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EFFECTS OF ROAD CONSTRUCTION ON BIODIVERSITY AND COMPOSITION OF HERBACEOUS SPECIES COVER, ASALEM FOREST, NORTHERN IRAN

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Abstract

We assessed a forest road impact on the diversity and the composition of herbaceous plant communities in the forest road margins, referring to illuminance and soil moisture percentage, to understand which of them is more important after more than 50 years from the building of the road. For this purpose six transects of approximately one kilometer length parallel to the forest road were established. Along each transect, 15 square sample plots of 1m^2 each were chosen by systematic random sampling. The average cover of herbaceous species on the cut and fill slopes was significantly higher than that inside the forest and that of the roadsides. There wasn't a significant correlation between biodiversity indicators and illuminance and soil moisture percentage. Entering invasive species altered the composition of the herbaceous cover and increased the richness of species on cut and fill slopes. Roadside plots under completely closed canopies of edge trees since the road has been built, have returned to original composition of the forest vegetation, showing contents similar to that of the forest plots.

Key words: forest roads, herbaceous plants diversity, illuminance, soil moisture percentage, Northern Iran.

Introduction

Due to climate change, rising global temperatures, forest fires and air pollution, the importance of forest conservation is growing (Dale et al. 2001, Honnay et al. 2002, Zhu et al. 2014), and the direct connection between forest sustainability and sustainability of human society is recognized. An issue of significant importance is the construction of forest road network designed to allow access needed for logging, wildlife conservation, entertainment and recreation purposes, pest, diseases and fire control. Forest roads affect forest ecosystem biotic and abiotic factors by changing the population dynamics of plants and animals, entering alien species, redirecting the flow of material, and controlling the accessibility of natural resources such as sunlight, water and nutrients (Angold 1997, Spellerberg 1998, Maynadier and Hunter 2000, Hill and Pickering 2006, Coffin 2007, Flory and Clay 2009, Zang and Ding 2009, Freitas et al. 2010). For understanding the impact of roads on forest ecosystems, the evaluation of edge effects of roads on the diversity and the composition of herbaceous species is crucial.

Biodiversity has been identified as one of the key factors to sustainable forest management (Brand 1995, Research 1999, Castaneda 2000). Loss of biodiversity, therefore, should be addressed as an environmental issue in sustainable forest management and forestry activities (Nouri et al. 2008). Roads increase forest fragmentation and affect species diversity (Laska 2001). Previous studies show that roads affect all herbaceous plants, trees, shrubs and even edge trees regeneration, altering their composition and diversity (Fredericksen and Pariona 2002, Landenberger and Ostergren 2002, Buckley et al. 2003, Bernhardt−Romermann et al. 2006, Bowering et al. 2006, Flory and Clay 2006, Delgado et al. 2007, Parsakhoo et al. 2009, Najafi et al. 2011). Herbaceous plants of these communities play an important role in the conservation of forest soils along roads that often lack trees. In northern Iran, this issue is significant because forests are located mostly on the steep slopes of the mountains. Moreover, herbaceous plants constitute a significant part of Iranian forest biodiversity. Ecological conditions of forest road edges serve as a corridor for invasive and non−native species, and play a major role in the formation of plant communities. At the disturbed road edges, invasive species have more adaptive and competitive abilities compared to native species and are quickly entering open sites. Different levels of degradation have different effects on the biodiversity. In communities that are constantly being destroyed due to the inability of the species to survive, diversity also decreases. Competition between species in moderate levels of degradation is high. No species, however is able to dominate. Thus, the richness of species reaches a maximum and such communities are associated with high diversity (Ejtehadi et al. 2008). In this study, we assessed the forest road impact referring to the rate of illuminance and soil moisture on the diversity and composition of herbaceous plant communities in the margins of forest roads. We assumed that illuminance and soil moisture do not affect biodiversity and composition of edge herbaceous plants.

Material and Methods

Study area

The Shendol study site (inside Asalem forest in Asalem, Gilan – 48°44′36″–48°49′58″ longitude and 37°42′31″–37°37′23″ latitude) with an area of 129 hectare (for 20–27 parcels) is located in watershed No 7 in the Hyrcanian forests of Iran. The dominant forest type in the parcels is *Fagus orientalis* – *Carpinus betulus* – *Acer insigne* as a group mixed with *Alnus subcordata* C.A. Mey, *Tilia begonifolia* Steven, *Ulmus glabra* Huds. With young – middle−aged to older foundations and 2–3 ranches structure. Other details are given in Table 1.

Table 1. Details about study area.

Slope, %	Elevation, m	Herbaceous cover, %	Leaf litter depth, cm	Canopy cover, %	pH	Average annual rainfall, mm	Soil type
31–60	820–1120	15–25	2–3	80–90	5.5–6.2	1867	Sandy Limonite, Clay Limonite

We focused on one kilometer of a secondary unpaved forest road built in the early 1960s to implement shelterwood system. On the basis of conducted surveys and studies the single−tree selection method was replaced with the selection system after three periods with the same logging method. Last logging of the area was performed in 2007 and the roads haven`t been used since then.

Sampling procedure

Six transects of approximately one kilometer length parallel to the road were established. Two of the transects were taken on cut and fill slopes, other two – on roadsides 6 meters above and below cut and fill slopes. To understand different road effects, the last two transects were taken in the forest 150 meters above and below the road axes. Along each transect, 15 square sample plots of 1 m^2 each were established by systematic random sampling (Buckley et al. 2003) (Fig. 1).

For each plot, we documented slope, aspect, illuminance (measured by TES Digital light meter – Model: TES−1336A between 11:00 and 14:00 hours in sunny days), elevation, canopy cover percentage of trees, herbaceous cover, and the species of forest floor. Additionally, 15 soil samples from the center of each plot, were immediately taken to a laboratory for measuring soil moisture content using the over drying method. Herbaceous species were collected in summer from June 2013 to July 2013. All herbaceous species were identified using resources from the Herbarium of the Faculty of Natural Resources at the Guilan University, the Book of Flora of Iran (Khatamsaz 1991), the Iranian Herbs Guide (Mobin 1984), the Flora of Turkey (Raunkiær 1934, Davis et al. 1988).

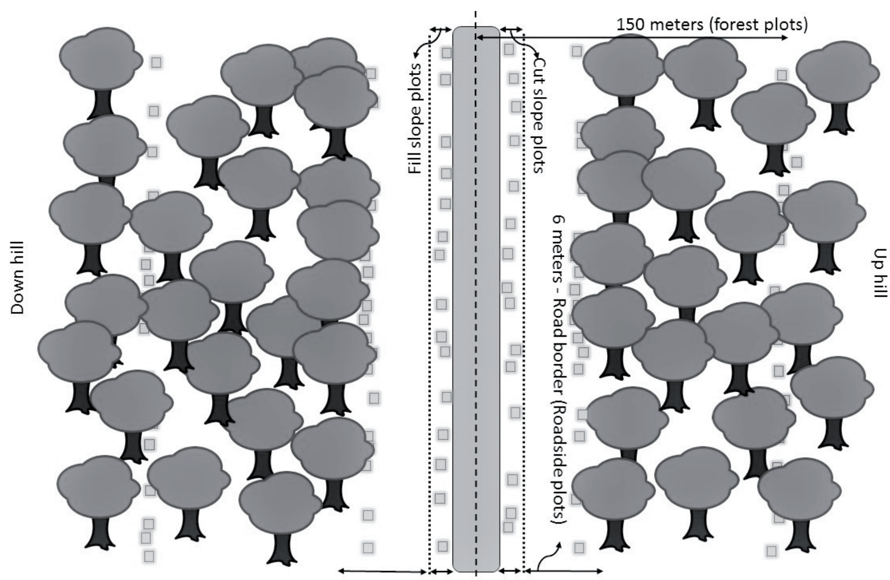

Fig. 1. Herbaceous species sampling design (scales are not considered accurate, drawn by written).

Data analysis

To evaluate the herbaceous diversity, we calculated Shannon−Wiener diversity (*H*') (Ludwig and Reynolds 1988, Krebs 1999), evenness was also assessed using the Pielou's index (*J*) (Krebs 1999) and the species richness was estimated by counting the number of species (*S*) (Humphries et al. 1996). The equations of all indices are presented in Table 2.

Table 2. The equations of indices.

Indices	Details
Shannon−Wiener: $H' = \sum_{i=1}^{n} p_i \cdot \ln p_i$	P_i is the relative frequency of the i^{th} species
Pielou's measure of species evenness: $J = \frac{H'}{\ln(S)}$	H' is Shannon Weiner diversity and S is the total number of species in a sample, across all samples in dataset.
Species richness: $R = S$	*S* is number of species

For statistical analysis, Kolmogorov–Smirnov tests were used to study the normality of the data distribution. A one−way ANOVA test was used for normally distributed data and non−parametric equivalent (Kruskal Wallis test) was conducted. SPSS 22.00, PAST (Hammer et al. 2001) and Ecological Methodology software, version 6.0 (Kenney and Kerbs 2001) were used for statistical analysis.

Results

The average cover of herbaceous species on the cut and fill slopes was significantly higher than these inside the forest and on the roadsides. The lowest cover was found in the forest plots ($\alpha < 0.05$) (Fig. 2).

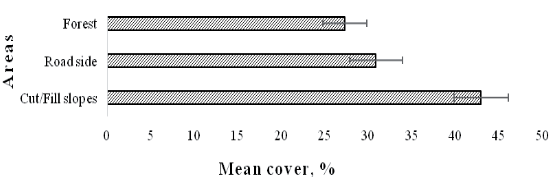

Fig. 2. Mean cover in each area (in percent).

Totally 51 species belonging to 35 families were identified in the three areas of study, at that – 26, 37 and 36 species were found respectively on cut and fill slopes, on roadsides and within the forest.

Average cover showed significant differences in the three areas ($\alpha < 0.05$). *Lolium temulentum* L. had both the highest cover and frequency on cut and fill slopes. On roadsides, highest coverage was shown by *Solanum kieseritzky* C.A.M., and the highest frequency by *Dryopteris pallida* (Bory) Fomin. In the forest plots, *Microstegium vimineum* (T.) was the most frequent species, and *Dryopteris pallida* had the highest percentage cover. Frequency and cover (in percent) of other species are listed in Table 3.

Results show that there is a negative relationship between light and soil humidity at the road edges. Along roads, the canopy opens, the illuminance increases and the soil moisture content is reduced especially on cut slopes. This reduction is also clearly evident on fill slopes except that the amount of light on such slopes is relatively lower than that of cut slopes. With increasing distance from the road, the amount of light is reduced and soil moisture increases. Accord-

Table 3. Frequency and mean cover of herbaceous species on cut and fill slopes, on the roadsides (*RS*) and in the forest.

Species	Family	Mean cover, %			Frequency, %			p
		Cut/Fill	RS	Forest	Cut/Fill	RS	Forest	
Acalypha australis L.	Euphorbiaceae	–	–	5.5	–	–	10	0.151
Agrimonia eupatoria L.	Rosaceae	5.5	7	1	10	10	5	0.728
Alliaria petiolaa (M.B.) Cavara & Grande.	Brassiacaceae	–	1	–	–	5	–	0.111
Apium repens (Jacq.) Lag.	Apiaceae	1	–	–	5	–	–	0.368
Asplenium septentrionale (L.) Hoffm.	Aspleniaceae	–	10	7	–	5	10	0.387
Bidens tripartita L.	Compositeae	–	–	4	–	–	5	0.395
Bromus catharticus Vahl	Poaceae	–	6.8	6.6	–	25	25	0.053
Campanula patula L.	Campanulceae	8	–	4	10		5	0.364
Carex buxbaumii Wahlenb.	Cyperaceae	–	5	–	–	15	–	0.035*
Carex conjuncta Boott	Cyperaceae	5.98	3.6	4.83	40	50	30	0.816
Carex hordeistichos Vill.	Cyperaceae	9.2	10	11	25	5	10	0.169
Carex hirta L.	Cyperaceae	–	2.67	–	–	15	–	0.035*
Carex plantaginea Lam.	Cyperaceae	–	1	–	–	5	–	0.340
Chelidonium majus L.	Papaveraceae	4	–	5	15	–	10	0.243
Chenopodium sp. L.	Chenopodiaceae	1	–	–	5	–	–	0.368
Circaea lutetiana L.	Onagraceae	4.11	2	2.25	45	10	20	0.022*
Convolvulus arvensis L.	Convolvulaceae	3.67	5.8	5.67	40	25	15	0.312
Convolvulus sp. L.	Convolvulaceae	–	–	6	–	–	5	0.395
Dactylis glomerata L.	gramineae	–	6	–	–	5	–	0.340
Dryopteris pallida L.	Hypolepidaceae	14.11	7.26	9.31	80	65	90	0.094
Epilobium hirsutum L.	Onagraceae	–	2	–	–	5	–	0.340
Euphorbia heliscopia L.	Euphorbiaceae	1	–	–	5	–	–	0.368
Galium triflorum Michx.	Rubiaceae	–	4.56	1	–	30	5	0.004*
Geranium persicum L.	Geraniaceae	5.5	5.33	2	25	15	5	0.188
Geum urbanum L.	Rosaceae	4.5	5.5	4.67	20	10	15	0.687
Hypericum androsaemum L.	Hypericaceae	5.56	4	2.67	65	10	15	0.000*
Juncus rigidus Desf.	Juncaceae	4	–	–	5	–	–	0.368
Lolium temulentum L.	Poaceae	15.80	9.09	15.10	85	55	65	0.060
Lepidium latifolium L.	Cruciferaceae	–	4	–	–	5	–	0.340
Microstegium vimineum (T.)	Poaceae	7.29	4	23	40	5	15	0.025*
Oplismenus undulatifollius (L.) P.Beauv.	Poaceae	7.14	8.75	10.17	35	20	10	0.187

Phyllitis scolopendrium (L.) Newn.	Aspleniaceae	–	1	2.33	–	5	15	0.175
Phytolacca americana L.	Phytolaccaceae	10	4.81	–	10	35	–	0.007*
Poa pretense L.	Poaceae	–	6.78	3	–	30	5	0.010*
Polygonatum orientale Schrak.	Liliaceae	–	4	–	–	5	–	0.340
Polygonum hydropiper L.	Polygonaceae	–	–	3	–	–	10	0.151
Primula heterochroma stapf	Primulaceae	1	1	2.5	10	5	10	0.837
Prunella vulgaris L.	Labiateae	–	10	–	–	5	–	0.340
Rosa canina L.	Rosaceae	–	10	–	–	5	–	0.340
Rubus hyrcanus Juz.	Rosaceae	9.58	7.38	9.37	80	40	50	0.024*
Rumex sanguinus L.	Polygonaceae	1	–	3	5	–	20	0.070
Salvia glutinosa L.	Labiateae	–	1.5	5.5	–	10	10	0.175
Sambucus ebulus L.	Adoxaceae	8.25	2	12.92	10	5	20	0.341
Scutellaria lateriflora B.	Lamiaceae	–	5.67	2	–	15	5	0.344
Solanum kieseritzky C.A.M.	Solanaceae	–	13.6	13.33	–	25	10	0.044*
Tamus communis L.	Dioscoraceae	–	–	1	–	–	5	0.395
Urtica dioica L.	Urticaceae	4	3.75	2.8	10	40	25	0.080
Urtica urens L.	Urticaceae	–	–	10	–	–	5	0.395
Vaccinium sp. L.	Ericaceae	–	–	2	–	–	5	0.395
Vincetoxicum scandens Sommiers Levier	Apocynaceae	7	5.67	3	10	15	15	0.876
Viola odorata L.	Violaceae	5.73	7.2833	6.25	55	50	60	0.568

Note: * – Represents a significant difference in the percent cover at the 0.05 level.

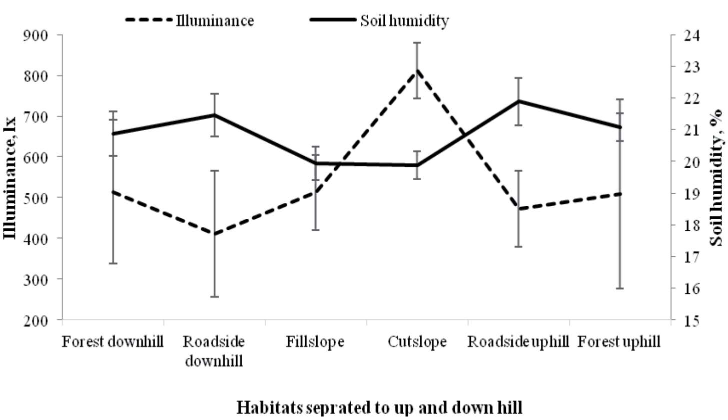

Fig. 3. Illuminance−soil humidity mean curve for the studied types of habitat.

ing to the Kruskal−Wallis test, there were no significant differences between the amounts of soil humidity and illuminance between treatments (Fig. 3).

ANOVA test of results on diversity, richness and evenness indices showed that diversity and richness were significantly higher on the cut and fill slopes compared to forest and roadsides. In

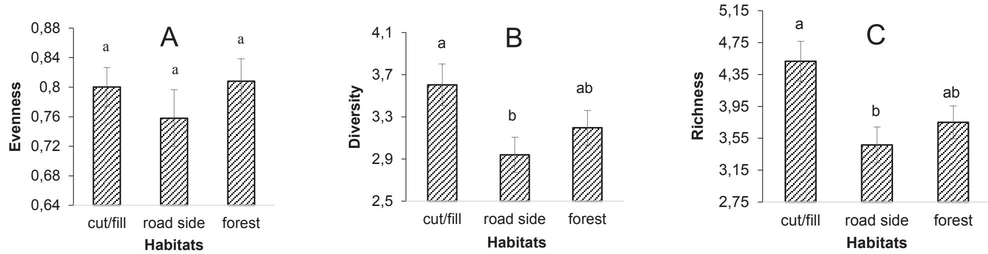

Fig. 4. Comparison of means of evenness (A), diversity (B) and richness (C) indices on cut and fill slopes, roadsides and inside the forest. a, b and ab indicates significant difference.

the forest, these values were greater than on roadsides but not significantly. Evenness index values in the three areas were similar while the highest evenness value was obtained in the forest (Fig. 4).

According to the Spearman correlation test, there is a positive significant difference between the diversity index and richness (at the 0.01 level). On the slopes, the correlation was stronger compared to that of the forest and road edges. However, the observed correlation between diversity and evenness indices in the forest and on the roadsides was higher than on the slopes with lower correlation toward richness indices (Table 4).

Table 4. Spearman correlations between diversity, richness and evenness indices.

Indices	Diversity index		
	Cut and fill slope	Roadside	Forest
R = *S*	0.945**	0.923**	0.922**
J	0.493**	0.500**	0.599**

Note: ** – Significant at the 0.01 level.

On the slopes, diversity, evenness and richness indices showed negative correlation with soil moisture, while the evenness indices showed positive correlation with the amount of light. A significant correlation was observed between the richness and light on the slopes. On the roadsides, diversity and richness indices were correlated positively with soil moisture unlike evenness index. All indicators were negatively correlated with light. Only for inside the forest, the evenness index showed a positive correlation with the amount of light. However, soil moisture continued to correlate negatively. Diversity and evenness indices inside forest were positively correlated with soil moisture and negatively with the light intensity (Table 5).

Based on the results of the CCA ordination test that was performed to investigate the composition of herbaceous species in

Table 5. Spearman correlations among the soil moisture, illuminance and diversity indices.

Indices	Cut and fill slopes		Roadside		Forest	
	Soil moisture	Illuminance	Soil moisture	Illuminance	Soil moisture	illuminance
Shannon–Wiener	–0.346	0.392	0.115	–0.329	0.265	–0.029
J	–0.159	–0.038	–0.249	–0.128	–0.019	0.240
R=S	–0.273	0.511*	0.203	–0.198	0.292	–0.164

Note: * – Significant at the 0.05 level.

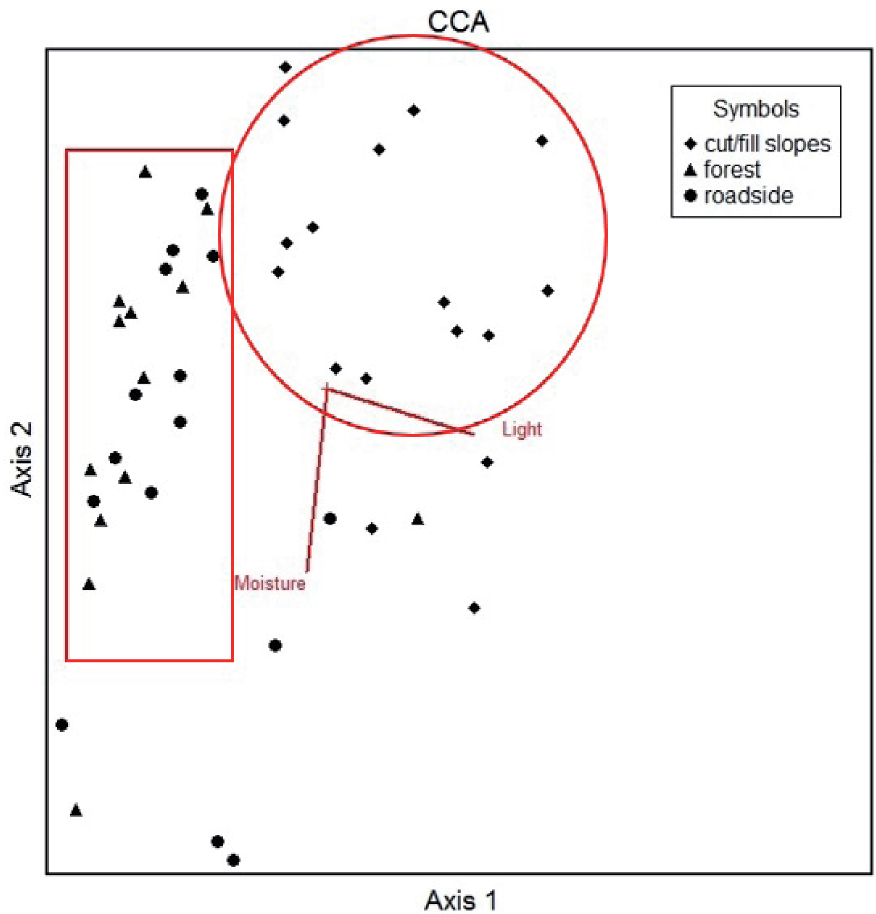

Fig. 5. CCA ordination results performed in PC−ord version 5.0 software (McCune and Mefford 1999).

Note: Ordination have been conducted based on species with light and soil moisture environmental variables entered in the analysis. Cut and fill slope plots are shown as lozenges (♦), roadside plots as circles (●) and forest plots as triangles (▲).

area, two different ecological groups are indivisible in the graph. The first group includes cut and fill slopes plots and the second group – plots of Roadside and within the forest (Fig. 5).

Table 6. Pearson correlations with ordination axes.

Indices	Axis 1		Axis 2	
	R	*r*–square	*R*	*r*–square
Light	0.979**	0.947**	–0.191	0.037
Soil moisture	–0.185	0.034	–0.989**	0.979**

Note: ** – Significant at the 0.05 level.

CCA Ordination analysis showed significant positive correlation between light and Axis 1, and a significant negative correlation between soil moisture and Axis 2 in CCA graph (Table 6).

Discussion

Due to topographic and different environmental conditions, forest roads have wider range of diversity compared to forests (Parsakhoo et al. 2009). Exposure to light and soil moisture are the most important ecological factors affecting biodiversity of the forest communities (Marvie Mohadjer 2011) where soil moisture is controlled by the amount of light (Anderson et al. 1969). Forest herbaceous species require certain amount of light (Tinya et al. 2009) and moisture. Based on our results, the maximum soil moisture and minimum light is reached on the roadsides. Due to exposure to more light and space, the roadside trees are thicker with more leaves than the forest trees, and therefore, have denser canopy cover. This inhibits light penetration under the tree crowns. All of these factors can explain the lower percentage of herbaceous cover on roadsides compared to cut and fill slopes (Fig. 2) but it still was higher compared to the forest closed canopy.

Percent cover of some species (e.g., *Carex buxbaumii*, *Carex hirta*, *Circaea lutetiana*, *Galium triflorum*, *Hypericum androsaemum*, *Microstegium vimineum*, *Phytolacca americana*, *Poa pretense*, *Rubus hyrcanus* and *Solanum kieseritzky*) differed significantly within the roadsides, slopes and forest interior ($\alpha < 0.05$). This can be explained by the differences in the amount of light and soil moisture (Fig. 3). Recent investigation in this area indicate that the growth of some of the native species, such as *Carex buxbaumii*, *C. hordeistichos*, *C. hyrta*, *C. plantaginea*, *Euphorbia heliscopia*, *Galium triflorum*, *Geum urbanum*, *Hypericum androsaemum*, *Primula vulgaris* and *Solanum kieseritzky*, (Natural resources office of Guilan 2006), was suppressed by the road construction, and hence, their percent cover was lowered significantly.

Buckley et al. (2003) found that species richness along forest roads is higher compared to the forest interior. As seen in Fig. 4, there is a significant difference in Shannon diversity and richness values along the road margin, slope and forest interior. The highest values of diversity, richness and evenness have been observed on the cut and fill slopes, with the diversity and richness significantly greater than the other two habitats. After increasing the light over the cut and fill slopes due to clear felling along the road, light tolerant and invasive species such as *Microstegium vimineum* (Devine and Fei 2011), *Sambucus ebulus* (Najafi et al. 2012), *Rumex* sp. (Parendes and Jones 2000) and *Prunella vulgaris* (Godoy et al. 2011) enter the area, increasing species richness (Muthuramkumar et al. 2006). *Lolium temulentum* has especially shown rapid growth in areas with an open canopy and more light. On roadsides, where we observed minimum species diversity, canopy density and low herbaceous cover impact the species richness. Species richness along roads is controlled by several factors such as light, soil moisture (Buckley et al. 2003), soil compaction and disorganization and soil physical properties (Smith et al. 2007). Entering the seeds of alien species due to removal of physical barriers is also a significant factor affecting species richness around forest roads (Buckley et al. 2003).

In addition, the diversity and richness indices on cut and fill slopes are significantly higher than inside the forest and on roadsides. The evenness index is also greater in the forest interior, although not significantly.

Based on the correlation test results between Shannon diversity, richness and evenness, we conclude that the diversity has a significant positive correlation with species richness and evenness and has been influenced more by richness in all areas. This means that with any increase of richness, biodiversity is increasing and the correlation between diversity and richness is much stronger than the correlation between diversity and evenness (Table 4). It can be stated that 94 % of changes in biodiversity on cut and fill slopes depend on evenness value variations ($R^2 = 0.945$) and almost 60 % of biodiversity changes in the forest depend on changes in the values of evenness. Contrary to our assumptions, however, there is no significant correlation between the amount of light or moisture and diversity indicators (Table 5). Hardtle et al. (2003) concluded that in the beech forests, richness is closely correlated with soil activity and with the base and nitrogen supply. Furthermore, several studies show that changes in biodiversity have a direct relationship with the type of forest management (Gardner 2012, Boch et al. 2013). In this study, illuminance and soil moisture, indirectly affected the biodiversity of the ecosystem by influencing its species and community composition (Fig. 5).

As marked with red lines in CCA ordination graph, communities on cut and fill slopes are situated at the top right of the axis 1 and communities on roadsides and forest plots are located to the left along the second axis. In degraded and disturbed areas with open canopy, invasive species affect the community composition (Anderson and Hoffman 2007). Species in plots located above axis 1, were more sensitive to illuminance. Open canopy and increasing illuminance over cut and fill slopes created a competition between native and invasive species where shade−intolerant species like *Dryopteris pallida* are out−competed. Native and shade−tolerant species of beech forests of Iran observed in the study area including *Euphorbia heliscopia*, some *Carex* species, *Chenopodium* sp. and *Galium triflorum* (Abkenar and Pilevar 2008) were eliminated by this competition. As a result, plant communities in this area are currently composed mostly of shade−intolerant species. Due to completely closed canopy of edge trees developed since the road was constructed, roadside plots have returned to original composition of the forest vegetation and show similar compounds to that of forest plots. Similar pattern was observed along moisture gradient.

Conclusions

This study investigated the effects of light and soil moisture on diversity and composition of herbaceous cover of forest road edges. On cut and fill slopes, increasing illuminance followed by decreasing soil moisture and disturbances due to road construction created and enhanced the growth of invasive and shade−intolerant species that are currently replacing the native species. Invasive species altered the composition of the herbaceous cover and increased the richness of species on cut and fill slopes. These changes, however, are only relevant to areas with open canopy. Plots sampled within 6 m distance from the road (along the road border) underneath the closed and large canopy of edge trees kept their composition and were scattered along soil humidity gradient.

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