DOI: 10.5152/forestist.2020.19022
Forestist 2020, 70(2): 151-159

İSTANBUL UNIVERSITY
CERRAHPAŞA

Original Article

Effects of forest roads on species composition of trees regeneration in selection cutting management of high forests

Orman yollarının farklı rakımlardaki değişik yaşlı seçme işletmesi ormanlarında bulunan gençliğin tür karışımı üzerindeki etkileri

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ABSTRACT

Forest road network is one of the most essential forest management infrastructures. Nevertheless, roads can change the plant's biodiversity by changing the environmental conditions around them. The aim of the present study was to evaluate the road effect on density and species diversity of trees regeneration and to determine the road effect zone on species composition of trees regeneration in different altitudes of mixed broadleaves high forests in northern Iran. For this reason, the density and composition of trees regeneration were analyzed in three altitude classes (<600, 600–1200, and 1200–1800 masl) and five distance classes (0–30, 30–60, 60–90, 90–120, and 120–150 m) from the road edge. Results indicated that the roads had a significant impact on the density and species diversity of trees regeneration at a distance of 30 m from the road edge, although the impact distance on the presence or absence of a tree regeneration was >30 m, depending on the regeneration species and altitude. Density (stem ha^{-1}) and species diversity (Shannon index) of trees regeneration around forest roads (30 m) were 35% and 33%, respectively, higher than those of forest interior zones. The range of road effect on the diversity, richness, and density of trees regeneration species was approximately 30 m. The impact of forest road on the trees regeneration population was mostly influenced by trees species of stand rather than the altitude.

Keywords: Road effect, selection cutting, shannon index, species importance value, trees regeneration

ÖZ

Orman yol ağları, en önemli orman yönetimi altyapılarından biridir. Bununla birlikte, yollar çevrelerindeki çevresel koşulları değiştirerek bitkilerin biyolojik çeşitliliğini değiştirebilmektedir. Bu çalışmanın amacı, Kuzey İran'da karışık geniş yapraklı ormanların farklı rakımlarında orman yollarının ağaç tür karışımının yoğunluk ve tür çeşitliliği üzerinde etkisinin değerlendirilmesi ve ayrıca gençliğin tür karışımı üzerindeki orman yolu etki alanının belirlenmesidir. Bu nedenle çalışma, gençleştirme yoğunluğu ve bileşimi üzerindeki etkiler için üç rakım sınıfında (<600, 600-1200 ve 1200-1800 metre) ve yol kenarından beş mesafe sınıfında (0-30, 30–60, 60–90, 90– 120 ve 120-150 metre) gerçekleştirilmiştir. Elde edilen sonuçlara göre, orman yollarının 30 m etki mesafesinde gençleştirme yoğunluğu ve tür çeşitliliği üzerinde önemli bir etkiye sahip olduğunu, ancak gençliğin türüne ve rakıma bağlı olarak 30 m üzerindeki yol etki mesafesinde gençliğin varlığı ya da yokluğu ve rakımın önem kazandığı görülmektedir. Orman yollarına 30 metre mesafede gençliğin kök yoğunluğunun (kök ha^{-1}) %35 ve tür çeşitliliğinin (Shannon indeksi) %33 oranında olduğu ve bu değerlerin diğer yol etki mesafe sınıflarına göre daha fazla olduğu tespit edilmiştir. Gençlik türü, çeşitliliği ve yoğunluğu üzerindeki yol etki aralığının yaklaşık 30 m olduğu tespit edilmiştir. Orman yollarının gençlik üzerindeki etki miktarı rakımdan çok meşçeredeki ağaç türüne bağlı olarak değişmektedir.

Anahtar Kelimeler: Yol etkisi, seçme kesimi, shannon indeksi, türlerin önem değeri, gençleştirme

Cite this paper as:
Zamani, M., Nikooy, M., Tavankar, F., 2020. Effects of forest roads on species composition of trees regeneration in selection cutting management of high forests. *Forestist* 70(2): 151-159.

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Received Date:
25.08.2019
Accepted Date:
24.10.2019

INTRODUCTION

Forest road networks have a variety of uses and are of particular social and economic importance in rural areas. Forest roads play an important role in the development of rural communities. Attention to the impact of forest roads on the environment is growing these days (Demir et al., 2008; Gumus et al., 2008; Grigolato et al., 2013; Picchio et al., 2018). Forest road as a basic infrastructure of forestry operations could include the most basic costs in forest management plans. The construction of forest roads also has a profound impact on adjacent ecosystems.

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; Coffin, 2007; Flory and Keith, 2006; Flory and Clay, 2009; Freitas et al., 2010; Hill and Pickering, 2006; Maynadier and Hunter, 2000; Picchio et al., 2018; Spellerberg, 1998; Tarvirdizadeh et al., 2014; Zang and Ding, 2009). Road specification (age, pavement future, width, traffic volume, and maintenance activities) and plant successional stage may also influence roadside environment and preserving plant species (Demir et al., 2008; Gelbard and Belnap, 2003). It is clear that roads are considered as a threat to regional biodiversity, as they provide the conditions for non-native invader species and threaten the survival of native species (Forman and Alexander, 2002; Gungor et al., 2008; Makineci et al., 2008). The percentage of canopy cover decreases in the early steps of forest road construction process, which consequently results in the creation of roadside and gap, soil displacement, and decreased density of forest cover. Roads can have detrimental impacts on native flora by changes in soil properties, especially soil compaction, and by changes in site ecological factors (Demir et al., 2008; Gungor et al., 2008; Makineci et al., 2008). Roadside areas can be considered as a transition ecosystem between forest and open-air environments, which may result in consequences, such as modified forest micro-climates, trees with high longevity, higher trees density, and increased growth of herbaceous and invader species (Müllerová et al., 2011).

Changes in trees regeneration, light, and soil disturbance conditions occur due to the opening of tree canopy after construction of forest road (Bowering et al., 2006). Generally, the areas around the road are warmer, drier, and with more light than inside the forest (Forman and Deblinger, 2000). Given a road width of 10 m and its impact margin of 50 m on each side, the impact area of the road will be 10 times that of the roads themselves, covering a large percentage of forest area (Reed et al., 1996). The percentage of canopy cover decreases in the early steps of forest road construction process, which consequently results in the creation of roadside and gap, soil displacement, and decreased density of forest cover. Owing to more exposure to sunlight and increase amount of ambient temperature, soil moisture level is reduced at a distance of 20 m from the edge of forest roads (Berenji Tehrani et al., 2015; Fallahchai et al., 2018). Changes in the amount of light and ambient temperature and soil moisture can affect plant biodiversity, natural regeneration of trees, and the quality of trees along forest roads. In a newly constructed forest road, many marginal trees are not compatible with stressful conditions, such as higher temperatures and faster winds (Laurance et al., 2007). Picchio et al. (2018) studied the effects of forest roads on trees composition and stand structure in three temperate mixed hardwood forests. The results of their research showed that along the 20 m margin of the forest road network, the composition, quality, and quantity of the trees varied with the forest interior zones, the frequency of dead trees was higher than the forest interior zones, and in both three forests from the road edge to interior zones, a similar trees community was observed. Tarvirdizadeh et al. (2014) studied and compared the species diversity and composition of understory herbaceous layer in the road edges with interior zones in the Hyrcanian forests of Iran. Their research results showed a higher value of richness of herbal species due to entering invasive species in the road edges than in the interior forest zones. In the study conducted by Avon et al. (2010), the effects of forest roads on species diversity of understory plants were investigated in natural oak stands in lowland forests of France. They reported that generally, plant species composition on roads verge was different with interior forest zones, and that the impact zone of forest road was dependent to stand age, which was <5 m. In another research conducted by Watkins et al. (2003), the road effects on species diversity of understory plants were analyzed in managed hardwood forests. Their research results indicated that up to 10–15 m from roads edge, richness and diversity of native plants decreased, whereas richness and diversity of exotic plants increased. Deljouei et al. (2018) studied the road effect on vegetation and soil properties in a beech stand in the Hyrcanian forests of Iran. They studied the effects of forest roads on adjacent soil properties and plant communities in natural beech stands in northern Iran and concluded that soil and stand structure were affected within a range of 30 m from the forest road edge. Forest roads, as one of the main components of sustainable forestry operation and management, affect surrounding vegetation communities. Forest road construction plays an important role in the log extraction in diffused harvesting methods, such as single tree selection, while it can have ecological effects.

The main aims of the present study were to (1) evaluate the road effect on density and species diversity of trees regeneration, (2) determine the road effect zone on composition of trees regeneration, and (3) compare the road effect on composition of trees regeneration in different altitude classes in the Hyrcanian forests of Iran.

MATERIALS AND METHODS

Study Area

This research was conducted in the districts of Nav-Asalem region in the Caspian forests of Iran, Guilan Province (Figure 1). The elevation in the district ranges from 250 to 1800 masl. The average annual rainfall ranged from 920 to 1100 mm where the heaviest precipitation occurs in summer and fall. The average daily temperature in December, January, and February is a few degrees <0 °C and up to +25 °C in summer (Tavankar, 2015). The forest type is natural uneven aged beech (*Fagus orientalis* Lipsky) (45%) stands mixed with other tree species, such as hornbeam (*Carpinus betulus* L.) (15%), Caucasian alder (*Alnus subcordata* C.A. May) (12%), velvet maple (*Acer insigne* Boiss.) (8%), common alder (*Alnus glutinosa* L.) (5%), Cappadocian maple (*Acer cappadocicum* Gled.) (5%), Norway maple (*Acer platanoides* L.) (5%), chestnut-leaved oak (*Quercus castaneifolia* Gled) (2%), lime tree

(*Tilia begonifolia* Stev.) (1%), and other tree species (2%) (Tavankar et al., 2013; 2014). Most of the studied areas are characterized by a slope varying from 30% to 60%, with predominantly northern aspect. The soil type is brown forest (*Alfisols*) with a depth of 60–90 cm and well-drained; soil texture ranges from clay loam to loamy (Tavankar et al., 2018).

Data Collection

Data were collected by transect sampling method in three altitude classes: (1) <600, (2) 600–1200, and (3) 1200–1800 masl in the Nav-Asalem forest. In each altitude class, data were collected in five classes of distance from the road: 0–30, 30–60, 60–90, 90–120, and 120–150 m (Bowering et al., 2006). Transects were layout perpendicular on roads, and length of each transect was 300 m (150 m in each side of the road). Technical characteristics of the roads are shown in Table 1. Distance of transects from each other was 100 m. In each altitude class, five transects were layout. Species, diameter at breast height (DBH), and height of trees (DBH ≥7.5 cm) that their crowns images were placed on transects were identified and measured. DBH and height of trees were measured using dendrometric caliper and clinometer, respectively. Species and number of trees regeneration were identified and measured in 4 m^2 (2 m×2 m) microplates on transects in regular distances of 10 m. In total, 30 microplates on each transect and 150 microplates in each altitude class were collected for analyzing trees regeneration (Berenji Tehrani et al., 2015; Buckley et al., 2003).

Figure 1. Localization of the study area in the Hyrcanian forests of Iran highlighted with a red circle

Data Analysis

Species importance value (SIV) for each specious was calculated by summing the relative values of density (RD), frequency (RF), and dominance (RD_o) as shown in Eq. (1) (Ganesh et al., 1996; Krebs, 1999; Tavankar, 2015):

$$SIV=RD_e+RF+RD_o \quad (1)$$

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 seedling height was considered for dominancy, and the relative dominance (RD_o) was calculated by:

RD_o=(Sum of the height of a species×100)/sum of total height of all species.

The species diversity index was computed using the Shannon–Wiener information function (Hill, 1973; Ozcelik et al., 2008) as:

$$H'=-\Sigma(n_i/n)\ Ln\ (n_i/n) \quad (2)$$

Where n_i was the SIV of a species and n was the sum of the total SIV of all species.

Normality of data and equality of variances were checked by Kolmogorov–Smirnov and Levene tests, respectively. Analysis of variance (ANOVA) was used for checking the effect of distance class on density, number of species, and species diversity (Shannon index) of trees regeneration. Duncan test was used for comparison of means of density, number of species, and species diversity of trees regeneration in different distances from the road edge (α=0.05).

RESULTS AND DISCUSSION

Results showed that the composition of tree species was different in the altitude classes (Table 2). Iron wood tree (*Parrotia persica* C.A. Mey) had the highest frequency in the altitude <600 m, whereas beech tree (*F. orientalis* Lipsky) had the highest frequency in the altitudes 600–1200 and 1200–1800 m. Hornbeam tree (*C. betulus* L.) had the highest frequency in all the altitude classes. Species of maple tree (*Acer* sp.) was present in all the alti-

Table 1. Road technical characteristics in the study area

Site	Road width (m)	Road length (m)	Road surface condition	Longitudinal slope of road (%)	Road age (year)
A	5.5	750	Unpaved	8.5	35
B	5.5	610	Unpaved	10	35
C	5.5	790	Unpaved	8.2	35

Table 2. Forest silviculture, tree composition, and stand type in altitude classes of the study area

Site	Altitude (m)	Silviculture	Tree species composition (%)	Stand type
A	< 600	Selection cutting – high forest	Iron wood (36), hornbeam (29), maple (17), oak (14), other sp. (4)	*Parrotia-carpinatum,* mixed species
B	600 – 1200	Selection cutting – high forest	Beech (43), hornbeam (22), maple (20), alder (10), oak (3), other sp. (2)	*Fagus-carpinatum,* mixed species
C	1200 – 1800	Selection cutting – high forest	Beech (55), hornbeam (17), maple (16), alder (6), oak (4), other sp. (2)	*Fagetum,* mixed species

Table 3. Dendrometric and stand characteristics in altitude classes of the study area

Site	Density (stem ha^{-1})	DBH (cm)	Height (m)	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Canopy closure (%)
A	176	36	17.1	16.7	120	75
B	189	45	18.6	28.2	170	83
C	218	51	19.7	35.5	238	92

Table 4. Regeneration species of trees in distance and altitude classes (a: presence in the altitude of <600 m, b: presence in the altitude of 600–1200 m, c: presence in the altitude of 1200–1800 m, and –: absence)

		Distance from forest road edge (m)				
Regeneration species	Family	0-30	30-60	60-90	90-120	120-150
Acer cappadocicum Gled.	Aceraceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Acer insigne Boiss.	Aceraceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Acer platanoides L.	Aceraceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Alnus glutinosa L.	Betulaceae	a	a	a	a	a,b
Alnus subcordata C.A. Mey	Betulaceae	b,c	b,c	b,c	b,c	b,c
Carpinus betulus L.	Corylaceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Cerasus avium (L.) Moench	Rosaceae	b	b,c	b,c	b,c	a,b,c
Fagus orientalis Lipsky	Fagaceae	b,c	b,c	b,c	b,c	b,c
Fraxinus coriarifolia Scheel	Oleaceae	-	-	b	b,c	b,c
Mespilus germanica L.	Rosaceae	a	b	b,c	-	-
Parrotia persica C.A. Mey	Hamamelidaceae	a	a	a	a	a
Pyrus communis L.	Rosaceae	a	a,b	a	-	-
Pyrus divericata Ledeb.	Rosaceae	-	-	a,b	a,b	a,b
Quercus castaneifolia Gled	Fagaceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Sorbus torminalis (L.) Crantz	Rosaceae	a	a	a,b	a,b	a,b,c
Tilia begonifolia Stev.	Tiliaceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Ulmus glabra Huds.	Ulmaceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c
Zelkova carpinifolia Diopp.	Ulmaceae	a,b,c	a,b,c	a,b,c	a,b,c	a,b,c

tude classes. On the base of tree species, frequency stand types were *Parrotia-carpinatum*, mixed species in the altitude <600 m, *Fagus-carpinatum*, mixed species in the altitude 600–1200 m, and *Fagetum*, mixed species in the altitude 1200–1800 m.

Tree density, basal area, and stand volume were highest in the stand C (altitude of 1200–1800 m) and were lowest in the stand A (altitude <600 m). In addition, mean DBH and height of trees were highest in the stand C (Table 3).

Table 5. ANOVA results for road impact on seedlings density, number of species, and diversity in the altitude classes

Altitude (m a.s.l.)	Seedling characteristics	df	MS	F	Sig.
<600	Diversity	4	142.6	35.61	0.024
	Number of species	4	179.3	44.80	0.010
	Density	4	150.1	37.52	0.017
600-1200	Diversity	4	171.4	42.85	0.016
	Number of species	4	127.3	31.82	0.021
	Density	4	158.0	39.50	0.011
1200-1800	Diversity	4	228.4	57.09	0.009
	Number of species	4	21.6	5.40	0.212
	Density	4	177.2	44.30	0.026

A total number of 18 species of tree regeneration were observed in the study area (Table 4). The observed regeneration species belonged to nine families. Five species were from Rosaceae, three species from Aceracea, two species from each family of Betulaceae, Fagaceae, and Ulmaceae, and one species from each family of Corylaceae, Hamamelidaceae, Oleaceae, and Tiliaceae. Regeneration of Aceraceae species (*A. cappadocicum*, *A. insigne*, and *A. platanoides*) was found in all altitude and distance from forest road edge classes (Table 4). In addition, regeneration species of *C. betulus*, *Q. castaneifolia*, *T. begonifolia*, *Ulmus glabra*, and *Zelkova carpinifolia* was found in all of the altitude and distance from forest road edge classes. Regeneration of *A. glutinosa* was found only in the altitude of <600 m in all of the distance classes and in the more interior positions (120–150 m) in the altitude of 1200–1800 m. Regeneration of *A. subcordata* was not found in the altitude of <600 m and was found in all of the distance classes in the altitude of >600 m. However, regeneration of *Cerasus avium* was found in all of the distance classes, but the altitude of <600 m was found only in the more interior positions (120–150 m), and the distance class of 0–30 m was found only in the altitude of 600–1200 m. Regeneration of *F. orientalis* was found in all of the distance classes in the altitude of >600 m. Regeneration of *Fraxinus coriarifolia* was not found in the altitude of <600 m and in the distance of <60 m and was found in the altitude of >600 m in the distance of >60 m and in the altitude of 1200–1800 m in the distance of >90 m. Regeneration of *Mespilus germanica* was not found in the distance of >90 m and was found in the distance of 0–30 m in the altitude of <600 m, in the distance of 30–60 m in the altitude of 600–1200 m, and in the distance of 60–90 m in the altitude of >600 m. Regeneration of *P. persica* was found in all of the distance classes only in the altitude of <600 m. Regeneration of *Pyrus communis* was found in the distance of <90 m and altitude of <1200 m. Regeneration of *Pyrus divericata* was found in the distance of >60 m in the altitude of <1200 m. Regeneration of *Sorbus torminalis* in the altitude of <600 m was found in all of the distances, whereas it was found only in the altitude of 600–1800 m in the distance of >60 m and in the altitude of 1200–1800 m in the distance of >120 m.

Results of ANOVA indicated that the averages of seedlings density and diversity had significant differences in the distance classes in all altitudes, whereas the averages of species number of regeneration had significant differences in the distance classes in the altitudes of <600 m and 600–1200 m (Table 5).

The regeneration of *P. persica* had the highest SIV in the altitude of <600 m, whereas the regeneration of *F. orientalis* had the highest SIV in the altitudes of 600–1200 m and 1200–1800 m (Figure 2). The SIV of both species regeneration (*P. persica* and *F. orientalis*) was increased with increasing distance from the forest road. The regeneration of *C. betulus* had the second highest SIV rank in all of the altitudes. The SIV of this regeneration was increased with increasing distance in the altitude of <600 m, whereas it was decreased with increasing distance in the altitudes of 600–1200 m and 1200–1800 m. The SIV of regeneration of *A. cappadocicum*, *A. insigne*, *A. platanoides*, *A. glutinosa*, and *A. subcordata* was decreased with increasing distance from the road, whereas the SIV of regeneration of *Q. castaneifolia*, *U. glabra*, and *Z. carpinifolia* was increased with increasing distance from the forest road.

Shannon index of trees regeneration in the 0–30 m distance from the forest road was significantly higher than that in the interior distances in the three altitude classes (Figure 3a-c). Species number of trees regeneration in the 0–30 m distance from the forest road was significantly higher than that in the interior distances in the altitudes of <600 m and 600–1200 m, whereas the distance from the forest road had no significant effect on the species number of trees regeneration in the altitude of 1200–1800 m (Figure 3d-f). The density of trees regeneration in the 0–30 m distance from the forest road was significantly higher than that in the interior distances in the three altitude classes (Figure 3g-i).

The results showed that regardless of the distance and altitude effect, there were 18 species of trees regeneration in the study area that indicates a high biodiversity potential of the area. The results indicated that the presence or absence of six species of trees regeneration was affected by the forest road, including *F.*

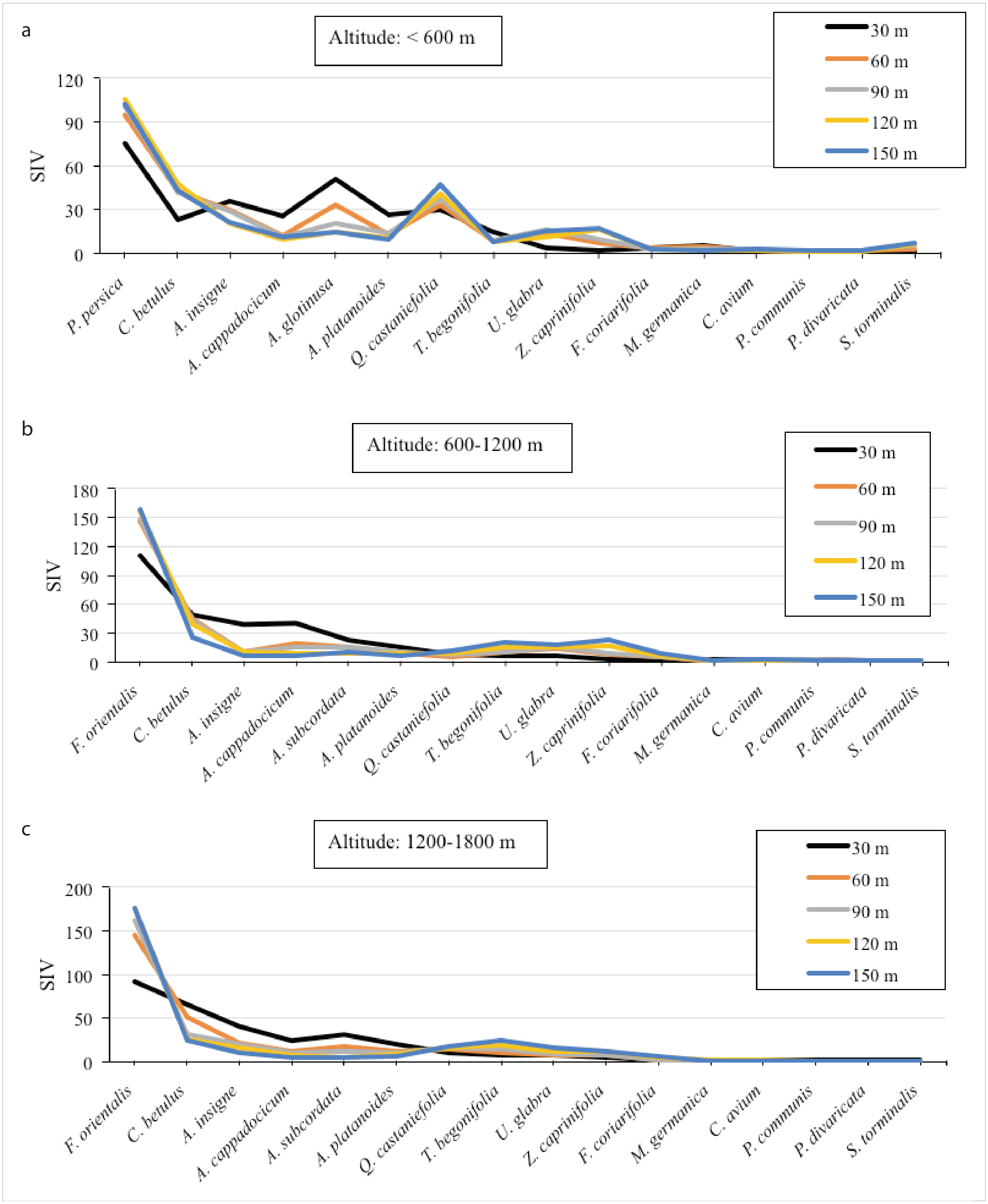

Figure 2. a-c. Road effect on SIV of trees regeneration in three altitude classes

coriarifolia, *P. communis*, *P. divericata*, *C. avium*, *M. germanica*, and *S. torminalis*. Forest road had a negative effect on the presence of regeneration of *F. coriarifolia* in the distance of <60 m in the altitude of >600 m, *P. divericata* in the distance of <60 m in all altitude classes, *S. torminalis* in the distance of <60 m in the altitude of >600 m, and *C. avium* in the distance of <30 m in the altitude of >600 m. On the other hand, forest road had a positive effect on the presence of regeneration of: *M. germanica* in the

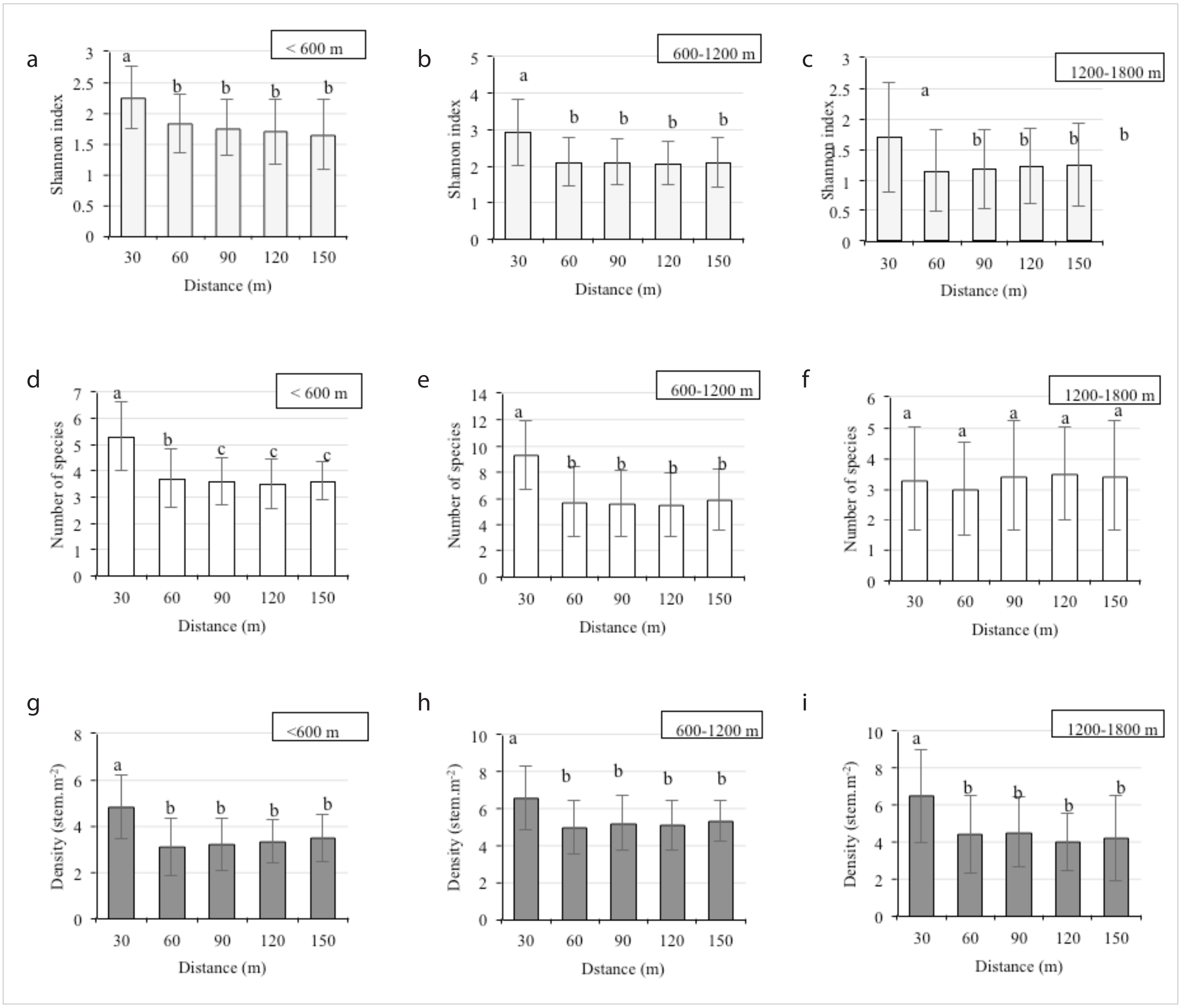

Figure 3. a-i. Road effect on diversity, number of species, and density of trees regeneration

distance of <60 m in all altitude classes and *P. communis* in the distance of <90 m in the altitude of <600 m.

Results showed that the SIV of five species of trees regeneration (*A. cappadocicum*, *A. insigne*, *A. platanoides*, *A. glutinosa*, and *A. subcordata*) decreased with increasing distance from the forest road, whereas the SIV of five species of trees regeneration (*P. persica*, *F. orientalis*, *Q. castaneifolia*, *U. glabra*, and *Z. carpinifolia*) increased with increasing distance from the forest road. For other regeneration species (*C. betulus*, *C. avium*, *F. coriarifolia*, *M. germanica*, *P. communis*, *P. divericata*, *S. torminalis*, and *T. begonifolia*), the effect of forest roads on SIV depended on the altitude. The presence of regeneration seedlings of *A. subcordata* species on the roadside is due to having small seeds in slipped areas and the establishment in displaced soils with high light intensity, as well as low drainage and high water accumulation conditions, which facilitates the establishment of seedlings of this species in the roadside (Deljouei et al., 2018; Najafi et al., 2012; Tavankar et al., 2013).

Results of a study conducted in mixed broadleaved species in the mountainous Hyrcanian forest in Iran showed that the density of tree regeneration on 7.5 m distance from the road edge was significantly higher than the interior zones, and seedling density of light-demanding species, such as *Acer* sp. (Maple), was higher on the effect zone of the road, whereas seedling density of shade tolerant species, such as *Fagus* spp. (Beech), increased with increasing distance from the road (Najafi et al., 2012).

Results showed that the affected distance by the forest road on the Shannon index of trees regeneration species was <30 m in all of the altitude classes. The Shannon index in the 0–30 m distance from the forest road was significantly higher than that in the distance of >30 m. Results of a research conducted in the Iranian Hyrcanian forests showed that indices of species diversity of trees seedling and herb layer were higher around the forest roads than the interior zones (Fallahchai et al., 2018). Forest roads had a significant effect on the number of regeneration species in the altitude classes of <600 m and 600–1200 m, whereas forest road had no significant effect on the number of regeneration species in the altitude of 1200–1800 m. The number of regeneration species in the 0–30 m distance class was significantly higher than the further distances from the forest road.

A higher number of exotic species on the edge of forest roads usually cause increase species richness value on the edge of forest roads (Brothers and Spingarn, 1992; Picchio et al., 2018). The density of trees regeneration in the 0–30 m distance class was significantly higher than the further distances from the forest road. Fallahchai et al. (2018) also reported that tree regeneration density along 20 m distance from the forest road is significantly higher than the interior stand in the Caspian forests of Iran. The roadside area is desirable for non-indigenous and non-forest species because of having the highest level of degradation and special site conditions, such as soil degradation, increased light, and moist soils (Parendes and Jones, 2000). Increasing 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., 2018). During the construction of forest roads, the shelter of plants are removed, and the environmental conditions are changed as the gap is formed and the composition of the plants is expected to change. 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). Gungor et al. (2008) reported that Compositae and Liliaceae are the most abundant families and have the highest establishment and growth rate on compacted skid roads in a pure sessile oak (*Quercus petraea* L.) forest. In addition, Makineci et al. (2008) studied herbaceous plant recovery on skid roads and reported that Compositae is the most common family on skid roads in a fir (*Abies bornmuelleriana* Mattf.) forest. In another research, Demir et al. (2008) reported that the family of Liliaceae has the highest abundance on skid road in a beech (*F. orientalis* Lipsky.) stand. It is important to note that the high density of forest roads and the broad environmental disturbances caused by them can have compounded effects on the landscape level (Reed et al., 1996; Saunders et al., 2002).

CONCLUSION

In this research, we studied the road effect on the composition of trees regeneration at different altitudes in the high forests of northern Iran. The results showed that the density (stem ha^{-1}) of trees regeneration around roads (30 m) was 30%–40% higher than the forest interior zones. In addition, the number of regeneration species and species diversity (Shannon index) around roads (30 m) was 20% and 33%, respectively, higher than the forest interior zones.

The results indicated:

- Range of road effect on the diversity, richness, and density of trees regeneration species was approximately 30 m.
- Range of road effect on the presence of trees regeneration species was more than the effect on the diversity, richness, and density of trees regeneration species.
- Impact of forest road on the trees regeneration population was mostly influenced by trees species of stand rather than the altitude.
- Forest road caused an increase of the diversity, richness, and density of trees regeneration species in a zone of 30 m.

The main aim of selection cutting, as close to nature silviculture, in addition to continuous high quality timber, is the conservation of composition and species diversity of forest trees. Road effects on trees regeneration should be considered in the planning of road network and in the selection of trees to cut.

Ethics Committee Approval: This study does not contain any studies performed on human or animal participants by any of the authors. Therefore, ethics committee approval was not necessary.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.N., M.Z.; Design - M.N., F.T.; Supervision - M.N., F.T.; Resource - M.N., F.T., M.Z.; Materials - M.N., F.T., M.Z.; Data Collection and/or Processing - M.Z., M.N., F.T.; Analysis and/or Interpretation - F.T., M.N., M.Z.; Literature Search - F.T., M.N., M.Z.; Writing – F.T., M.N., M.Z.; Critical Reviews - M.N., F.T.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

- Angold, P.G., 1997. The impact of a road upon adjacent heathland vegetation: effects on plant species composition. *Journal of Applied Ecology* 34(2): 409-417. **[CrossRef]**
- Avon, C., Bergès, L., Dumas, Y., Dupouey, JL., 2010. Does the effect of forest roads extend a few meters or more into the adjacent forest? A study on understory plant diversity in managed oak stands. *Forest Ecology and Management* 259(8): 1546-1555. **[CrossRef]**
- Berenji Tehrani, F., Majnounian, B., Abdi E., Zahedi Amiri, GH., 2015. Impacts of forest road on plant species diversity in a Hyrcanian forest, Iran. *Croatian Journal of Forest Engineering* 36(1): 63-71.
- Bowering, M., LeMay, V., Marshal, P., 2006. Effects of forest road on the growth of adjacent lodgepole pine trees. *Journal of Forest Research* 36(4): 919-929. **[CrossRef]**
- Brothers TS, Spingarn A, 1992. Forest fragmentation and alien plant invasion of central Indiana old-growth forests. *Conservation Biology* 6(1): 91-100. **[CrossRef]**
- Buckley, D.S., Crow, TR., Nauertz, E.A., Schulz K.E., 2003. Influence of skid trails and haul roads on understory plant richness and composition in managed forest landscapes in Upper Michigan, USA. *Forest Ecology and Management* 175(1-3): 509-520. **[CrossRef]**
- Coffin, A.W., 2007. From roadkill to road ecology: a review of the ecological effects of roads. *Journal of Transport Geography* 15(5): 396-406. **[CrossRef]**
- Deljouei, A., Moein Sadeghi, S.M., Abdi, E., Bernhardt-Römermann, M., Pascoe, E.L., Marcantonio, M., 2018. The impact of road disturbance on vegetation and soil properties in a beech stand, Hyrcanian forest. *European Journal of Forest Research* 137(6): 759-770. **[CrossRef]**

- Demir, M., Makineci, E., Gungor, B.S., 2008. Plant Species Recovery on a Compacted Skid Road. *Sensors* 8(5): 3123-3133. **[CrossRef]**
- Fallahchai, M.M., Haghverdi, K., Mojaddam, M.S., 2018. Ecological effects of forest roads on plant species diversity in Caspian forests of Iran. *Acta Ecologia Sinica* 38(3): 255-261. **[CrossRef]**
- Flory, S.L., Clay, K., 2009. Effects of roads and forest successional age on experimental plant invasions. *Biological Conservation* 142(11): 2531-2537. **[CrossRef]**
- Flory, S., Keith, C., 2006. Invasive shrub distribution varies with distance to roads and stands age in eastern deciduous forests in Indiana, USA. *Plant Ecology* 184: 131-141. **[CrossRef]**
- Forman, R.T.T., Deblinger, R.D., 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. *Journal of Conservation Biology* 14(1): 36–46. **[CrossRef]**
- Forman, R.T.T., Alexander, L.E., 2002. Roads and their major ecological effects. *Annual* Review *of Ecology and Systematics* 29: 207-231. **[CrossRef]**
- Freitas, S.R., Hawbaker, T.J., Metzger, J.P., 2010. Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic forest. *Forest Ecology and Management* 259(3): 410-417. **[CrossRef]**
- Ganesh, T., Ganesan, R., Soubadra, Devy, M., Davidar, P., Bawa, K., 1996. Assessment of Plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. *Current Science* 71(5): 379-392.
- Gelbard, J.L., Belnap, J., 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17(2): 420-432. **[CrossRef]**
- Grigolato, S., Pellegrini, M., Cavalli, R., 2013. Temporal analysis of the traffic loads on forest road networks. *IForest* 6(5): 255-261. **[CrossRef]**
- Gumus, S., Acar, H.H., Toksoy, D., 2008. Functional forest road network planning by consideration of environmental impact assessment for wood harvesting. *Environmental Monitoring and Assessment* 142(1): 109-116. **[CrossRef]**
- Gungor, B.S., Makineci, E., Demir, M., 2008. Revegetated herbaceous plant species on a compacted skid road. *Journal of Terramechanics* 45: 45-49. **[CrossRef]**
- Hill, W., Pickering, C.M., 2006. Vegetation associated with different walking track types in the Kosciuszko alpine area, Australia. *Journal of Environmental Management* 78(1): 24-34. **[CrossRef]**
- Krebs, C.J., 1999. Ecological Methodology. Harper and Row, New York.
- Laurance, W.F., Nascimento, H.E.M., Laurance, S.G., Andrade, A., Ewers, R.M., Harms, K.E., Luizão, R.C.C., Ribeiro, J.E., 2007. Habitat fragmentation, variable edge effects, and the landscape-divergence hypothesis. Plos One 2(10): e1017. **[CrossRef]**
- Makineci, E., Gungor, B.S., Demir, M., 2008. Survived herbaceous plant species on compacted skid road in a fir (*Abies bornmulleriana* Mattf.) forest – A note. *Transportation Research- Part D* 13: 187-192. **[CrossRef]**
- Maynadier, P., Hunter, J.R.M., 2000. Road effects on amphibian movements in a forested landscape. *Natural Areas Journal* 20(1): 56-65.
- Müllerová, J., Vítková, M., Vítek, O., 2011. The impacts of road and walking trails upon adjacent vegetation: Effects of road building materials on species composition in a nutrient poor environment. *Science of the Total Environment* 409(19):3839-3849. **[CrossRef]**
- Najafi, A., Torabi, M., Abbas-Ali Nowbakht, A., Moafi, M., Eslami, A., Sotoudeh Foumani, B., 2012. Effect of forest roads on adjacent tree regeneration in a mountainous forest. *Annals of Biological Research* 3(4): 1700-1703.
- Parendes, L.A., Jones, J.A., 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. *Conservation Biology* 14(1): 64-75. **[CrossRef]**
- Picchio, R., Tavankar, F., Venanzi, R., Lo Monaco, A., Nikooy, M., 2018. Study of forest road effect on tree community and stand structure in three Italian and Iranian temperate forests. *Croatian Journal of Forest Engineering* 39(1): 57-70.
- Reed, R.A., Johnson-Barnard, J., Baker, W.L., 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. *Conservation Biology* 10(4): 1098-1106. **[CrossRef]**
- Saunders, S.C., Mislivets, M.R., Chen, J., Cleland, D.T., 2002. Effects of roads on landscape structure within nested ecological units of the northern Great Lakes region, USA. *Biological Conservation* 103(2): 209-225. **[CrossRef]**
- Spellerberg, I.F., 1998. Ecological effects of roads and traffic: a literature review. *Global Ecology and Amp* 7(5): 317-333. **[CrossRef]**
- Tarvirdizadeh, H., Nikooy, M., Pourbabaei, H., Naghdi, R., 2014. Effects of road construction on biodiversity and composition of herbaceous species cover, Asalem forest, northern Iran. *Forestry Ideas* 20(2): 157-169.
- Tavankar, F., Nikooy, M., Picchio, R., Venanzi, R., Lo Monaco, A., 2018. Long-term effects of single-tree selection cutting management on coarse woody debris in natural mixed beech stands in the Caspian forest (Iran). *iForest* 10: 652-658. **[CrossRef]**
- Tavankar, F., 2015. Structure of natural *Juniperus excelsa* stands in Northwest of Iran. *Biodiversitas* 16(2): 161-167 **[CrossRef]**
- Tavankar, F., Picchio, R., Lo Monaco, A., Bonyad, A.E., 2014. Forest management and snag characteristics in Northern Iran lowland forests. *Journal of Forest Science* 60(10): 431-441. **[CrossRef]**
- Tavankar, F., Bonyad, A.E., Iranparast Bodaghi, A., 2013. Effects of snags on the species diversity and frequency of tree natural regeneration in natural forest ecosystems of Guilan. *Iranian Journal of Plant Research* 26(3): 267-280.
- Watkins, R.Z., Chen, J., Pickens, J., Brosofske, K.D., 2003. Effects of forest roads on understory plants in a managed hardwood landscape. *Conservation Biology* 17(2): 411-419. **[CrossRef]**
- Zang, R., Ding, Y., 2009. Forest recovery on abandoned logging roads in a tropical montane rain forest of Hainan Island, China. *Acta Oecologica* 35(3): 462-470. **[CrossRef]**