Quantitative characteristics, regeneration status, Physicochemical soil properties within and at different distance of abandoned skid trails in the Hyrcanian forests.

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Abstract

Background

Creating skid trails for wood extraction in mechanized harvesting is unavoidable. Creating such a trail is a temporary changes in forest condition that causes significant influences on the disturbed area. The area gradually turns to the forest that depends on several edaphic and climatic factors. The process from bared land in the skid trails to the forest area need to be investigated in order to know the time and process of changes. It is also interesting to know the stand condition around the skid trail due to harvesting. The objective of the study was to investigate the stand characteristics within the abounded skid trails and as well as within the stand.

Methods

In this study, three 35-year-old abounded skid trails were selected and 63 rectangular plots with the dimensions of 200 m x 5 m for stand characteristics and 100 m² (20 m x 5 m) for regeneration were established within and at intervals of 25, 50 and more than 75 m on both sides of the skid trails. Soil sample were also taken at center of each plot. Stand characteristics such as species, d.b.h, height, and crown diameter were measured. A factorial test was used to examine the relationship between various distances of trails and position of samples and independent variables such as d.b.h.

Results

The average d.b.h was 27.3 cm, 35.9 cm, 30.9 cm, 25.8 cm, 35.1 cm, 32.6 cm, and 16.4 cm at 25+, 50+, 75+, 25-, 50-, 75-, and within the trails, respectively. Along the skid trails, the main trees were alder and around the skid trails, the dominant trees were beech. Available *P* level was high within the trails. The regeneration status was relatively favorable within the trails and at different intervals of skid trails.

Discussion

In the study of stand composition, beech trees had the highest percentage at all intervals of the skid trails, and maple and alder trees were rarely found; however inside the trails the alder trees were dominant. Creating skid trails is an interference within an ecosystem which may lead to the creation of side effects due to harvesting and soil disturbance. Along the skid trails, where the canopy is opened-up, and the soil is disturbed, alder trees are established. The abundance of beech trees in the area was due to the altitude and climatic conditions which is suitable for establishment of beech stands. Results for frequency of regeneration less than 1.30 m in height indicate that with increasing distance from the skid trails, the rate of regeneration decreased. Getting enough light to the forest floor inside the trails by opening the canopy, provides a suitable condition for regeneration, especially for pioneer species. Regeneration of alder trees

in the skid trails was higher than outside of the skid trails, which has a direct relationship with the displacement of soils and increased light as a pioneer species.

Conclusion

Abandoned skid trail provides suitable opportunity to study dynamic of forest stand in the bared area due to harvesting operations. As it was expected; pioneer species like alder trees occupied abandoned lands. Beech trees as a climax trees take places at the last stage of natural succession. Management and silvicultural treatment should focus on reducing unwanted species and enrichment abandoned skid trail by other species. Further study can be done after 15 years to see what happened after half century.

Background

The northern forests of Iran are geographically located in the provinces of Guilan, Mazandaran, and Golestan. The forests consisting of strips of approximately 800 km long and 20–70 km wide, with a surface area of 1.8 million ha located in the northern aspect of Alborz Mountain. The northern forests of Iran are the main provider of wood for woody industries in Iran. The forest harvesting is one of the most important operations and the link between the biological and industrial production sections (Tavankar et al. 2009). Forest harvesting operations in the last few decades due to the high volume of cuttings, the steepness of a large part of these forests, shortening the time of wood extraction, and the development of mechanization tended toward using heavier machinery. Moving machines inside the forest need to be prepared trails in advance, so that skidders can travel along these trails. Skid trails have no excavation and embankment and are generally designed in a slope direction (Sarikhani 1991). Apart from the felling of occasional trees to provide a clear path, few improvements are made to skid roads (Buckley et al. 2003). The width of the skid trails is usually 4–5 m and the length of skid trails vary depends on the skidder type and forest conditions, which starts from 50 m and reaches at a maximum of 1500 m, while the optimum skidding distance for rubber tired skidder is 700 m. Due to the passing of skidder on the skid trails, damage to the forest and soil occurs (Murphy 2004; Tavankar et al. 2009). According to the current rule, re-skidding in the area should be preceded over the previous skid trail to avoid damage to the nature. Some of these trails have been abandoned for decades due to a lack or change of removal (skidding) plan or due to environmental obligation. In these types of trails, the regeneration established and a forest floor covered by the herbaceous plants. The structure of the soil in these trails can be considered as a natural platform with unique characteristics and provide a good opportunity to study the regeneration of various tree species (Salehi et al. 2011). There are relatively few studies on the effects of harvesting within and outside of these trails. Lotfalian (1996) investigated the effects of skid trails on regeneration, grass cover and soil characteristics in the Hyrcanian broadleaved forests, and concluded that the use of skidding machines caused soil compaction, poor soil ventilation, and preventing root growth, and ultimately weaken and eliminate vegetation coverage. Zare et al. (2011) showed that on the border of skid trails due to the movement of heavy machinery, unprotected soil has been displaced and this disturbance to the soil surface has reduced the growth of existing trees or future seedlings and also

affect the biodiversity of plant species (Jafari and Najafi 2015). According to researches, ten years after the skidding operation, the recovery rate of organic matter has increased significantly in comparison with new harvested trails. Similar studies have been carried out on these issues, for example, Forman et al. (2002) concluded that forest roads would change the amount of light, humidity, wind and small-scale temperature fluctuations and increase or decrease biodiversity around them. Eric et al. (2008) showed that concentrating skidder traffic to a designated skid trail system can result in less area disturbed and spatially connected networks of larger, untrafficked remnant forest patches that may maintain species that are sensitive to forest floor and soil disturbance. Beaudet et al. (2014) showed that the ratio of soil and humus to be greatly increased in post-harvest skid trails. Similarly, the ratio of rotting wood inside the skid trails is greater than the outside of the trails.

Cambi et al. (2015) in his research showed the impact of heavy machinery on the forest soil. Mechanized harvesting for high productivity may cause serious damage to forest soil. Wei et al. (2016) showed that soil compaction and herbaceous diversity richness in skid trails are more than in intact areas. In Iran, the entire skid trails are reused after 10 years (harvesting rotation) and all trails are cleared before skidding. Presently, due to limitation for forest removal, abandoned trails can be reforested in order to improve forest cover. Turning these trails to the forest area is time consuming process and may takes several years and need to be studied to know the process of forest restoration; therefore, the study aimed to show the quantitative characteristics of an established stand, regeneration condition, and soil compaction.

Methods

Study area

The study was conducted in Northern Iran, in the Nav Watershed in the Hyrcanian forests. The study area was located between 37°37' and 37°42' N, and between 48°44' and 48°49' E (Fig. 1). The nearest meteorological station is situated in Pilambara (37° 34' N, 49° 5' E). On the basis of the meteorological observations and according to Köppen's classification (Kimmel 2001), the climate of the area is temperate; the mean annual temperature is 15 °C, and average daily amplitude 0–6 °C. In general, the relative humidity is high; with the annual rain fall varying between 1500–2000 mm per year (Action Plan 2000). The Nav watershed is located in an altitude between 600–1800 m above sea level. Geologically this area belongs to the ancient basement formation. Acidic soils (pH < 5.5) predominate, which are suitable for the growth of broadleaves, for example, oriental beech *Fagus orientalis*.

On the basis of information mentioned in the Action Plan (2000) the dominant soils are classified as Rendzine, brownish in color and weathered to a considerable depth (Mousavi Mirkala 2009). The forest stand description for the study area is mentioned in the Table 1.

Table 1
Stand descriptions for district 2, parcels 262

Characteristic of the stand	Description
Surface Area for district and compartment (ha)	3359 and 70
Harvested area (ha)	2140
Silvicultural treatment	Single tree selection method
Elevation range (m)	1720 – 1550
Aspect	North-west
Soil pH	5-5.7
Regeneration status	Medium to good
Degree and quality of forest	2 and production potential is good
Crown cover percent	60–65%
Number of trees per hectare (volume)	230 (236)

Data Collection

To investigate the effect of logging operations on the quantitative characteristics of trees within and outside of skid trails, the study was carried out. Data were collected from 63 sampling plots within the skid trails and at 25, 50, and 75 m (as a control plots) distances from the border of skid trails on both sides up and down or left and right side, respectively (first point randomly and subsequent sampling plots systematically established). The skid trails has been abounded since 1982 and the data is collected in spring 2017. The sample plots were rectangular with an area of 1000 square meters (200 m * 5 m). Information such as species, diameter, height, the crown diameter was recorded. In the center of each plot, the regeneration sample plot was established with a 20 m * 5 m dimension. The regeneration status was recorded by diameter at breast height (0-2.5 cm, 2.5-5 cm, 5-7.5 cm) and height below 1.30 m. At the center of each plot, soil samples were collected from 0–30 cm depth and then transferred to the soil laboratory for analysis. In the laboratory, soil samples were sieved after drying. The percentage of sand, silt, clay in the samples was determined by using bouyoucos hydrometric method. Other soil properties such as pH measured by potentiometric method, organic carbon content by Walkley and Black method, total nitrogen by Kjeldahl method, potassium adsorbed by ammonium acetate extraction and by using photometric film method.

Data analysis

This study was conducted as a completely randomized design. Normal distribution of data and variance homogeneity of the experimental groups were analyzed by Shapiro-Wilk and Leven test, respectively. All

data were analyzed using two-way ANOVA. Tukey's mean test was used for the separation of experimental groups if ANOVA ($P < 0.05$) was considered significant. All statistical analyses were performed by IBM SPSS Statistics for Windows, Version 24.0. Results were reported as average $\pm$ standard error"

Results

Table 2
The status of tree species composition within and around the skid trail.

Species/Distance	25+	25-	50+	50-	>75+	<75-	Within the trail
<i>Fagus orientalis</i> (%)	97	99	100	100	95	98	-
<i>Acer insigne</i> (%)	1	-	-	-	-	-	-
<i>Alnus subcordata</i> (%)	2	1	-	-	5	2	100
<i>Carpinus betulus</i> (%)		-	-	-	-	-	-

Specifications of the diameter at breath height for abounded skid trail after 35 years are presented in Table 3. The results show that in the upper part of the skid trails, the highest mean d.b.h was 35.9 cm at a distance of 50 m and the lowest was 27.36 cm at a distance of 25 m away from the skid trails. At the bottom of the skid trails, the highest mean d.b.h was 35.1 cm at a distance of 50 m while the lowest was 25.8 cm at 25 m away from the skid trails. Within the trails, the highest d.b.h was 19.6 cm and the lowest was 13.3 cm.

Table 3
Status of trees diameter (d.b.h) at different intervals of skidding

Distance from skid trails	Number	Diameter average(cm)	Std. dev	Highest diameter(cm)	Lowest diameter(cm)
25+	223	27.36	15.8	103	8
50+	178	35.9	23.54	122	11
75+	199	30.8	17.12	103	10
25-	237	25.8	15.81	117	10
50-	198	35.11	23.33	132	7
75-	197	32.6	16.38	136	9
S.trails ₁	41	16.3	1.4	17.6	14.8
S.trails ₂	46	16.6	2.2	19.2	14.8
S.trails ₃	60	16.4	3.1	19.6	13.3

Table 4 shows the height of trees in the upper part of the abandoned skid trails for 35 years. The results show that in the upper part of the skid trails, the highest average height of trees was 13.7 m at a distance of 50 m and the lowest average height of trees was 12.39 m at 75 m distance away from skid trails. At the bottom of the skid trails, the highest mean height was 13.6 m at 50 m and the lowest was 12.7 m at a distance of 25 m away from skid trails. Within the trails, the highest average height was 8.97 m and the lowest was 7.04 m.

Table 4
Status of trees height at different distance from trails

Distance from skid trails	n	Height average(cm)	Std. dev	highest height(cm)	Lowest Height (cm)
25+	223	12.51	3.77	31.3	5.6
50+	178	13.74	4.96	29.3	5
75+	199	12.39	3.87	31.3	6.1
25-	237	12.73	4.18	31.1	5.3
50-	198	13.74	4.20	26.2	5.9
75-	197	12.86	3.02	24.2	6.3
S.trails ₁	41	8.4	0.49	12.1	6.6
S.trails ₂	46	8.5	0.56	12.1	6.2
S.trails ₃	60	7.3	0.26	12.4	3.6

The results show that at the upper side of the skid trails, the highest mean crown area was 22.05 m² at 50 m and the lowest mean crown area was 15.7 m² at 75 m away from skid trails. At the bottom side, the highest mean crown area was 33.5 m² at 75 m and the lowest mean crown area was 20.5 m² at 25 m away from skid trails. Within the trails, the highest average crown diameter was 8.3 m² and the lowest was 5.9 m² (Table 5).

Table 5
Status of trees crown at different intervals of skid trails

Distance from skid trails	n	Average crown diameter (m)	Crown area average(m ²)	Std. dev	Highest crown(m ²)	Lowest crown(m ²)
25+	223	4.57	18.47	15.34	113	2.54
50+	178	4.91	22.05	23.83	213.71	4.90
75+	199	4.23	15.73	13.86	113	4.15
25-	237	4.71	20.52	25.8	295.44	2.26
50-	198	5.13	26.05	31.1	234.9	4.15
75-	197	5.57	33.52	47.26	295.4	4.15
S.trails ₁	41	3.01	7.14	0.18	7.54	6.15
S.trails ₂	46	3.05	7.34	0.27	8.54	5.9
S.trails ₃	60	3.06	7.44	0.33	8.34	5.6

The results of comparison of mean d.b.h in the upper and lower part of the skid trails as well as at different distances of the skid trails showed that the distance from the skid trails was considered as an influencing factor and the position of plots and their interaction were not affected (Table 6). The results of comparing the mean total height of the trees in the upper and lower part of the skid trails as well as at different distances of the skid trails showed that the distance from the skid trails was considered as an influencing factor, the position, and their interaction was not affected. The results of comparison of mean crown diameter in the upper and lower part of the skid trails as well as at different distances of the skid trails showed that the interaction of distance from the trails and position of the samples was effective. Table 6 shows more details on the significant factors affecting d.b.h, total height, and crown diameter.

Table 6
Significance of factors affecting breast diameter, total height, and crown diameter

Factor		F
Diameter at breast height	Location of samples	0.085
	Distance from trails	30.56
	Interaction between position of samples and distance from trails	2.1
Height	position of samples	2.29
	Distance from trails	9.49
	Interaction between position of samples and distance from skid trails	0.652
Diameter crown	Position of samples	9.47
	Distance from skid trails	2.39
	Interaction between position of samples and distance from trails	6.73

Regeneration condition in the skid trails

Table 7 shows the percent of regeneration at different regeneration classes. As expected, the highest frequencies were below the height of 1.30 m followed by 0.5–2.5 cm d.b.h class and the lowest regeneration percentage was in the 2.5-5 cm d.b.h class.

Table 7
Percentage of regeneration at different regeneration classes

Distance from skid trailsDiameter class (cm)				
Distance (m)	(5-7.5) %	(2.5-5) %	(0-2.5) %	Height below 1.30 (m)
25+	1.7	0.5	27.4	70.3
50+	1.1	0.7	29.1	69
75+	1.1	1.7	25.7	71.5
25-	1.9	1.4	29.2	67.5
50-	0.8	1.9	27.1	70.2
75-	32	1.2	2.3	64.4

Table 8 shows the percentages of regeneration in diameter classes within the skid trails sorted by species. The height class below 1.30 m took the largest share.

Table 8
Percentage of regeneration and composition of species in different
regeneration classes within skid trails

Species	(0-2.5)	(2.5-5)	(5-7.5)	Height below 1.30 (m)
<i>Fagus orientalis (%)</i>	34.5	2.4	3.5	59.6
<i>Acer insigne (%)</i>	18.7	14.1	20.3	46.9
<i>Alnus subcordata</i>	31.8	1.3	1.2	65.2

Table 9 and Table 10 show the results of the soil samples analysis around and within the skid trails. Based on these results, soil texture was sandy loamy, pH level was acidic to neutral, soil nitrogen status was not favorable, soil organic matter was in favor condition and available *P* within the skid trails was high.

Table 9
Results of soil analysis within and around the skid trails

Sample plot	Sand (%)	Silt (%)	Clay (%)	Lime (%)	EC(μ s)	PH
25a-	1.15 $\pm$ 54	0 $\pm$ 26	1.15 $\pm$ 20	0 $\pm$ 0.5	131 $\pm$ 437 ^a	0.07 $\pm$ 7.2
25b-	1.15 $\pm$ 54	0 $\pm$ 26	1.15 $\pm$ 20	0 $\pm$ 0.5	131 $\pm$ 533 ^a	0.07 $\pm$ 7.22
25c-	1.15 $\pm$ 52	0 $\pm$ 26	1.15 $\pm$ 22	0 $\pm$ 0.5	131 $\pm$ 290 ^a	0.07 $\pm$ 7.08
25a+	2 $\pm$ 52	1.15 $\pm$ 28	0 $\pm$ 20	0.5 $\pm$ 0.5	76 $\pm$ 331 ^{ab}	0.07 $\pm$ 7.27
25b+	2 $\pm$ 54	1.15 $\pm$ 26	0 $\pm$ 20	0.5 $\pm$ 1	76 $\pm$ 268 ^{ab}	0.07 $\pm$ 7.22
25c+	2 $\pm$ 56	1.15 $\pm$ 26	0 $\pm$ 20	0.5 $\pm$ 0.5	76 $\pm$ 420 ^{ab}	0.07 $\pm$ 6.94
50a-	2 $\pm$ 54	1.15 $\pm$ 28	1.15 $\pm$ 18	0.28 $\pm$ 1.5	135 $\pm$ 677 ^{ab}	0.08 $\pm$ 7.04
50b-	2 $\pm$ 52	1.15 $\pm$ 28	1.15 $\pm$ 20	0.28 $\pm$ 1.5	135 $\pm$ 413 ^{ab}	0.08 $\pm$ 7.05
50c-	2 $\pm$ 56	1.15 $\pm$ 26	1.15 $\pm$ 18	0.28 $\pm$ 2	135 $\pm$ 489 ^{ab}	0.08 $\pm$ 6.89
50a+	3 $\pm$ 54	2 $\pm$ 26	1.15 $\pm$ 20	0.28 $\pm$ 1.5	79 $\pm$ 489 ^{bc}	0.12 $\pm$ 7.01
50b+	3 $\pm$ 48	2 $\pm$ 30	1.15 $\pm$ 22	0.28 $\pm$ 0.5	79 $\pm$ 354 ^{bc}	0.12 $\pm$ 7.04
50c+	3 $\pm$ 52	2 $\pm$ 28	1.15 $\pm$ 20	0.28 $\pm$ 1	79 $\pm$ 494 ^{bc}	0.12 $\pm$ 7.08
75 a-	31 $\pm$ 17	0 $\pm$ 16	1.15 $\pm$ 14	1 $\pm$ 0.5	77 $\pm$ 582 ^{ab}	0.19 $\pm$ 6.86
75 b-	31 $\pm$ 70	0 $\pm$ 16	1.15 $\pm$ 14	1 $\pm$ 1	77 $\pm$ 736 ^{ab}	0.19 $\pm$ 7.22
75 c-	31 $\pm$ 72	0 $\pm$ 16	1.15 $\pm$ 12	1 $\pm$ 2.5	77 $\pm$ 659 ^{ab}	0.19 $\pm$ 7.15
75 a+	1.15 $\pm$ 66	0 $\pm$ 18	1.15 $\pm$ 16	0.57 $\pm$ 1.5	165 $\pm$ 638 ^c	0.06 $\pm$ 7.09
75 b+	1.15 $\pm$ 68	0 $\pm$ 18	1.15 $\pm$ 14	0.57 $\pm$ 0.5	165 $\pm$ 308 ^c	0.06 $\pm$ 6.98
75 c+	1.15 $\pm$ 68	0 $\pm$ 18	1.15 $\pm$ 14	0.57 $\pm$ 0.5	165 $\pm$ 481 ^c	0.06 $\pm$ 6.98
S.trails ₁	2 $\pm$ 60	1.15 $\pm$ 22	1.15 $\pm$ 18	0.76 $\pm$ 2.5	105 $\pm$ 768 ^c	0.09 $\pm$ 6.77
S.trails ₂	2 $\pm$ 58	1.15 $\pm$ 24	1.15 $\pm$ 18	0.76 $\pm$ 1	105 $\pm$ 652 ^c	0.09 $\pm$ 6.85
S.trails ₃	2 $\pm$ 62	1.15 $\pm$ 22	1.15 $\pm$ 16	0.76 $\pm$ 2	105 $\pm$ 557 ^c	0.09 $\pm$ 6.96

Table 10
Resume of the results of soil analysis within and around the skid trails

Sample plot	Organic matter (%)	Potassium (K)	Phosphorus (P)	Nitrogen(N)
25a-	0.65 ± 5.97 ^a	7.97 ± 18.74 ^a	0.58 ± 10.13	0.03 ± 0.38 ^a
25b-	0.65 ± 22.79 ^a	7.97 ± 22.79 ^a	0.58 ± 9.55	0.03 ± 0.37 ^a
25c-	0.65 ± 34.13 ^a	7.97 ± 18.74 ^a	0.58 ± 8.96	0.03 ± 0.31 ^a
25a+	0.56 ± 2.67 ^{ab}	7.72 ± 22.79 ^a	1.79 ± 8.37	0.01 ± 0.15 ^{ab}
25b+	0.56 ± 2.67 ^{ab}	7.72 ± 36.56 ^a	1.79 ± 10.72	0.01 ± 0.14 ^{ab}
25c+	0.56 ± 1.7 ^{ab}	7.72 ± 35.75 ^a	1.79 ± 7.2	0.01 ± 0.13 ^{ab}
50a-	1.51 ± 7.39 ^c	23.45 ± 79 ^{ab}	2.21 ± 13.06	0.04 ± 0.43 ^c
50b-	1.51 ± 5.97 ^c	23.45 ± 32.51 ^{ab}	2.21 ± 9.55	0.04 ± 0.37 ^c
50c-	1.51 ± 4.83 ^c	23.45 ± 50.32 ^{ab}	2.21 ± 8.96	0.04 ± 0.34 ^c
50a+	0.62 ± 11.37 ^{ab}	10.25 ± 53.56 ^{ab}	1.35 ± 8.96	0.06 ± .092 ^b
50b+	0.62 ± 11.26 ^{ab}	10.25 ± 49.51 ^{ab}	1.35 ± 6.62	0.06 ± .091 ^b
50c+	0.62 ± 10.24 ^{ab}	10.25 ± 34.13 ^{ab}	1.35 ± 8.96	0.06 ± .08 ^b
75 a-	0.87 ± 7.96 ^{ab}	2.46 ± 43.84 ^a	0.89 ± 10.13	0.03 ± 0.49 ^{ab}
75 b-	0.87 ± 7.39 ^{ab}	2.46 ± 48.70 ^a	0.89 ± 9.55	0.03 ± 0.46 ^{ab}
75 c-	0.87 ± 6.25 ^{ab}	2.46 ± 47.01 ^a	0.89 ± 8.37	0.03 ± 0.42 ^{ab}
75 a+	1.7 ± 5.97 ^b	2.92 ± 25.22 ^{ab}	1.69 ± 11.30	0.09 ± 0.35 ^b
75 b+	1.7 ± 3.24 ^b	2.92 ± 29.27 ^{ab}	1.69 ± 8.37	0.09 ± 0.27 ^b
75 c+	1.7 ± 2.84 ^b	2.92 ± 30.892 ^{ab}	1.69 ± 8.37	0.09 ± 0.16 ^b
S.trails1	2.47 ± 3.41 ^{ab}	4.13 ± 62.72 ^c	1.47 ± 10.13	0.15 ± 0.26 ^{ab}
S.trails2	2.47 ± 4.39 ^{ab}	4.13 ± 70.56 ^c	1.47 ± 11.30	0.15 ± 0.48 ^{ab}
S.trails3	2.47 ± 2.84 ^{ab}	4.13 ± 68.94 ^c	1.47 ± 8.37	0.15 ± 0.17 ^{ab}

Discussion

Given the limitations on the number of skid trails considered and the study area, the results of this study may not be generalized to all forests but can be used for similar broadleaves forests. In the study of stand composition, beech trees had the highest percentage at all intervals of the skid trails, and maple and alder trees were rarely found.

Methodologically, the study was empirical study and the method has been used in other studies (Salehi et al. 2011). Creating skid trails is an interference within an ecosystem which may lead to the creation of side effects due to harvesting that characterized by a change in the tree microclimate as well as a disruption in the growth and development of trees and it may even lead to the disruption of the integrity of the stand ecosystem (Buckley et al. 2003; Delgado et al. 2007; Bembenek et al. 2013; Naghdi et al. 2017).

Along the skid trails, where the canopy is opened-up, and the soil is disturbed, alder trees are established. The abundance of beech trees in the area was due to the altitude and climatic conditions which is suitable for establishment of beech stands. The beech trees could be recovered in the absence of human intervention. The results of diameter measurements showed that the lowest mean diameter of trees was at a distance of 25 m away from the skid trails and the highest mean diameter was located at 50 m away from skid trails. At a distance of 50 m away from skid trails, the number of trees is lower which causes the diameter of trees to be increased due to reducing light competition and absorbing more nutrition. These changes can be due to the random variation of trees or due to the impact of exploitation. At a distance of 25 m from the skid trails, the average growth of injured trees is less than that of healthy trees. Trees affected by skidding and be injured on the trunk, resulting in lower growth and getting decay (Kertouli Nezhad 2013). With opening the stand due to harvesting, the alder trees are established as low-demand light and pioneering species (Marvi Mohajer 2011). Following the removal many of trees to construct a skid trail, the received light from the forest floor increased, and since the alder is a light demand species, it has settled in the area.

According to the results obtained of total height at different distances from the skid trails, the highest average trees belonged to 50 m and the lowest was recorded at 75 m away from skid trails. The main reasons for the decrease in the height of trees in this distance may related to the higher slope and lower depth of the soil. Low soil depth makes rooting of trees difficult and maybe a reason for inappropriate tree growth (Xiao and Hu, 2017, Xiao et al. 2020). At a distance of 50 m away from the trails, the average height of trees increases due to lower influence by harvesting, greater soil depth, lower slope, higher soil moisture content, and better conditions for rooting. The results show that the average height of the trees within the trails is low. Increasing the soil compaction reduces the root respiratory space and halts root growth (Ballard 2000, Heilman 1981). Along the trails, the trees are younger than outside; therefore they have a low average height. Adequate space due to low number of trees reduces the competition and ultimately height of trees. Increasing the hardness of aggregates reduces the root respiratory space and halts root growth. Skidder traffic causes the mixing of soil horizons and eliminates fertile O and A horizons, which results in a reduced availability of elements and reduced tree growth (Kertouli Nezhad 2013).

The results show that in the upper and lower part of the abandoned skid trails, the highest mean crown diameter was at 25 m distance from the skid trails and the lowest belonged to a distance of 75 m from the skid trails. Trees crown at 25 m distance of trails are more likely to grow because of the canopy opening and compensation of light demand. Soil organic matter content is directly related to the crown area. Soils with more clay and silt usually contain more organic matter than sandy soils. The number of organic wastes returned to the soil is higher in the fine-grained soils, as the water and nutrient retention capacity of these soils increases the production and growth of trees. The decomposition of the debris of the harvested trees provides nutrients for the trees near the trails and increases the area of their canopy (Habashi and Rahmani 2015).

Results for frequency of regeneration less than 1.30 m in height indicate that with increasing distance from the skid trails, the rate of regeneration decreased. This result was similar for regenerations less than 7.5 cm in diameter. On both sides of the logging trails and alongside of the skid trails, the highest regeneration was related to classes below 1.30 m height and 0 -2.5 cm which indicates that the regeneration were in early stage. Percentage of regeneration in the 0-2.5 cm class inside the trails was higher than outside the trails which indicate the condition for establishment of seedling and sapling within the trails is better than in different distance form trails. Getting enough light to the forest floor inside the trails by opening the canopy, provides a suitable condition for regeneration, especially for pioneer species. Regeneration of alder trees in the skid trails was higher than outside of the skid trails, which has a direct relationship with the displacement of soils and increased light as a pioneer species (Zare and Habashi 2000). In addition to improving soil conditions, organic matter resulting from harvesting had positive effect on soil conditions and regeneration. The results showed that the natural regeneration of beech and maple on both sides of trails was high and was not significantly different. These two species, especially maple, are not sensitive to soil conditions in the study area and can regenerate in different soil conditions (Salehi et al. 2010).

A well-structured soil plays an important role for soil fauna and flora which are essential components of all soils. In forest soils, the thickness of the litter layer is important in the ability of the soil to be crushed by raindrops. This layer preserves soil moisture, increases porosity, permeability, and soil tolerance (Greacen and Sands 1980). Soil destruction is the result of the construction of skid trails, exploitation and site preparation activities that cause heavy machinery traffic and extraction of trees to cause serious damage to the soil. Soil compaction is the first adverse effect of heavy machinery. Increasing soil compaction reduces microbial activity and soil bacterial communities and halts plant root development. Ultimately, it results in the loss of soil nutrients and a prolonged decline in fertility (Jaafari et al. 2014).

Logging operations in forests can cause significant and wide spread soil disturbance, including removal, mixing and compaction of various soil layers (Demir et al. 2008). Disturbance can adversely affect both soil physical properties and soil nutrient levels to such an extent that severely diminished growth of subsequent tree rotations as well as significant increase in runoff and sediment loads may result (Laffan et al. 2008). The influence of harvesting may change the physical and chemical properties of the soil, especially changes in soil organic matter (SOM), nitrogen content, phosphors. Soil available *P* is the main

factors affecting understory diversity and species richness, while pH value and available K were the main factors affecting species number and target species (Xianzhao et al. 2011). Soil P provides plants with a means of using the energy harnessed by photosynthesis to drive its metabolism. A deficiency of this nutrient can lead to impaired vegetative growth, weak root systems, poor fruit and seed quality, and low yield. Plants require fairly large quantities of phosphorus, but the levels of phosphorus available to plant roots at any given time are usually quite low (Spargo 2013). Potassium rivals nitrogen as the nutrient absorbed in greatest amounts by plants. Plants deficient in potassium are unable to utilize nitrogen and water efficiently and are more susceptible to disease. Most available potassium exists as an exchangeable cation. Sandy soils tend to lose substantial quantities due to leaching and will require more frequent applications of fertilizer. Soil organic carbon (SOC) is the main component of soil organic matter (Koutika et al. 2019). Soil organic matter (SOM) is composed of materials containing carbon. These materials include plant and animal remains in various stages of decomposition, root and microbial exudates and humus. Well-drained, coarse textured soils tend to naturally have lower levels of SOM. Soil temperature and moisture also influence soil organic matter decomposition (Yan et al. 2019). This is due, in part, to the rapid microbial decomposition rates favored by these soil conditions. Soil organic matter in the study are similar to other studies (Demir et al. 2008). The level of organic, matte 15 years after firing in burned area was lower than in unburned area. N, available P, and extractable K were lower 2-years and 5-years after the fire but are higher than unburned plot after 15-years (Verma et al. 2019). The optimum range for SOM for soil health varies across soil types. Generally, lower levels of SOM are sufficient, and practical to achieve, in coarse textured, sandy soils as compared to finer soils with more clay content. Nitrogen is essential to nearly every aspect of plant growth. Nitrogen is absorbed by plants as nitrate (NO_3^-) and ammonium (NH_4^+). Soil NO_3^- and NH_4^+ levels can fluctuate widely with soil and weather conditions over very short periods of time. In general, a soil NO_3^- -N concentration of 30 ppm or higher during the active growing season is sufficient for most plants.

In the present study, samples from the upper side of the skid trails are more favorable in terms of total nitrogen content. In most of the samples except soil samples from 50 m distance, the nitrogen status of the soil in the upper part of the trails is much better than in the lower part, however, the amount of nitrogen is still very low. Nitrogen status is critical that requires the use of nitrogen fertilizer. Since soil nitrogen content in the forest is generally directly related to soil organic carbon, skidder slipping leads to losses in the soil nitrogen content. Concerning phosphorus, there is no significant difference between sampling points. If we consider the critical limit of phosphorus (0.033) in the soil by the Olsen extractor method, all sampling points require high levels of fertilizer. This finding is in line with the results of studies by Jaafari et al. (2014) that stated that soil density affects soil phosphorus content. Barzegar (2006) also stated that soil compaction in addition to decreasing root growth can lead to swamp conditions. Swamp conditions restore the soluble elements, such as iron and manganese, and thus remove them from the root of the plants. Besides, decreasing root growth reduces the uptake of inactive nutrients such as phosphorus. Soil available P was the main factors affecting understory diversity and species richness (Xianzhao et al. 2011). Except for the two points (-75c,-50a), the plant's potassium absorption by one-molar ammonium acetate is lower than the plant's requirement, and potassium

fertilization must be used. The soil samples at the bottom of the trails consists of higher amounts of organic matter, therefore they can be classified as Mollisols. The amount of potassium alongside the skid trails was higher than around which has effect on the regeneration status. Available *K* was the main factors affecting species number and target species (Xianzhao et al. 2011). The results show that the percentage of lime in the soil samples inside the trails is higher than the top and bottom of the trails. This difference could be due to less vegetation in the trails. All sampling points are classified in the range of neutral to slightly acidic soils. Given the low percentage of lime, this is a natural result. The soils located at the top of the trails have a lighter texture due to the erosion of the clay from surface layer. Natural forest soil consists of more silt and clay and is therefore heavier. Lack of water storage capacity causes water to flow in the skid trails and leaching of clay and silt, leaving large particles of sand in the skid trails. Due to low value recorded for all nutrients in the study, the substitution by chemical fertilizers increases the number of nutrients available to plants and make faster establishment of future stand.

Conclusion

The study showed that abandoned skid trail could be potentially as a productive part of forest which can recover itself without human interference. The study revealed that after 35 years natural regeneration is established and the young stand was in good condition. The study also showed at various distance from border of skid trail, variation in d.h.h, height, and crown diameter was observed. Within the trails, alder trees as a pioneer species took place and has grown properly. The study showed that regeneration condition was relatively favorable within and at various distance form trails. Nutrient condition within the trails and at different distance from border of trails was poor and need to be fertilized.

Declarations

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References

1. Action Plan (Booklet) (2000) Professional group of TakSabz, Shafaroud Company, 483 p. (in Persian)
2. Barzegar AR, Nadian H, Heidari F, Herbert SJ, Hashemi AM (2006) Interaction of soil compaction, phosphorus and zinc on clover growth and accumulation of phosphorus. SOIL TILL RES 87:155–162
3. Beaudet M, Angers V, Messier C (2014) Seedbed proportions in and outside skid trails: Temporal variation following selection cutting in northern hardwood forests. For Ecol Manag 318:151–157
4. Bembenek M, Giefing DF, Karaszewski Z, Łacka A, Mederski PS (2013) Strip road impact on selected wood defects of Norway spruce (*Piceaabies* (L.) H. Karst). Drewno 56:63–76

5. Buckley DS, Crow TR, Nauertz EA, Schulz KE (2003) Influence of skid trails and haul roads on understory plant richness and composition in managed forest landscapes in Upper Michigan, USA. *For Ecol Manag* 175:509–520
6. Cambi M, Certini G, Neri F, Marchi E (2015) The impact of heavy traffic on forest soils: A review. *For Ecol Manag* 338:124–138
7. Delgado JD, Arroyo NL, Arévalo JR, Fernández-Palacios JM (2007) Edge effects of roads on temperature, light, canopy cover, and canopy height in laurel and pine forests (Tenerife, Canary Islands). *LANDSCAPE URBAN PLAN*, 81: 328–340
8. Demir M, Makineci E, Sat Gungor B (2008) Plant Species Recovery on a Compacted Skid Road. *Sensors* 8(5):3123–3133
9. Eric KZ, Alaina LB (2008) Influence of skidder traffic and canopy removal intensities on the ground flora in a clear cut-with-reserves northern hardwood stand in Minnesota, USA. *For Ecol Manag* 256:1785–1794
10. Ezzati S, Najafi A, Rab MA, Zenner E (2012) Recovery of soil bulk density, porosity and rutting from ground skidding over a 20 year period after timber harvesting in Iran. *Silva Fenn* 46(4):521–538
11. Forman R, Sperling D, Bissonette JA, Clevenger AP, Cutshall CD, Dale VH, Fahrig L, France RL, Goldman CR, Heanue K, Jones J, Swanson F, Turrentine T, Winter TC (2002) *Road Ecology, Science and Solution*. Island press, Washington, 467p
12. Greacen EL, Sands R (1980) Compaction of Forest Soils: a review *Aust. J Soil Res* 18(4):163–189
13. Auf. 1. *Soil Res*.
14. Habashi H, Rahmani R (2015) The relationship of canopy cover with organic matter and microbial respiration of soil in mixed beech forest of 60th Kalateh of Gorgan. *WOOD SCI TECHNOL* 23:157–143
15. Heilman P (1981) Root penetration of Douglas-fir seedlings into compacted soil. *For Sci* 27:660–666
16. Jaafari A, Najafi A, Zenner E (2014) Ground-based skidder traffic changes chemical soil properties in a mountainous Oriental beech (*Fagus orientalis* Lipsky) forest in Iran. *J TERRAMECHANICS* 55:39–46
17. Jafari A, Najafi A (2015) The process of recovery of organic matter which has been degraded during a ten-year period after forestry operations. *Iranian Journal of Forest Range Protection Research* 13:19–11
18. Koutika LS, Ngoyi S, Cafiero L, Bevivino A (2019) Soil organic matter quality along rotations in acacia and eucalypt plantations in the Congolese coastal plains. *FOR ECOSYST* 6:(36)
19. Kertouli Nezhad D, Najafi A, Portahmasbi K (2014) The long term effect of skidding with a rubber-tired skidder on the growth of trees around the skid trails. *J SUSTAIN FOREST* 1(2):179–193 (in Persian)
20. Kimmel TM (2001) Köppen climate classification flowchart. Geography Department, University of Texas at Austin. Available

from:<http://www.utexas.edu/depts/grg/kimmel/GRG301K/grg301kkoppen.html>. [Cited 10 April 2007]

21. Laffan M, Jordan G, Duhig N (2001) Impacts on soils from cable-logging steep slopes in Northeastern Tasmania, Australia. *For Ecol Manag* 144:91–99
22. Marvi Mohajer R (2006) *Silviculture*. Tehran University Press, Iran, 388 pp
23. Mousavi Mirkala SR (2009) Comparison of productivity, cost and environmental impacts of two harvesting methods in Northern Iran: short-log vs. long-log. Ph. D. Thesis. University of Joensuu, Finland
24. Murphy G (2004) Long-term impacts of forest harvesting related soil disturbance on log product yields and economic potential in a New Zealand forest. *Silva Fenn* 38(3):279–289
25. Naghdi R, Bonyad A, Mobasher Amini A (2017) Road effect on diameter growth of trees in Caspian forests of Iran, Casp. *J Environ Sci* 15(1):47–55
26. Najafi A, Hosseini SM, Ezati S, Torabi Varaki M, Fakhari MA (2010) Comparison of regeneration and biodiversity of trees in the cut slope and fill slopes of the forest road with increasing distance from it (Case study: Chamestan and Lavij, Noor forests), **WOOD SCI TECHNOL** 4:152 – 139
27. Salehi A, Taheri Abkenar K, Basiri R (2011) Surveying the physical properties of the soil and the establishment of natural regeneration in skid trails in the Nav forests. *Forest Journal of Iran* 4(3):329–317
28. Sarikhani N (2008) *Forest utilization*, Tehran University Press. 728 p
29. Spargo J (2013) Interpreting your soil test results, UMass Soil and Plant Nutrient Testing Laboratory University of Massachusetts, 4p
30. Tavankar F, Majnounian B, Bounyad AI (2009) Study of the effects of utilization on regeneration and compaction of forest soils in the ground skidding system in Asalem forest in Guilan province. *J agric nat resour sci* 48(13):456–449
31. United States Office of Technology Assessment (1987) *Technologies to maintain biological diversity* 330: 335
32. Verma S, Singh D, Singh AK, Jayakumar, S (2019) Post-fire soil nutrient dynamics in a tropical dry deciduous forest of Western Ghats, India, *FOR ECOSYST* 6(3)
33. Wei L, Hulin F, Chevalier R, Archaux F, Gosselin F (2016) Is plant diversity on tractor trails ore influenced by disturbance than by soil characteristics? *For Ecol Manag* 379:173–184
34. Xianzhao L, Yuanchang L, Yanhua Z, Xiangdong L, Xiongqing Z, Jinghui J (2011) *The influence of soil conditions on regeneration establishment for degraded secondary forest restoration, Southern China, For Ecol Manag* 261(11): 1771–1780
35. Xiao Q, Xiao Y, Liu Y, Tao J (2020) Driving forest succession in karst areas of Chongqing municipality over the past decade. *FOR ECOSYST* 7(3)
36. Yan MLZ, Tian X, Zhang L, Zhao Y, Improved simulation of carbon and water fluxes by assimilating multi-layer soil temperature and moisture into process-based biogeochemical model, *FOR ECOSYST*,

37. Zare N, Lotfalian M, Hojjati SM, Fallah A (2011) Effects of Skidding Trails on Combination and Biodiversity of Tree Regeneration (Case Study: Circular Forest Forests, Mazandaran Wood and Paper Mill), *Regional Conference of Forests and the Environment, Promoting Sustainable Development*
38. Zarea H, Habashi H (2000) Alder, Ecological forest species in the Northern Forests. *Journal of Forest Range* 48:63–55 (in Persian)

Figures

Figure 1

Location of the study area.