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Full Paper

Effects of forest road clearings on understory diversity beneath *Alnus subcordata* L. stands in Iran

Seyed A. Hosseini *, Hamid Jalilvand, Mohammad R. Pourmajidian and Aidin Parsakhoo

Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, P.O. Box 737, Mazandaran, Iran

* Corresponding author, e-mail: Ata_hosseiny2002@yahoo.com

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Abstract: This study was conducted in Darab Kola forest which is located east of Sari city. After confirming the identity of Alder trees (*Alnus subcordata* L., Betulaceae) at the edge of forest roads, the cross section geometry was classified into without earth works and with earth works. Road clearing limits were divided into less than 10 metres and 10-15 metres. The understory density and canopy cover underneath Alder stands were measured in 20 micro plots. The diversity of woody and herbaceous plant species was calculated by the Simpson index. The results indicated that the canopy cover at the edge of cross sections without earth works was greater than that of sections with earth works at a probability level of 5%. In both classes, the percentage of *Rubus hyrcanus* L. canopy cover on filled slopes was more than that on cut slopes, whereas the percentage of canopy cover of this species and of bare soil was similar, as well as the biodiversity indices for both sides of cross sections without earth works.

Keywords: understory diversity, forest road clearing, *Alnus subcordata* L.

INTRODUCTION

The water balance of roads depends on the geometry and on the course of the road through the land [1]. It has been demonstrated that the locations of the trees on the down-slope and up-slope of roads affect the foliage discolouration level. Mean foliage discolouration level of trees was highest in the down-slope plots, followed by up-slope and forest interior plots [1]. Roadside soil receives at least twice as much rainfall water as other areas and the interception of subsurface flows by roads further increases the water availability in road side areas [2].

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The environmental effects of forest roads were categorised into abiotic and biotic categories. For abiotic conditions, the effects of roads on hydrology, geomorphology, natural disturbances and edaphic properties were studied [3-4]. In a pine forest, Delgado et al. [5] detected a highly significant gradient of soil temperature along asphalt roads and a significant light gradient for both asphalt and unpaved roads. The biotic consequences are divided into genetic factors and plant and wildlife population situations [6].

Forest roads create edge effects on plant communities through fragmenting habitats and introducing disturbances [7-8]. These effects may vary with the width of roads as well as the geometry of road cross sections [9-10]. Solar radiation, soil moisture content, and soil temperature in gaps created by forest roads are significantly greater than adjacent closed canopy plots [11-12]. Gaps have significantly less exchangeable base cations (K, Ca and Mg) compared to forest plots with mineral soil (0–25 cm). Gaps also have significantly more dissolved organic N and extractable nitrates at 25–50 cm, indicating increased nutrient leaching in gaps. In situ N mineralisation is significantly greater in gaps and roadside plots compared to forest plots [13-15]. Zhou et al. [16] showed that wide and narrow roads have different edge effects. For wide roads, plant diversity and soil moisture tend to increase, whereas herbaceous biomass tends to decrease from the road edge to the forest interior.

The objective of this study is to assess the edge effects of wide (10-15 m) and narrow (less than 10 m) roadside clearings of forest roads on plant species diversity under the alder trees in the Darab Kola forest, Mazandaran, Iran. The effects of the geometry of forest road cross sections including those with earth works and without earth works on plant species diversity was investigated.

STUDY AREA AND METHODS

Darab Kola forest with an area of 2,612 hectares is located in south-east Sari city in Mazandaran province, Iran. The latitude, longitude and elevation ranges of this forest are 36° 33′ 20″ to 36° 33′ 30″ N, 52° 14′ 40″ to 52° 31′ 55″ E and 180-800 metres above sea level respectively. The average slope of the forest is about 40%. The forest has four types of soil consisting of (I) non-developed randzin to washed randzin soil, (II) brown soil with an alkaline pH, (III) washed brown calsic soil and (IV) washed brown pseudoclay (Figure 1). The climate is very moist with average temperature ranging from 26.1°C in August to 7.5°C in February. The mean annual air temperature is 16.7°C. The region receives 983.8 mm of precipitation annually. Minimum and maximum rainfall is 36.1 to 119.8 mm, which occur in July and November respectively.

The cross section shapes were classified into that without earth works and that with earth works (Figure 2). In addition, roadside clearings were divided into that less than 10 metres and that between 10-15 metres wide. According to the cross section shapes of forest roads and clearing classes, the understory density and canopy cover in were measured in 20 1×1-m plots. All data were collected in July 2009. The diversity of woody and herbaceous plant species was calculated by Simpson’s index (λ) :

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$$\lambda = 1 - \sum \left[\frac{n_i(n_i - 1)}{N(N-1)} \right]$$

where n_i is number of individuals of species i in the sample and N is total number of individuals in the sample.

The data were analysed by the ANOVA procedure using SAS software. Statistical significance was judged at p<0.05. When the analysis was statistically significant, the Student Newman Keuls (SNK) test for separation of means was performed.

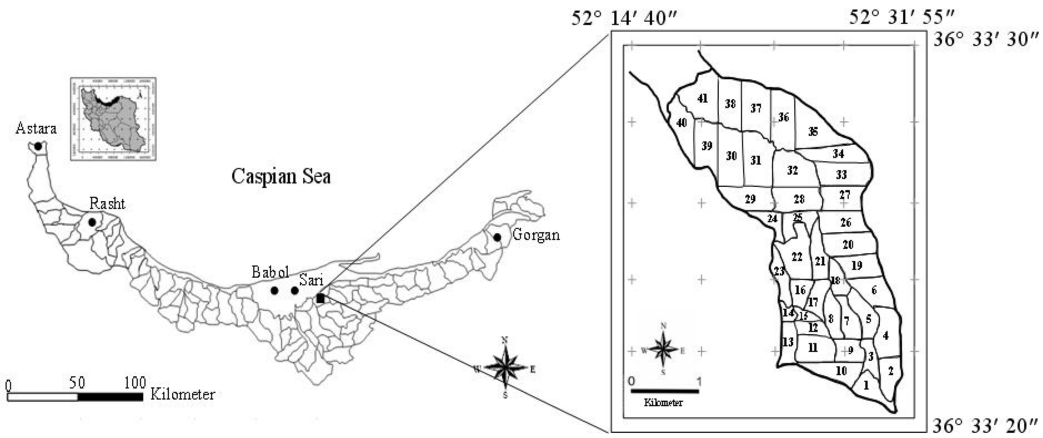

Figure 1. Location of the study area

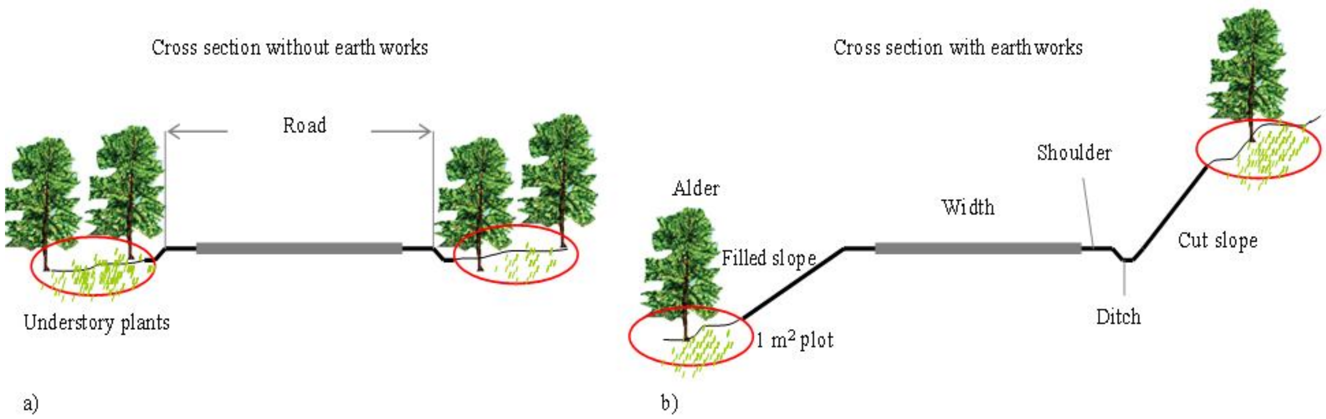

Figure 2. (a) Cross section without earth works; (b) cross section with earth works

RESULTS AND DISCUSSION

Our results indicate that the percentage of canopy cover of *Diospyrus lotus* L. was affected by the clearing size of the forest road at a probability level of 5% (Table 1). In road cross sections both with and without earth works, the percentage of *Rubus hyrcanus* L. canopy cover on filled slopes was more than that on cut slopes. The percentage of canopy cover of this species and that of bare soil were similar, as well as the biodiversity indices for both sides of cross sections without earth works. The percentage of bare soil on cut slopes was more than that on filled slopes (Table 2).

Table 1. ANOVA for independent effect of the clearing size (0-10m and 10-15 m) on canopy coverage of woody and non-woody plant species along Darab Kola forest road

Species	Habit	SS	MS	F
Oplismenus undulatifolius (Ard) P. Beauv	Herb	726.01	726.01	3.52 ns
Rubus hyrcanus Juz.	Shrub	649.80	649.80	0.58 ns
Lamium album L.	Herb	211.25	211.25	1.98 ns
Phyllitis scolopendrium (L.) Newm	Herb	0.11	0.11	0.15 ns
Urtica dioica L.	Herb	2.81	2.81	1.00 ns
Equisetum sp.	Herb	31.25	31.25	3.51 ns
Chelidonium majus L.	Herb	1.25	1.25	0.07 ns
Mentha sp.	Herb	5.00	5.00	1.19 ns
Petris cretica L.	Herb	2.81	2.81	0.84 ns
Hedera helix L.	Vine	0.00	0.00	0.00 ns
Hypericum androsaemum L.	Herb	0.01	0.01	0.01 ns
Euphorbia amygdaloides L.	Herb	3.20	3.20	1.39 ns
Acer insigne L.	Tree	0.61	0.61	0.29 ns
Brachypodium sylvaticum (Huds.) Beauv.	Herb	9.11	9.11	1.56 ns
Convolvulus arvensis L.	Vine	165.31	165.31	1.83 ns
Carex silvatica (L.) Auct.	Herb	7.81	7.81	1.84 ns
Diospyrus lotus L.	Tree	68.45	68.45	1.55*
Rumex acetossa L.	Herb	16.20	16.20	4.32 ns
Viola odorata L.	Herb	28.80	28.80	0.50 ns
Potentilla reptens L.	Herb	0.31	0.31	1.00 ns
Oxalis corniculatum L.	Herb	1.25	1.25	1.00 ns
Bare soil		0.31	0.31	1.00 ns
Total plant coverage		1.25	1.25	1.00 ns

Note: SS = Sum of squares of error; MS = Mean square; F = Value calculated by dividing MS source with MS error in SAS software; * = Significant in probability level of 5 %; ns = Not significant

The Simpson index revealed that in clearings 10-15 m wide, the diversity of understory species on cut slopes was significantly greater than that on filled slopes at cross sections with earth works (Table 3). Understory species diversity was higher on roads with clearings of 10-15 m. We found increased numbers of both native and exotic species associated with increased width clearings (Table 4). In Shawnigan Lake on southern Vancouver Island of British Columbia, it has been proved that after 27 years of thinning and fertilisation, there was little effect on understory

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Table 2. ANOVA for independent effect of the cross section type (with earth works and without earth works) on canopy coverage of woody and non-woody species along Darab Kola forest road

Species	Habit	SS	MS	F
Oplismenus undulatifolius (Ard) P. Beauv	Herb	632.81	632.81	2.92 ns
Rubus hyrcanus L.	Shrub	42.05	42.05	0.05 ns
Lamium album L.	Herb	162.45	162.45	1.57 ns
Phyllitis scolopendrium (L.) Newm	Herb	0.11	0.11	0.16 ns
Urtica dioica L.	Herb	2.81	2.81	1.00 ns
Equisetum sp.	Herb	5.00	5.00	0.56 ns
Chelidonium majus L.	Herb	5.00	5.00	0.30 ns
Mentha sp.	Herb	5.00	5.00	1.18 ns
Petris cretica L.	Herb	2.81	2.81	0.90 ns
Hedera helix L.	Vine	5.00	5.00	2.76 ns
Hypericum androsaemum L.	Herb	1.51	1.51	0.76 ns
Euphorbia amygdaloides L.	Herb	8.45	8.45	3.60 ns
Acer insigne L.	Tree	0.11	0.11	0.06 ns
Berachypodium silvaticum L.	Herb	7.81	7.81	0.09 ns
Convolvulus arvensis L.	Vine	1.51	1.51	0.35 ns
Carex silvatica (L.) Auct.	Herb	405.00	405.00	9.34**
Diospyrus lotus L.	Tree	0.20	0.20	0.05 ns
Polygonum sp.	Herb	186.05	186.05	3.38 ns
Rumex acetossa L.	Herb	0.31	0.31	1.00 ns
Viola odorata L.	Herb	1.25	1.25	1.00 ns
Potentilla reptens L.	Herb	0.31	0.31	1.00 ns
Oxalis corniculatum L.	Herb	1.25	1.25	1.00 ns
Bare soil		20.00	20.00	3.04 ns
Total plant coverage		3850.31	3850.31	13.76***

Note: SS = Sum of squares of error; MS = Mean Square; F = Value calculated by dividing MS source with MS error in SAS software; **,*** = Significant in probability level of 1 and 0.1 % respectively; ns = Not significant

vegetation in terms of species richness or vegetation cover [9]. An effective way to conserve species diversity is to protect specific substrate types, e.g. tree trunks, stumps and coarse woody debris [9].

The plant diversity on cut slopes was significantly higher than that on filled slopes in clearings of 10-15 metres (Figure 3). No significant difference between cut and filled slopes was for plant diversity in clearings of less that 10 metres. In cross sections without earth works, none of the measured variables showed a statistically significant difference between the right and left sides of the road clearings (Figure 4).

Bartemucci et al. [3] found that light transmission through the canopy influenced the structure and function of understory plants more than their diversity and composition. This is likely due to the strong effect of the upper understory layers, which tend to homogenise light levels at the forest

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Table 3. Canopy cover percentage of woody and non-woody plant species in the two clearing classes with earth works

Species	≤10 m clearing width		10-15 m clearing width	
	Cut slope	Filled slope	Cut slope	Filled slope
Oplismenus undulatifolius (Ard) P. Beauv	7.8	7.0	5.5	2.5
Rubus hyrcanus L.	24.7	57.5	19.2	69.0
Lamium album L.	2.0	12.7	1.5	4.0
Phyllitis scolopendrium (L.) Newm	0.0	0.0	0.5	0.0
Urtica dioica L.	0.0	0.0	0.0	1.5
Equisetum sp	0.0	0.0	0.0	1.5
Chelidonium majus L.	0.0	2.0	0.0	0.0
Mentha sp.	0.0	0.0	0.0	1.0
Petris cretica L.	0.0	1.0	0.0	1.5
Hedera helix L.	0.5	0.5	1.0	0.0
Hypericum androsaemum L.	0.9	0.0	0.3	0.0
Euphorbia amygdaloides L.	1.3	0.8	0.5	0.0
Acer insigne L.	0.5	0.0	1.3	0.0
Berachypodium silvaticum L.	5.5	1.0	2.5	0.0
Convolvulus arvensis L.	0.8	1.0	0.8	0.0
Carex silvatica (L.) Auct.	0.0	0.0	0.7	0.0
Diospyrus lotus L.	1.5	0.5	0.0	0.0
Bare soil	54.5	16.0	64.0	18.5

floor regardless of forest type. The understory community acts as a filter, thereby reducing light levels at the forest floor to uniformly low levels [15].

Zhou et al. [16] demonstrated that forest roads tend to increase plant biomass mainly because of increased light availability, but reduce plant diversity probably due to increased competition at the edges of forests. These findings have important implications for forest conservation and landscape planning so as to maximise biodiversity and minimise habitat fragmentation and edge effects.

The abruptness of microclimate and canopy gradient is slightly higher in a laurel forest than in a pine forest due to a higher edge contrast in the former [8]. The depth of the road edge effect found in laurel and pine forests is small, but it can have cumulative effects on forest microclimate and forest associated biota at the island scale. It has been proven that the mean canopy cover on roadsides is less than the forest interior [10].

Along roadsides, coarse woody debris cover and litter depth and cover were lowest, and the abundance and diversity of native species were also lower [11]. Figure 5 shows some plants in the study area. It was apparent that the right and left sides of the road with different cleared widths had no significant effect on canopy coverage of herbaceous plants and regeneration of woody species, especially for *Rubus hyrcanus* (Table 4). Roads supported a greater diversity of plants as a result of

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Table 4. Canopy cover percentage of woody and non-woody plant species in the two clearing classes without earth works

Species	≤10 m clearing width		10-15 m clearing width	
	Left	Right	Left	Right
Oplismenus undulatifolius (Ard) P. Beauv	12.3	19	9	5
Rubus hyrcanus L.	37	42.7	40.5	56
Lamium album L.	1	5.3	0.5	2
Phyllitis scolopendrium (L.) Newm	0.5	0	0.3	0
Equisetum sp.	0	0	3.5	0
Chelidonium majus L.	0.5	0	0.5	3
Mentha sp.	1	0	0.5	1.5
Petris cretica L.	0	0	0	1
Hypericum androsaemum L.	0	0.8	1	0.5
Acer insigne L.	0.7	0.4	0.5	0.5
Sepholantara sp.	1	0	0.5	0.5
Berachypodium silvaticum L.	2.5	7	2	0
Convolvulus arvensis L.	1	0.5	0	0
Carex silvatica L.	3.7	2.3	9.7	3
Tussila sp.	1	0	2	1
Polygonum sp.	3.7	0	7.5	1
Rumex acetossa L.	0	0	0	0.5
Viola odorata L.	0	0	1	0
Potentilla reptens L.	0	0	0.5	0
Oxalis corniculatum L.	0	0	0	1
Diospyrus lotus L.	0.6	1	0	0
Bare soil	33.5	21	20.5	23.5

variation in topographic features. The management of roadside vegetation should take this into account and avoid disturbance of marginal vegetation as far as possible. Drain cleaning should be done only when necessary and mechanical clearance of roadside scrub for safety purpose would be preferable to using herbicides [12]. The main reasons for the presence of non-native species along roads are disturbance of soil and vegetation during construction, altered light conditions, as well as intentionally introduced plants (ornamentals) [14].

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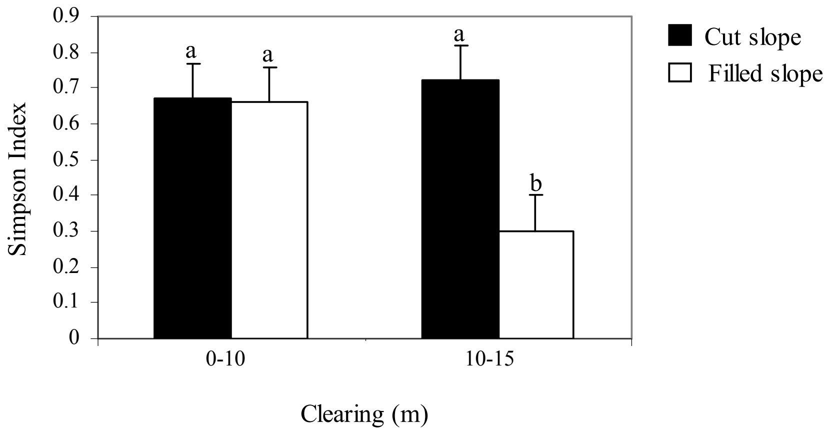

Figure 3. Comparison of plant diversity for different clearing widths with earth works (Letters a and b indicate different groups according to SNK test ($p < 0.05$).)

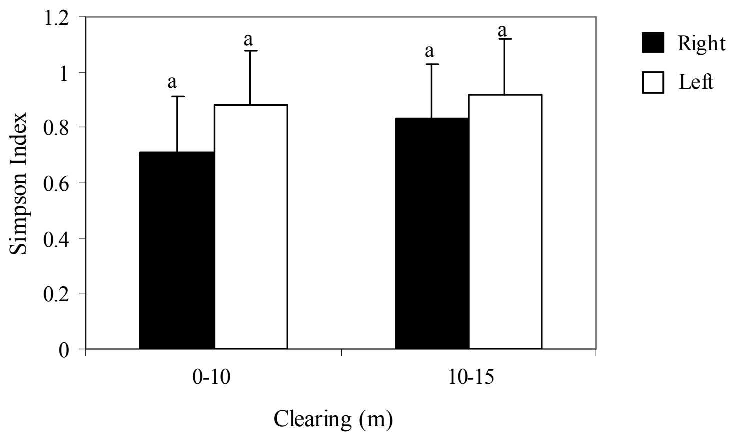

Figure 4. Comparison of plant diversity for different clearing widths without earth works (Letter a indicates same group according to SNK test ($p < 0.05$).)

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Figure 5. Some plants along the Darab Kola forest road

CONCLUSIONS

Canopy coverage was observed to show a significant effect on plant species diversity. The understory below Alder stands had significantly more species and higher species richness than the understory of other areas. This result suggests that Alder canopies create conditions to support more understory species. The percentage of bare soil on cut slopes was more than that on filled slopes. Simpson's index revealed that in clearing widths of 10-15 m, the diversity of the understory plants on cut slopes was significantly greater than that on filled slopes with earth works. Despite the importance of road gaps in the dynamics and management of many forest types, very little is known about the medium to long-term understory plant dynamics associated with this disturbance. It is proposed that the effects of roads on the chemical and physical properties of forest soils and consequently the effect on vegetation cover be investigated using PC-ORD or CANOCO softwares in future studies.

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