Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28

Maejo International Journal of Science and Technology

ISSN 1905-7873
Available online at www.mijst.mju.ac.th

Full Paper

Herbaceous biodiversity and soil properties of stabilised landslide area in northern mountain forest of Iran

Seyed Ata ollah Hosseini *, Mohsen Gorgandipour and Ehsan Abdi

Forestry and Forest Economics Department, University of Tehran, Iran

* Corresponding author, e-mail: at.hosseini@ut.ac.ir

Received: 18 July 2017 / Accepted: 28 January 2019 / Published: 8 February 2019

Abstract: Landslides create many ecological processes on a local scale in the landscape, including subsequent ecological processes. Landslide geological effects and their management as well as physical hazards have been thoroughly investigated, but the ecological processes created by landslides and their relationship with measures to rebuild the stability of unstable domains have not been well investigated. The comparison of a landslide area with its adjacent control area in terms of soil properties and vegetation can help us determine the time it takes for recovery. Soil properties and herbaceous biodiversity of a stabilised landslide area in the Northern Mountain Forest (Kheyrud Forest) were investigated and compared with a non-slide adjacent area. In order to study the properties of soil and herbaceous biodiversity in the two areas, 2 * 2 (m) sample plots were used. To calculate biodiversity indexes, PAST software was used. To compare properties of the areas, Independent Sample T-test was used. Statistical test results showed an insignificant difference between chemical properties and herbaceous diversity of the areas. In this study the means of Margalef and Menhinick richness were 1.27 and 0.68 respectively in the stabilised area, and 1.43 and 0.73 respectively in the control area. The means of Simpson diversity in the stabilised area and control area were 0.76 and 0.66 respectively.The results of the soil mechanical properties comparison showed that the soil texture of the areas of interest was fine grained. Soil liquid and plasticity limits were 42.78 and 28.42 respectively in the stabilised area and 42.42 and 29.34 respectively in the control area. It was concluded that the soil mechanical, physical and chemical properties of the stabilised area returned to the original situation over two decades.

Keywords: landslide, herbaceous biodiversity, northern mountain forest of Iran

---

INTRODUCTION

Occurrences of landslides are prevalent in hill complexes both in the highlands and lowlands. These landslides have caused loss of lives and properties in recent years. While

Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28

agriculture in landslide-prone areas has caused severe soil erosion downstream, hill construction projects for infrastructure and residential purposes are the main triggering factors of landslides [1]. Landslides are a variety of slope movements causing mass movement of sediment, rock, soil or a combination of them down the slope under the influence of gravity. They are divided into various types (fall, topple, flow, slide, lateral spread, debris and creep) [2]. Landslides are one of the common natural phenomena on steep slopes of forest ecosystems [3] causing restriction of management and forest utilisation along the forest roads [4]. So far, many studies have been done around the effects of landslide on human's life and infrastructure, but few studies have been conducted on its effects on the natural environment [5]. Moreover, the role that landslide plays in ecology disturbances has rarely been investigated [6]. Landslides encompass many ecological processes on a local scale, including ecological succession processes; they recover nutrients and provide habitats for colonisation of species [3]. It is well known that the stability and productivity of ecosystems are fundamental components of the earth's biophysical integrity. Therefore, biodiversity should act as a measure of biophysical integrity and biodiversity conservation might provide a viable framework for policies that drive economic activity towards overall biophysical sustainability [7].

Landslides have a varied morphology and a mosaic arrangement of natural habitats occurring within them. These habitats are adapted to the diversified landforms. Such an arrangement of habitats imparts a character to the landscape of these areas that differs from the surrounding landscape. These differences are true both on a local and a regional scale. The landslide areas are characterised by a specific geo- and biodiversity. Research on the diversity in this context has hardly ever been conducted; if some investigations are launched, then they refer, in general, to some selected aspects of transforming the natural environment [8, 9]. Therefore, it is necessary to study the effects of landslides on herbaceous biodiversity and soil properties. Alexandrowicz and Margielewski [10] simultaneously studied the geological, geomorphological and biocenotic features of landslide areas in the Polish Outer (Flysch) Carpathians. The research allowed them to define the relations between the diversity of the landslide-originating landforms and the biotopes occurring within them. High geodiversity (diversity of landforms, soil and water) of landslide areas allows for a mosaic network of extremely diversified natural habitats. All of these natural habitats together are characterised by a specific biodiversity. Dependence between geo- and biodiversity in landslide areas is connected with a specific co-evolution that is related to the adaptation of the ecosystems to landforms. The study of the floristic and vegetation analysis in seven Mediterranean landslides led to the understanding of the successional processes occurring in different landslide-disturbed sectors [11]. This study shows that in landslides there is a clear differentiation between three main landslide sectors (scarp, main body and foot) concerning floristic composition, vegetation structure, floristic richness, successional processes and plant functional type. Additional differences were found between landslide areas and undisturbed agricultural areas adjacent to the landslides [11]. To explore the characteristics of the early secondary succession on landslides, the plant community on landslides within the Longxi-Hongkou National Nature Reserve, Dujiangyan County, Sichuan Province, China was monitored. Species richness, cumulative species richness, and Shannon-Weiner index were calculated to describe the dynamics of the species diversity. It was found that the species richness and cumulative species richness peaked earlier in landslide scale than that in a 2 m × 2 m quadrat scale. Species turnover rates were high during the first two years and then tapered off from the third year onwards [12]. Pandey and Singh [13], Reddy and Singh [14] and Zarin and Johnson [15] studied the restoration process of soil chemical properties and vegetation in different landslide areas of the forest ecosystems. In Iran Hosseini [16] studied landslide phenomenon in Kheyrud forest in terms of physical and mechanical properties of the soil and Varedi Koolaei [17] compared the diversity of the understorey cover and some soil properties in afforestation and landslide areas of Alder stands with adjacent natural Darabkola forest in the north of Iran. In Iran although landslide geological effects and their management as well as physical hazards have been investigated, the ecological processes created by landslides and their relationship with measures to rebuild the stability of unstable domains have not been well examined. The comparison of a landslide area with its adjacent control area in terms of soil properties and vegetation can help us determine the time it takes for recovery. This study was conducted with the aim of investigating the herbaceous biodiversity and soil mechanical, physical and chemical properties of the stabilised landslide area and comparing it with the adjacent non-slide area.

METHODS

This study was conducted in the Hyrcanian Forest (Kheyrud) in the north of Iran, in compartment No. 11 of the Patom district. This forest is located at seven kilometres east of Nowshahr city between latitudes of 36° 27' and 36° 40' and longitudes of 51° 32' and 51° 43' (Figure 1). The average precipitation is 1330 mm per year. The climate of the region is moist and temperate. Patom district is located at the altitude of 42 m to 934 m above sea level and the parent rock is limestone and the soil is formed from limestone with clay and sand [18]. Patom district is the first district of Kheyrud Forest and thus the first road was opened in this district. Although the road was constructed based on scientific standards and technical principles, in 1994 after years of exploitation, the road at 4th km the Pich-e-senobar, was slipping and unusable. This area has a slope of 15% and is directed towards the northern slope [18].

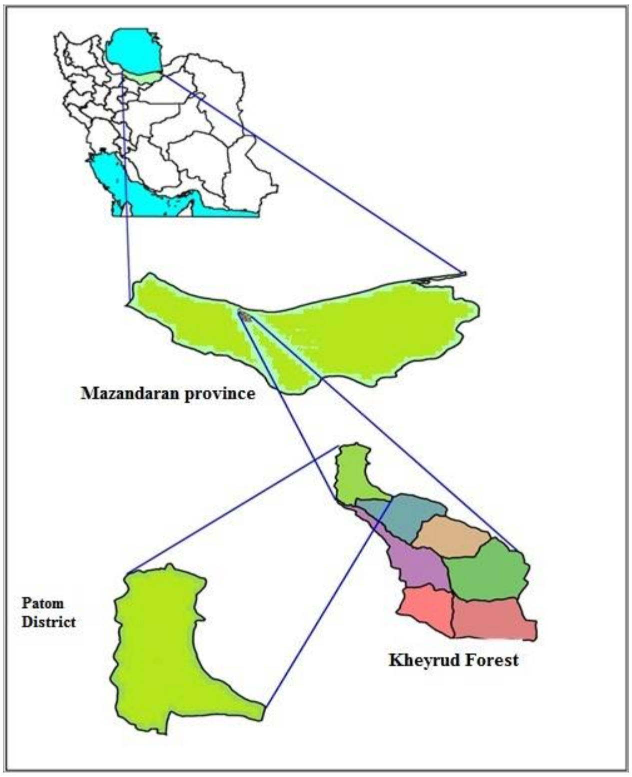

Figure 1. Study area location

Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28

In this study stabilised landslide area covered by Alder 20 years ago and its adjacent area (control area) with the same topographical situation (slope, aspect and elevation) were selected. The areas were surveyed using Global Positioning System (GPS). To measure the herbaceous biodiversity and soil mechanical, physical and chemical properties of the stabilised landslide area and control area, a 10 m × 10 m network was used and a total of 20 pieces of 2 m × 2 m plots were established [19, 20]. In each plot all herbaceous species and their abundance or dominance were recorded based on the abundance table of Braun-Blanquet [21]. Species richness index expresses the state of the environment in terms of its appropriate conditions contributing to an increase in the presence of species. Menhinick's and Margalef's richness indices are two indices for testing species richness. The former is the ratio of the number of taxa to the square root of sample size while the latter is the ratio of the number of taxa and to the number of individuals [22]. To calculate Shannon-Weiner and Simpson biodiversity indices, Margalef and Menhinick richness and Sheldon evenness were used in each plot in PAST software using equations 1-5 [19, 20]:

Margalef : $R1=\frac{S-1}{Ln_N}$ (1)

Sheldon : $E = \frac{E^{H'}}{S}$ (2) Menhinick : $R2 = \frac{S}{\sqrt{N}}$ (3)

Shannon- Wiener : $LN\frac{N_i}{N}$ $H' = \sum_{i=1}^{S}\frac{N_i}{N}$ (4)

Simpson : $1\text{-}D = 1- \sum_{i=1}^{S}\left[\frac{Ni\,(Ni-1)}{N\,(N-1)}\right]$ (5)

R= Richness, E= evenness, S= Total number of species per sample, N= frequency of each species in the sample, Ln_N= natural logarithm of N, Ni= number of i-th population, 1-D = Simpson's index, H '= Shannon -Wiener index

Soil samples (20-30 cm deep) were collected in each plot in order to determine the soil chemical properties (pH, electrical conductivity, nitrogen, phosphorus, potassium, calcium carbonate and organic carbon) [23]. Soil mechanical properties viz. Atterberg Limits [soil plasticity limit (as per ASTM-D424-59) and liquid limit (as per ASTM-D423-66) and physical properties (soil classification using Unified System (as per ASTM-D422-63)] were determined with samples 40-50 cm deep [24]. Collected data included average indices of diversity, richness and evenness. Soil chemical properties were analysed and compared statistically using independent sample T test by SPSS 17.0 after ensuring the normality of data set (Kolmogorov–Smirnov test) and homogeneity of variances (Leven test).

RESULTS AND DISCUSSION

There were 19 herbaceous species in the study area belonging to 18 genus and 15 families. Families *Rosaceae, Poaceae, Cyperaceae* and *Lamiaceae* were the most common ones in the area (Table 1). Kolmogorov-Smirnov test [20, 21] results showed that for biodiversity indices and soil chemical properties, the data were normally distributed. Leven test [20, 21] results showed homogeneous variances for all biodiversity indices except Equitability J indices and all the soil chemical properties were homogeneous. Independent sample T test results showed that there was no significant difference between Simpson and Shannon-Wiener diversity and Margalef and

Menhinick richness in the study area. However; there was a significant difference at 95% level between Sheldon and Equitability J evenness in the two areas (Table 2). Independent sample T test results also showed that there was no significant difference between the soil chemical properties of the two study areas (Table 3). The results of soil classification using Unified System showed that the soil type in the two study areas was fine-grained (Tables 4, 5). Soil Liquid Limit test result based on the Atterberg Limits was between 30-50, suggesting normal liquid limit and the calculated soil texture based on Unified System for all plots was 'low liquid limit clay' (Tables 4, 5).

Table 1. Existing herbaceous species in the plots

Scientific name	Family	Area
Rubus sp.	Rosaceae	Stabilised landslide and control
Athyrium fillix-femina (L) Roth	Athyriaceae	Stabilised landslide and control
Dryopteris affinis (Lowe) Fraser-Jenk.	Dryopteridaceae	Stabilised landslide and control
Oplismenus undulatifolius P. Beauv.	Gramineae (Poaceae)	Stabilised landslide and control
Circea lutetiana L.	Onagraceae	Stabilised landslide and control
Carex pendula Huds.	Cyperaceae	Stabilised landslide and control
Euphorbia amygdaloides L.	Euphorbiaceae	Stabilised landslide and control
Brachypodium sylvaticum (Huds.) P. beauv.	Poaceae	Stabilised landslide and control
Viola sylvestris Lam	Violaceaee	Stabilised landslide and control
Carex remota L.	Cyperaceae	Stabilised landslide and control
Urtica dioica L.	Urticaceae	Stabilised landslide and control
Pteris cretica L.	Pteridaceae	Stabilised landslide and control
Solanum kieseritzky C.A.M.	Solanaceae	Stabilised landslide and control
Hypericum androsaemum L.	Hypericaceae	Stabilised landslide and control
Phyllitis scolopendrium (L.) Newn.	Aspleniaceae	Stabilised landslide and control
Scutellaria tournefortii Benth.	Lamiaceae	Stabilised landslide and control
Hedera pastuchovii Woron. Ex Grossh	Araliaceae	Stabilised landslide and control
Geum urbanum L.	Rosaceae	Stabilised landslide and control
Mentha longifolia (L.) Huds.	Lamiaceae	Control

Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28

Table 2. Comparison of biodiversity average, richness and evenness indices

		Control area	Stabilised landslide area	P-value
Shannon-Wiener	mean	1.48	1.62	
diversity	SD	0.29	0.24	0.285^{ns}
Simpson diversity	mean	0.66	0.76	0.076^{ns}
	SD	0.14	0.08	
Margalef richness	mean	1.43	1.27	0.347^{ns}
	SD	0.34	0.4	
Menhinick	mean	0.73	0.68	0.526^{ns}
richness	SD	0.14	0.19	
Equitability J	mean	0.73	0.86	0.01*
evenness	SD	0.08	0.05	
Sheldon evenness	mean	0.59	0.77	0.01*
	SD	0.11	0.08	

Note: ns = non-significant, SD = standard deviation, * Significant at 95% level

Table 3. Comparison of soil chemical properties between study areas

		Control area	Stabilised landslide area	P-value
pH	mean	6.41	6.02	0.113^{ns}
	SD	0.49	0.53	
Electrical conductivity (dS/cm)	mean	0.08	0.09	0.646^{ns}
	SD	0.05	0.03	
% Organic carbon	mean	1.05	0.98	0.751^{ns}
	SD	0.32	0.18	
K (ppm)	mean	276	288	0.584^{ns}
	SD	59.47	32.93	
% $CaCO_3$	mean	2.12	1.91	0.251^{ns}
	SD	0.33	0.43	
% N	mean	0.07	0.08	0.377^{ns}
	SD	0.31	0.21	
% P	mean	2.57	2.76	0.658^{ns}
	SD	0.94	0.92	

Note: ns = non-significant, SD = standard deviation

Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28

Table 4. Mechanical properties of soil in stabilised landslide area plots

Plot	Liquid limit %	Plasticity limit %	Plasticity index	Fine-grained %	Coarse-grained %	Soil texture
1	43	29.94	13.1	94.33	5.67	CL
2	43	29.94	13.06	88.87	11.13	CL
3	43.2	29.09	14.11	90.52	9.48	CL
4	42.9	27.84	15.06	90.98	9.02	CL
5	42.9	28.27	14.63	95.09	4.91	CL
6	42.2	26.49	15.71	96.28	3.72	CL
7	42.8	28	14.8	91.15	8.85	CL
8	42.1	28.39	13.71	90.76	9.24	CL
9	42.2	26.92	15.28	92.75	7.25	CL
10	43.9	29.32	14.58	93.01	6.99	CL

Note: CL='low liquid limit clay'

Table 5. Mechanical properties of soil in control area plots

Plot	Liquid limit %	Plasticity limit %	Plasticity index	Fine-grained %	Coarse-grained %	Soil texture
1	43	29.09	13.91	88.96	11.04	CL
2	42.5	30.06	12.44	93.53	6.47	CL
3	43.2	30.64	12.56	92.56	7.44	CL
4	43	29.53	13.47	90.78	9.22	CL
5	43	30.80	12.2	91.65	8.35	CL
6	42.5	30.05	12.45	91.72	8.28	CL
7	39	25.89	13.11	91.27	8.73	CL
8	43.5	30.4	13.1	92.83	7.17	CL
9	43	29.03	13.97	84.8	15.2	CL
10	41.5	27.94	13.56	90.17	9.83	CL

Note: CL='low liquid limit clay'

In this study the means of Margalef and Menhinick richness were 1.27 and 0.68 respectively in the stabilised area and were 1.43 and 0.73 respectively in the control area (Table 2).The means of Simpson diversity in the stabilised area and control area were 0.76 and 0.66 respectively (Table 2). The Simpson diversity index varies between zero and one, and as the index is closer to zero, the variation of the species is lower [25].

Shannon Wiener biodiversity index varies from zero for communities with only one species and high values for communities with many species. In this study the means of Shannon Wiener biodiversity index in the stabilised area and control area were 1.62 and 1.48 respectively (Table 2), which is consistent with the results by Mohammadpour et al. [26] and Seyd et al. [27], who compared managed and unmanaged areas.

One of the most important issues in landslide ecology is the great length of time required for the soil and vegetation characteristics of the landslide to return to their original state. Precise conditions prior to landslide may be unknown due to complex soil changes that simultaneously change the patterns of living organisms in the manner that are not understandable. Thus, there is a need for a long-term (decades and sometimes centuries) assessment of landslides in order to examine precisely how long it is necessary for the landslide characteristics of the soil and vegetation to return to the state before the occurrence of the slip [3].

Our results of comparison of soil chemical properties show that there is no significant difference between stabilised landslide area and control area in terms of soil chemical properties (Table 3), which is consistent with the results obtained by Varedi Koolaei [17].

The results of the soil texture and Atterberg limits show that the means of soil liquid and plasticity limits were 42.78 and 28.42 respectively in the stabilised landslide area and 42.42 and 29.34 respectively in the control area (Tables 4, 5). Hosseini [16] studied landslide phenomenon in the Kheyrud Forest (Pich-e-senobar) and his results showed that the means of the soil liquid and plasticity limits in the study area were 73.2 and 44.43 respectively. Our results indicate a significant decrease in adjacent soil liquid and plasticity limits compared to the early years of slipping (20 years ago) in the slipping area of the Pich-e-senobar, indicating an improvement of the mechanical properties of the slipping soil after 20 years.

CONCLUSIONS

The slipping area of Pich-e-senobar has apparently returned to its original state after 20 years according to the comparative study of physicochemical and mechanical properties of soil and biodiversity, and has no significant difference compared to the adjacent area. Also, the planting of alder trees and their growth after the occurrence of landslide may be considered as a factor in increasing the diversity of the species and improving the soil quality, hence the return of soil characteristics and herbaceous diversity of the area to the original state.

REFERENCES

1. N. M. Yousof and B. Paradhan, “Landslide susceptibility mapping along PLUS expressways in Malaysia using probabilistic based model in GIS”, Proceedings of 7th IGRSM International Remote Sensing and GIS Conference and Exhibition, **2014**, Koalulumpour, Malaysia, pp.123-146.
2. K. Sassa and P. Canuti, “Landslides – Disaster Risk Reduction”, Springer-Verlag, Berlin, **2009**, Ch.4.
3. L. R. Walker and A. B. Shiels, “Landslide Ecology”, Cambridge University Press, Cambridge, **2012**, Ch.5.
4. M. Gorji and N. Sarikhani, “Possibilities of stabilizing landslide and mass movement in forest roads (Case study: Kheyrudkenar Forest as a scientific model)”, *Iran. J. Nat. Res.*, **2003**, *56*, 29-37.

5. R. L. Schuster and L. M. Highland, "Overview of the effects of mass wasting the natural environment", *Env. Eng. Geosci.*, **2007**, *13*, 25-44.
6. M. Geertsema and J. J. Pojar, "Influence of landslides on biophysical diversity–a perspective from British Columbia", *Geomorphol.*, **2007**, *89*, 55-69.
7. M. Christensen and J. Emborg, "Biodiversity in natural versus managed forest in Denmark", *Forest Eco. Manage.*, **1996**, *85*, 47-51.
8. A. Cendrero and F. Dramis, "The contribution of landslides to landscape evolution in Europe", *Geomorphol.,* **1996**, *15*, 191-211.
9. J. Hradecký, T. Pánek and J. Švarc, "Geoecological imprints of slope deformations on habitats – case studies from the Western Carpathians (Czech Republic)", *Moravian Geograph. Rep.*, **2008**, *16*, 25-35.
10. Z. Alexandrowicz and W. Margielewski, "Impact of mass movements on geo- and biodiversity in the Polish Outer (Flysch) Carpathians", *Geomorphol.*, **2010**, *123*, 290-304.
11. C. Neto, P. Cardigos, S. C. Oliveira and J. L. Zêzere, "Floristic and vegetation successional processes within landslides in a Mediterranean environment", *Sci. Total Environ.*, **2017**, *574*, 969-981.
12. B. Li, T. Zeng, J. Ran, B. Yue, M. Zhang, T. Shang and D. Zhu, "Characteristics of the early secondary succession after landslides in a broad-leaved deciduous forest in the south Minshan Mountains", *Forest Ecol. Manage.*, **2017**, *405*, 238-245.
13. A. N. Pandey and J. S. Singh, "Mechanism of ecosystem recovery: A case study from Kumaun Himalaya", *Reclam. Reveg. Res.*, **1985**, *3*, 271-292.
14. V. S. Reddy and J. S. Singh, "Changes in vegetation and soil during succession following landslide disturbance in the Central Himalaya", *J. Environ. Manage.*, **1993**, *39*, 235-250.
15. D. J. Zarin and A. H. Johnson, "Nutrient accumulation during primary succession in a montane tropical forest, Puerto Rico", *Soil Sci. Soc. Am. J.*, **1995**, *59*, 1444-1452.
16. S. A. Hosseini, "Study of landslide phenomenon in mountainous forest roads", *MSc Thesis*, **1994**, Faculty of Natural Recourses, University of Tehran, Iran.
17. S. M. V. Koolaei, "Comparison of regeneration, diversity of understory vegetation cover and some of the soil factors in afforestation and land sliding areas of alder stands with adjacent forest (Case study: district No.1 Darabkola Forest)", *MSc Thesis*, **2011**, Faculty of Natural Recourse, Sari Agricultural Sciences and Natural Resources University, Iran.
18. Patom Forest Management Plan, "The third revision of Patom district of Research and Education Forest", Faculty of Natural Resources, University of Tehran, Iran, **1994**.
19. M. Mesdaghi, "Plant Ecology", 2nd Edn., Jahad Daneshgahi Publications, Tehran, **2011**.
20. M. Bazyari, H. Jalilvand, Y. Kooch and S. A. Hosseini, "Ecological effects of forest roads on biodiversity and floristic composition (Case study: Leeresar, Galanderood, Makarood)", *J. Plant Res.*, **2014**, *27*, 41-51.
21. O. Esmailzadeh, S. M. Hosseini, H. Asadi, P. Ghadiripour and A. Ahmadi, "Plant biodiversity in relation to physiographical factors in Afratakhteh Yew (*Taxus baccata* L.) habitat, NE Iran", *Iran. J. Plant Biol.*, **2012**, *4*, 1-12.
22. M. R. Ardakani, "Ecology", 4th Edn., University of Tehran Press, Tehran, **2012**.
23. K. Soon and W. H. Hendershot, "Soil Chemical Analyses", Taylor and Francis Group, Boca Raton, **2007**.
24. I. Ishibashi and H. Hazarika "Soil Mechanics Fundamental and Applications", CRC Press, Boca Raton, **2015**.

Maejo Int. J. Sci. Technol. **2019**, *13*(01), 19-28
25. H. Ejtehadi, A. Sepehry and H. Akkafi, "Methods of Measuring Biodiversity", 2nd Edn., Ferdowsi University of Mashhad Press, Mashhad, **2012**.
26. F. Mohammadpour, S. M. Hojati, A. Fallah and M. Asadian, "The effects of forest management on biodiversity (Case study: Nowdeh District, Mazandaran wood and paper forestry plan, Sari County)", Proceedings of National Conference of Engineering and Management of Agriculture, Environment and Sustainable Natural Resources, **2015**, Tehran, Iran, pp.85-96.
27. S. Z. Seyd, M. H. Moayeri and J. Mohammadi, "Comparison of tree species diversity in the beech managed (selection cutting) and unmanaged forest stands (Case study: Shastkalateh Forest- Gorgan)", *Iran. J. Biol.*, **2015**, *28*, 784-793.