Original scientific paper

Impacts of Forest Road on Plant Species Diversity in a Hyrcanian Forest, Iran

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Abstract

Forest roads facilitate various activities such as forest management, tending of forest, timber logging, and fire and pest control, but the fact remains that roads can interrupt the natural function of forest ecosystem. They divert water flow and increase the amount of sediment. They can also alter plant species composition. Furthermore, the network structure of roads divides the land to small patches, which ends in habitat fragmentation. In this study, which was carried out in the Hyrcanian Forest in the north of Iran, effects of a forest road on plant species diversity (including trees, saplings and herbs) was investigated on both cut and fill slopes. At 10 points along the road, toward the fill slope and cut slope, ten 100 meter transects perpendicular to the road were established. Within each transect, ten 10×10 m plots were sampled to record the tree and sapling species and ten 2 × 2 m plots to record the herbal species. Results showed that road segment had no significant effects on plant species diversity. Since the studied road is constructed using environmentally sound techniques and criteria, unnecessary cut and fill operations were avoided. The other factor is the width of the road, which is as narrow as possible, so the habitat fragmentation is not so considerable. The traffic on this road is also limited; therefore soil pollution does not affect plant composition. These items together with the ability of the Hyrcanian ecosystem to repair itself can mitigate negative effects of this road.

Keywords: Caspian Forest, road effects, plant species diversity, habitat fragmentation, environmentally sound techniques, Iran

1. Introduction

Forest roads provide access to a variety of activities including forest management, tending of forest, timber logging, and fire and pest control. Roads are also associated with economic growth and national wealth (Wikie et al. 2000), but they have various direct and indirect effects on their adjacent environment. In fact, since the roads are external factors imposed on nature, they can have some profound ecological effects. Roads are accompanied by ecological disturbances and landscape degradation, and they introduce broad changes in ecosystem structure and function. They may alter the natural composition of the forest ecosystem, such as plant species composition and diversity (Findlay and Houlahan 1997, Buckley et al. 2003, Godefroid and Koedom 2004, Marchand and Houle 2005, Avon et al. 2010). Habitat destruction, introduction of exotic species and changes to the physical and chemical environment (Trombulak and Frissel 2000, Formann 2000) can be cited as some ecological disorders. Moreover, the network structure of roads divides a large forest land into smaller patches, which results in some degree of habitat fragmentation. Roads are a barrier for natural drainage and, by cutting the natural flow, they divert water and disturb the natural aquatic balance in the region (Burroughs et al. 1972, Megahan 1972, Rummer 1997, Wemple 1998). Typically the amount of sediment will be increased (Reid and Dunne 1984, Luce and Cundy 1994, Rummer et al. 1997, Connolly et al. 1999, Luce and Black 1999, Elliott 2001, Fransen et al. 2001, Kahklen 2001, Appelboom et al. 2002, Jha et al. 2006, Lopez et al. 2008, Baihua et al. 2009).

2. Overview of studies

Many different investigations have been done concerning road ecology and the effects of roads on plant species. Some of them are summarized below.

According to the results by Avon et al. (2010) in young and adult oak stands in French lowland forest with a long history of management and road construction, plant composition strongly differed between road verge and forest interior habitats. The main road effect extends less than 5 m into the forest stand. Non forest species were not observed from the forest interior, while many bryophytes and vascular plants kept away from the road.

According to the results obtained by Bernhardt-Romermann et al. (2006) in the Munich-area, Southern Germany, motorways have an impact on the vegetation composition in the neighbourhood of roads. Depending on wind direction, influences of motorways reaches up to 230 m on the downwind side and up to 80 m on the upwind side.

A study of Godefroid and Koedom (2004), carried out in the Sonian forest, south of Brussels, Belgium, showed that forest paths have significant effect on the surrounding plant assemblages, and they increase the number of ruderal species, disturbance indicators, nitrogen-demanding indicators and indicators of basic conditions.

Buckley et al. (2003) evaluated impacts of haul roads and skid trails on understory vegetation. The results showed that understory plant richness was significantly greater in haul roads than in skid trails and forest, as a result of significantly greater percentages of introduced species (13%) and wetland species. Skid trails had a greater percentage of wetland species (9%) than in forest, but differences in richness between skid trails and forest were not statistically significant.

Results obtained by Findlay and Houlahan (1997) in Southeastern Ontario, Canada wetlands showed a strong positive relationship between wetland area and species richness. The species richness was negatively correlated with the density of paved roads on lands up to 2 km from the wetland.

3. The problem area

In this study, the effects of a forest road on plant species diversity, which includes trees, saplings and herbs, was investigated so that some environmentally friendly principles for forest road construction and maintenance can be achieved in order to alleviate their negative effects and conserve the natural cycle of the forest ecosystem.

This study specifically addresses the following questions:

⇒ Does the forest road affect the plant species diversity?

⇒ Are there any significant differences between plant species diversity on cut slope and fill slope by the effects of road?

⇒ What are the environmentally friendly principles to alleviate the roads negative effects?

4. Area of study

The study was conducted in the educational and experimental forest of the University of Tehran (Kheyrud Forest). It is located on the northern slopes of the Albourz Mountains, approximately 7 km east of the port of Noshahr (36°34'–36°37'N, 51°32'E). The area of the forest is about 8000 ha, and the altitude ranges from 0 m to 2200 m from sea level. This broad range of altitude is the basis for different plant communities. The plant communities are as listed below (Marvie Mohajer 2005):

⇒ *Querco-Buxetum, Pterocaryo-Alnetum*	0–100 m
⇒ *Querco-Carpinetum, Parrotio-Carpinetum*	100–700 m
⇒ *Fagetum hyrcanum* *Rusco-Fagetum* *Vaccinio-Fagetum*	700–1800 m
⇒ *Quercetum macranthera, Carpinetum oriental*	1800–2200 m

Kheyrud forest has seven districts. The current research was done in the lowest district, which is called Patom. It covers 900 ha and its altitude ranges from 0 m to 934 m above sea level. The Patom district has 18 parcels. Five parcels are protected and 13 parcels are productive and under logging since 1969. The plant community in this region is mostly *Querco-carpinetum*, that is to say *Quercus castaneifolia* and *Carpinus betulus* are characteristic species, and the other tree species are mostly *Diospyros lotus, Fagus orientalis, Acer velutinum, Alnus glutinosa.* (Tab. 1, 2, 3).

The road in Kheyrud forest was constructed in the period 1971–1994 with the density of 21 m/ha, and in the study area (Patom district) the forest road route was constructed in 1972–1973. The width of the road is 5–6 m, which includes roadbed with the width of 3.5–4 m, two one-meter-ditches, and two banks each half a meter wide. Material for the road is from the mine and the river bed: mineral sand and gravel of the region. However, now riverbed exploitation for road building is banned. Some parts of the road, which has clay soil, were first fixed by the lime stabilization method.

Table 1 Herbal species

No.	Scientific name	Points along the road	
1	*Oplismenus undolatifolius*	10–9–8–7–6–5–4–3–2–1	invasive
2	*Euphorbia amygdaloides*	10–9–8–7–6–5–4–3–2–1	invasive
3	*Carex sylvatica*	10–9–8–7–6–5–4–3–2–1	endemic
4	*Pteridium aquilinum*	10–9–8–7–6–5–4–3–2–1	invasive
5	*Epimedium pinnatum*	10–9–8–7–6–5–4–3–2–1	endemic
6	*Rubus* spp.	10–9–8–7–6–5–4–3–2–1	semi-endemic
7	*Urtica dioica*	10–9–6	endemic
8	*Hedera pastoshawii*	10–9–8–7–6–5–3–2–1	endemic
9	*Phyllitis scolopendrium hill*	10–9–5–3–2–1	endemic
10	*Pteridium aquilinum*	10–9–8–7–5–4–3–2–1	invasive
11	*Mentha longifolia*	10–7	endemic
12	*Ruscus hyrcanus*	10–9–8–7–6–5–4–3–2–1	semi-endemic
13	*Hypericum androsaemum*	9–8–7–6–4–3–2–1	endemic
14	*Cyclamen coum*	5–3–2–1	endemic
15	*Convolvulus sp*	4	Indefinite*
16	*Smilax excelsa*	7–5–4–1	endemic
17	*Equisetum ramosissimum*	4	endemic
18	*Potentilla reptans*	8–7–1	endemic
19	*Malva* sp.	1	Indefinite*
20	*Circaea lutetiana*	7–6–2–1	endemic

* Since the species is not identified, it is not possible to recognize according to genus

Table 2 Shrub species

No.	Scientific name	Points along the road	
1	*Crataegus* spp.	10–9–2–1	endemic
2	*Crataegus* spp.	10–9–8–7–6–5–4–3–2–1	endemic
3	*Prunus divaricata Ledeb*	9–1	endemic
4	*Prunus divaricata Ledeb*	9–5–4–3–2–1	endemic
5	*Mespilus germanica*	9–5–3–2–1	endemic
6	*Mespilus germanica*	9–8–7–6–5–4–3–2–1	endemic
7	*Ilex spinigiera*	10–9–8–7–6–5–4–3–2–1	endemic

5. Materials and methods

In this study, at 10 points along the road, toward fill and cut slope, ten 100 meter transect were sampled from the top of the embankment and established perpendicular to the road. Ten 10 × 10 m plots to record the trees and shrubs species and ten 2 × 2 m plots to record the herbal species were set up along each transect (Fig. 1).

The species diversity of cut and fill slope for each macro and micro plot was analysed by the Shannon

Table 3 Tree species

No.	Scientific name	Points along the road	
1	*Frangula alnus*	4	endemic
2	*Diospyros lotus*	10–9–8– 7– 6– 5– 4– 3– 2–1	endemic
3	*Carpinus betulus*	10–9–8–7–6–5–4–3–2–1	endemic
4	*Fagus orientalis*	10–9–8–7–6–5–4–3–2–1	endemic
5	*Acer velutinum*	10–9–8–7–6–5–4–3–2–1	semi-endemic
6	*Acer cappadocicum*	10–9–8–7–6	endemic
7	*Tilia platyphyllus*	10–9–7–5	endemic
8	*Alnus glutinosa*	10–7–6–4	endemic
9	*Parrotia persica*	10–6–5–4–1	endemic
10	*Ulmus glabra*	10–9–8	endemic
11	*Ficus carica*	10–8–7	endemic
12	*Quercus castaneifolia*	6–5–4–2	semi-endemic
13	*Fraxinus excelsior*	4	semi-endemic

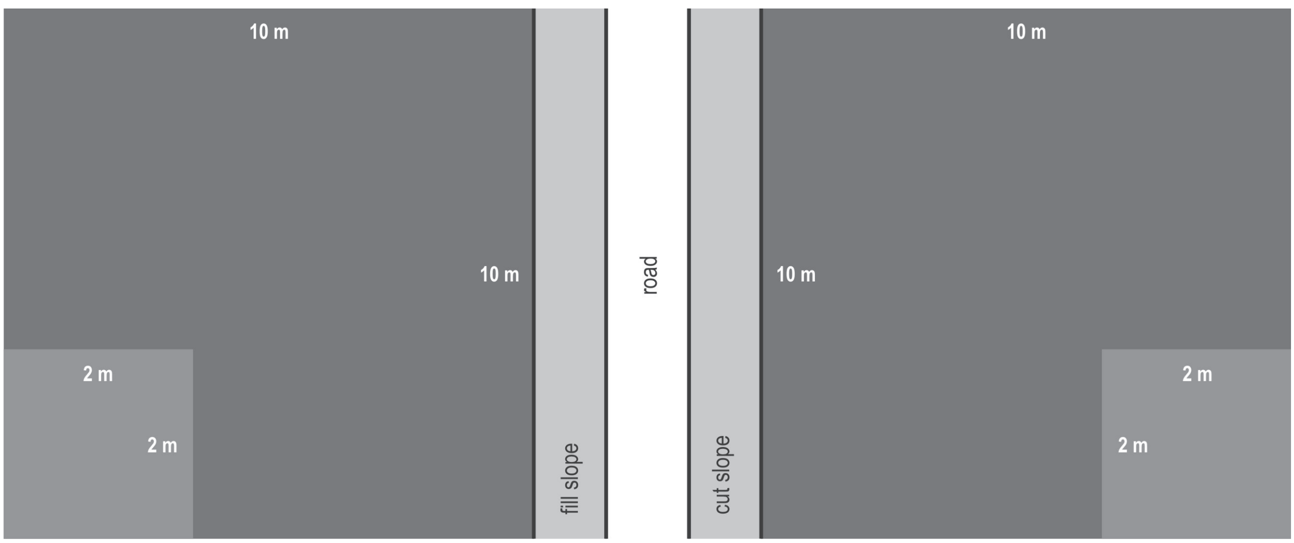

Fig. 1 The position of plots scaled to road

index[1] in PAST software[2] (Hammer and Harper 2006, Hammer et al. 2001, Harper 1999). Then, normality of data was tested by Kolmogorov- Smirnov of SPSS software. The significance of the effect was tested by ANOVA, and then the comparison of means was tested by Duncan.

[1] the Shannon index (H) is a diversity index that is commonly used to characterize species diversity in a community. Shannon's index accounts for both abundance and evenness of the species present. The proportion of species i relative to the total number of species (pi) is calculated, and then multiplied by the natural logarithm of this proportion (lnpi) $H = \sum_{i=1}^{s} P_i \ln P_i$

[2] a software for scientific data analysis, with functions for data manipulation, plotting, univariate and multivariate statistics, ecological analysis, time series and spatial analysis, morphometrics and stratigraphy.

6. Results and Discussion

In this study, as above said, two questions should have been addressed.

Does the forest road affect the plant species diversity?

What are the environmentally friendly principles to alleviate the roads negative effects?

According to the results, the diversity of trees, saplings and herbs are not influenced by road (distance from road) on both cut (Fig. 2, 4, 6) and fill slope (Fig. 3, 5, 7). The only significant difference for tree species diversity was recorded at the first plot on the cut slope, set up between the embankment and 10 meters (Tab. 4).

The number of tree and herb species is not influenced by road (Fig. 8, 9, 12, 13), but the number of sapling species on the cut slope shows significant differences (Fig. 10).

To answer our first research question, these results showed that the studied road had no significant effect on the number of species and diversity, which is not in accordance with the results of Avon (2010), Marchand and Houle (2005) and Houlahan (1997), who con-

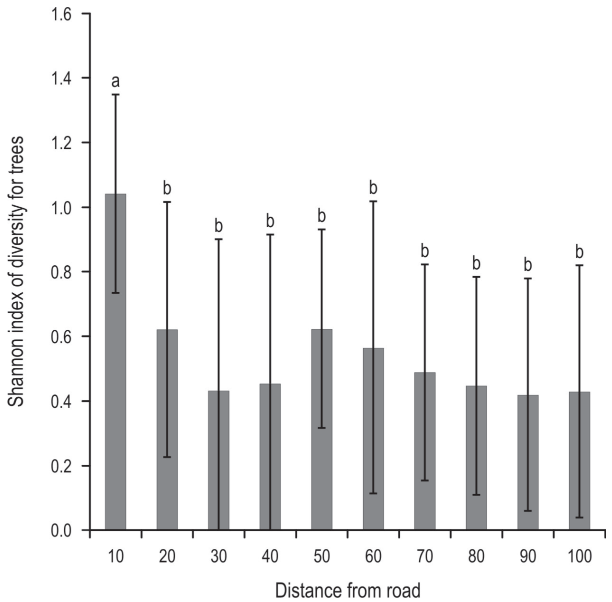

Fig. 2 Variation in tree species diversity from road to interior forest on cut slope

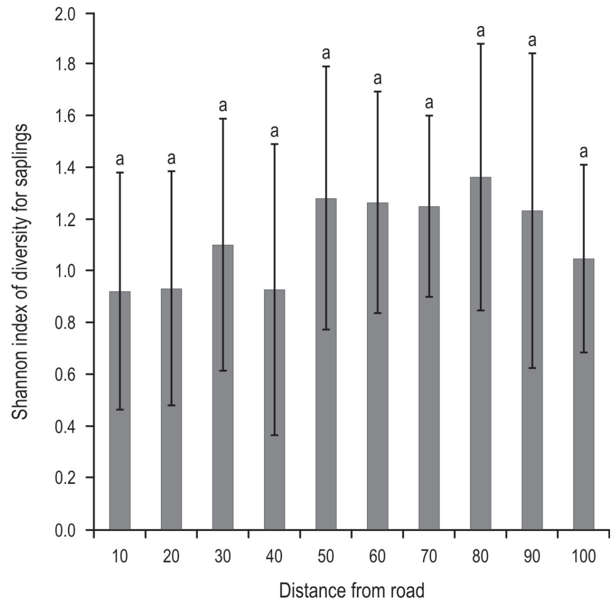

Fig. 4 Variation in sapling species diversity from road to interior of forest on cut slope

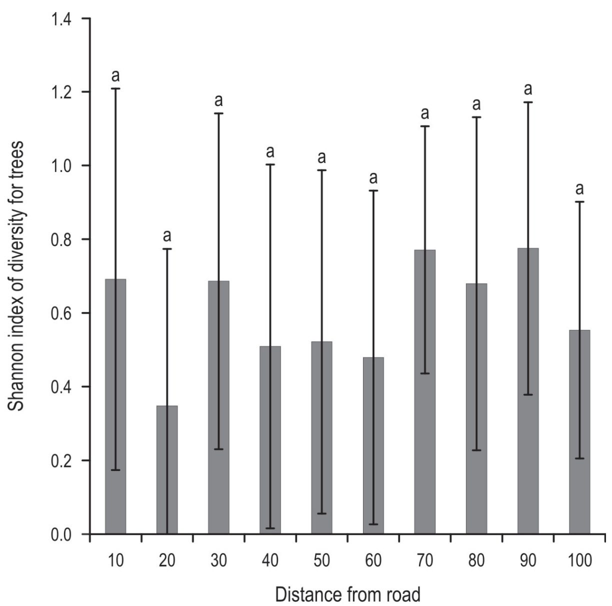

Fig. 3 Variation in tree species diversity from road to interior of forest on fill slope

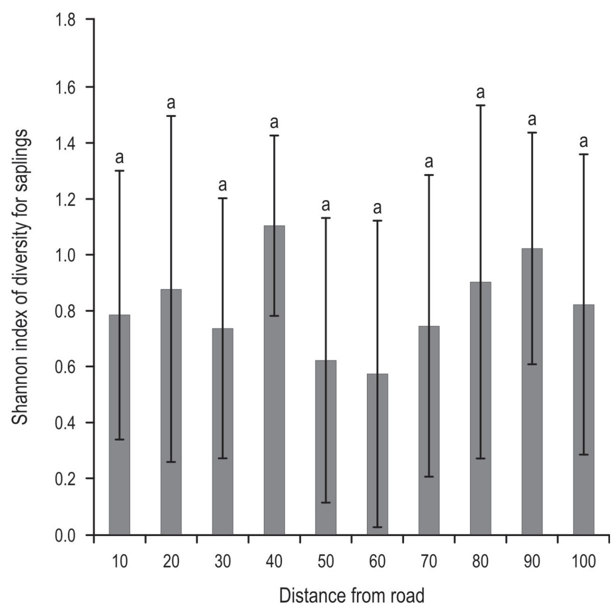

Fig. 5 Variation in sapling species diversity from road to interior of forest on fill slope

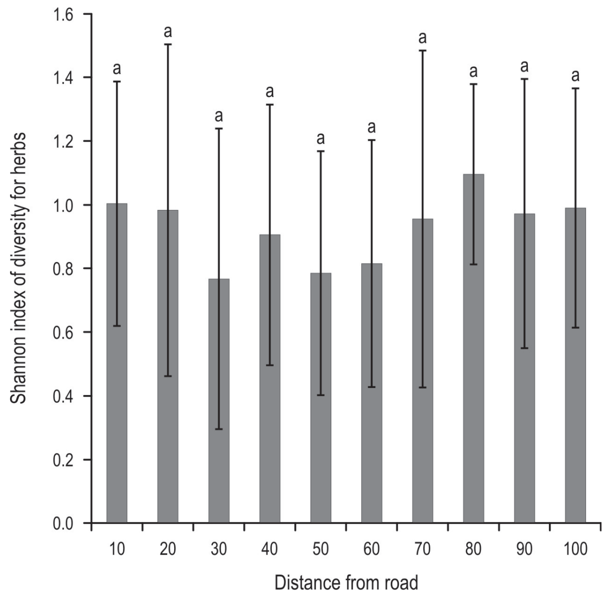

Fig. 6 Variation in herb species diversity from road to interior of forest on cut slope

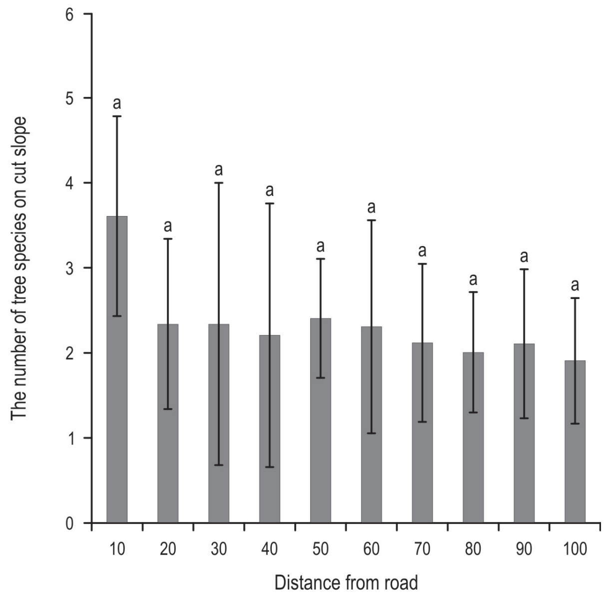

Fig. 8 Variation in the number of tree species from road to interior of forest on cut slope

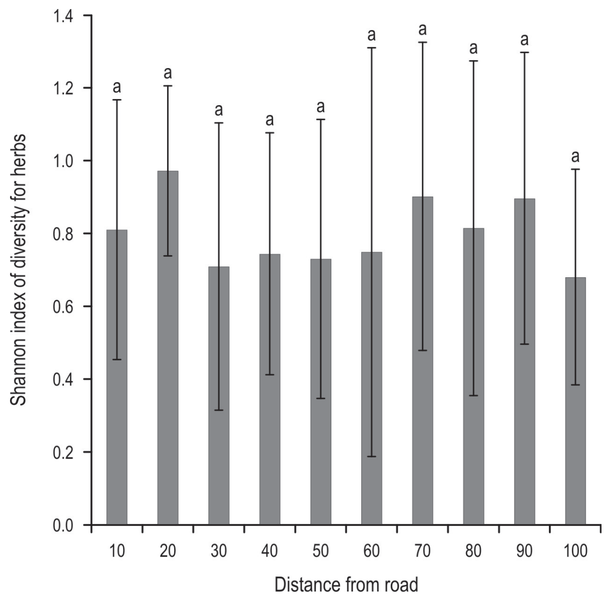

Fig. 7 Variation in herb species diversity from road to interior of forest on fill slope

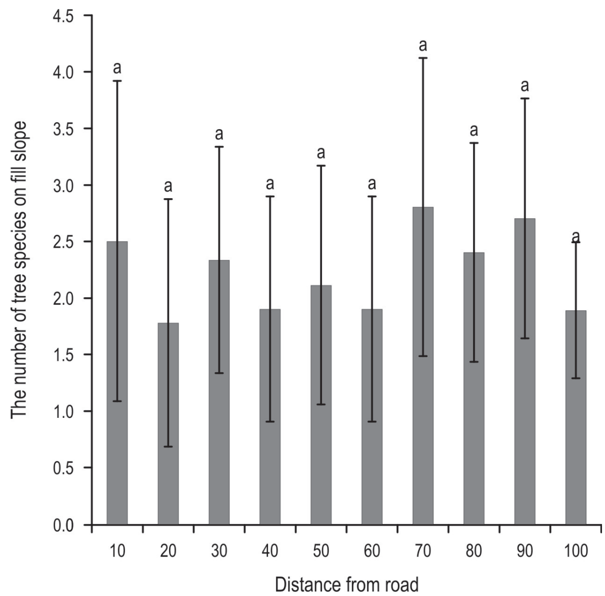

Fig. 9 Variation in the number of tree species from road to interior of forest on fill slope

cluded that the plant species diversity changes with the distance from the road. The only significant differences in the present study are for tree species diversity on cut slope at the first plot (between the embankment and 10 m from the road) and the number of saplings on the cut slope. This result can be due to the following reasons: firstly, the Kheyrud forest road has not only been planned, designed and constructed by road construction standards, but the environmentally friendly principles have also been considered, especially in design. These environmentally friendly principles include the minimum dimensions of travel way, right of way, sub grade, curves and radius and avoiding straight lines and huge curves. That is to say that nature has not been sacrificed by the road, and that this road which is synchronized and accorded with the topography and nature. Also, local materials were used for construction: mineral sand and gravel of the

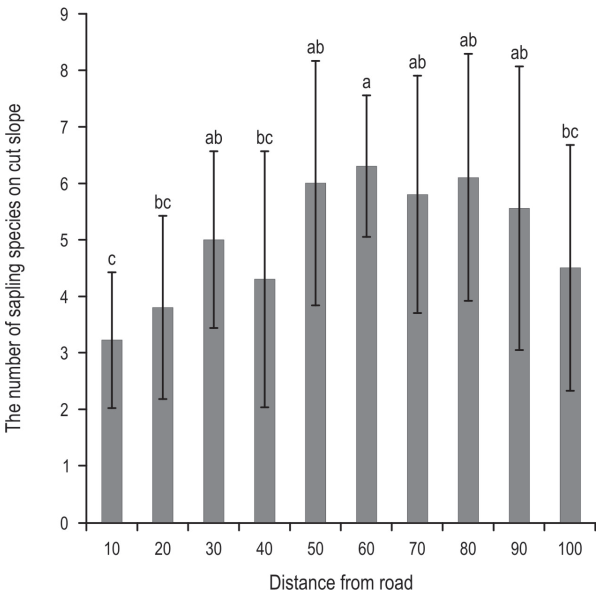

Fig. 10 Variation in the number of sapling species from road to interior of forest on cut slope

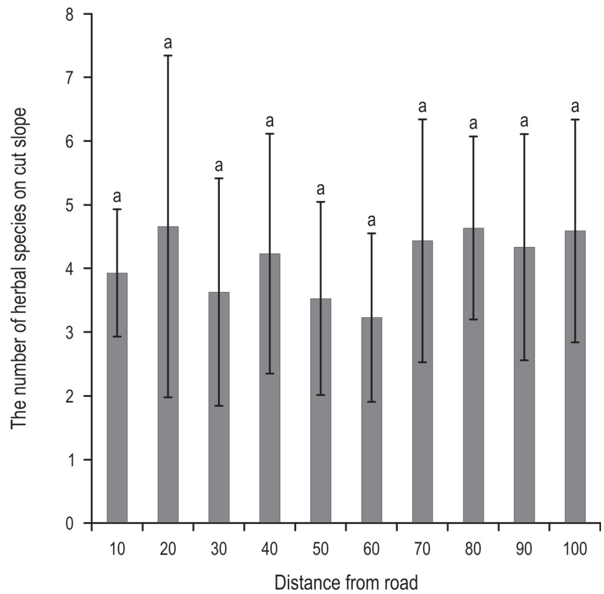

Fig. 12 Variation in the number of herbal species from road to interior of forest on cut slope

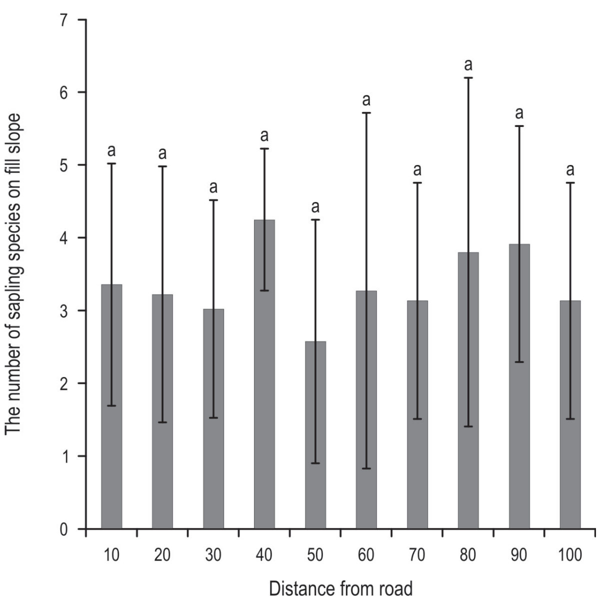

Fig. 11 Variation in the number of sapling species from road to interior of forest on fill slope

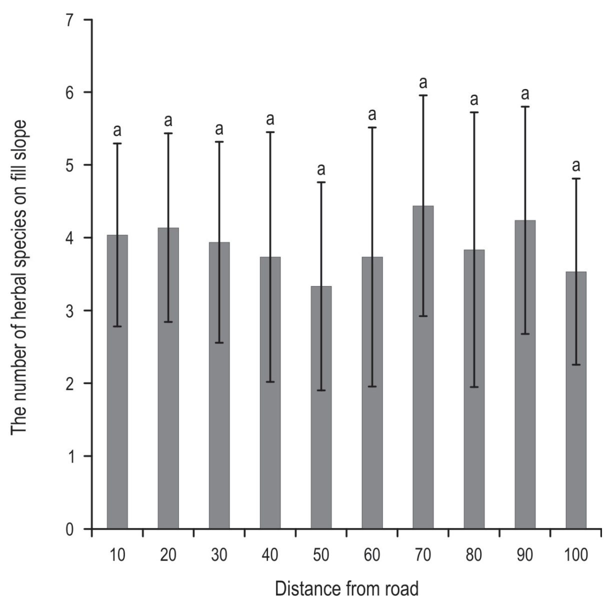

Fig. 13 Variation in the number of herbal species from road to interior of forest on fill slope

region from the mine in the forest and the river bed, which is an important factor in order to not disturb the local soil composition by introducing new materials. Secondly, the width of the road is as narrow as possible, which is a critical factor in maintaining the ecological balance. In the other words, the new patches made by the road are almost as large as their former size. As a result, the connection between two patches is still retained, and this connection can be a guarantee to prevent habitat fragmentation. This is proved by the study of Hilty et al. (2006). This is completely in accordance with the results provided by the studies of Laurance (2000) and Fahrig (2009), who showed that more species in the newly made habitat provided more chance for conserving the native species. The significant difference in the number of saplings, which are fewer on the first plot from the road, might be due to the grazing by cattle, which is more considerable on

Table 4 The result of Duncan's test

	Significance	
	Cut slope	Fill slope
Trees	0.045	0.079
Saplings	0.091	0.068
Herbs	0.157	0.171

the road verge. On the other hand, the snow and rainfall are more intense on the road verge than in the interior forest, which can cause more damage to the saplings near the road. Thirdly, the limited traffic of this road can be mentioned as another beneficial item for reducing the adverse effects of the road. This last observation needs more investigation, but according to the study of Godefroid and Koedam (2004), pollution from traffic can affect plant composition. Fourthly, the ability of the Hyrcanian ecosystem to repair itself should not be ignored. In this ecosystem, the growing season is about 300 days per year, so it would be long enough to repair all the unnatural disturbs.

Therefore, our second research question was answered by all the items mentioned, which can mitigate the negative effects of this road, when compared with previous studies, in which the roads are wider and less synchronized with nature (Coffin 2007).

7. Conclusion

In the experimental area, plant species diversity does not show any significant changes related to distance from the road. According to the structure of the studied road, it can be concluded that to limit the effects of the road on adjacent forest, environmentally sound techniques and criteria should be considered as well as road construction standards.

In other words, nature should dictate the route to conserve the natural habitat by avoiding unnecessary cut and fill operations. As the size of retained patches is an important factor influencing species survival, the width of the forest road should be as narrow as possible to mitigate the disconnection between two patches. All in all, considering the items analysed in this paper can prevent major hazardous effects, so the Hyrcanian forest ecosystem can proceed along its natural path of development.

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