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The effects of roadside on composition of tree communities in forests of West Guilan Province, Iran

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ABSTRACT
Forest roads are one of the main affecting factors on diversity and composition of plant species. This study aimed to investigate the effects of forest road on composition of tree communities of forests in west of Guilan Province, Iran. Therefore, in two age classes (0-10 and 10-20 years old) of forest roads with five different distances from the road edge, totally, 240 sample plots (150 square meters) were taken by line transect method. The results showed that the relative importance of *Fagus orientalis*, *Quercus castaneifolia* and *Acer velutinum* trees on roads with lower age (0-10 years old) was higher than those with higher age (10-20 years old). The results also indicated that on the newly-constructed roads, the presence of pioneer species (*Alnus subcordata* and *A. cappadocicum*) became lower than the other species by moving from the roadside into the forest. In this study, the species importance values of *A. subcordata*, *A. cappadocicum*, and *A. velutinum* decreased from roadside to the forest interior. The results also showed that the Simpson's diversity and evenness index in old roads were higher than the young ones. The results of ANOVA analysis showed that by increasing distance from the road, the species diversity and richness declined, while species evenness elevated. The results indicated that there are higher dead trees on the roadside (0-30 and 31-60 m) compared to the inside of forest.

Keywords: Road age, Diversity, Forest road, SIV.

INTRODUCTION
Road age is one of the factors affecting the distribution of non-native species (Hodkinson & Thompson 1997). By increasing in the forest road's age over time, many factors related to trees and shrubs around the road, such as canopy cover, trunk diameter, and regeneration rate could be changed. So that, some species occupy the roadside area and thereby diversity of tree and shrub species could be changed by regenerating and increasing the number of these species (Mirzaee 2004). Therefore, road age is among the most important factors affecting the structure of trees and shrubs at roadside areas (Spooner & Smallbone 2009). From ecological point of view, the proper time at which a road is constructed is important to maintain valuable and endangered species (Deljouei *et al.*, 2013). An ecosystem needs time to achieve sustainability, and as forest roads become older, the ecosystem become more sustainable, resulting in less negative effects on the road (Akay *et al*. 2008; Fu *et al*. 2009).
After road construction, changes in forest regeneration occurs due to the opening of tree canopy, change in light conditions as well as soil displacement and erosion (Bowering *et al*. 2006). Roads are clearly considered as a threat to regional biodiversity, since they provide conditions for non-native invader species, while threaten the survival of native ones (Forman & Alexander 2002). The percentage of canopy cover declines in the early steps of forest road construction process, which consequently results in creation of roadside and gap, soil displacement, as well as decreased density of forest cover. Increase or decreasing biodiversity within the forest is highly affected by the light passing through the tree cover and establishment of light-demanding species (Deljouei *et al*. 2013).

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Tree mortality mostly occurs at the forest margins, because trees suffer physical harms such as strong winds (Murcia 1995; Nikooy *et al*. 2010). Many trees die because of excessive desiccation due to drier conditions and increased light exposure (Olupot 2009; Tavankar *et al*. 2017). In addition, dead trees are ecologically significant for forest function. Dead trees play a major role in long-term carbon storage by slightly releasing carbon into the atmosphere. Deadwoods also preserves biodiversity and serve as a nutrient source for most plant species. However, few studies have been carried out about the effects of roads on natural plant communities (Benitez *et al*. 2010). In a study, Deljouei *et al*. (2018) observed an obvious effect of the road on the vertical structure of the adjacent forests and also found that forest roads can have significant impacts on soil, stand characteristics, and vegetation composition. Deljouei *et al*. (2017) also observed that in a hornbeam-beech forest, the edge effect of roads was apparent up to 5 m from the road edge and at higher distances, some tree species (*Alnus subcordata*) did not exist.

Most previous studies have assessed the distribution of exotic plants (Pauchard & Alaback 2006; Flory & Clay 2006). To date, the relationship between distance from road and global plant communities in the edge forest habitats has received little attention. It was also found that forest roads lead to important changes in vegetation communities and can alter ground flora from forest interior species to open-habitat or exotic plant species (Zenner *et al*. 2007). Therefore, understanding the historic development of roads is critical to understanding the current conditions of roadside environments. The objectives of this study were to evaluate the effects of road age on (1) composition of trees in forest roads, (2) on plant biodiversity, (3) on dead wood in terms of distance from road and (4) to evaluate the changes in species importance value (SIV) of plant communities at different distances from the road. We also tried to understand the effects of the road construction age on plant communities for better conservation of them, along with to evaluate deadwood, diversity indices and relative importance values at different distances from road.

MATERIALS AND METHODS

Study areas

This study was performed in Hyrcanian forests located in north of Iran. The Caspian forests (also called the Hyrcanian forests) cover about 1.9 million ha and are rich in biological diversity and ecological niches, containing many endemic and endangered species (Heshmati 2007; Tavankar *et al*. 2014). The present study was carried out in District 2 of Nav forest area (37°37'23" to 37°42'31" N) in watershed number 7 of Guilan Province, forests of North Iran (Fig. 1). Mean annual rainfall ranged from 920 to 1100 mm, with the most precipitation in fall and winter. Mean daily temperature varied from -3 °C in December, January and February, and up to +25 °C during the summer. The area is characterized by uneven aged mixed forests dominated by *Fagus orientalis* Lipsky and *Carpinus betulus* L., accompanied by *Alnus subcordata* C.A. May, *Acer cappadocicum* Gled species. The forests of area are characterized by mixed and uneven-aged high forest stands, manage with single and group selective cutting methods. The soil is brown forest (*Alfisols*) one with well drainage. Soil texture is loamy to clay loam (Tavankar *et al*. 2014). Width of all roads is 5.5 m with unpaved surface, characterizing by a density of 22.9 m ha^{-1}, with a total length of 8.09 km. It is protected by barbed wire with no grazing (Tavankar *et al*. 2014).

Data collection and analysis

Age and distance from the forest road composed treatments in this study. Therefore, two age classes (<10 and > 10 year old) and five distance groups (0-30, 31-60, 61-90, 91-120, and 121-150 m) were selected (Li *et al*. 2010; Avon *et al*. 2010; Bergès *et al*. 2013). In any age classes, 16 line transects (each 150 m in length) with 100 m away from each other (Berenji Tehrani *et al*. 2014) were selected perpendicular to the road (Fig. 2).

In selecting the study samples, we considered the other influential variables (slope, aspect and elevation above sea level) to be the same. The slope, aspect and elevation above sea level were also measured using inclinometer, compass and GPS, respectively.

In each rectangular sample plot consisting of 150 m^2 (30 m in length and 5 m in width), all live (DBH ≥ 7.5 cm) and dead trees (snag) were counted, then species were identified. Thereafter, diameters at breast height (DBH) and trees height were measured.

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The dead tree index (DTI) was computed as the ratio of dead to live trees in each plot (Sefidi *et al*. 2008). Species importance value (SIV) for each species was calculated as reported by other authors (Ganesh *et al*. 1996; Krebs 1999; Pourbabaei & Abedi 2013; Tavankar 2015).

SIV = Relative density (RDe) + Relative frequency (RF) + Relative dominance (RDo). Where: *RD*e = number of individuals of a species × 100 / total number of individuals of all species. *RF* = number of plots containing a species × 100 / sum of frequencies of all species. The Basal area was considered for dominancy, while relative dominance (*RDo*) was calculated by: *RD*o basal area of a species × 100 / total basal area of all species (Tavankar 2015). The species diversity index was computed using the Shannon–Wiener information function (Hill 1980; Ozcelik *et al*. 2008; Tarvirdizadeh *et al*. 2014) as:

$$H' = -\Sigma (n_i / n) \times Ln (n_i / n)$$

where: n_i denotes the SIV of a species and n the sum of total SIV of all species.

Simpson biodiversity index:

$$S = 1-\sum [(n_i (n_i-1) / N (N-1))$$

where, n_i = the number of individuals in species *i* in sample, N: number of total species.

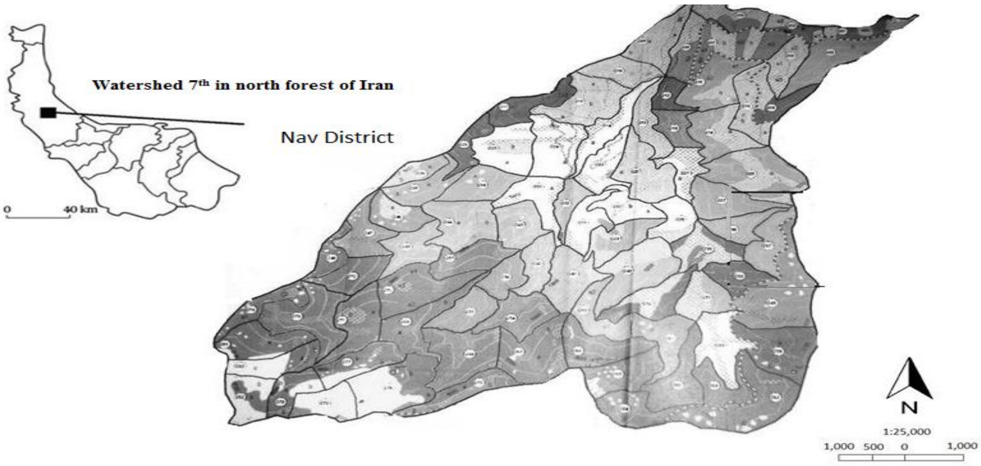

Fig. 1. Location of the study area (Nav District No. 2).

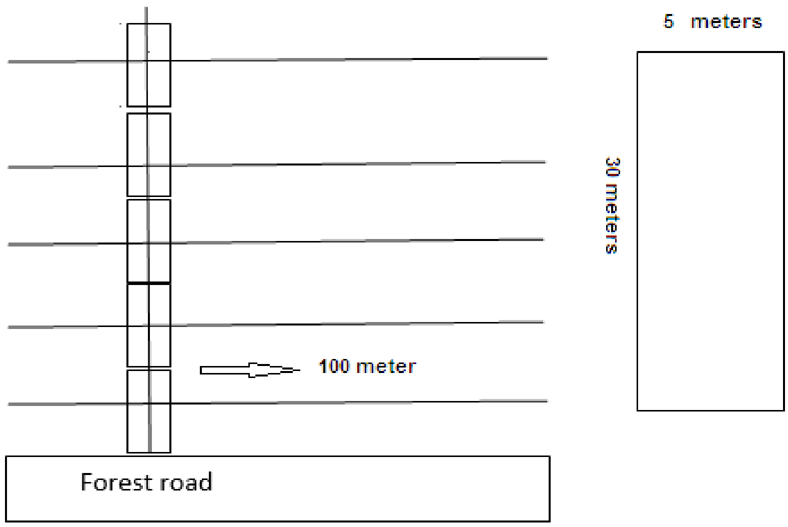

Fig. 2. The sampling along the forest road.

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Species richness was determined according to the Margalef index:
$R = S-1/ \ln N$,
where S is total number of species and N is total number of individuals.
Menhenick's richness index:
$R = S/\sqrt{D}$
where S = number of species, D = number of individuals (Menhenick 1964).
Species evenness was determined by measuring the relative abundance of each species per plot (Valencia *et al*. 2004).
Smith Wilson's index is the best index for evenness, because it is affected by species richness, while it is sensitive to rare species in the community (Ejtehadi *et al*, 2008). This index (Smith & Wilson 1996) was used to calculate species evenness:
$E_{var} = 2/ \pi \arctan [\sum \log (n_i)-\sum \log (n_j/s)^2 / s]$
where n_i is number of individuals of the i^{th} species in a plot, n_j number of individuals of the j^{th} species and S total number of species in areas.
$E_1 = 1/\sum (P^2 \times S)$, where P = individuals or abundance of species I, S = number of species.
After checking the normality using Kolmogorov-Smirnov test (Zar 1984) and homogeneity of variance using Levene's test, average values of stand characteristics (tree density, basal area, stand volume) were calculated. To assess interactions between biodiversity index, DTI and SIV indices were obtained at different distances from the road.
ANOVA test was employed to analyze the compared means, while Duncan-test were used for comparing multiple means. The mean of variables related to the two age classes was compared using independent sample t-test. All statistical analyses were performed using SPSS 16.0 software.

RESULTS

Species Importance Value of trees in different age and distance from road classes

Results indicated that SIV values of *F. orientalis*, *Q. castaneifolia* and *A. velutinum* at the edge of <10 year-old roads were higher than that of >10 year-old ones. SIV value of *C. betulus* was equal in the two classes.
In the cases of *A. cappadocicum, A. subcordata* and other species, SIV values at the edge of <10 years-old were lower than those of >10 year-old ones (Fig. 3). SIV of tree species at different distances from the road is illustrated in Fig. 4. Results exhibited that by increasing distance from the road, SIV of *F. orientalis* was raised, while those of *A. subcordata, A. cappadocicum,* and A. *velutinum* were declined.

Tree diversity in different age- and distance from road- classes

Results exhibited that Simpson diversity and evenness indices in old roads were significantly higher than young ones, whereas Smith-Wilson's evenness and richness indices were higher in young roads than in old ones (Table 1). The results also indicated that distance from road had a significant impact on diversity indices ($p < 0.05$). Table 2 illustrates that by increasing in distance from the roadside, diversity and richness indices were declined, while evenness index was elevated. There was a significant difference between tree species richness in 0-30 m from roadside and the other distances.

DTI (Dead Tree Index)

DTI (as the ratio of dead to live trees), regardless of distance, at different age classes i.e. <10 and >10 years old, were 0.21 and 0.20, respectively (Fig. 5). This index for distance classes, i.e., 0-30, 31-60, 61-90, 91-120, and 121-150 m from the road were 0.32, 0.25, 0.15, 0.14 and 0.14, respectively.
The results indicated that there is significant difference between DTI coefficients at different distances from the road (Sig = 0.00 and F = 114.22) (Fig. 6).
The maximum index value (0.32) was observed at 0-30 m, while minimum (0.14) at 91-120 and 121-150 m from the road.

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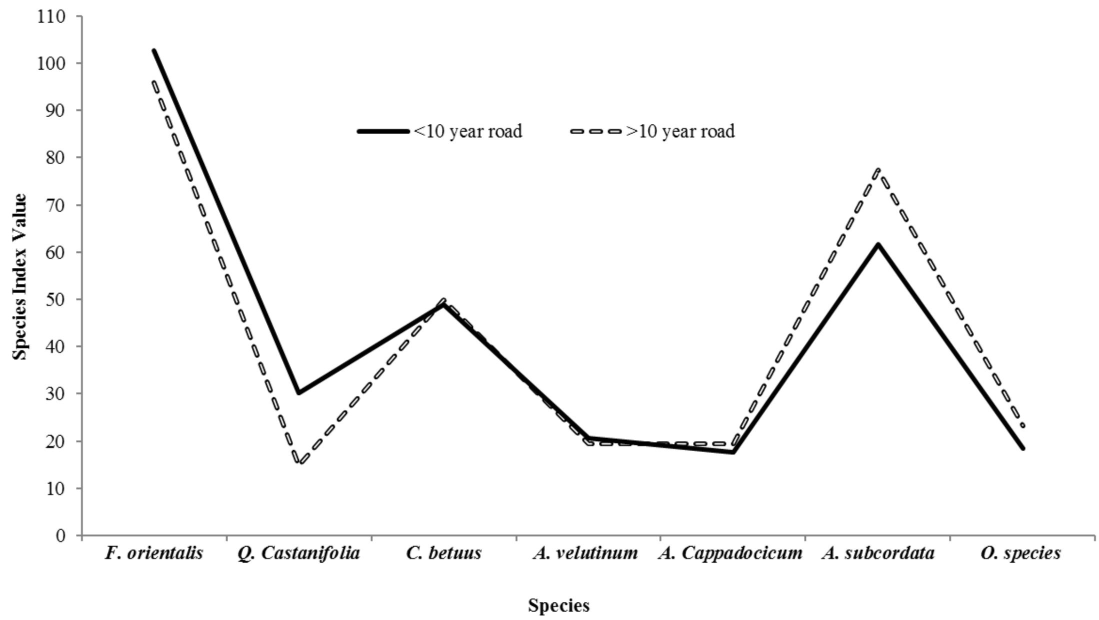

Fig. 3. Tree species importance values in two age classes of roads.

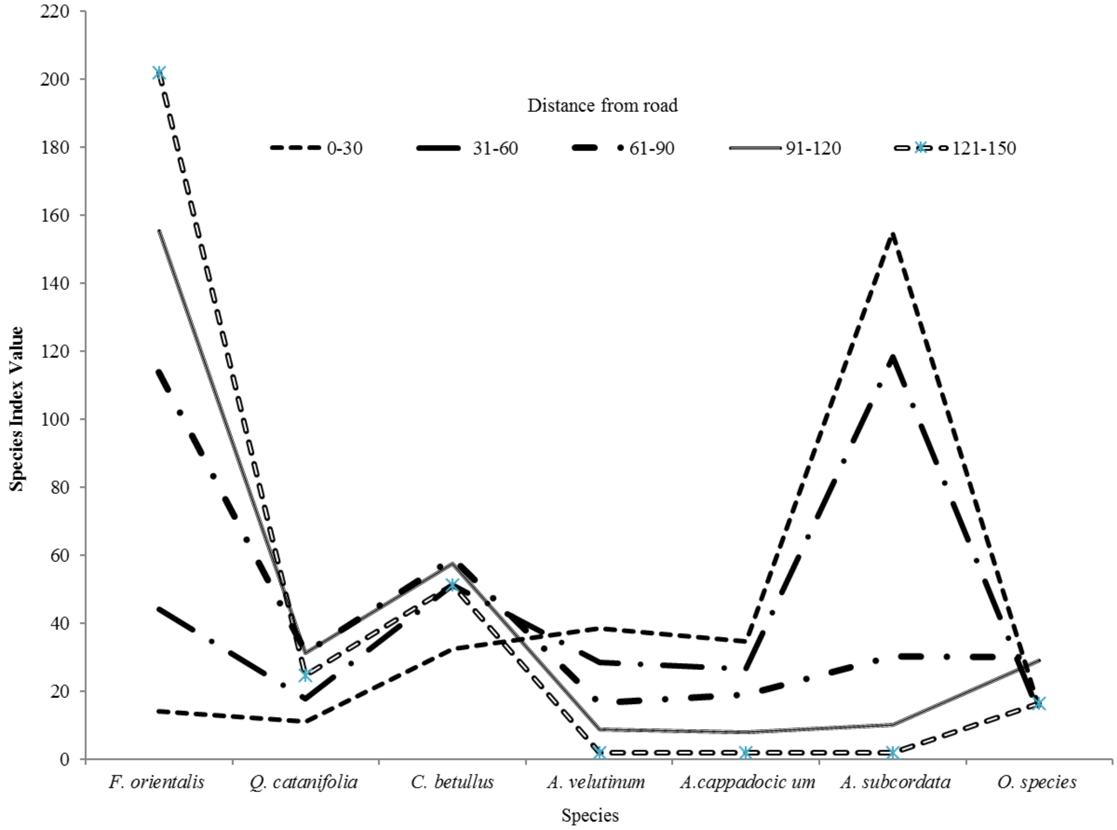

Fig. 4. SIV values at different distances from two age classes of forest road.

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Table 1. Diversity indices in different age classes of the road

Indices		Road age (year) <10	>10
Diversity			
Shannon (H′)	mean ± SD	$0.77^b \pm 0.66$	$0.95^a \pm 0.63$
	t value	0.05	
	P value	0.027	
Simpson (1-D)	mean ± SD	$0.24^b \pm 0.24$	$0.34^a \pm 0.24$
	t value	3.02	
	P value	.001	
Evenness			
Smith and Wilsons	mean ± SD	$0.21^a \pm 0.21$	$0.19^b \pm 0.15$
	t value	0.6	
	P value	0.1	
Simpson ($E_{1/D}$)	mean ± SD	$0.39^b \pm 0.21$	$0.42^a \pm 0.15$
	t value	1.62	
	P value	0.20	
Richness			
Menhenick	mean ± SD	$1.80^a \pm 1.29$	$1.30^b \pm 1.09$
	t value	1.38	
	P value	0.001	
Margalef	mean ± SD	$2.21^a \pm 1.85$	$1.58^b \pm 1.60$
	t value	2.79	
	P value	0.001	

Letters a and b indicate significant differences between means ($p < 0.05$).

Table 2. Diversity indices of tree species at the different distances from the road (<10 and >10 years old)**.**

Indices		Distance from road (m) 0-30	31-60	61-90	91-120	121-150
Diversity Shannon (H′)	mean ± SD	$1.46^a \pm 0.63$	$1.12^b \pm 0.66$	$0.87^c \pm 0.52$	$0.54^d \pm 0.44$	$0.44^d \pm 0.42$
	F value	1.72				
	P value	0.00				
Simpson (1-D)	mean ± SD	$0.54^a \pm 0.19$	$0.37^b \pm 0.24$	$0.23^c \pm 0.20$	$0.17^d \pm 0.19$	$0.13^d \pm 0.16$
	F value	3.06				
	P value	0.00				
Evenness Smith and Wilsons	mean ± SD	$0.16^c \pm 0.09$	$0.17^c \pm 0.07$	$0.16^c \pm 0.11$	$0.23^b \pm 0.22$	$0.30^a \pm 0.28$
	F value	1.68				
	P value	0.00				
Simpson ($E_{1/D}$)	mean ± SD	$0.30^e \pm 0.11$	$0.38^c \pm 0.13$	$0.34^d \pm 0.15$	$0.52^a \pm 0.18$	$0.48^b \pm 0.23$
	F value	5.79				
	P value	0.00				
Richness Menhenick	mean ± SD	$1.93^a \pm 1.22$	$1.98^a \pm 1.54$	$1.40^b \pm 1.17$	$1.20^c \pm 1.09$	$1.24^c \pm 0.70$
	F value	1.17				
	P value	0.001				
Margalef	mean ± SD	$2.52^a \pm 1.88$	$2.38^a \pm 2.28$	$1.61^b \pm 1.41$	$1.54^b \pm 1.77$	$1.43^c \pm 0.83$
	F value	0.74				
	P value	0.002				

Different letters indicate significant differences ($p < 0.05$). Mean values are always expressed ± standard deviation.

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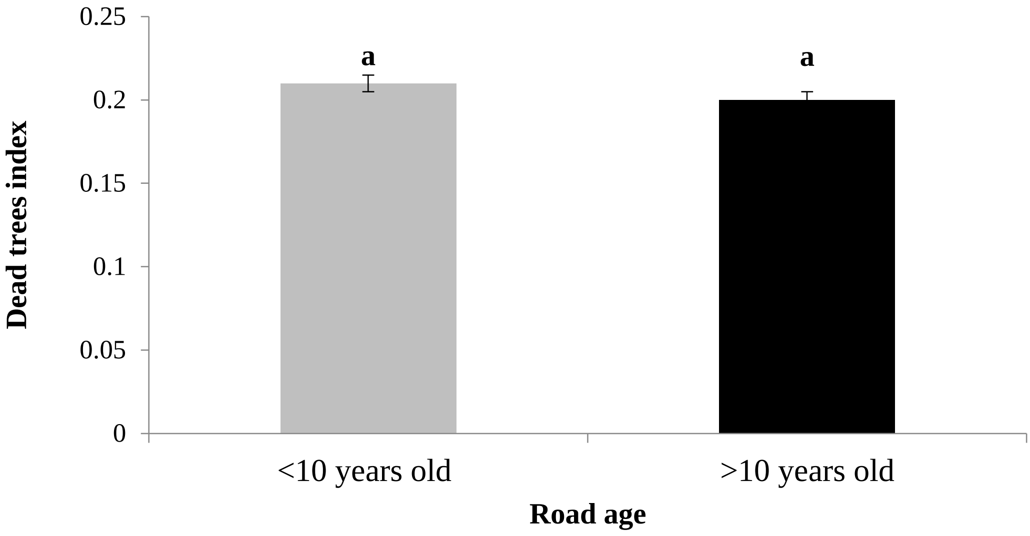

Fig. 5. DTI (dead tree index) values at different age classes.

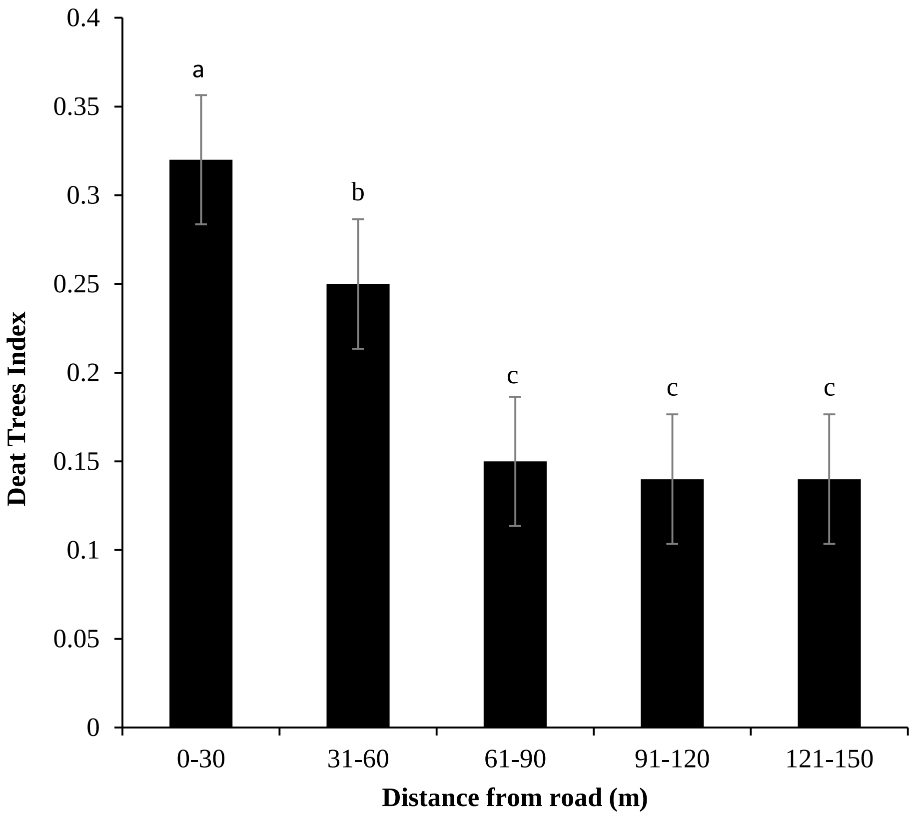

Fig. 6. Dead tree index values at different distances from road.

DISCUSSION

Species importance value (SIV) of trees in different age- and the distance from road- classes

Results of the present study indicated that SIV of *F. orientalis, Q. castaneifolia* and *A. velutinum* on roads at the edge of <10 year-old roads are higher than those of >10 year-old ones (Fig. 3), which are not consistent with

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those of Harper *et al*. (2004). Once working in a boreal forest of northwestern Quebec, they reported that the abundance of tree species decreased in newly-constructed roads (1-5 years). These roads receive more light compared to older ones. As the road increases in age, the amount of light receiving the roadside area declines and the vegetation density raises in upcoming years which makes stand closer to low-light receiving forest floor (Delgado *et al*. 2007).

In the present study, species importance value of pioneer tree species i.e. *A. subcordata* was higher in distances 0-30 and 31-60 m from road compared to inside the forest. Also *F. orientalis* exhibited the highest species importance value in plots located inside the forest (Fig. 4). It was consistent with findings of Hosseini (2010) who reported that the density of tree species changed significantly over a 10 m distance from road in Darab Kola forest, Sari, Iran, and also with those of Delgado *et al.* (2007) in laurel and pine forests in Tenerife, Canary Islands. Other authors also reported that construction of forest roads may result in higher presence of light-demanding species, such as *A. subcordata* in roadside area, while the presence of shade-tolerant species, such as *F. orientalis* raised with increased distance from road (Lotfalian *et al*. 2012; Najafi *et al*. 2012). Furthermore, Wei *et al*. (2015) reported that constructing a road results in a greater abundance of light-demanding tree species due to declining competition, provides more resources for some species. Hence *A. subcordata* was the most abundant species close to the road, probably due to its capability of growing fast in mineral soils.

Diversity of trees in different road age and distance from road classes

Road construction and maintenance negatively influence on plant communities, because most of these communities are destroyed during road construction, and consequently, few plant species are able to survive (Gelbard & Harrison 2003; Keller *et al*. 2004; Coffin 2007). In the present study, results indicated that stand structure varies by elevating road age and distance from forest road, as well as by other environmental conditions.

The highest tree diversity index was observed on the roadside with 0-10 years old, while the lowest in 10-20 years old (Table 1). Enoki *et al*. (2014) reported larger intercepts for old roads, suggesting that canopy height at the edge increased over the time of road construction, which is in line with the present study. Olander *et al*. (1998) described that how older roads are characterized by different ecosystem compositions and structures, as a result of recovery from past disturbances compared to younger roads. Some studies exhibited that the tree species abundance declined in the forest roadside habitats due to possessing specific characteristics, e.g., they were emergent, large-seeded (Santos *et al*. 2008) or understory trees and shade-tolerant species (Tabarelli *et al*. 1999).

These patterns are explained by this fact that the roadside environments after road construction are at early successional condition (Tabarelli *et al*. 2008). Our results exhibited that Simpson's diversity and evenness indices in old roads were higher than in the young ones (Table 1). Enoki *et al*. (2014) during a study on subtropical evergreen broad-leaved Okinawa Island forest, noted that diversity was highest at the roadside with 20 years old, while was lowest at the 3-year-old roads, which was consistent with the present results. As a road age increases over time, many alterations occur in canopy cover, trunk diameter as well as the regeneration of trees and shrubs in roadside area (Mirzaee 2004).

In the present study, the Smith-Wilson's evenness and richness indices were higher in young roads than in old ones (Table 1). Santos *et al*. (2008) reported that the evenness and richness indices were higher in younger roads than older ones, similar to our results. It may be due to the fact that the newly-constructed roads are characterized by the higher light levels, soil temperature, soil oxygen, nutrient exchanges, as well as the lower soil moisture content, organic matter and nitrogen, in comparison with old roads (Olander *et al*. 1998). In the present study, we found that the diversity and richness indices for tree species declined with increased distance from the road.

There was a significant difference in terms of tree species richness between short distances (0-30 and 31-60 m) and farther away (Table 2), similar to other reports (Avon *et al*. 2010; Berenji Tehrani *et al*. 2015). Bergès *et al*. (2013) evaluated Scots and Corsican pine stands in a large-managed forest, Northern France and reported higher species richness of all plant groups on the roadside, compared to the forest inside, which was in accordance with our results.

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In the present study, species evenness index elevated gradually with distance from roadside (Table 2). Zeng *et al*. (2011) during a study in Yellow River Delta, in China reported the low species evenness along with the high species richness and diversity values adjacent to the road, similar to the results found in the present study.

Forest roadsides are characterized by higher temperatures, lower relative humidity and strong winds that play an important role in increased species diversity (Laurance 2000).

Dead tree index (DTI) in different age classes and at various distances of road

DTI at different age classes of <10 and >10 year-old were 0.21 and 0.20, respectively (Fig. 5). Higher DTI for old roads in the present study was similar to findings of some other authors (Kubota *et al*. 2005; Nepstad *et al*. 2007; Barazmand *et al*. 2012). Over time, the number of dead trees elevates in old roads in comparison with newly-constructed ones (Gelbard & Harrison 2003). Furthermore, in the present study the highest and lowest DTI were found in 0-30 and 91-150 m distances from the road respectively (Fig. 6), in line with the results obtained by Picchio *et al*. (2018) in Italian and Iranian temperate forests. In Iranian forest, standing dead beech, *F. orientalis*, *Carpinus betulus* create a sheltered environment which improves the successful establishment of seedlings. The higher dead trees on the roadside areas may be due to presence of pests, declined soil moisture, higher light intensity, soil biological weakness, higher disturbances and environmental stresses on the trees at the roadside, compared to other trees (Sefidi *et al*. 2008).

CONCLUSION

In the present study, effects of forest roads on forest tree species structure, diversity and dead tree presence were assessed in two age classes of a forest roadside. This study aimed to investigate the indices in forest roadside in comparison with in forest inside. Results would lead to a better understanding of roadside effects which can be considered in construction of new roads as well as in maintenance of already constructed roads. According to the results, awareness of road age and applying of environmental techniques are the great necessity to reduce the negative environmental impacts during constructing forest roads. The forest road influences on the species diversity and there were significant differences between the diversity of tree species at different distances from the road. There are also significant differences between roadside and inside forest structure point of view as well as live and dead trees. Also, significant differences were found between the different road age classes in terms of tree diversity and presence. These results are expected to provide important information for the forest decision-makers and watershed managers to manage plant species transmittance and to maintain the integrity of biological communities. In summary, forest road construction and maintenance are considered to be some challenges encountered by researchers and managers. Crossing the roads from forest ecosystem has local and regional effects. Determining the road age may be a useful and cost-effective method to rapidly identify potential habitat for cavity-dependent species, depending on local land-use histories, and mobility of individual species.

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اثرات حاشیه جاده بر ترکیب جوامع درختی در جنگل‌های غرب استان گیلان

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چکیده

جاده‌های جنگلی یکی از عوامل مؤثر بر تنوع و ترکیب گونه‌ها است. هدف از این مطالعه، بررسی اثرات جاده بر ترکیب جوامع درختی در جنگل‌های غرب استان گیلان بود. بدین‌منظور، داده‌های تحقیق در دو کلاسهٔ سنی جاده جنگلی (۱۰-۰ سال و ۲۰-۱۰ سال) با پنج فاصله‌ی مختلف از کنار جاده به روش ترانسکت خطی با ۲۴۰ قطعه نمونه (۱۵۰ متر مربعی) در حاشیه‌ی جاده های جنگلی در سری دو ناو اسالم برداشت شد. نتایج نشان داد مقدار اهمیت نسبی گونه‌های راش، بلندمازو و پلت نسبت به دیگر گونه‌ها در جاده‌هایی با سن کم (۱۰-۰ سال) نسبت به سن زیاد (۲۰-۱۰ سال) بیشتر بود. هم‌چنین نتایج نشان داد که با حرکت در جاده‌های تازه‌ساخت از حاشیه‌ی جاده به سمت جنگل، حضور گونه‌های پیشگام کاهش می‌یابد. در این تحقیق، مقدار اهمیت نسبی گونه‌های درختی توسکای ییلاقی، شیردار و پلت از حاشیه‌ی جاده به داخل جنگل کاهش یافت. نتایج نشان داد مقدار تنوع سیمپسون و یکنواختی درختی در جاده‌های با سن زیاد بیش از جاده‌های با سن کم است. نتایج آنالیز ANOVA نشان داد با افزایش فاصله از جاده، تنوع و غنای گونه‌ای کاهش و یکنواختی افزایش می‌یابد. یافته‌های تحقیق نشان داد که خشکه دارهای بیشتری در حاشیه‌ی جاده (۳۰-۰ و ۶۰-۳۰ متر) نسبت به درون جنگل وجود دارد.

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