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Assessment of Road Construction Effects on Biodiversity and Forest Composition

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Abstract

forest roads construction as one of the factors contributing to ecological changes can affect the diversity and composition of species on the road edge area. This study examines the biodiversity of herbaceous species and the establishment of tree regeneration at various distances from the edge of the road with the aim of investigating the impact of the road. For this purpose, macroplots with dimension of 100 m^2 (20 x 5 m) in six intervals of 0, 5, 10, 25, 50 and 100 meters, in both side of road was designed and inside them, 2 × 2 m microplots for sampling of herbaceous spices and tree species regeneration was done too. In order to study the diversity, the Simpson and Shannon-Weiner index, the species richness index (s) and Pylo's uniformity index were used. The results showed that there were no significant differences between the index of herbaceous diversity and regeneration of trees on the top and bottom parts of roads, and the most important factor is the distance. As the distance from the road increases, the biodiversity, richness and uniformity of the herbaceousplants decreases but the regeneration of trees increases. Also, the richness index indicates that herbaceous species on the edges of the road (10-0 m) and tree regeneration in the inner parts of forest are the major. Based on the results, among environmental factors and soil parameters, light condition is the main determinant factor of the establishment of species, as well as the frequency and distribution of species in the distance between roads to the forest. As a result, minimizing road density is necessary to maintain the diversity and composition of forest species for the sustainability of forest resources.

Keywords: Biodiversity, Forest Road, Herbaceous, Richness Index, Tree Regeneration.

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Introduction

Although man's presence in nature provides many of his social and economic needs, on the contrary, these activities undermine the natural communities (Davis and pullin 2007) and have an impact on the quantity and quality of plant populations, composition, structure and biodiversity (Flory and Clay 2009; Spooner et al 2004). Construction of the road and maintenance of it are the most extensive human interactions in nature. So that the development of the road network is one of the primary mechanisms in the distribution of habitats, vegetation abandonment, alteration of structure by increasing human access to each area (Saunders et al.2002). Roads are highly sources of pollutants such as dust, chemicals, heavy metals (Campbell and Doeg.1989; Amaranthus et al.1985; Goosem.1997; Hamilton and Harrison, 1987), as well as nutrient uptake (Hamiltin as nitrogen and phosphorus) to the water or earth ecosystem (Forman and Deblinger 2000), and these multiple non-biological impacts along the road are changing the dynamics of communities and the process of developing ecosystems such as decomposition, mortality, (Ruth and Yorder. 1953), the initial production (Laurance et al.1997) and the exchange of Co2 (Oberbauer et al.1992). During the construction of forest roads, cutting down trees also increases the amount of light and levels of activity of photosynthesis in the lower parts (Buckley et al.2003), which provides favorable conditions for the presence of non- indigenous and indigenous species along the roads. Light intensity and degradation levels are key factors in the penetration of non-indigenous species from the road to the inside of the forest, and also the openness of the canopy is an important factor in changing the composition of vegetation coverages in forest stands. The crowns Coverage is more likely to be invaded by non-native species (Parendes and Jones.2000) and Light friendly species (Arevalo et al 2005). Roadside coverage, due to better access to resources, especially light, has many differences within the inner parts of forest and this increases the reshaping and growth, as well as the richness and diversity of roadside vegetation (Runker 1985; Runkle, 1984). In fact, roads, due to changes in the abundance of native and non-native species, are factors that can effect on local biodiversity. Many studies have shown that roads are damaging local biodiversity as they accelerate the presence of non-native species (invaders) and threaten the lives of unique

native species (Gelbard and Belnap.2003; Forman and Alexander.1998). Although roads have a small share of the stands, but they are primary channels in spreading of new species into managed stands and participate in the changingofrichness and composition of plants at the stand level (Buckley et al.2003). Buckley et al (2003) examined the impact of forest paths on the richness and composition of plants in Michigan forests, and concluded that soil compaction, photosynthetic active radiation, soil moisture and vegetation richness was higher on the sides of the road. Sheng-Lan Zeng et al (2011) studied the effect of road age and distance from the road on the biodiversity on some Chinese plants. The results showed that the gap between diversity and richness decreases (m200 <) and there is the greatest diversity along the road. On the other hand, diversity and richness also increase with the age of the road, so that they have reached the maximum diversity at age twenty.

Material and Methods

The present study was carried out in northern forests of Iran, (Bonshaki forest in Ramsar), Mazandaran province. The study area is located between 1200 and 1450 meters above sea level. The general slope of this region is above 40%. The average annual rainfall is 773 mm and the average annual temperature is 12.3°C.

At first, on the typology map the type of forest was conducted from the roadside up to a depth of 100 m in the forest (Avon al, 2010, Delgado et al. 2007, Park et al., 2005). Thirteen sample lines were traversed along the route and its intersection with the route of the road was determined. Then, using GPS in nature, these points were retrieved and sampled on both sides of the road (excavation trenches and embankments) perpendicular to the center axis. For a closer look, firstly, the lengths of the 20 m (Avon et al. 2010; Arevalo et al 2005) at the distance of 0, 5, 10, 25, 50 and 100 meters (Hansen et al 2005) from the road side drowned and then, for the harvesting of herbaceous species and tree regeneration, 2 × 2 m plots were designed on four sides. When doing plots, a transect perpendicular to the road and plot along the transects parallel to the road designed too (Fig. 1).

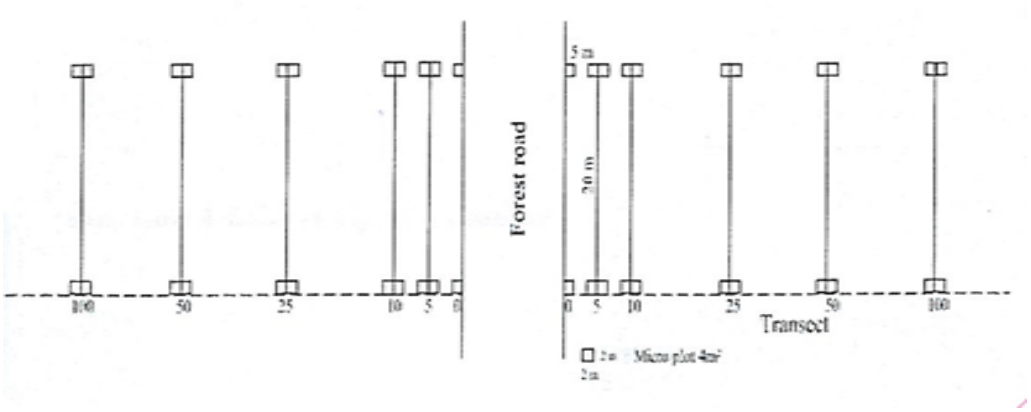

Figure 1: Sampling method around the road

Also, in each plot, the canopy cover percentage, abundance and sociality, and their bioforms were also noted. It should be noted that the species coverage was done according to the Londo decimal scale (Londo.1976).

To compare biodiversity of herbaceous and tree regeneration the Simpson and Shannon Wiener diversity index were employed (Peltzer et al. 2000; Marcantonio et al. 2013; Osterhorn and Kappelle 2000). The species richness index (S) (Magurran 1988) and Peltzer index (Peltzer et al. 2000) were used too. In the following, for data analysis, the percentage coverage of herbaceous species and the number of wooden species entered the Past Software V 1.39, and the variation rate by Shannon Wiener and Simson, richness indexes by Margalf and Munnich indicators and uniformity by the Pylo index were calculated. At first, the normality of the data was investigated by Kolmogorov-Smirnov test and homogeneity of variance by using Loon test. Then, the effect of distance from road on variance, richness, and uniformity indexes was determined using one-way ANOVA in the general linear model (GLM). It should be noted that all statistical calculations were performed in SPSS16 software.

Results

The composition and diversity of herbaceous species

A total of 50 herbaceous species were identified in this study. The average percentage of coverage in the study area was measured at intervals of 0-10 and 25-100 meters at the top and bottom of the road. According to the results, herbaceous species at a distance of 10-0 meters from the road in two slopes was more than 25- 100-meter distance.

Simpson Diversity Index

Table 1 shows the Simpson diversity index of herbaceous species in a completely randomized block design and Figure 2 shows the trend of changes in this index.

Table 1 Simpson diversity index of herbaceous species in a completely randomized block design

Source	Df	Sum Squair	Mean Squair	F	P
Block	12	0.11	0.01	3.23	0.03
Range	1	0.01	0.01	2.74	0.12
Range error	12	0.03	0.003		

Distance	5	0.17	0.03	15.67	0.00
Reaction	5	0.02	0.00	1.93	0.10
Error	120	0.26	0.02		
Total	155	0.6			

Two-way analysis of variance shows that the effect of position (distance from the road) on diversity is quite significant. By increasing distance from the road, Simpson's diversity of herbaceous species decreases. Top and bottom of road do not show a significant relationship on the biodiversity index. The Simpson index is also significant in various blocks.

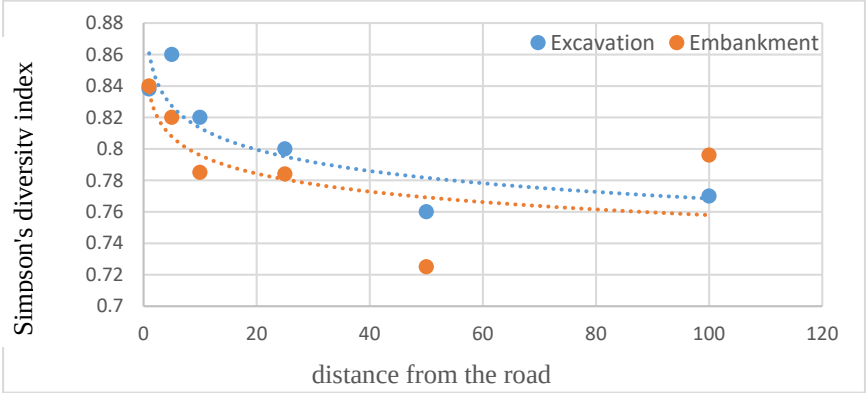

Figure 2. Changes in Simpson's diversity index of herbaceous species at various distances from the road

Also, the trend of changes in this indicator at different distances from the road to the inner parts of forest is a decreasing trend, which indicates a decrease in the diversity of herbaceous species from 0 to 100 meters (Fig. 2).

Shannon Diversity Index

Table 2 shows the Shannon diversity index of herbaceous species in a completely randomized block design, and Figure 3 shows the trend of changes in this index. two-way analysis of variance shows that the effect of position (distance from road) on Shannon diversity is quite significant. Top and bottom places index are not significant. However, Shannon diversity in different blocks has a significant effect.

Table 2: Shannon diversity index of herbaceous species in a completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	4.67	0.39	2.65	0.05
Range	1	0.02	0.02	0.14	0.72
Range error	12	1.76	0.15		
Distance	5	5.15	1.03	20.06	0.00
Reaction	5	0.29	0.06	1.11	0.36
Error	120	6.16	0.00		
Total	155	18.05			

Based on Fig. 3, the trend of Shannon diversity index variation of herbaceous species shows a decreasing trend with increasing distance from the road, so that these conditions are the same on both sides of the road.

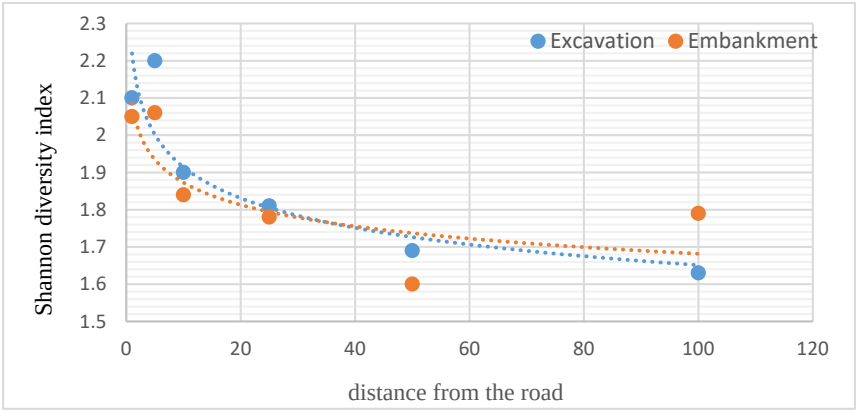

Figure 3. Changes in Shannon diversity index of herbaceous species at various distances from the road

S Richness index (number of species)

Table 3 shows the richness index (S) of herbaceous species in the form of a completely randomized block design. Figure 4 shows the variation of this index. Two-way analysis of variance shows that the distance from the road is significant so that the distance from the road decreases the amount of herbaceous species, but in top and bottom places, the richness index does not show a significant effect.

Table 3: Richness index of herbaceous species in a completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	155.103	12.925	1.268	0.334
Range	1	3.692	3.692	0.362	0.558
Range error	12	122.308	10.192		
Distance	5	623.974	124.795	24.137	0.00
Reaction	5	13.923	2.785	0.539	0.747
Error	120	620.436	5.70		
Total	155	1593.436			

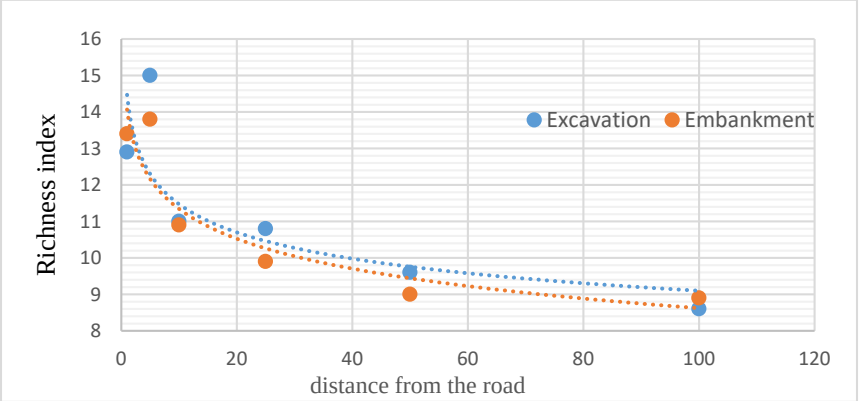

Figure 4. Changes in richness index of herbaceous species at various distances from the road

The trend of changes in the number of species is declining, and it shows that as the distance goes from the road, the number of herbaceous species is reduced.

Pylo uniformity index

Table 4 shows the pylo uniformity index of the herbaceous species in the form of a completely randomized block design, and Figure 5 shows the trend of changes in this index.

In the case of uniformity index, two-way analysis of variance shows that distance from the road is significant. However, in the top and bottom places of the road, the uniformity index does not show a significant effect.

The process of changes in this indicator is also a downward trend. Although it shows approximately the same trend at three, 0, 5 and 10 meter intervals, it shows that with increasing distance from the road, the uniformity of herbaceous species decreases.

Table 4: pylo index of herbaceous species in a completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	0.20	0.02	4.02	0.01
Range	1	0.01	0.01	1.78	0.21
Range error	12	0.05	0.00		
Distance	5	0.07	0.01	3.25	0.01
Reaction	5	0.02	0.01	1.05	0.39
Error	120	0.52	0.004		
Total	155	0.87			

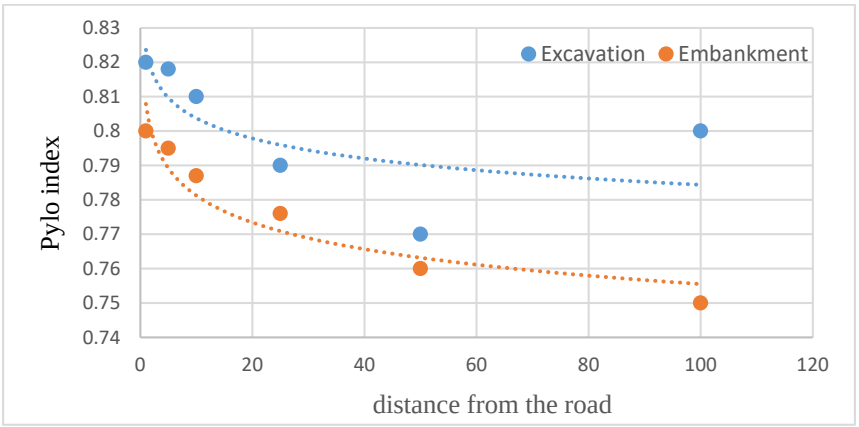

Figure 5. Changes in pylo index of herbaceous species at various distances from the road

composition and diversity of tree regeneration species

In this study, 17 species were identified and harvested in 0-10 and 25-100-meter top and bottom of road. The results showed that Acer velutinum, in the distance of 0-10 m, Fagus orientalis and Carpinus betulus, are seen in the inner parts of forest at a distance of 25 to 25 meter.

Simpson Diversity Index

Table 5 shows the Simpson diversity index of tree regeneration in a completely randomized block design and Figure 6 shows the trend of this indicator change.

Table 5. Simpson diversity index of tree regeneration in a completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	4.68	0.39	7.93	0.00
Range	1	0.08	0.08	1.52	0.24
Range error	12	0.59	0.049		
Distance	5	1.31	0.26	8.24	0.00
Reaction	5	0.43	0.09	2.68	0.03
Error	120	3.82	0.32		
Total	155	10.90			

Two-way analysis of variance shows that the effect of the position (distance from the road) on the Simpson index, as well as the interaction between the distance from the road and the range, is quite significant, top and bottom places on the diversity index are not significant.

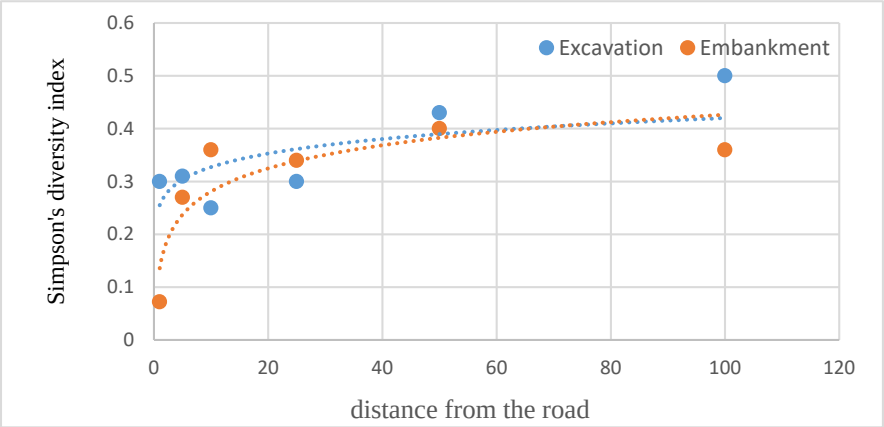

Figure 6. Chart of Changes in the Simpson Variety Index of Tree regeneration at Different Distance from the Road

The fig 6 shows the upward trend, which states that as distance increases from the road, the index of regeneration diversity increases, but at the end of the embankment range, the trend is the same.

Shannon Diversity Index

Table 6 shows the Shannon diversity index of tree regeneration in a completely randomized block design and Figure 7 shows the trend of this indicator change.

Table 6. Shannon diversity index of tree regeneration in a completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	15.89	1.32	7.43	0.00
Range	1	0.28	0.28	1.55	0.24
Range error	12	2.14	0.18		
Distance	5	5.34	1.07	11.55	0.00
Reaction	5	1.17	0.23	2.54	0.03
Error	120	11.09	0.092		
Total	155	35.91			

The analysis of two-way variance shows that the effect of position (distance from the road) on the Shannon index is quite significant. The range of excavation and embankment on the biodiversity index is not significant. Also, the significant effect of the region and road position on the Shannon index is significant.

The trend is an upward trend, indicating that with increasing distance from the road, the index of regeneration diversity also increases.

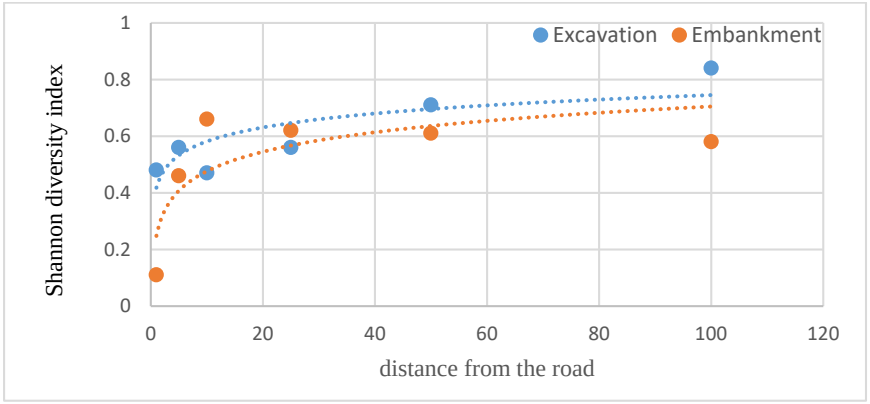

Figure 7. Changes of Shannon Variety Index of Tree regeneration at different distances from the road

Richness index number of species (S)

Table 7 shows the richness index number of tree regeneration species in the form of a completely randomized block design, and Figure 8 shows the trend of changes in this index.

In this index, the table of analysis of variance shows that the effect of distance from the road on the number of species is quite significant. The range of excavation and embankment on the richness index is not significant. The interaction between the area and the road position for the number of species is also significant.

Table 7. Richness index of Tree regeneration number in completely randomized block design

Source	df	Sum Squair	Mean Squair	F	P
Block	12	122.026	10.169	3.517	0.019
Range	1	1.641	1.641	0.568	0.466
Range error	12	34.692	2.891		
Distance	5	113.385	22.677	226.696	0.00
Reaction	5	10.51	2.010	2.012	0.082
Error	120	119.897	0.999		
Total	155	401.692			

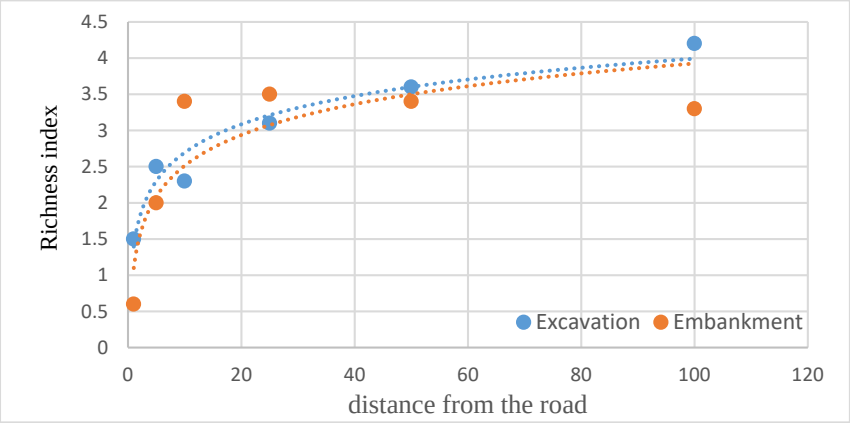

Figure 8. Changes in richness number of tree regeneration at different distances from the road

The trend is to increase as it shows that with increasing distance from the road, the number of tree regeneration also increases.

Pylo uniformity index

Table 8 shows the pylo index of tree regeneration in a completely randomized block design, and Figure 9 shows the trend of changes in this index.

In this index, the two-way ANOVA shows that the distance from the road and the interaction between the area and the road position on the Pylo index are significant. The excavation and embankment domain does not show a significant difference.

Table 8. pylo index of Tree regeneration number in completely randomized block design

Source	Df	Sum Squair	Mean Squair	F	P
Block	12	6.20	0.52	7.48	0.00
Range	1	0.20	0.20	2.87	0.12
Range error	12	0.83	0.07		
Distance	5	1.84	0.37	4.79	0.00
Reaction	5	0.88	0.18	2.29	0.05
Error	120	9.23	0.077		
Total	155	19.18			

The process of changing the index at a different of distance from the edge of the road to the inner parts forest is upward. In fact, regeneration uniformity at the initial intervals shows the same trend, except for the embankment ranges which show a rising distance of 0 to 5 m, but at a distance of 50 to 100 m the relation is approximately the same.

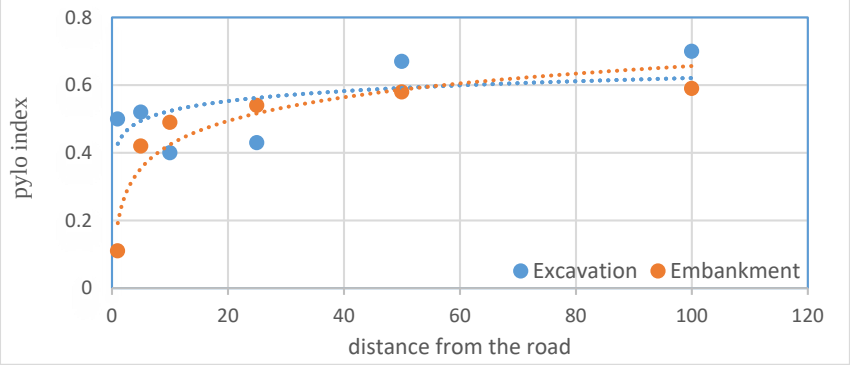

Figure 9. Chart of variations of the pylo index of uniformity of tree regeneration at different distances from the road

Discussion and Conclusion

Roads and forest paths have an important impact on environment. Its major biological and non-biological effects include changes in the dynamics of plant and animal communities, introduction of invasive species, changes in levels of available resources, such as light, water and food (Coffin, 2007; Hill and Pickering, 2006; spellerberg, 1998; Angold, 1997), which results in degradation and compaction of the soil, the change in light exposure and variation in plant diversity (Decocq et al.2004, Christine J Small and McCarthy, 2002 Godefroid and Koedam, 2004). In fact, plants are able to survive and increase energy and food from the sun, but the amount of light varies in different environments. In the event of removal of the canopy for the construction of the road, the greatest amount of light reaches the floor of the forest. In this situation, the plants display different responses to light intensity variations.

Biodiversity of herbaceous

As the results showed, the diversity of species and the richness diminished by increasing distance from road. In fact, near the road, species have more access to light sources (Jones, 1991), and this increases the biodiversity of the forest. Modified light conditions often affect the temperature and amount of humidity, which also affects the composition of the species. In addition, according to Gehlhausen et al (2000), relative humidity is high on the side of the road, while the soil moisture is low. In fact, one of the probabilities is the high density of herbaceous species due to the favorable conditions of this area. These conditions include light intensity or increased food. Therefore, due to the variability in heat, light, moisture and crown and the height of trees between the outside and inside of the forest (Delgado et al., 2007), the greatest changes in the environment are observed in the first few meters from the side of the road (Arevalo et al. 2005; Delgado et al., 2007). This is why the highest changes in trend of species composition is observed near the road (Didham et al.1998, Forman et al., 2002).

The richness index (S) also shows that the distance between the herbaceous species is more than zero in 5 meters from the roadside. On the edge of the road, some shadowy species that are sensitive to the canopy are located in this position. On the other hand, the increase in shadow at this distance and the organic matter derived from the decomposition of the leaf cause an increase in the percentage of indigenous species. In addition to the destruction and displacement of soil by woodcarving machines (Schmidt, 1989), road management as well as management activities that cause surface erosion, soil masses, soil compaction, and wheel tracking, are based on physical, chemical and the biological effect of soil is affected, which results in a reduction in production along the road. Seed accumulation or dispersal from other areas is another factor in increasing the number of species in this distance (Watkins, 2003). On the other hand, indigenous species are less well-established due to exposure to car spraying and road grazing. (Trombulak and frissel, 2000).

The monotony index, which is affected by species abundance, is at a distance of 10 to 25 meters while the rest of the plots have the same composition, which can be due to conditions in the forest such as the close canopy, so the sensitive species to the close canopy is deployed less in the inner parts of forest (Zenner and Berger, 2008; Buckley et al, 2003).

Soil can be another factor in the frequent amount of herbaceous cover at the side of the road. The increase in carbon (Lee et al, 2010) and Nitrogen concentration increase production. Species such as *Festucadrymeia*, *Equisetum telmateia* and *Bromusstrilis* are present due to more light exposure (USDA, NRCS, 2012). These plants use more of the micronutrients along the road in neutral pH conditions (Lee et al., 2012; Grime, 1977).

Biodiversity of tree regeneration

Based on the results of quantitative regeneration in the marginal areas of the road, the ability to deploy of regeneration depend to a large extent on the distribution, germination, competition and seed viability (Cavallin and Vasseur, 2008). Because of low moisture and food on the shoulder of the road the species of this section consume more energy to absorb moisture and food from the lower parts (Tilman, 1988), which can be considered as limiting factors in the regeneration and seeding (Newsome, 1984). In fact, the problem of regeneration of many species at initial intervals is related to the competition between species and the density of soil. But the diversity, richness, and unevenness of regeneration grows within the forest, where better conditions for seeding are provided. The results of this study are consistent with the results of research that stated distance from the road can affect variety, richness and uniformity. near the road, high soil temperatures and sunlight, as a result of the removal of the canopy, moisture and low food due to the compaction of soil, limit the regeneration and survival of trees (Pinard et al., 1996). Also, the diversity of competitive species near the road in particular *SambucusEbulus*, *Rubushyrcanus*, and the removal of the canopy, litter and deep crown effects in biodiversity along the road.

In fact, road-side conditions provide suitable conditions for aggressive species, so the tree breeding does not have the ability to compete and is eliminated. As a result, biodiversity of regeneration communities tends to move into the forest. other reasons of the absence of regeneration could be, the grazing and sinking of the soil by livestock, which exerts pressure on some of the species being deployed (Barchuck et al., 1998).

As a result, we can mention that the forest roads have a significant effect on species composition. So that the percentage of coverage of light-friendly species decreases with distance from the road. While shadowy species tend to be more likely to be present in the forest. In fact, the distance from the road is a significant factor in regeneration distribution modeling. The presence of *Acer ulmusglabra and glotinusa*, *elutinumAlnus* at the side of the road, show that there are many light friendly on the near road than the inside of the forest, which is consistent with the findings of Delgado et el (2007). The regeneration of light-

friendly species along the road, due to the removal of the canopy, can increase the intensity and duration of light (Christine J Small and McCarthy 2002), and the soil temperature rises above the surface during the summer Also, soil compaction and soil density increase as well as lack of proper soil depth on the road have been reported (Karim and Malik, 2008). Therefore, compared to the inside of the forest, the edge of the road has a higher degree of heat, lower relative humidity, and higher shear forces (Didham and lowtone, 1999; laurance, 1997). The total percentage of tree crop coverage indicates that tree crops increase with distance from the road and confirm the previous results.

The overall results indicated that the road significantly affects the biodiversity of herbaceous species and the establishment of regeneration. Also, biodiversity values in the marginal areas of the road are more than in the forest. Forest roads have a significant effect on the surrounding communities of plants. In fact, due to the removal of the forest area, the road has opened and reduced the canopy, and therefore more light friendly herbaceous species were seen near the road, which increased the richness and biodiversity of this there. Due to inadequate conditions for the establishment of tree regeneration near the road, less tree regeneration was established on the margin of the road. Results of this study showed that light is the most important ecological factor that its amount and intensity can be changed within forest stands. Among different environmental factors, optical conditions are the main determinant factor in the establishment of species under the other trees. Therefore, determining the width of the roadblock to build roads is another issue in protecting the biodiversity of the roadside. In fact, minimizing the inclination and cutting of trees, as well as determining the perimeter of the road according to environmental criteria, could bring less effect on the diversity and composition of the roadway.

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