



## Evaluation of the Lack of Implementation of Maintenance Operations on Forest Road Pavements

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### Abstract

The cost of maintaining forest roads is an important factor in forest management and is related to pavement deterioration and the identification of factors affecting the pavement. The aim of this study was to evaluate the deterioration of forest road pavements over a four-year period in watershed 25 of Shenroud in Guilan Province. For this purpose, 213 sample plots were selected through systematic random sampling and measured. In each sample plot, the pavement deterioration index was measured based on seven indicators: deteriorated cross-section, deteriorated drainage, dust production, corrugation, potholes, ruts, and soil mass loss. Friedman test, analysis of variance, and Duncan's test were used to analyze the data. The results showed that over time, deterioration caused by cross-section, roadside drainage, dust production, corrugation, and soil mass loss increased, and there was a statistically significant difference between the beginning and the end of the study period. The mean depth (from 4.57 to 4.77 cm), area (from 4.44 to 4.50 cm<sup>2</sup>), and number of potholes (from 1.23 to 2.20), as well as the mean depth (from 1.95 to 2.00 cm), area (from 1.22 to 1.24 cm<sup>2</sup>), and number of ruts (from 0.43 to 0.45), showed an increasing trend. The statistical results showed that there was a significant difference between the number of potholes in different years, while there was no significant difference among pothole area and depth or rut area, depth, and number across the different study periods. The results of Duncan's mean comparison test also showed that there was a significant difference between the average number of potholes created at the end of the study period (2023) and at the beginning of the period (2020). In general, the results of this study show the importance of carrying out continuous maintenance operations and the need to use evaluation indicators in planning forest road pavement maintenance.

**Keywords:** Deterioration index, Forest road, Maintenance operations, Road construction.

### 1. Introduction

The growth and development of natural resources and the implementation of conservation programs are directly related to the development of forest roads and the ease of access to the interior of forests, especially in mountainous areas. Therefore, road construction is essential for the management and optimal use of forest services. The construction of forest roads to access forests in order to utilize their various services, implement conservation operations, and transport wood and non-wood products is a fundamental need and plays a special role in the national income of the country (Salmalian et al., 2016; Deljouei et al., 2017;

Lotfalian et al., 2018). One of the most important structural components of a road is the pavement layer, which plays an important role in the load-bearing capacity and trafficability of the road. The pavement of forest roads is a valuable asset in forest management, for which large sums are spent annually on repair and maintenance. Therefore, the pavement layer of forest roads must be managed in such a way that it can be used at an acceptable level over time while maintaining its efficiency (Visser et al., 2009). Maintenance and repair operations, if carried out in a timely manner and with the appropriate maintenance method, not only delay road deterioration, but also reduce vehicle operating

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costs and keep the road continuously open by improving the quality of the road surface (Grigolato et al., 2013). Pavement evaluation is part of pavement management, which has recently received a great deal of attention. A pavement management system includes a complete and coordinated set of activities in the fields of planning, design, construction, maintenance, evaluation, rehabilitation, reconstruction, and pavement research (Johnson et al., 2014). Since the conditions prevailing on forest roads (mountainous terrain, steeper slopes, lower design speeds, transportation role, access role, and social role) are different from those on non-forest roads, their maintenance and repair management depends more on human and visual factors. Therefore, techniques and indicators that can model pavement performance, deterioration trends, and warning levels more cheaply and quickly have been developed (Niu, 2013). Usually, due to budget constraints, it is not possible to repair and rebuild all parts of the roads simultaneously, so the sections that are prioritized and have economic and technical importance should be selected. While in leading countries in natural resource management, the condition of existing roads is continuously monitored using accepted international quality control indicators, and prompt action is taken for their proper repair, unfortunately, in the current situation of forest management in Iran, the implementation of the so-called "rest plan" in recent years has led to the abandonment of forest roads, this vast capital for which huge costs have been paid for construction, and the necessary measures for their repair and maintenance have not been taken.

One of the most important indicators for examining pavement condition on public roads, and to some extent on gravel roads, is the Pavement Condition Index (PCI), which was proposed by the United States Army Engineering Group and has been developed to classify the degree of pavement deterioration. Due to its very high flexibility, low cost, and high accuracy, PCI is used on public roads. Eaton et al. (1987) used PCI to examine gravel roads connected to urban roads in America and renamed the index the Urban Gravel Road Condition Index (URCI). The characteristics they examined were potholes, ruts, road dust, corrugation, and soil mass loss, but road drainage condition was not considered in this index, and as a result, the index lost its

efficiency. Heidari et al. (2017) investigated the application of the genetic algorithm technique in identifying the warning level of forest road pavement and planning pavement repair and maintenance. The results showed that the most appropriate warning level for heaving was 5 cm and for rutting was 10 cm. Ghajar et al. (2019) examined the effect of tree shading on pavement deterioration indicators of forest roads (deteriorated cross-section, deteriorated drainage, corrugation, dust production, potholes, ruts, and soil mass loss) in watershed 10 of Chafrud in Guilan, and the results showed that deterioration caused by the mentioned indicators was greater in the shaded area than in the non-shaded area. Ghavidel et al. (2021) evaluated pavement deterioration of forest roads at curves in the Shanderman forests of Guilan Province and showed that the severity of deterioration caused by deteriorated roadside drainage and deteriorated cross-section, as well as the depth and area of potholes and ruts, and soil mass loss at the curves, were greater than in adjacent sections, and there was a statistically significant difference between the curves and the adjacent sections. Rezaei Motlagh et al. (2023) evaluated the characteristics of forest road surface potholes using UAV images, and the results of the study demonstrated that the orthomosaic images generated from photogrammetric calculations exhibited high accuracy, providing a reliable basis for further analysis, and all three algorithms displayed strong capabilities in identifying road surface damage. Parsakhoo et al. (2024) studied the impacts of forestry project suspensions on forest road network conditions in the forests of Golestan Province, and the results of UPCI analysis showed that the second- and third-class roads degraded to poor condition (UPCI: 3.9 and 2.9, respectively), while first-class roads remained in good condition (UPCI: 6.29), whereas second- and third-class roads (UPCI: 4.23 and 3.97) declined to fair condition (UPCI = 5.23). The most important perspective on forest roads is their use for forest harvesting operations and timber extraction. For this reason, in forest management policymaking, the preservation and maintenance of these roads is unclear, and sometimes, due to lack of sufficient budget, these operations are not feasible. However, forest roads are used not only for timber transportation, but also for implementing conservation and silvicultural programs, ecotourism, wildfire management and control,

and access to villages within the forest. Therefore, having a perspective solely dependent on forest exploitation regarding forest roads and ignoring these linear structures as a fundamental infrastructure for forest management leads to their deterioration and makes them unusable. Therefore, for the implementation of these broader objectives, monitoring these roads and carrying out repair and maintenance operations under any circumstances is essential and will reduce or eliminate reconstruction and rehabilitation costs. The aim of this research is to evaluate the types of pavement deterioration of secondary forest roads over a four-year period (from 2020 to 2023) based on the PCI index in the Shenroud forests of Guilan Province. Conducting the present research is very important considering the existence of kilometers of forest roads in the north of the country and the high annual maintenance and repair costs of these roads. Moreover, in recent years, the existence of financial constraints and economic bottlenecks in the management of the northern forests of the country has doubled the importance of using the above-mentioned indicators.

## 2. Materials and Methods

### 2.1. Study Area

The study area is District No. 7 of the Shenroud Watershed 25, located 15 kilometers south of Siahkal City in the eastern part of Guilan Province. This district is managed by Lahijan Forestry under the supervision of the Guilan Provincial Department of Natural Resources (Figure 1). The area is located between 49°50' and 49°57' east longitude and 37°10' and 37°36' north latitude. In the study area, there are 27.23 km of second-class forest roads, of which 12.13 km were built between 1991 and 1995 and 15.1 km were built between 2009 and 2012. Based on the available information, protection, repair, and maintenance operations on forest roads were carried out continuously every year, and the last repair and maintenance operation on this type of road was conducted in 2017, before the implementation of the forest rest plan. According to the available data from the Lahijan climatological station, the average annual precipitation is 1264.5 mm and the average annual temperature is 16°C. The study area has a semi-humid temperate climate (Teifsaz Sabz Corporation, 2015).

### 2.2. Method

In this research, a 27.23 km secondary forest road was selected. Systematic random sampling was used to measure the sample plots. In this method, the starting point for each plot was selected randomly, and the sample points were laid out at 100-meter intervals along the road network. The spatial location of the center of each sample plot was recorded using a global positioning system device. The pavement characteristics were recorded over a four-year period from 2020 to 2023. The length of each sample was 10 meters (5 meters upstream and 5 meters downstream of the road), and the width was equal to the road right-of-way. The longitudinal slope of the road in the sampled plots was the same (less than 5%).

For each sample plot, seven types of deterioration were measured according to the Pavement Condition Index (PCI), including: 1) deteriorated cross-section in three classes: low (small potholes or evidence of them on the road surface, or a completely flat road surface), medium (medium-sized potholes or evidence of them on the road surface, or a bowl-shaped road surface), and high (large potholes or evidence of them on the road surface, or large depressions on the road surface); 2) improper condition of roadside ditches in three classes: low (small potholes or evidence of them in the ditches, or vegetation or debris in the ditches), medium (medium-sized potholes or evidence of them in the roadside ditches, or vegetation or debris in the ditches, or ditch erosion reaching the shoulder or road surface), and high (large potholes or evidence of them in the roadside ditches, or water flowing from the ditches onto the road width or surface, or vegetation or debris in the ditches, or ditch erosion reaching the shoulder or road surface); 3) soil mass loss in three classes: low (loose particles on the road surface, or a narrow embankment less than 5 cm deep on the shoulders or less-trafficked areas), medium (a medium embankment 5 to 10 cm deep on the shoulders or less-trafficked areas; a large amount of fine particles is usually found on the road surface), and high (a large embankment more than 10 cm deep on the shoulders or less-trafficked areas); 4) corrugation; 5) potholes (depth, area, and number); 6) ruts (depth, area, and number); and 7) dust. For dust measurement, a car traveled at a speed of 40 km/h and the dust cloud was observed. Dust

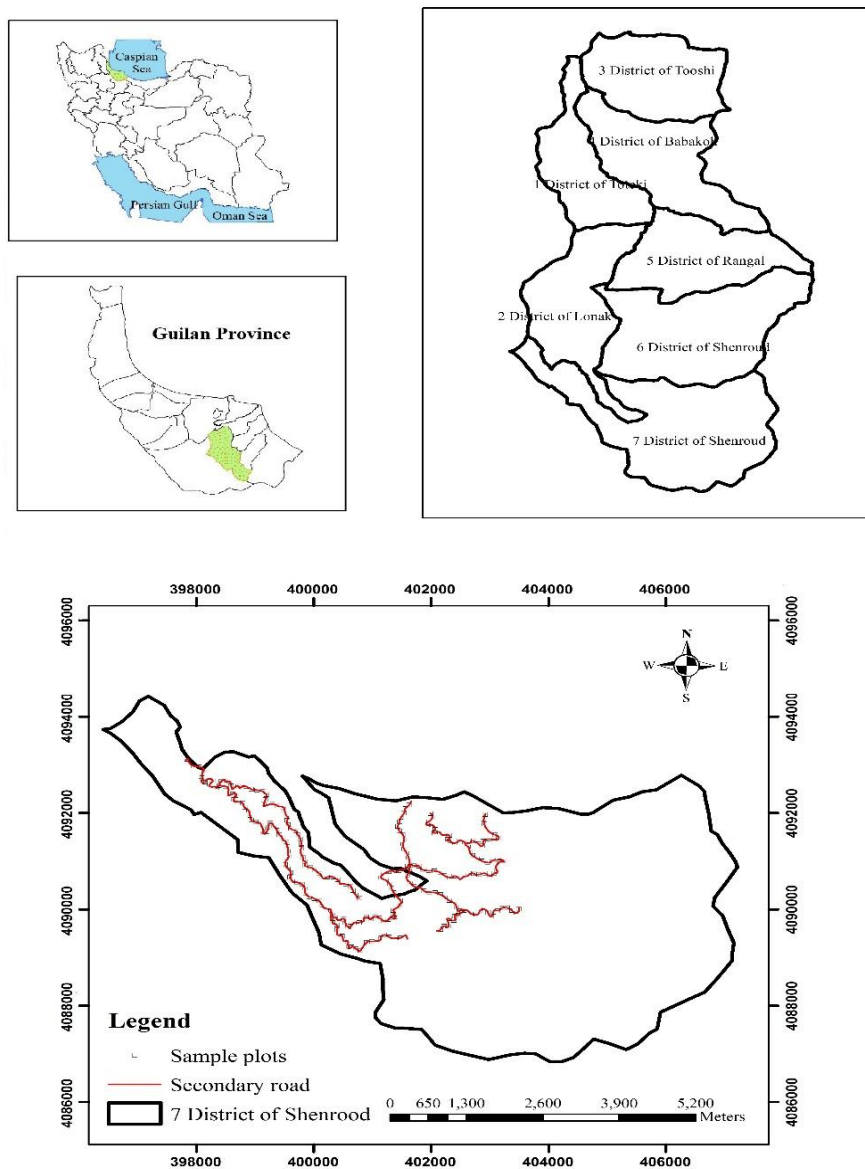


Figure 1. Location of study area

was measured in three classes: low (normal traffic creates a light dust cloud that does not obstruct visibility), medium (normal traffic creates a relatively heavy cloud that locally obstructs visibility and reduces traffic speed), and high (normal traffic creates a very heavy cloud that significantly reduces visibility and causes a reduction in traffic speed or vehicle stoppages) (Eaton et al., 1987; Ghajar et al., 2019). The Kolmogorov-Smirnov test was used to investigate the normality of the quantitative data. To compare the types of deterioration examined in different years, ANOVA and Friedman tests were used for quantitative and qualitative data, respectively. Duncan's test was also used to compare the means of the

quantitative data. All statistical analyses were performed using IBM SPSS Statistics version 22 software, and all graphs were plotted using Excel 2013 software.

### 3. Results

The results of examining the deteriorated cross-section and drainage variables during the study period showed that, over time, the deterioration of these two characteristics increased (Table 1). The Friedman test results also showed that the deterioration of the cross-section and roadside drainage variables was significant over the four-year period (2020 to 2023), and the results are presented in Table 2.

**Table 1.** Mean rank of deteriorated cross-section and drainage variables in different years

Variable	Mean rank in Friedman's test in different years			
	2020	2021	2022	2023
Deteriorated cross-section	1.48	2.29	3.01	3.22
Deteriorated drainage	1.62	2.27	2.94	3.16

**Table 2.** Friedman test results of deteriorated cross-section and drainage variables in different years

Variable	No. of samples	Chi-square	d.f.	Sig.
Deteriorated cross-section	213	401.56	3	0.00
Deteriorated drainage	213	350.70	3	0.00

The results for the corrugation and soil mass loss variables showed that the deterioration of these characteristics increased over time, as presented in Table 3. The results for the dust production variable also showed that from 2020 to 2022, the deterioration due to dust production did not change, but by the end of the period, the level of deterioration increased (Table 3). Statistically, the Friedman test showed a significant difference in the level of deterioration for corrugation, dust production, and soil mass loss over the four-year period (2020 to 2023), and the results are presented in Table 4.

The results for the deterioration indices of pothole area, rut area, rut depth, and rut number showed that the mean values of these indices remained constant from 2020 to 2022, but increased in 2023 (the end of the study period). The results for pothole depth and

pothole number showed that the mean values of these deterioration indices increased over time, from the beginning to the end of the study period (Table 5).

The results of the ANOVA test for the deterioration indices of pothole and rut area, depth, and number in different years are presented in Table 6. According to the results, there was a significant difference in the pothole number index between different years, while there was no significant difference in the deterioration indices of pothole area and depth, or rut area, depth, and number, during the study period. Duncan's mean comparison test also showed a significant difference between the mean pothole number deterioration index in the last year of the study period (2023) and those in the initial years of the study (2020 and 2021), and the results are presented in Figure 2.

**Table 3.** Mean rank of corrugation, dust production, and soil mass loss variables in different years

Variable	Mean rank in Friedman's test in different years			
	2020	2021	2022	2023
Corrugation	2.08	2.26	2.46	3.20
Dust production	2.48	2.48	2.48	2.55
Soil mass loss	2.38	2.41	2.44	2.77

**Table 4.** Friedman test results of corrugation, dust production, and soil mass loss variables in different years

Variable	No. of samples	Chi-square	d.f.	Sig.
Corrugation	213	260.34	3	0.00
Dust production	213	21.00	3	0.00
Soil mass loss	213	104.81	3	0.00

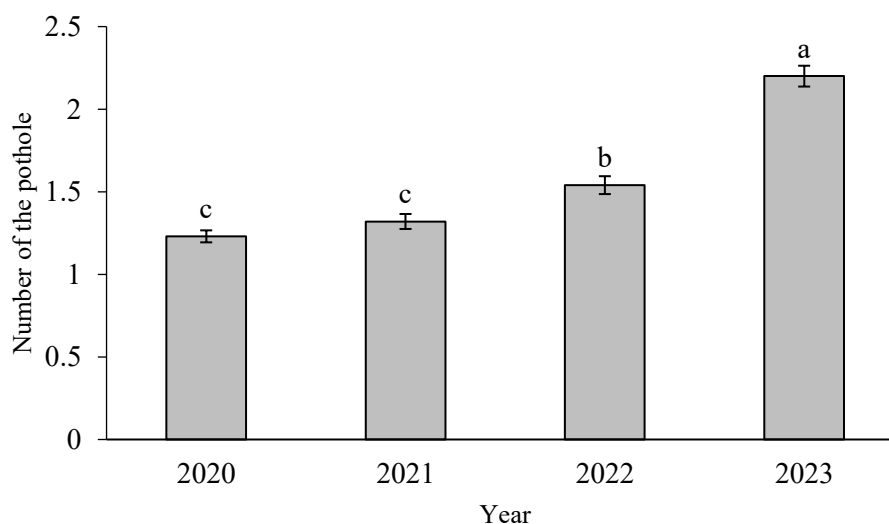
**Table 5.** Mean  $\pm$  standard deviation of pothole and rut area, depth, and number in different years

Deterioration index	Different years			
	2020	2021	2022	2023
Area of the pothole	4.44 $\pm$ 2.46	4.44 $\pm$ 2.46	4.44 $\pm$ 2.46	4.50 $\pm$ 2.46
Depth of the pothole	4.57 $\pm$ 3.98	4.61 $\pm$ 3.95	4.67 $\pm$ 3.91	4.77 $\pm$ 3.87
Number of the pothole	1.23 $\pm$ 0.53	1.32 $\pm$ 0.66	1.54 $\pm$ 0.79	2.20 $\pm$ 0.92
Area of the rut	1.22 $\pm$ 2.23	1.22 $\pm$ 2.23	1.22 $\pm$ 2.23	1.24 $\pm$ 2.25
Depth of the rut	1.95 $\pm$ 2.69	1.95 $\pm$ 2.69	1.95 $\pm$ 2.69	2.00 $\pm$ 2.76
Number of the rut	0.43 $\pm$ 0.49	0.43 $\pm$ 0.49	0.43 $\pm$ 0.49	0.45 $\pm$ 0.53

**Table 6.** ANOVA test on the deterioration indices of pothole and rut area, depth, and number in different years

Deterioration index	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Area of the pothole	Between Groups	0.642	3	0.214	0.035	0.991 <sup>ns</sup>
	Within Groups	5144.246	848	6.066		
	Total	5144.887	851			
Depth of the pothole	Between Groups	4.912	3	1.637	0.106	0.957 <sup>ns</sup>
	Within Groups	13128.296	848	15.481		
	Total	13133.208	851			
Number of the pothole	Between Groups	123.427	3	41.142	73.845	0.000*
	Within Groups	472.460	848	0.557		
	Total	595.887	851			
Area of the rut	Between Groups	0.085	3	0.028	0.006	0.999 <sup>ns</sup>
	Within Groups	4237.108	848	4.997		
	Total	4237.193	851			
Depth of the rut	Between Groups	0.550	3	0.183	0.025	0.995 <sup>ns</sup>
	Within Groups	6240.038	848	7.359		
	Total	6240.589	851			
Number of the rut	Between Groups	0.056	3	0.019	0.073	0.974 <sup>ns</sup>
	Within Groups	218.009	848	0.257		
	Total	218.066	851			

\* Significant difference at the probability level of 0.05 and ns no significant difference at the probability level of 0.05

**Figure 2.** Comparison of mean pothole number in different years

#### 4. Discussion

Forest roads are generally located in heterogeneous environmental, biological, and climatic conditions; therefore, the probability of deterioration and blockage of these roads is high. On the other hand, due to the urgent need to implement forestry plans on these linear structures and the high costs of their construction, their annual and periodic maintenance and protection are essential. However, due to the implementation of the forest respiration plan, the annual and periodic maintenance and protection operations of these roads are not carried out. In the present study, the pavement condition index of secondary forest roads in District No. 7 of the 25 Shenroud

Watershed forests of Guilan Province was investigated over a four-year period. The results showed that, over time, the deterioration of the cross-section and drainage characteristics increased compared with the beginning of the study period, and there was a statistically significant difference between the beginning and the end of the period. The results for these two deterioration characteristics, which indicate their alignment, show that more materials were removed from the road surface and accumulated in the side ditches. Hosseini et al. (2012) and Lotfalian et al. (2013) stated that the quality of road pavement and, consequently, the quality of drainage are effective factors influencing the amount of sediment produced by forest roads.

The results of the present study showed that most of the sample plots had deteriorated drainage, and the deterioration of the road cross-section led to changes in the geometric characteristics of the side ditches and even to their disappearance. Parsakhoo et al. (2009) stated that the passage of heavy logging machinery causes changes in the shape of the cut and fill slopes. On the other hand, the friction of timber transport truck wheels on the road surface in steeper areas increases pavement deterioration (Jafari et al., 2015). Also, on roads with slopes close to zero, potholes are formed due to the accumulation of water on the pavement surface, inadequate cross-drainage, deformation of the crown, and other factors (Ouma et al., 2015). A comparison of the pavement condition with roads in the Kalibar watershed area of the Arasbaran region, which was the subject of the study by Talebi et al. (2015), showed that about 19.25% of the road length was free of pavement defects, whereas in the present study, most of the sampled plots had pavement defects (deteriorated cross-section and drainage).

The results for the dust production index showed that in the first three years of the study period, the level of deterioration due to this index did not change, but in the last year of the study period, the level of deterioration increased, and a statistically significant difference was observed. The results for corrugation and soil mass loss also showed that, over time, the level of deterioration of these characteristics increased, and a statistically significant difference was observed between the beginning and the end of the period. Dust is generated due to wheel impact, loosening of particles, and then the suction created during wheel passage (lifting of particles). This phenomenon becomes more pronounced depending on soil dryness and traffic density, and it disrupts soil texture in terms of grading and strength. Ghajar et al. (2019), in the forests of the Chafrud 10 watershed, showed that the higher dust production in the non-shaded section could be due to the faster drying of the road surface in this section, which, on the one hand, provides conditions for greater dust production and, on the other hand, does not allow sufficient time for pavement surface disruption, rut formation, or movement of particles to the sides of the road. In the present study, the amount and

intensity of dust production increased over time. One reason for this may be the lack of annual road maintenance and protection operations, which leads to soil discontinuity and the separation of finer particles. If road maintenance operations are carried out on time and the appropriate maintenance method is selected, in addition to delaying road deterioration, they will also reduce vehicle operating costs and keep the road continuously open by improving road surface quality (Grigolato et al., 2013). In other studies, Parsakhoo et al. (2024) showed that, as a result of the implementation of the forest rest plan, the condition of the pavement of second-class forest roads in the Golestan forests has deteriorated, which is consistent with the results of the present study.

The results of the investigation of pothole and rut characteristics (area, depth, and number) showed that the level of deterioration caused by potholes and ruts at the end of the study period was higher than at the beginning of the period, and the level of deterioration increased over time. In general, wheel tracks have a negative effect on the hydraulic properties of the roadbed (proper drainage of running water), increasing compaction and reducing permeability, while water flow in the wheel-track paths leads to increased rutting and pavement deterioration. Over time, and especially with the passage of timber transport trucks and heavy logging and transportation machinery, shallow ruts become deeper, leading to increased rutting and the presence of exposed rock materials or a mixture (Shoop et al., 2006). In areas with low road slopes (less than 3%), the impact of raindrops on the pavement surface causes soil particles to disintegrate, creating potholes on the road surface. Potholes along the road path allow water and the materials deposited in the potholes to enter the pavement structure, thereby causing deterioration of the road pavement. Nasiri et al. (2012) investigated the role of timber extraction operations in the development of rutting on forest road pavements and found a significant difference in rut development before and after timber extraction operations.

## 5. Conclusions

The use of pavement deterioration indices to evaluate the condition of forest road

pavements ensures that road condition is continuously monitored, and planning based on these indices is easier than traditional forest road surveys. In general, the results of this study showed that, over time, due to the lack of forest road maintenance operations, the level of pavement deterioration increased. The results indicate that management measures should be taken to reduce the effects of pavement damage; otherwise, in the near future, irreparable damage to the surface of forest

roads may occur. Given that forest road maintenance is not carried out because of the implementation of the forest respiration plan in the northern forests of the country, and since road pavements are considered major assets in forest management, it is suggested that road condition evaluation indices such as the PCI be used. Also, examining the difference in the actual costs of pavement maintenance at curves and their side sections can be considered in future research.

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## ارزیابی عدم اجرای عملیات تعمیر و نگهداری روسازی جاده‌های جنگلی

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### چکیده

هزینه‌های تعمیر و نگهداری جاده‌های جنگلی یکی از عوامل مهم در مدیریت جنگل است و با زوال روسازی و شناسایی عوامل مؤثر بر آن ارتباط دارد. هدف این مطالعه، ارزیابی میزان تخریب روسازی جاده‌های جنگلی طی یک دوره چهار ساله در حوزه آبخیز ۲۵ شنرود در استان گیلان بود. بدین منظور، تعداد ۲۱۳ قطعه نمونه با استفاده از روش نمونه‌برداری تصادفی منظم انتخاب و مورد اندازه‌گیری قرار گرفت. در هر قطعه نمونه، شاخص زوال روسازی براساس هفت معیار شامل: مقطع عرضی تخریب شده، زهکشی تخریب شده، تولید غبار، کرکره‌ای شدن، چاله، شیار و سستی توده خاک اندازه‌گیری شد. به منظور تجزیه و تحلیل داده‌ها از آزمون‌های آماری فریدمن، تجزیه واریانس و دانکن استفاده شد. نتایج نشان داد که با گذشت زمان، میزان تخریب ناشی از مقطع عرضی، زهکشی کنار جاده، تولید غبار، کرکره‌ای شدن و سستی توده خاک افزایش یافته است و از نظر آماری نیز اختلاف معنی‌داری بین ابتدا و انتهای دوره بررسی شده وجود دارد. میانگین عمق (از ۴/۵۷ به ۴/۷۷ سانتی‌متر)، مساحت (از ۴/۴۴ به ۴/۵۰ سانتی‌مترمربع) و تعداد (از ۱/۲۳ به ۲/۲۰) چاله و همچنین میانگین عمق (از ۱/۹۵ به ۲/۰۰ سانتی‌متر)، مساحت (از ۱/۲۲ به ۱/۲۴ سانتی‌مترمربع) و تعداد (از ۰/۴۳ به ۰/۴۵) شیار روند افزایشی دارد. نتایج آماری نشان داد که بین تعداد چاله‌ها در سال‌های مختلف اختلاف معنی‌داری وجود دارد، در حالی که بین مساحت و عمق چاله‌ها و همچنین مساحت، عمق و تعداد شیارها در دوره‌های مختلف مطالعه اختلاف معنی‌داری مشاهده نشد. نتایج آزمون مقایسه میانگین دانکن نیز نشان داد که بین میانگین تعداد چاله‌های ایجاد شده در پایان دوره مطالعه (سال ۱۴۰۲) و ابتدای دوره (سال ۱۳۹۹) تفاوت معنی‌داری وجود دارد. به طور کلی، نتایج این پژوهش بر اهمیت انجام عملیات تعمیر و نگهداری مستمر و همچنین ضرورت استفاده از شاخص‌های ارزیابی در برنامه‌ریزی نگهداری روسازی جاده‌های جنگلی تأکید دارد.

**واژه‌های کلیدی:** شاخص زوال، جاده جنگلی، عملیات تعمیر و نگهداری، جاده‌سازی.