Changes in soil physical properties and understory vegetation in abandoned skidding trails

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Abstract

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Skidding trails are primary pathways for transporting harvested timber from stumps to landings near forest roads. While they function as temporary routes for logging, their construction can alter ecological dynamics, potentially affecting plant regeneration, diversity, and species composition. This study investigated the physical properties of soil specifically bulk density, soil moisture, saturation, and field capacity as well as the biodiversity of understory vegetation within abandoned skidding trails in the Hazarjarib forest of Iran. Four skidding trails of varying ages (15, 25, 35, and 45 years past-skidding) were selected for the analysis. At each logging route, three plots were established; for each plot, an off-route control plot was placed nearby. To assess the richness and diversity of understory vegetation, we employed various metrics including evenness, Margalef richness index, and the Simpson, Shannon, and Sorenson diversity indices. Results showed that there is significant difference in all investigated soil parameters between the skidding trails and the untrafficked areas (control) except skidding trail with 45 years. The 15-years skidding trail exhibited the highest bulk density (1.80 g cm^{-3}), while the 45-year skidding trail showed the lowest (1.46 g cm^{-3}). This suggests that after 45 years since the last skidding, the bulk density has decreased and is now comparable to that of the untrafficked control area. Also, we observe a higher diversity of species and genera in the control areas compared to the skidding trials.

Keywords

biodiversity, ecological restoration, skidding trail, soil characters

Introduction

The construction of roads and skidding trails in forested areas is vital for the effective management of forest ecosystems, as well as timber transportation, fire protection, and recreation (Akay et al., 2012). While road construction facilitates numerous human activities, it has also been identified as a significant contributor to forest degradation. Despite the advantages that forest road networks provide, their adverse effects due to forest fragmentation pose serious threats to the health and dynamics of forest ecosystems worldwide (Niu et al., 2018; Kartoolinejad et al., 2017). For instance, factors such as seed dispersal limitations, reduced relative humidity, and increased litter accumulation can hinder seed germination and seedling establishment (Naghdi et al., 2022).

Although the relationships between machinery trafficking and forest soil conditions have been extensively studied, further research is essential to determine the recovery potential of soils and the duration required for full ecological recovery (Ezzati et al., 2012; Kartoolinejad et al., 2017). One of the most significant negative impacts

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of logging trails is soil compaction, which alters various soil properties (Abukari et al., 2021). Skidding operations can adversely affect the physical, chemical, and biological characteristics of soil, as well as the populations of soil fauna and overall plant biodiversity (Kartoolinejad et al., 2013; Naghdi et al., 2016a).

The effects of soil compaction can persist for several decades, modified by factors such as soil texture, machinery type, and soil moisture content. Undisturbed forest soils typically exhibit high macro porosity and low bulk density, rendering them vulnerable to compaction from logging machinery (Lacey and Ryan, 2000, Ezzati et al., 2012). This compaction process involves the rearrangement and compression of soil particles, resulting in increased bulk density and decreased total porosity (Solgi and Najafi, 2014; Frey et al., 2009; Najafi et al., 2009). Such changes can negatively impact tree height, diameter, and overall volume growth (Tan et al., 2006; Zhao et al., 2010). During compaction, while solid particles remain unchanged in volume, their arrangement is disturbed, leading to detrimental modifications in soil characteristics. These changes include increased bulk density, heightened surface runoff and erosion, and decreased total porosity. The effects of these alterations can vary depending on the timing and conditions following skidding operations (Naghdi et al., 2016b; Soltanpour and Jourgholami, 2013).

Some studies have reported recovery of soil properties—including bulk density, fine root biomass, and macro-porosity—within 5 to 15 years following logging activities. Recent long-term chronosequence studies of skidding trails have indicated that while many soil properties have not fully recovered after 25 to 30 years, significant improvements over time suggest an ongoing recovery process (Dearmond et al., 2023).

Beyond their effects on soil properties, skidding trails significantly influence understory vegetation dynamics. Soil compaction induced by logging machinery restricts root development and plant establishment, while changes in microenvironmental conditions, particularly increased light availability, create favorable conditions for disturbance-adapted and non-native species. These combined effects drive shifts in species composition, reduce native plant diversity, and contribute to long-term degradation of forest ecosystem structure and function (Kartoolinejad et al., 2013).

The micro-site environment of skidding trails contrasts with that of the forest interior, influenced by factors such as canopy openings, loss of soil nutrients, increased compaction, and altered soil moisture conditions. These environmental changes likely account for the differences in ground flora observed in areas on and off skidding trails (Wei et al., 2015).

Richness and diversity have been extensively studied globally. For instance, Buckley et al. (2003) assessed the impacts of haul roads and skidding trails on understory vegetation richness and composition, reporting that understory plant richness was significantly greater in haul roads compared to skidding trails and forested areas.

Hyrcanian forests in the north of Iran are known for their cover, biodiversity and landscape in the world. The Hazarjarib forest, one of these forest areas, located in the Neka region of Mazandaran Province, has a rich history of forest management. This study investigated temporal changes in soil physical properties and vegetation characteristics along abandoned logging routes at 15, 25, 35, and 45 years following the cessation of logging activities. Soil bulk density, moisture content, saturation, and field capacity, as well as understory vegetation attributes, including biodiversity indices, were compared between skidding trails and adjacent undisturbed reference forest sites.

Materials and methods

Study area

The present study was conducted in one of the forest areas of the Hazarjarib region of Neka city (district three of Neka-Zalemroud), which is dominated by Caucasian alder (*Alnus subcordata* C.A. Mey). The study area has the same northern slope and is located at longitude 27°29′53″ to 40°28′53″ and latitude 48°30′36″ to 55°30′36″ and its height is 780 meters above sea level. The soil type of these areas is Cambisols (IUSS-Working Groups WRB, 2022) with clay-loam texture, and pH is near to neutral (7.1). Abandoned skidding trails (for 15, 25, 35 and 45 years past-skidding) are located in parcels 23, 26, 28 and 30 of series 4, respectively, and the approximate length of these trails was between 520 and 780 meters and their width was about 4 meters.

Understory soil and plant sampling

In order to carry out this research, four logging routes were selected, each of which had been out of wood extraction for 15, 25, 35, and 45 years, respectively. The main type of vegetation was *Alnus subcordata* C.A. Mey and had almost the same direction, slope, and height from the sea level. In order to measure the physical characteristics of the soil and understory cover in each logging route, three replicate plots (each plot covers an area of 1 m²) were used. Sampling proceeded as follows:

The first plot was chosen at random. The other samples were selected at intervals of at least 100 meters from the first sample plot. At each sampling interval, three samples were collected from distinct parts of the logging route. For each plot, a control sample plot (include three samples) was defined at a distance of 100 meters from the road edge, oriented toward the forest, and located farther from the road than the sampling points (Han et al., 2009).

An undisturbed forested control plot was selected from within the same geographic region as the experimental plots. Control point was established at a greater distance from the trail, at 100 m from the edge of the road toward the forest (Kartoolinejad et al., 2013; Ezzati et al., 2012). Each control plot was assessed for the absence of disturbance indicators (logging debris, soil compaction, skid trails, recent fire, and canopy disruption) and for similarity in vegetation structure (dominant species, stand density, and basal area). To measure the physical characteristics, soil samples were collected from a depth of 0–10 cm from each of the mentioned areas. A total of 36 samples were collected. On each skid trail, 9 samples were taken. Within each trail, the 9 samples were subdivided into three groups (three samples per group) and combined to form three composite samples. Samples from the control area were collected in the same manner, and using the same sampling method and sample size, as those obtained from the skidding trails. The composite samples were then transported to the laboratory for further analysis. Soil texture was determined based on particle size analysis using the Bouyoucos hydrometer method (Bouyoucos, 1962).

The samples were dried in the open air away from direct sunlight. The roots, stones and impurities were removed from the samples, grounded and passed through a 2 mm sieve. Then, in the laboratory, the physical properties of the soil (soil texture, bulk density, soil moisture, saturation and field capacity) were examined and determined for all soil samples. Bulk density (BD) was measured using the clod method (Blake and Hartge, 1986), moisture content was assessed through weighing and drying (Nielsen, 2009), the percentage of saturated soil moisture was determined using a standard gravimetric method. Saturated soil paste was prepared from sieved soil samples, followed by oven-drying at 110 °C for 24 h. The moisture content was calculated based on the mass difference before and after drying and expressed as a percentage of the dry soil weigh (Jamalzehi Samareh et al., 2024). Field capacity was determined using a pressure plate apparatus. Undisturbed soil samples were collected at each sampling point using cylindrical cores. The cores were saturated by submerging them in water for 24 h to ensure complete saturation. Subsequently, the saturated samples were placed in the pressure plate apparatus and subjected to the prescribed pressure to determine field capacity values (Mashayekhi, 2021).

To measure plant diversity, richness, and evenness indices along the skidding trails, we established 1 m^2 sampling plots (Fakhar and Keshtkar, 2020). Simpson's, Soreson and Shannon's biodiversity, Margalef's richness, Hill's evenness indices were calculated to compare the diversity status of understory plants in the abandoned skidding trails as well as control understory (Jafari et al., 2017; Ahmadi et al., 2018; Kartoolinejad et al., 2013). Past software was used to calculate biodiversity index. Figure 1 shows a view of the Control area and skidding trails of different ages.

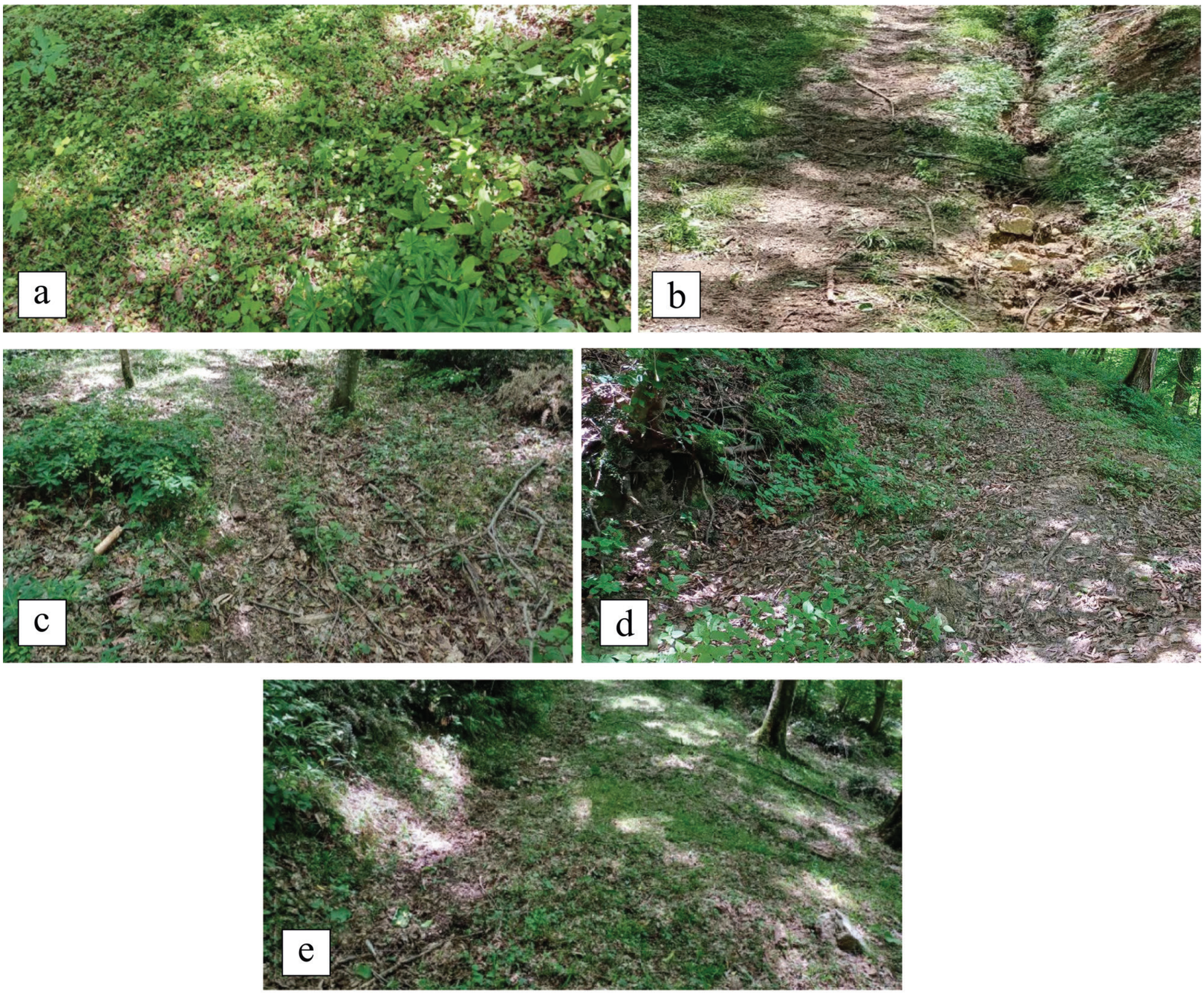

Fig. 1. Photography of understory plants from each skidding trail. Control site (Fig. a), skidding trail with 15-year ages (Fig. b), skidding trail with 25-year ages (Fig. c), skidding trail with 35-year ages (Fig. d), skidding trail with 45-year ages (Fig. e).

Data analysis

To compare different treatments (i.e., different ages of skid trails) in terms of soil properties and vegetation characteristics, a one-way analysis of variance (ANOVA) was applied. In addition, within each treatment, all soil and vegetation variables were compared with those of a nearby control area using an independent samples t-test. The statistical tests were conducted using SPSS 26 package. Table 1 shows the biodiversity measurement formulas that are used.

Results

Soil texture at depth of 0–10 cm is shown in Table 2. The range of particle size was < (0.002, 0.002–0.05 and 0.05–2.0) mm for clay, silt, and sand, respectively.

Table 1. Biodiversity measurement formulas

Biological factor	Indices	Formula
Biodiversity	Simpson	$D = 1 - (\sum n(n-1)) / (N(N-1))$
	Shannon Wiener	$H = -\sum P_i \operatorname{Ln} P_i$
	Sorensen	$S = 2C/S1 + S2$
Richness	Margalef	$R = (S-1)/\operatorname{Ln} N$
Evenness	Hill	$N1 = e^H$

D = Simpson's index of diversity, which measures the probability that two randomly selected individuals from a sample will belong to the same species (or a category other than species); R = Margalef index of species richness, which is a measure of species richness that accounts for the number of species in a community and the total number of individuals; n = the total number of organisms of a particular species; N = the total number of organisms of all species; pi = the proportion of individuals of each species belonging to the ith species of the total number of individuals; S = total number of species; S1 = total number of species in the community 1; S2 = total number of species in the community 1; C = number of shared species; H = the Shannon Wiener diversity index; *e* = natural logarithm.

Table 2. Soil particle distribution (%)

Soil texture	Sand	Clay	Silt
Clay loam	33	29	38

Table 3 shows the results of t-test analysis comparing soil characteristics between each skidding trails and their corresponding control samples. A significant difference was noted in all investigated parameters between the skidding trails and the untrafficked areas (control).

Comparison of the average bulk density (a), soil moisture (b), soil saturation (c) and field capacity (d) between the skidding trails and their untrafficked areas were shown in Fig. 2. The bulk density in the untrafficked areas ranged between 1.43 and 1.6 cm^{-3} and did not differ significantly between control sites. However, there were significant differences (*p*-value 0.00) between each skidding trail and its corresponding control area. For all four skidding trails except skidding trail with 45 years, the bulk density values were higher compared to their corresponding control areas.

Chart (b) illustrates the percentage of soil moisture for each skidding trail compared to its respective control area. As shown, there is a significant difference in the percentage of moisture between the control sample and the skidding trail in all four routes. Chart (c) depicts the comparison of the average percentage of saturated soil moisture in the skidding trails and their respective control samples, revealing a significant difference in all routes under investigation except skidding trail abandoned 45 years ago.

As seen in Table 4 there is a significant difference between bulk density in four skidding routes. The skidding trail with an age of 15 years old had the highest bulk density (1.80 g cm^{-3}), while the skidding trail with an age of 45 years old had the lowest bulk density (1.46 g cm^{-3}) (Table 5).

Table 6 displays the most significant understory plant species based on the age of the logging routes. It is evident that the number of grass species in the surveyed plots along each skidding trail is notably lower compared to the control area.

Table 7 shows the results of the t-test between the biodiversity indices of each skidding trial and its control area. The table highlights significant differences in most indicators among the four skidding trails. Average biodiversity factor comparisons to their respective control areas are shown in Fig. 3. The Richness, Simpson, and Shannon indices all showed higher values in the control areas. How

Table 3. The results of the T-test between the soil characteristics of each Skidding trial and its control area

Skidding trail ages		Bulk density	Soil moisture	Soil saturates	Field capacity
15 years post skidding	Student-t	–4.8	3.03	3.24	14.98
	df	4	4	4	4
	F	0.00**	1.9 *	2.02*	0.5**
25 years post skidding	Student-t	–5	3.07	3.21	2.62
	df	4	4	4	4
	F	0.4**	4.65 *	4.65 *	0.6 *
35 years post skidding	Student-t	–3.57	1.24	1.70	3.78
	df	4	4	4	4
	F	3.2**	0.56*	0.13**	3.4 **
45 years post skidding	Student-t	–1	2.7	1.5	0.68
	df	4	4	4	4
	F	0.4 n	0.25**	0.00 n	0.34 n

**: significant difference in 0.01 level, *: significant difference in 0.05 level, n: not significant.

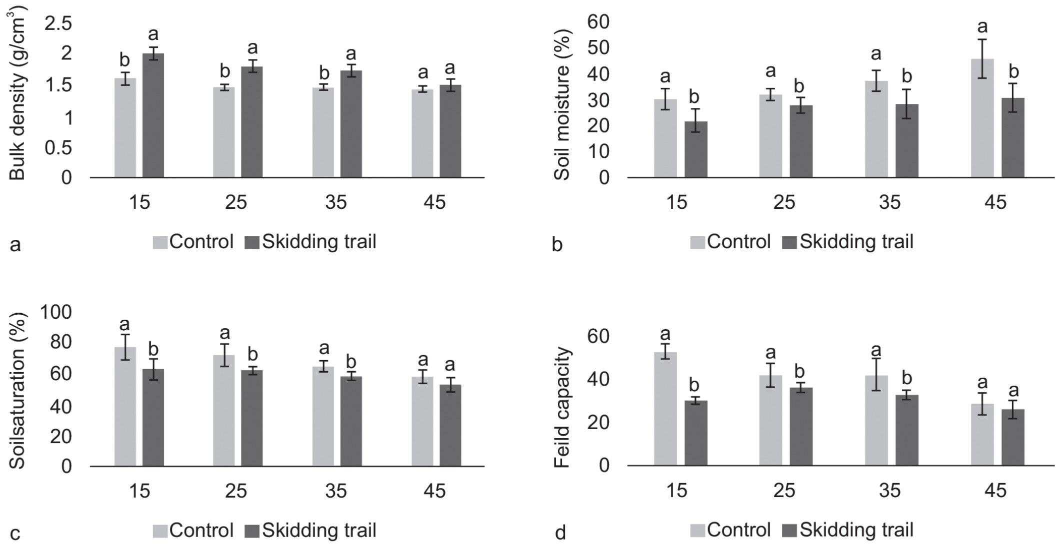

Fig. 2. Comparison of the average bulk density(a), soil moisture (b), soil saturation (c) and field capacity (d) in each skidding trail and control area along with SD.

Table 4. Analysis of the variance of soil properties in the studied skidding trails

	Bulk density	Soil moisture	Saturation	Field capacity
Treatment	0.11	187.93	176.11	208.04
Error	0.42	1.57	1.50	1.73
Coefficient variation	0.12	0.24	0.11	0.23
Significant	0.03*	0.01*	0.02*	0.00**

**: significant difference in 0.01 level, *: significant difference in 0.05 level.

Table 5. Compares the mean and standard deviation of soil characteristics between the studied skidding trails

Skidding trail ages	Bulk density (g cm^{-3})	Soil moisture (%)	Saturation (%)	Field capacity (%)
15 years post skidding	1.80 ± 0.23a*	25.16 ± 4.19b*	68.33 ± 8.61a*	40.83±5.75a**
25 years post skidding	1.63 ± 0.19ab*	30.0 ± 2.52b**	66.16 ± 5.74a*	39.33±3.82a*
35 years post skidding	1.60 ± 0.16ab*	33.16 ± 5.19ab**	62.16 ± 3.65ab*	36.33±5.92ab**
45 years post skidding	1.46 ± 0.08b*	38.5 ± 5.13a**	56.0 ± 4.57b*	27.66±4.50b**

**: significant difference in 0.01 level; *: significant difference in 0.05 level.

Table 6. The list of the most important grass species. Relative abundance percentage by the age of the skidding road

	Years post skidding							
	15		25		35		45	
	Skidding trail	Control	Skidding trail	Control	Skidding trail	Control	Skidding trail	Control
Oplismenus undulatifolius (Ard.) P.Beauv.	52	39.13	32.60	35.43	44.87	14.85	27	28.92
Prunella vulgaris L.	5.2	4.34	10.86	0.78	1.28	0.99	1.35	4.13
Viola odorata L.	5.2	17.39	10.86	15.74	6.41	19.8	13.51	16.52
Euphorbia amygdaloides L.	0	4.34	21.73	9.44	19.23	17.82	20.27	16.52
Rubus Hyrcanus Juz.	26.31	0.86	10.86	0.78	12.82	4.95	20.27	4.13
Cyclamen coum Mill.	0	0.86	2.17	3.93	0	4.95	0	4.13
Pteris cretica L.	0	8.69	2.17	11.81	6.41	9.9	6.75	8.26
Fragaria vesca L.	0	0.86	2.17	0.78	1.28	0.99	1.35	0
Dryopteris filix-mass J.P.R	0	0.86	2.17	3.93	0	4.95	0	0.82
Festuca drymeia L.	5.2	4.34	2.17	0.78	6.41	0.99	1.35	0
Ruscus Hyrcanus Woronow	0	17.39	0	15.74	0	19.8	6.75	16.52
Lamium album L.	5.2	0.86	2.17	0.78	1.28	0	1.35	0

Table 7. The results of the t-test between the biodiversity indices of each skidding trial and its control area

Skidding trail ages		Richness	Evenness	Simpson	Shannon	Sorenson
15 years post skidding	Student-t	1.37	–2.9	2.9	3.71	0.85
	df	4	4	4	4	4
	F	0.68*	0.00*	0.00*	0.78*	0.6[n]
25 years post skidding	Student-t	1.59	–3.24	3.04	2.97	0.83
	df	4	4	4	4	4
	F	0.05*	0.00*	1.32*	0.73*	0.00[n]
35 years post skidding	Student-t	1.75	–3.12	2.91	5.6	1
	df	4	4	4	4	4
	F	0.18[n]	0.5*	0.34*	4.08**	0.09[n]
45 years post skidding	Student-t	3.9	–3.2	2.58	8.37	0.92
	df	4	4	4	4	4
	F	0.08[n]	0.07*	0.25[n]	0.09**	0.24[n]

:** significant difference in 0.01 level, *: significant difference in 0.05 level, n: not significant.

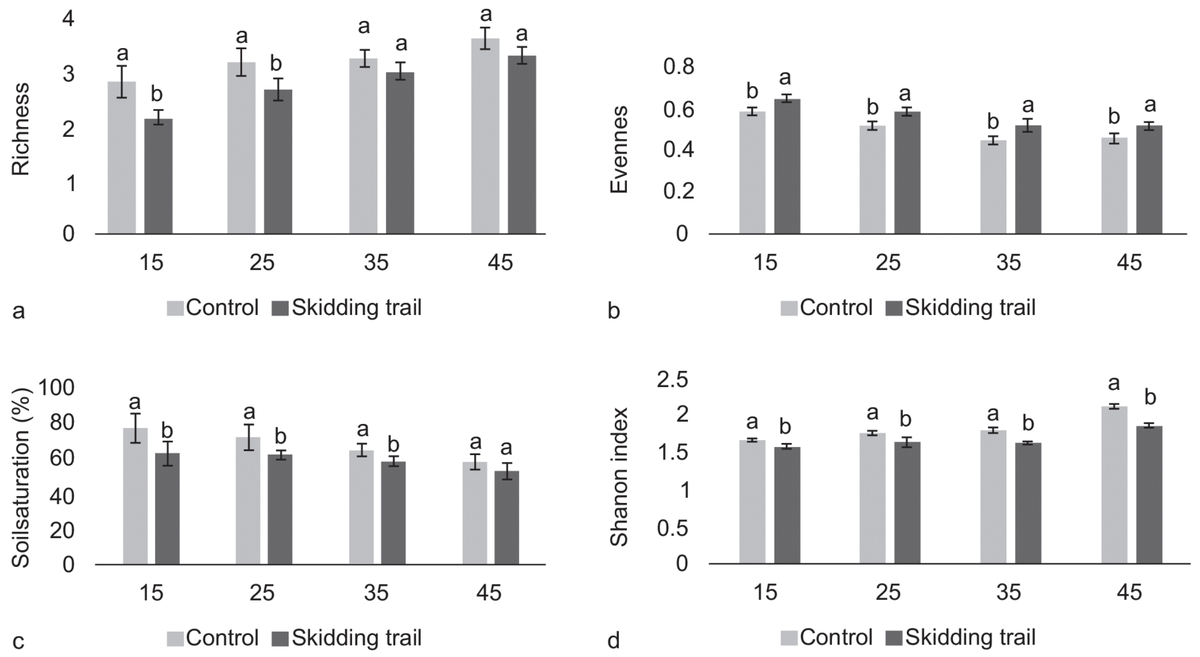

Fig 3. Comparison of mean of species richness (a), evenness (b), Simpson (c) and Shannon indices (d) in the skidding trials and control along with SD.

Table 8. Analysis variance of biodiversity indices in the skidding trails

	Richness	Evenness	Simpson	Shannon	Sorenson
Treatments	0.44	0.025	0.026	0.168	725.50
Error	0.71	0.013	0.014	0.035	2.50
Coefficient variation	0.11	0.11	0.10	0.09	0.24
Significance	0.00**	0.00**	0.00**	0.00**	0.00**

:** significant difference in 0.01 level, *: significant difference in 0.05 level, n: not significant.

Table 9. Mean comparison of biodiversity indices in the skidding trails (Mean ± Standard deviation)

Skidding trail ages	Biodiversity indices				
	Richness	Evenness	Simpson	Shannon	Sorenson
15 years post skidding	2.6 ± 0.25b**	0.63 ± 0.03a**	0.63 ± 0.02c**	1.62 ± 0.05b**	41.83 ± 6.99b**
25 years post skidding	3.01 ± 0.26a**	0.56 ± 0.04b**	0.70 ± 0.05b**	1.70 ± 0.07b**	44.33 ± 8.54b**
35 years post skidding	3.11 ± 0.19a**	0.49 ± 0.04c**	0.72 ± 0.03b**	1.72 ± 0.1b**	49.83 ± 9.1b**
45 years post skidding	3.31 ± 0.34a**	0.49 ± 0.03c**	0.79 ± 0.04a**	2.00 ± 0.1a**	66.33 ± 5.24a**

:** significant difference in 0.01 level, *: significant difference in 0.05 level, n: not significant.

ever, contrary to this expectation, the evenness index was higher in the investigated areas than in the control areas. The Sorenson index, however, showed no significant difference between the control and investigated areas.

Table 8 presents the analysis of variance comparing vegetation indices across different skidding trails. All studied indicators revealed significant differences among the four investigated routes. The mean comparison of biodiversity indices in the skidding trails is shown in Table 9.

Table 9 shows the average comparison of the studied indicators for each logging route in relation to the control area. There is a significant difference between the logging routes and the control area, particularly in the early years. As the age of the road increases since the last logging, the difference in indicators compared to the control area gradually decreases.

Discussion

The results of the current study indicate that the bulk density of the skidding trail is significantly higher than that of the control area. Naghdi et al., (2020) indicated that the movement of skidders on forest roads results in an increase in bulk density. Soil compaction significantly reduces soil porosity and permeability by decreasing the pore spaces between soil particles, which limits water infiltration and increases surface runoff and erosion (Zemke et al., 2019; Mara et al., 2022). Because soil porosity is inversely related to bulk density, compaction-induced increases in bulk density further contribute to the reduction of pore space (Ezzati et al., 2012; Lotfalian and Parsakho, 2019). In this research, the 15-years skidding trail exhibited the highest bulk density (1.80 g cm^{-3}), while the 45-year skidding trail showed the lowest (1.46 g cm^{-3}). This result illustrates that after 45 years since the last skidding, the bulk density has decreased and is now comparable to that of the untrafficked control area. Also, Dearmond et al. (2023) found that, despite 27 years passing since the last skidding, the bulk density in skidding trials (1.23 g cm^{-3}) significantly differed from that in the control area (1.05 g cm^{-3}). However, the results indicated a decreasing trend in bulk density compared with measurements from previous sampling years. Similarly, Ezzati et al. (2012) reported that 20 years after logging operations in the Mazandaran forests under low-intensity traffic, soil bulk density had partially recovered but remained approximately 12% higher than that of the control area. These findings are consistent with the results of the present study. Also, these findings are consistent with those of Salehi et al., (2012), who reported significant differences in soil bulk density between skidding trails and control areas.

Skidding trails can compact the soil, disrupt natural water flow patterns, and increase erosion, which can lead to changes in soil humidity and saturation levels. The results of this study indicate that soil moisture in abandoned skidding trails tends to be lower than in forested areas, primarily due to increased exposure to sunlight, which enhances evaporation. In addition, skidding activities reduce tree cover, allowing greater solar radiation to reach the soil surface and further contributing to soil moisture loss. The results of the ANOVA and Duncan tests for the four skidding trails are presented in Table 4. During the initial period following skidding (first 15 years), soil properties were significantly altered, showing marked differences compared to the control area. Over time, however, soil characteristics exhibited a gradual recovery as the skidding trails aged. In the present study, all soil variables remained significantly different from the control area up to 35 years after the last skidding operation. In contrast, after 45 years, no significant differences were observed for most soil properties, with the exception of soil moisture, which remained significantly lower than the control area.

In ecology, diversity indices are key parameters for characterizing a stand (Mounmemi et al., 2023). We observe a higher diversity of species and genera in the control areas compared to the skidding trials. Behjou (2017) also demonstrated that the proportion of forest floor vegetation in control areas was significantly greater than in areas impacted by skidder traffic. Presence of shade-intolerant species, such as *Rubus hyrcanus*, was significantly higher in skidding trial areas compared to control sites. This observation suggests that these species can notably affect the distribution and abundance of certain plants during forestry operations. It is crucial to consider the impacts of non-shade-tolerant species when planning and executing forestry activities to mitigate their effects on the surrounding ecosystem. Buckley et al. (2003) illustrated that skidding trails serve as primary conduits for the dispersal of introduced species into the managed stands and contribute to significant shift in plant richness and composition at the stand level. Not only native species can profit from the newly created habitat. Many studies also found exotic species favoured by the rather high disturbance levels and hence higher illumination rates (Mercier et al., 2019). Awareness and management strategies are necessary to preserve biodiversity and maintain ecological balance in these areas. In contrast, the abundance of shade-friendly perennial plants such as *Viola odorata*, *Pteris cretica*, and *Ruscus hyrcanus* is noticeably lower in the skidding trials compared to control areas, as indicated in Table 6. Instead, the presence of species such as *Rubus hyrcanus*, a marker of forest disturbance, is more frequent along logging routes. Babaei Ahmadabad et al. (2023) demonstrated that the abundance of *Viola* sp. in the control plots exceeded that of skidding trails. In Table 6, all study periods showed a higher proportion of this species in the control area than in logging route plots. The presence of both *Oplismenus undulatifolius* and *Euphorbia amygdaloides* on the logging routes and within the forest area signals the forest degradation. Furthermore, the continued proliferation of E*uphorbia amygdaloides* suggests a worsening situation, indicating a decline in the overall health of the forest.

Conclusions

The results of this study demonstrate that skidding operations have long-lasting effects on soil physical properties and understory vegetation in the Hazarjarib forest. Soil bulk density, moisture, saturation, and field capacity were significantly altered in skidding trails up to 35 years after logging compared to untrafficked control areas, indicating prolonged soil disturbance. However, after 45 years, most soil physical properties, particularly bulk density, had recovered to levels comparable with the control area, suggesting a slow but measurable process of soil recovery over time. In contrast, understory vegetation richness and diversity remained lower in skidding trails than in adjacent forested areas, highlighting a delayed biological recovery relative to soil physical properties. These findings underscore the long-term ecological impacts of skidding trails and emphasize the importance of implementing sustainable forest management practices to minimize soil compaction and promote vegetation recovery.

Declarations

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

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