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Plants Biodiversity and Canopy Coverage at the Edge of Main Communications Network in Hyrcanian Forests

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Abstract: To investigate the plants biodiversity and canopy coverage on cut and fill slopes of Lat Talar forest roads in Hyrcanian zone, the systematic randomize sampling method with 60 parallelogram shape plots was used. Within each plot the herbaceous plants and regeneration of woody species were recognized and their canopy coverage was recorded in percentage. Species similarity and biodiversity was estimated according to Jaccard, Shannon, Brillouin and Simpson indices. Results showed that the canopy coverage of herbaceous plants and regeneration on cut and fill slopes were 7.2% and 28.4%, respectively. *Rubus hyrcanus L.* had the most canopy coverage at the edge of forest road. 14 species were common between cut and fill slopes, therefore Jaccard index was obtained 0.74. Plants biodiversity on fill slopes and control plots was more than cut slopes ($p<0.05$). Canopy coverage on cut slopes with angles of 45˚-55˚ was more than angels of 55˚-65˚.

Key words: Vegetation; Biodiversity; Similarity index; Canopy coverage; Road edge

INTRODUCTION

The cut and fill slope angle of the road, largely determines soil stability, because both natural and artificially seeded vegetation rarely become permanently established on steep slopes, those with 100 percent slope or greater. Although seeds will often germinate on steep slopes, seedlings wash out when surface runoff and raindrops detach surface soil particles. Some natural revegetation on such cut and fillslopes occurs when mats of litter containing roots of woody and herbaceous plants break away from the top of the bank, lodge and take root on the slope below. Only after many years, however, when erosion at the top of the bank has reduced the percent slope, does natural vegetation from seed become permanently established (Lewis, 2000; Morschel, 2004).

The influence of transportation corridors on the frequency of non-native plant largely is due to factors associated with habitat characteristics. Habitat type, altered disturbance regimes, and intentionally introduced non-native species are essential to consider when describing the impact of non-native species on native plant communities along all types of transportation corridors (Acar, 2003; Hansen and Clevenger, 2005; Pauchard and Alaback, 2006; Delgado *et al*., 2007).

Several authors have observed the pattern of roadside plant communities (Lausi and Nimis, 1985; Ullman *et al*., 1995; Olander *et al*., 1998; Cilliers and Bredenkamp, 2000). They recognized zonation of plant communities across the road corridor with specific biophysical characteristics and floristic composition. They also reported that soil moisture, organic matter content, bulk density, pH and light regime change significantly within the narrow width of the road corridor, affecting plant community composition (Delgado *et al*., 2007; Karim and Mallik, 2008; Hamed, 2008).

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Bochet et al. (2005) studied the effect of slope conditions on vegetation cover and plant species composition near Valencia (East Spain). Results of this study indicated that the main factors influencing vegetation variables on road slopes were the angle, type and aspect of the slope. Vegetation was almost completely lacking on road cuts with slopes of > 45˚. On gentler slopes, vegetation cover was 44-78% on road fills according to the aspect, whereas it did not reach 10% in any case on road cuts. The type and aspect of the slope also determined species composition, differences in the organic matter content, soil available P and water content existed between road fills and road cuts. However, the environmental conditions of the slopes were more limiting for plant colonization. More specifically, the short duration of available water in the soil with respect to soil water potential proved to be a limiting factor to plant germination and establishment on road cuts and south-facing slopes, as well as the low soil fertility in the case of road cuts (Truscott *et al*., 2005; Elseroad *et al*., 2003).

Cao et al. (2006) showed that where the slope of the terrain was between 0˚ and 5˚ the average survival rate of planted grass over the 5 years was 94.69% compared to 82.64% when the slope of the terrain was more than 12.5˚. Among grass species, *A. cristatum* showed the best performance with an average survival rate of 95.68% on slopes steeper than 12.5˚. Soil moisture, organic matter content, bulk density, pH and light regime change significantly within the narrow width of the road corridor and affecting plant community composition. The research carried out by Cerdà et al. (2007) at the eastern Spain showed that the vegetation cover in under construction road is always lower than 7% during winter and 2% during summer for average values. But, the vegetation cover values were respectively 37 and 42% (summer and winter) and 46.4 and 54.8% which demonstrate the slow vegetation recovery after ten years and the lowest vegetation cover during summer.

Koukoura et al. (2007) studied the ability of different types of plants to become established on the road sides of the Egnatia highway, Thessaloniki, Greece. The results showed that drought tolerant species of all plant life forms had high survival percentages and contributed significantly to the vegetation cover at the end of the growing season. Drought tolerance and the existence of rhizomes benefited the establishment ability of grass species. The best adapted species were the grasses *Agropyrum cristatum L.*, *Bromus inermis Leyss.*, *Dactylis glomerata L.* and *Festuca valesiaca Schleich,* the legume *Medicago sativa L.* and the forb *Sanguisorba minor*.

The aims of this study were to assess plants biodiversity and canopy coverage on cut and fill slopes after one year from road construction in Lat Taler forest of Iran. Our results suggest that roads have associated effects that alter embankments conditions, plants biodiversity and abundance. Some of these vegetations are invader and expanse to the interior forest and damage to seedlings or saplings.

MATERIALS AND METHODS

Site Description:

The focus of this study is a two km, secondary unpaved road that was built by the company of wood and paper industry in March 2006 to provide access to the Lat Talar forest compartments. Lat Talar site with an area of 2020 hectare was located in watershed number of 71 in Hyrcanian forest of Iran. The experimental road sections were located in northern aspect of compartments C_{22} (81 ha), C_{24} (70.7 ha) and C_{25} (42.81 ha) of this Fagetum forests with an elevation of 800-100 m. a. s. l. (latitude 53 ˚9 40″ to 53 ˚13 55″ E and longitude 36˚ 12 55″ to 36 ˚15 45″ N). Average annual precipitation for the period 1973-1998 was 635 mm. The area has a mid moist and cold to very moist climate. Soils texture is dominated by deep loams and clay loam. These soils are snippet textured; bad drained, and have low organic matter content. The bedrock is typically marl, marl lime and limestone.

Collection of Field Data:

This study was conducted in August 2007. Sampling was carried out in the ground vegetation immediately adjacent to the road edge. Also, to determine the effects of cut and fill slopes gradient on vegetation canopy cover, the cut slopes gradient was classified into classes of 45˚-55˚ and 55˚-65˚ and the fill slopes gradient was classified into classes of 25˚-35˚ and 35˚-45˚. Our sampling scheme was based on a three transects with a length of 400 m which were systematic randomly located parallel to the road edge. The two transects were placed on cut and fill slopes. The same sampling design (third transect) was used as the control plots in distance of 150 m from the corridor edge. Each transects included of twenty parallelogram shape plots with a size of 15 m^2 and distances of 20 m from each other. Plots were divided in to fifteen 1×1 m^2 subplots to increase the accuracy of canopy coverage estimation. Within each subplot, the herbaceous plants and regeneration of woody species were recognized and their canopy coverage was recorded.

Similarity and Biodiversity Indices (SI):

Four similarity and biodiversity indices were chosen, all of which met the criterion that they took a value of zero when there were no species in common between two samples and a value of one when two samples had exactly the same species present (Boyce and Ellison, 2001; Aubert *et al*., 2004; Gondard *et al*., 2007). Formulas for each index are shown in Table 1.

Table 1: Similarity and biodiversity indices tested in this study

Similarity index	Formula	Biodiversity index	Formula
		Shannon	$H' = \sum P_i Ln P_i$
Jaccard	$J = \dfrac{a}{a+b+c}$	Simpson	$\lambda = 1 - \sum\left[\dfrac{n_i(n_i - 1)}{N(N-1)}\right]$
		Brillouin	$H = \dfrac{1}{N} Log \dfrac{N!}{N_1!N_2!..N_s!}$

Where *a* number of species in sample A and sample B (joint occurrences), *b* number of species in sample B but not sample A, *c* number of species in sample A but not sample B and *d* is the number of species absent in both samples (zero-zero matches). P_i each of specimen's frequency percentage ratios to total species in each of community. *N* number of total species and n is the each of specimen's frequency.

Data Analysis:

The study was established as a randomized complete block design with four blocks (hillside gradient including 30-40, 40-50, 50-60 and 60-70%) and two treatments (cut and fill slopes). The equation for the model of a randomized complete-block design is as follows:

$$Y_{ij} = \mu + \tau_i + \beta_j + \beta_{\tau ij} + \varepsilon_{ij}$$

Where: Y_{ij} is the response of treatment *i* in replication *j*, μ is the overall mean,τ_i is the treatment effect of the ith treatment, β_j is replication effect of the jth replication, $\beta\tau_{ij}$ is a replication x treatment interaction effect or plot error and ε_{ij} is experimental error (South and Vanderschaaf, 2003).

Data were analyzed using the ANOVA procedure provided by the SAS software. When the analysis was statistically significant, the SNK test for separation of means was performed. Statistical significance was judged at P<0.05.

RESULTS AND DISCUSSION

Results showed that cut and fill slopes had significant effect on canopy coverage of herbaceous plants and regeneration of woody species (P= 0.0007). But no significant differences were observed for canopy coverage in different slope gradients (Table 2).

Table 2: Embankment effects on vegetation canopy coverage

	Treatments	df	SS	MS	F
1	Cut and fill slopes	1	4494.4	4494.4	19.64***
2	Cut and fill slopes gradient	1	547.6	547.6	2.39^{ns}
3	1*2	1	14.4	14.4	0.06^{ns}
4	Block	9	2622.4	291.38	1.27^{ns}
5	Cut and fill slopes gradient and block	9	1098.4	122.04	0.53^{ns}
6	Cut and fill slopes and block	9	2637.6	293.07	1.78^{ns}

Canopy coverage on fill slopes with angles of 25°-35° and cut slopes with angles of 45°-55° were more than fill slopes with angels of 35°-45° and cut slopes with angels of 55°-65°, respectively (P= 0.06). The canopy coverage on cut and fill slopes were 7.2% and 28.4%, respectively (Fig. 1).

The characteristics of the embankments are not suitable for their resistance. The slope angle of the road bank on the uphill side determines soil stability, because both natural and artificially seeded vegetation rarely become permanently established on steep slopes, those with 45° slope or greater. Although seeds will often germinate on cut slopes, seedlings wash out when surface runoff and raindrops detach surface (Bochet *et al*., 2005).

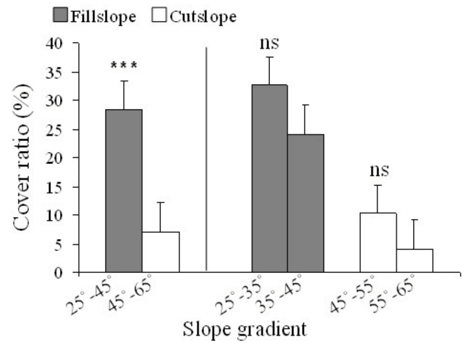

Fig. 1: Comparison of vegetation canopy coverage in different gradients and between fills and cut slopes

Rubus hyrcanus with canopy coverage of 3.2% was more concentrated on cut and fill slopes of road than control plots. *Cardamine pratensis* with coverage of 0.02% was less concentrated on cut and fill slopes plots than other species. Overall, we found 19 herbaceous and 3 woody species at the edge of main communications network (Table 3). 20 herbaceous plants and 4 seedlings of woody species were observed in control plots which were located in adjacent compartments. Mean canopy coverage in control plots was 45-55% (Tables 4 and 5).

High concentrations of non-native species have been observed near transportation corridors, suggesting that corridor edges acts microhabitats for many non-native species. The impact of these species on habitats adjacent to corridors may extend far beyond the corridor edge. Habitats along roads had equal frequencies of total non-native plant species, but had significantly higher frequencies than respective control sites. Our results agree with results from previous studies, where transportation corridors had high abundance of non-native plants (Hansen and Clevenger, 2005; Truscott *et al*., 2005; Pauchard and Alaback, 2006).

Table 3: Species occurrence in sampling plots on road embankments

no	Scientific name	(%)	no	Scientific name	(%)
1	*Oplismenus undulatifolius (Ard)P.Beauv*	0.25	12	*Polypodium auidinum*	0.95
2	*Cardamine pratensis (L.) cranty*	0.02	13	*Carex silvatica L.*	1.78
3	*Ceterach officinalis Lam. et DC.*	0.99	14	*Asperula odorata L.*	0.76
4	*Primula heterochroma Stapf*	0.1	15	*Lamium album L.*	0.32
5	*Euphorbia amygdaloides L.*	0.75	16	*Acer insigne*	0.49
6	*Hypericum androsaemum L.*	2.22	17	*Acer laetum*	0.11
7	*Rubus hyrcanus L.*	3.2	18	*Diospyrus lotus*	0.46
8	*Hedera helix L.*	0.6	19	*Oplismenus sp.*	0.3
9	*Ruscus hyrcanus Woron*	0.35	20	*Tussilago (Tourn.) L.*	0.75
10	*Phyllitis scolopendrium (L.) Newm*	0.03	21	*Salvia glutinosa*	1.46
11	*Solanum (Tourn.) L.*	1.35	22	*Viola odorata L.*	0.56

Table 4: Herbaceous plants in control plots

no	Scientific name	Family	no	Scientific name	Family
1	*Ceterach officinalis*	Aspleniaceae	11	Oplismenus sp.	Gramineae
2	*Oplismenus undulatifolius P.B.*	Gramineae	12	Hedera helix L.	Araliaceae
3	*Cyclamen europaeum L.*	Primulaceae	13	Viola odorata L.	Violaceae
4	*Primula heterochroma Stapf.*	Primulaceae	14	Carex silvatica L.	Cyperaceae
5	*Hypericum androsaemum L.*	Hypericaceae	15	Ribes qrossularia	Saxifragaceae
6	*Sanicula europaea L.*	Saniculaceae	16	Lamium album L.	Lamiaceae
7	*Polypodium auidinum.*	Hypolepidaceae	17	Gramineae	Gramineae
8	*Trifolium repens L.*	Leguminosae	18	Asperula odorata	Rubiaceae
9	*Euphorbia amygdaloides L.*	Euphorbiaceae	19	Equisetum sp L.	Equisetaceae
10	*Ruscus hyrcanus Woron.*	Asparaginaceae	20	Salvia glutinosa L.	Salviniaceae

Table 5: Regeneration of woody species in control plots

no	Scientific name	no	Scientific name
1	*Carpinus betulus L.*	3	*Diospyros lotus L.*
2	*Fagus orientalis*	4	*Parrotia persica C.A.M*

Carex silvatica L., *Solanum sp.*, *Rubus hyrcanus L.*, *Asperula odorata.*, *Euphorbia amygdaloides L.*, *Hypericum androsaemum L.* and *Tussilago (Tourn.) L.* canopy coverage on fillslopes was much more than that of cutslopes at probability of 5% (Fig. 2a, b, c, d).

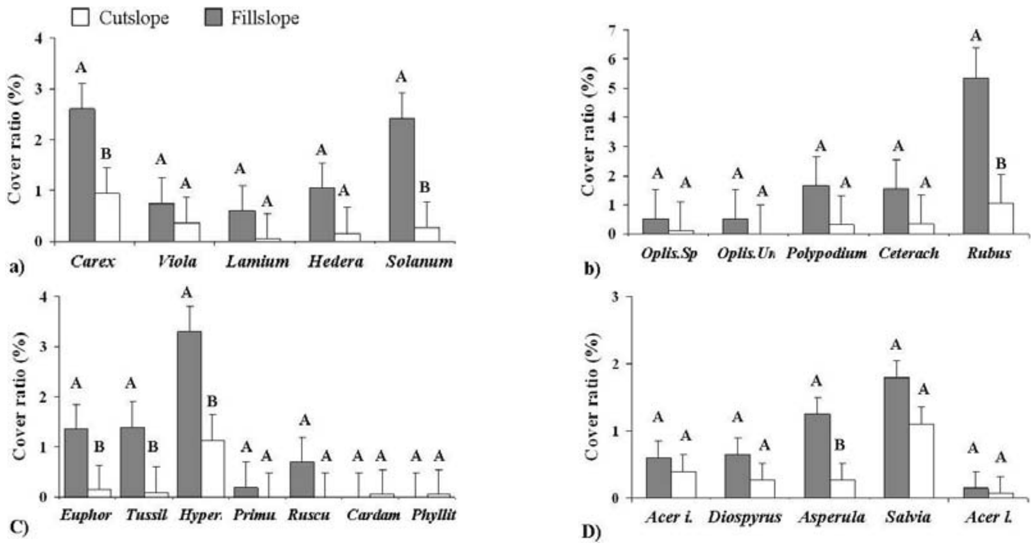

Fig. 2: Comparison of vegetation canopy coverage on forest road cut and fills slopes

Carex silvatica L., *Viola odorata L*. and *Rubus hyrcanus L*. canopy coverage on fill slope class of 35˚-45˚ was more than other classes (Table 6). Cao et al. (2006) showed that where the slope of the terrain was between 0˚ and 5˚ the average survival rate of planted grass over the 5 years was 94.69% compared to 82.64% when the slope of the terrain was more than 12.5˚. So, plants survival and consequently its canopy coverage decreased with increasing the cut slope gradient.

The main reasons for the presence of non-native species along transportation corridors are often altered disturbance regimes at the edges, such as physical disturbance of soil and vegetation during construction (Ullman *et al*., 1995), altered light conditions (Delgado *et al*., 2007), as well as intentionally introduced plants on corridor edges (Pauchard and Alaback, 2006).

Table 6: Vegetation canopy coverage in different slope classes (mean ± S.D)

Plant species	Cutslope gradient (degree)		Fillslope gradient (degree)	
	45-55	55-65	25-35	35-45
Oplismenus undulatifolius (Ard)	0.00a ± 0.00	0.00a ± 0.00	1.00a ± 0.13	0.00a ± 0.00
Oplismenus sp.	0.00a ± 0.00	0.00a ± 0.00	1.00a ± 0.16	0.20a ± 0.06
Viola odorata L.	0.55a ± 0.03	0.20a ± 0.06	0.70a ± 0.08	0.80a ± 0.01
Primula heterochroma Stapf	0.00a ± 0.00	0.00a ± 0.00	0.40a ± 0.01	0.00a ± 0.00
Lamium album L.	0.10a ± 0.02	0.00a ± 0.00	1.20a ± 0.01	0.00a ± 0.00
Hypericum androsaemum L.	1.98ab ± 0.14	0.30b ± 0.03	3.60a ± 0.20	3.00a ± 0.92
Rubus hyrcanus L.	1.41b ± 0.39	0.62b ± 0.03	5.00a ± 0.41	5.75a ± 0.87
Hedera helix L.	0.15a ± 0.06	0.17a ± 0.07	1.30a ± 0.58	0.80a ± 0.04
Ruscus hyrcanus Woron	0.00b ± 0.00	0.00b ± 0.00	1.40a ± 0.35	0.00b ± 0.00
Phyllitis scolopendrium (L.)	0.10a ± 0.02	0.00a ± 0.00	0.00a ± 0.00	0.00a ± 0.00
Solanum (Tourn.) L.	0.43b ± 0.03	0.12b ± 0.05	2.50a ± 0.19	2.35a ± 0.19
Polypodium auidinum	0.65a ± 0.03	0.00a ± 0.00	1.60a ± 0.06	1.70a ± 0.37
Carex silvatica L.	1.20ab ± 0.23	0.70b ± 0.06	2.00a ± 0.07	3.20ab ± 0.62
Asperula odorata L.	0.52a ± 0.03	0.00a ± 0.00	1.60a ± 0.49	0.90a ± 0.01
Euphorbia amygdaloides L.	0.20a ± 0.03	0.10a ± 0.02	1.60a ± 0.07	1.10a ± 0.08
Acer insigne	0.57a ± 0.07	0.20a ± 0.06	0.80 a ± 0.03	0.40a ± 0.01
Acer laetum	0.00a ± 0.00	0.15a ± 0.09	0.30a ± 0.05	0.00a ± 0.00
Diospyrus lotus	0.10a ± 0.01	0.43a ± 0.06	0.90a ± 0.02	0.40a ± 0.04
Cardamine pratensis (L.) cranty	0.10a ± 0.06	0.00a ± 0.00	0.00a ± 0.00	0.00a ± 0.00
Tussilago (Tourn.) L.	0.10b ± 0.03	0.10b ± 0.05	2.00a ± 0.65	0.80b ± 0.01
Salvia glutinosa	1.22b ± 0.01	1.00b ± 0.14	2.70a ± 0.16	0.90b ± 0.08
Ceterach officinalis Lam. et	0.70a ± 0.03	0.00a ± 0.05	1.10a ± 0.04	2.00a ± 0.11

*DC.*In a row, means with the same letters are not significantly different at 5% level based on SNK test

Cardamine pratensis (L.) cranty, *Tussilago (Tourn.) L*, *Phyllitis scolopendrium (L.) Newm*, *Rubus hyrcanus L.* and *Solanum (Tourn.) L.* was only observed on road edge, whereas *Trifolium repens L.* and *Gramineae* (*Poa annua*) were only observed on control plots. Totally, we found 14 common herbaceous species between the road edge and control plots. Therefore Jaccard similarity index was obtained 0.67, whereas this index for woody species was 0.33. Also, 14 common herbaceous species were found between the cut and fill slopes. Thus, Jaccard index was calculated 74%. This index for woody species was one. Plants biodiversity was higher on fill slopes and control plots than in cut slopes ($p<0.05$). This difference can be explained by different ecological and topographical conditions (Table 7).

Table 7: Plants biodiversity in different sampling plots

Biodiversity index	Plant community		
	Shannon	Simpson	Brillouin
Cut slope	0.51^{b}	0.16^{b}	0.36^{b}
Fill slope	0.74^{a}	0.88^{a}	0.67^{a}
Control plots	0.67^{a}	0.61^{a}	0.43^{a}

Decrease in biodiversity associated with canopy closure is especially pronounced in stands of adjacent roads (Wallace and Good, 1995; Ferris *et al*., 2000), whereas the additional habitats and species supported within open spaces such as forest road's embankments serve to increase biodiversity at the scale of the forest and possibly the landscape. For this reason, maintenance of open space within Hrcanian commercial forests has been proposed as one method for biodiversity enhancement of commercial forests (Smith *et al*., 2007; Husain *et al*., 2008).

Conclusion: Dominant plants from other microhabitats can also be suggested to revegetate side slopes, especially those species with high competitive ability and allelopathic potential to reduce the invasion of exotic species. For example, *Trifolium repens L.* and gramineae species are dominant plants, has high competitive ability and allelopathic properties that may reduce invasion of exotic plants in the side slope. Although, the autecological properties of this species have not been studied in the present study, it has potential for side slope revegetation because of its rapid vegetation growth (Sarikhani and Majnonian, 1994; Koukoura *et al*., 2007; Karim and Mallik, 2008). Further comprehensive studies using similar approaches will make significant contributions in developing guidelines for roadside revegetation with native plants. Bioengineering is another method that protects and establishes the fill and cut slopes (Lewis, 2000).

Roads supported a greater diversity of plants as a result of variation in topographic features, and the management of roadside vegetation should take this into account. Road maintenance should avoid disturbance of marginal vegetation as far as possible, for example cleaning drains only when necessary. Mechanical clearance of roadside scrub for safety purposes would be preferable to herbicide use.

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