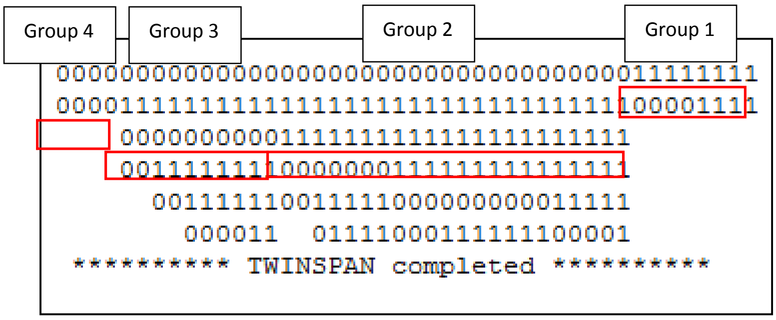

Fig. 1. TWINSPAN analytical diagram for studied area.

The eigenvalues, axis length, percentage of the first four axes explained variance, and the sum of the eigenvalues of all axes (total inertia) of DCA analysis are shown in Table 2. The results of this ordination method are shown in two-dimensional sample plots (Fig. 2).

Table 1. Eigenvalues and Gradient length of DCA analysis.

	Axe 1	Axe 2
Eigenvalues	0.718	0.299
Gradient length	4.177	2.943
Total variance (Total inertia) = 5.941		

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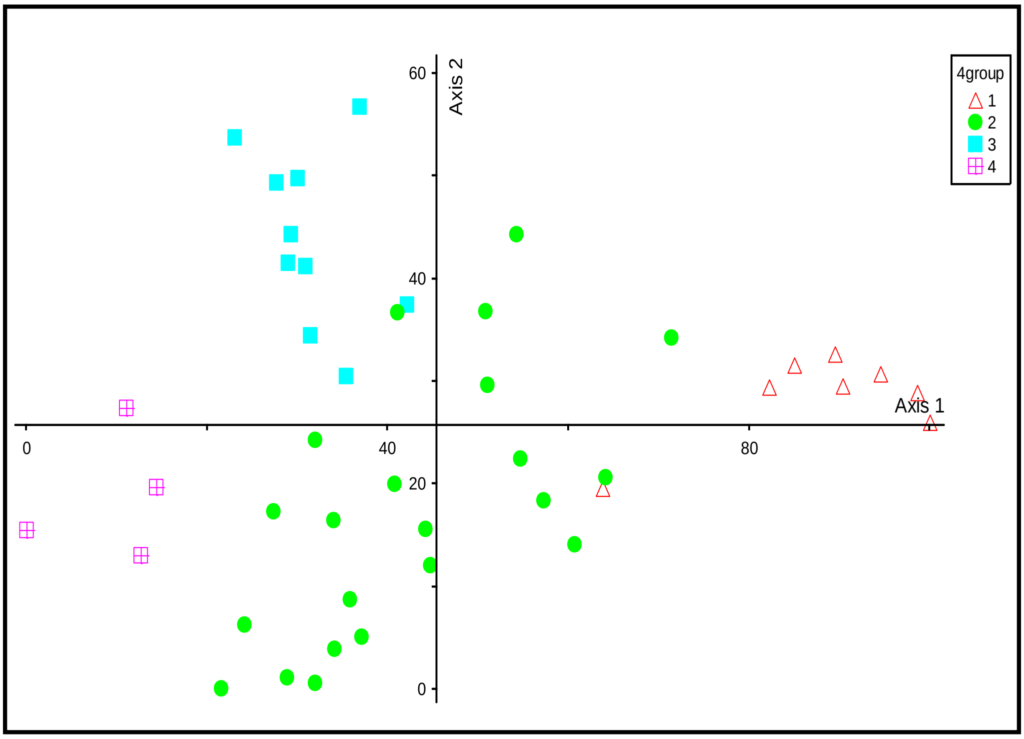

Fig. 2. DCA ordination diagram for sample plots of ecosystem units.

The DCA ordination diagram shows that the sample plot of each ecological group has its distinct margins and are separate from each other due to differences in floristic composition caused by differences in environmental properties. Significant differences between ecological groups of the area in terms of environmental variables (slope and altitude) and biodiversity indices were determined by One-Way ANOVA. These groups were compared to assess their status based on these environmental factors through a mean comparison test (Table 3).

Duncan test results revealed that the first and fourth ecological groups were at the highest and the lowest altitudes in the area, respectively, with the second and third groups being in the middle. There were no significant differences in slope between the ecological groups.

A comparison of ecological groups showed significant differences in terms of plant biodiversity indices. Shannon-Wiener and Simpson-Pilo of species diversity index values indicate that the first, fourth, and second ecological groups had maximum, minimum and mean values of species diversity indices, respectively. However, in terms of Pilo's uniformity index, the first and third groups, together with the second and fourth groups, exhibited maximum, minimum, and average uniformity index values, respectively. In terms of species richness index, the first, third, second, and fourth groups were ranked, respectively. Based on the results of this study, there are four plant groups with distinct floristic composition and environmental characteristics in the Tiremrud forest.

The results also revealed that ecological groups in the region also display different biodiversity indices. Indeed, ecotones were found to harbour relatively high richness and diversity in many regions (Kark 2013). The main cause of this discrepancy in biodiversity indices could be due to the wide range of alterations in environmental factors at the regional level.

It refers to how the local environment alters along some type of boundary or edge, and how biodiversity is affected by such edges, as well as the provision of optimal environmental conditions for establishment of different species in each ecological group in this area with different environmental conditions. The effect of environmental factors has been emphasized in different studies (Arekhi *et al.* 2010, Nogué *et al.* 2013, Irl *et al.* 2015, Singh *et al.* 2019, Sharma *et al.* 2019).

The classification of ecological groups in the DCA method, indicates that the sample plots of each group have their distinct margins and are completely recognized from each other. Studies on patterns of biodiversity in ecotonal areas have led to a range of ecological and evolutionary insights. Recent work is providing increased evidence exhibiting that boundary regions between ecological communities can be highly diverse at both the within-species and community levels (Kark 2017).

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Table 3. Analysis of variance and mean comparisons of environmental variables in ecological groups of the studied area.

Environmental variable	Group 1	Group 2	Group 3	Group 4	F	Sig.
Slope %	43.12 ± 4.90	50 ± 3.56	40 ± 2.98	58 ± 10.87	1.92	ns
Elevation (masl.)	2070 ± 127.19^{a}	1236 ± 102.91^{ab}	924 ± 194.93^{ab}	375 ± 32.27^{c}	13.74	P < 0.01
Richness (S)	28.5 ± 2.63^{a}	14.72 ± 0.82^{c}	22.30 ± 1.1^{b}	6.75 ± 0.85^{d}	29.40	P < 0.01
Shannon-Wiener diversity (H)	2.83 ± 0.13^{a}	1.87 ± 0.08^{ab}	1.90 ± 0.06^{ab}	1.08 ± 0.26^{b}	30.02	P < 0.01
Simpson diversity	0.90 ± 0.03^{a}	0.75 ± 0.02^{ab}	0.72 ± 0.02^{ab}	0.59 ± 0.04^{b}	12.58	P < 0.01
Pilo uniformity	0.62 ± 0.03^{a}	0.48 ± 0.03^{ab}	0.31 ± 0.02^{b}	0.44 ± 0.01^{ab}	9.49	P < 0.01

The numerical values of the table correspond to the mean of the variables with their standard error. ns: No significant difference, P <0.05 and P <0.01: Significant difference at 95% and 99% levels, respectively.

The differences in floristic and environmental characteristics reflect ecological groups and show the ecological relationships between plant groups and the environment. Study about composition, richness and floristic diversity along an elevation gradient in Jammu and Kashmir showed that the diversity and evenness rise along the rising elevation reaching maxima at the mid elevation (Singh *et al.* 2019). Slope direction affects sun energy intake, cloudiness, and moisture content of habitat. The slope factor influences soil depth, texture and moisture content as well as ground water depth (He *et al.* 2007). In addition, it controls plant species coverage and thus plays a decisive role in the distribution of plant communities in each region.

In the classification of plant communities of Kheyrodkenar forest, Mattaji & Babaikafaki (2006) reported that altitude was the most important habitat factor affecting the separation of the communities which were not different in terms of slope and aspect. Based on the findings of the present study, elevation can be considered as the main environmental factor resulting in the biodiversity of ecotones.

CONCLUSIONS

In conclusion, we evaluated different communities of Tiremrud basin in the southern part of Tonekabon, Iran by environmental factors such as elevation, slope and changes in floristic patterns for a comprehensive understanding of plant communities in Hyrcanian forests. At least four ecological groups were identified on different altitudes in this area exhibiting significant differences in terms of plant biodiversity. Most indices showed an increasing pattern along to altitude which not related to the slope and aspect.

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اکوتون‌ها و جمعیت‌های جنگلی در طول گرادیان ارتفاعی در جنگل‌های هیرکانی

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گروه جنگل‌داری دانشگاه آزاد اسلامی چالوس

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چکیده

درک جامع از اجتماعات گیاهی، به‌خصوص در نواحی انتقالی از طریق شناسایی پوشش و مطالعه ارتباط بین گونه‌های گیاهی و محیط آنها به دست می‌آید. مرز اکوتون‌ها و جمعیت‌های گیاهی (آبخیز تیرم‌رود در جنوب تنکابن) با مطالعه عوامل محیطی مانند ارتفاع، شیب و تغییرات الگوهای گیاهی مشخص شد. در کل ۴۴ قطعه نمونه (۲۰ × ۲۰ مترمربعی) در طول یک ترانسکت با فواصل ۵۰ متری بررسی و داده‌های کل گونه‌های درختی در هر قطعه نمونه جمع‌آوری شد. درصد پوشش جمعیت و فراوانی عناصر علفی به ترتیب با روش بروان-بلانکه و ریزقطعه نونه‌های ۲×۵ مترمربعی در چهارگوشه و مرکز قطعه نمونه اصلی تعیین شد. چهار گروه بوم شناختی به ترتیب در ارتفاع ۲۰۷۰، ۱۲۳۶، ۹۲۴ و ۳۷۵ متری از سطح دریا و شیب ۴۳، ۵۰، ۴۰ و ۵۹ درصد شناسایی شد. گروه‌های بوم شناختی اول، چهارم و دو گروه دوم و سوم به ترتیب در بالاترین، پایین‌ترین و ارتفاع میانی قرار داشتند. مقایسه گروه‌های بوم شناختی از نظر تنوع زیستی حکایت از وجود تفاوت آماری معنی دار داشت. براساس شاخص‌های تنوع گونه‌ای شانون-وینیر و سیمپسون-پیلو، گروه‌های اول، چهارم و دو گروه دوم و سوم به ترتیب بالاترین، پایین‌ترین و متوسط ارزش این شاخص‌ها را به خود اختصاص دادند. در کل بر مبنای یافته‌های این پژوهش، گروه‌های بوم شناختی تفاوت آماری معنی‌دار با تغییر ارتفاع را به نمایش گذاشتند.

*مولف مسئول

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