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Assessment of forest road pavement materials one year after restoration (Case study: Asalem forest in northern Iran)

Mahsa Hashemi[1], Ramin Naghdi[1], Mehrdad Nikooy[1], Vahid Hemmati[2]*

[1]Department of Forestry, Faculty of Natural Resources, University of Guilan, Iran
[2]Department of Forestry, Lahijan Branch, Islamic Azad University, Iran
**Corresponding author: rnaghdi@guilan.ac.ir*

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Abstract: The main purpose of this study was evaluating indicators of forest road pavement degradation and their relation with different longitudinal slope classes after one year. Therefore, 30 plots of 100 m^2 (10×10 m) area at a distance of 100 meters from each other were selected by a systematic method in the study forest road in the north of Iran. All effective factors on pavement degradation, like longitudinal and transverse slope, crown canopy on top of plots, azimuth and shape of road bed were measured. Additionally, to evaluate the mechanical characteristics of soil, 4 kg soil samples of pavement surface materials were taken from each mentioned plot. Regarding the results of average sifting through various sieves, we can state that in higher slope classes it is reduced by employing a bigger size of sieves. The percentage passing through sieve number 40 because of increasing slope in 4–7% slope classes was increased. There is a significant difference in the coefficient of uniformity between control treatment and classes 4–7% and above 7%. The treatments did not have an appropriate coefficient of curvature either. Totally, regarding negligible changes that were observed in class 4–7% in comparison with the other classes, we can figure out that this class is more suitable for the road construction.

Keywords: coefficient of variation; soil grading; forest road maintenance; road pavement degradation

Achieving the objectives of forest management and sustainable exploitation requires access to different parts of the forest. Forest roads consist of substructure and pavement while the soil of appropriate aggregation should be used. Otherwise it leads to the emergence of signs of destruction. The most important signs that could be mentioned are pit, rutting and rill erosion. All above-mentioned consequences could have many reasons. Knowledge of these factors could help managers to maintain road safety, reduce maintenance costs and ensure permanent access to the forest road. In addition to providing raw materials for industries, the forest as a complex and dynamic ecosystem on land is the most important factor in the stability of other known ecosystems in the world. In order to pursue principled and sustained utilization of this valuable resource, a perfect forest road network is needed. Forest roads have an important role on economic activities, access to touristic sites in the forest, wildlife management, transportation management, fire controlling and management of pests and disease-causing factors (Smith 1986; Queen et al. 1997; Lugo, Gucinski 2000; Najafi et al. 2012). Road construction is among the most expensive activities in forest engineering which includes design, construction, conservation and maintenance of roads. Experiences have shown that in designing forest roads, considering the terms of environmental factors, technical and grid roads could be essential. In other words, the inclusion of environmental aspects such as geology and soil erodibility will result in increasing the precision in the design of the road network and reduce possible losses. Due to the harmful effects of the road network that are in conflict with principles of sustainability, standards of

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the road network in terms of planning, designing, slope, width, pavement, drainage and etc. should be noticed (Demir 2007). Since the road is built on the natural bed, although employing design principles can be useful in reducing road costs, knowing the mechanical properties of the soil, used materials and determining technical characteristics for the construction and commissioning of stability could reduce costs significantly (Majnonian, Sadeghi 2005). In terms of forest road construction, building material as one of the most important things that should be considered provides appropriate resources for road pavement construction materials. Low attention to this issue will result in the signs of destruction in forest road pavement and generally, it can be seen in the form of pit, rutting and rill erosion. Regarding the diversity of mines and materials for pavement construction, lack of attention to the mechanical quality of materials could lead to negative effects on forest roads. Therefore, awareness of soil mechanical quality could diminish damage and costs of repairing in forest road pavement. Forest road construction requires special standards and technical notes because non-standard roads could cause extensive economic and environmental losses. Johann Eisbacher (1982) conducted a study on the construction of forest roads and soil mechanics. He suggested that measuring various parameters such as particle size, distribution of soil mechanics, natural moisture, etc. before starting to build is necessary in order to improve construction quality, increasing the road life and enhancing the role of transport services in forests. Majnonian (1989) examined the mechanical characteristics of soil in Namkhaneh series of Kheyrudkenar for the first time in Iran and found that the studied soil texture is fine with high clay content and he proposed, in order to build the road on the mentioned soil, that it is necessary to change the mechanical properties and fixing them is essential. Shoja (2003) evaluated soil mechanical factors in Gorazbon series, using the results of tests of soil mechanics, as well as geology, topography and soil. He prepared a stability map for that forest area and found that the fine and sticky soil of the land is only a limiting factor for the road construction in this series. Effective management of forest lands and the practical implementation of forestry projects are directly related to the quality and quantity of forest road networks (Majnounian et al. 2008). In other words, the road construction in forest areas due to physical and chemical properties of soils, geology, high humidity and precipitation, infiltration and motion sensitivity is problematic and might cause the imbalances in natural sequences (Jamshidy Koohsari et al. 2009). In order to reach a better understanding of forest soils and their role in the design of forest roads, it is needed to correct the understanding of the technical characteristics of forest soils. Decreasing the negative environmental and economic effects, paying more attention to technical standards in the design and construction of forest roads is necessary (Hoseini, Hashemi 2015). Since forest roads are designed and constructed in order to effectively protect the forest, the possibility of intervention in the rearing and rejuvenation forest management, forestry and ecotourism, to maximize the added value of production and avoid wasting forest products, standard of engineering and technical specifications should employ in the highest rate on them (Hoseini et al. 2012). Forest soils are the most important building materials that make up the road bed, so the knowledge of soil mechanical features (characteristics) is useful for road implementation and ensures its sustainability. So this study to understand forest road pavement materials one year after restoration was conducted.

MATERIAL AND METHODS

This research was conducted in June and July 2015 in the Asalem forest, Guilan province, northern Iran (37°37'N and 37°41'N and 48°48'E and 48°52'E). A researched road in this study is located in district 1 of Nav forests, in Guilan province (Fig. 1). The area is located at an altitude of 250 to 1,700 m a.s.l. with a mean height of 900 m. The study area has a humid climate. It is dominated by oriental beech (*Fagus orientalis* Lipsky), hornbeam (Carpinus betulus) and alder (Alnus glutinosa) trees. In the area, May, September, December, February and March are considered as wet months and the other months of the year are considered as dry or semi-dry months. Minimum average of annual temperature is 4.8°C, maximum average of temperature is 16.4°C, average annual temperature is 12.4°C and average annual rainfall is 945 mm. In series 1, most of the rocks are schist, granite and basalt. Permeability is relatively good and stability is medium to good.

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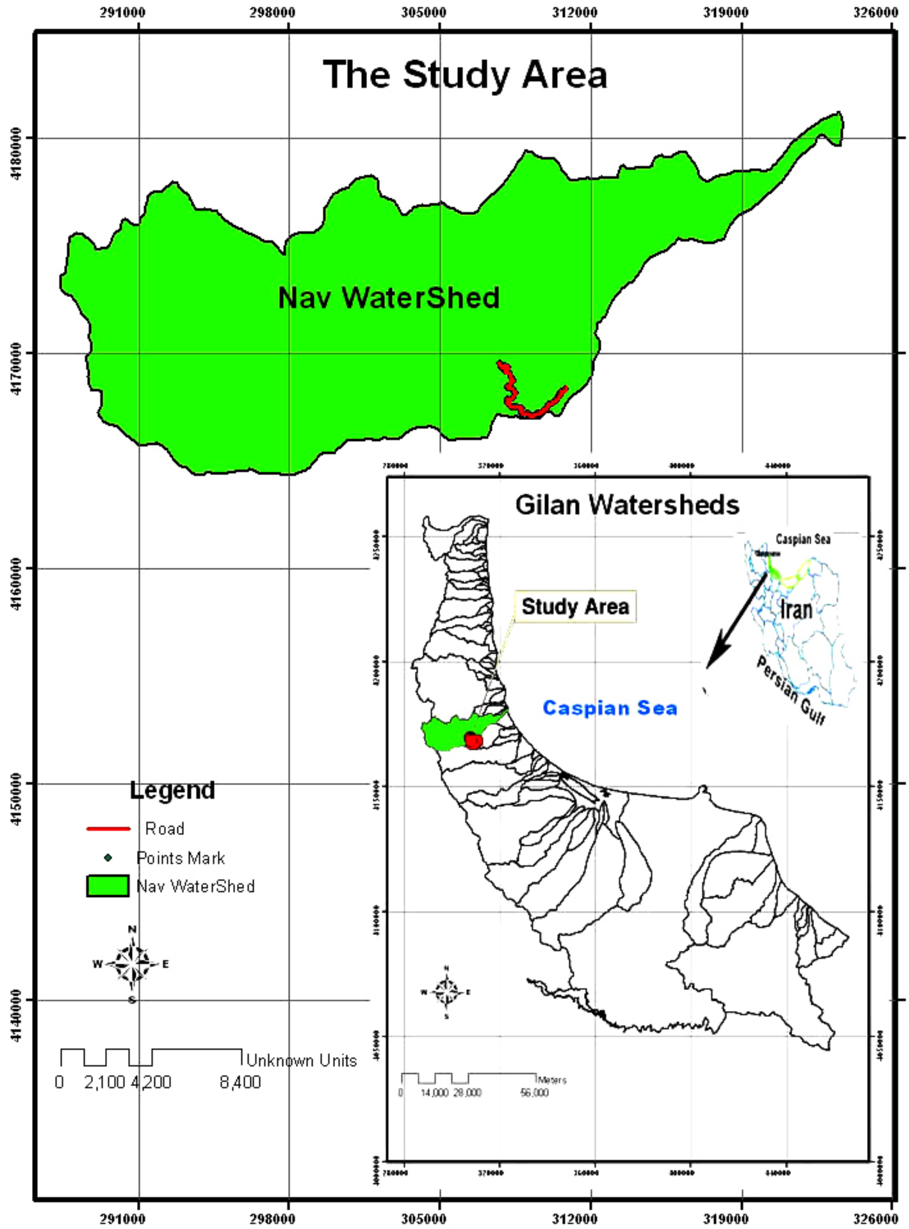

Fig. 1. The map of the study area

Method of study

As forest roads are built mainly in mountainous areas and in order to repair these roads, suitable building materials are needed and due to topography, the forest road pavement will be regularly altered greatly. That is why in this study in order to investigate soil degradation factors, in addition to mechanical properties of mine soil and mentioned plots, environmental factors including longitudinal and transverse slope of the road, percentage of crown canopy above the road, azimuth and shape of the bed were also investigated. There are several mines in this area from where materials are used for the pavement rehabilitation of forest roads. In this study, a mine among various mines was chosen and the effect of its aggregate used in road pavement was considered. Sampling was done according to standard samples of stone materials (AASHTO T2). Also 30 plots of 100 square meters (10×10 m) in size were chosen by systematic random sampling on the mentioned road. Indicators of road pavement degradation and possible factors contributing to it, such as longitudinal and transverse slope, percentage of crown canopy above the road, azimuth and bed shape were measured. Additionally, a sample from each plot containing 4 kg of pavement materials in accordance with the

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instructions for testing the mechanical properties of soil pavement (D3665) was collected and transported to the soil mechanical laboratory. Generally, to evaluate mechanical properties of construction materials used in the road pavement layer, the following tests were employed (Winkler 1998; Ryan et al. 2004). The forest road was divided into 3 slope classes: 0–4%, 4–7% and more than 7%. According to the soil gradation curves, uniformity coefficient was calculated for each treatment after one year.

Determining the moisture content of soil. To do this test, a piece of the sample was measured for humidity. Next, the soil samples were put in an oven for 24 h to lose their moisture. Dried soil samples were re-weighed and the percentage of moisture was obtained by subtraction of the dried soil weight from wet soil samples. Most natural soils that are sandy or gravel have moisture content up to 15 to 20% (Bazyar, Salehzadeh 2004). In this study in order to compare the actual moisture with moisture content the standard ASTM 2216-71 was employed.

Graded test by dry sieving. Graded materials in this research using sieves number 1.5, 1, 3.4, 1.2, 8.3, 4, 10, 40, 200 were tested. In comparison with each other, regarding the type of soil, particle size, distribution uniformity the coefficient of curvature was calculated and then the type and soil particle size distribution were determined according to the relevant standard. Well graded sands have the coefficient of uniformity greater than four and the coefficient of curvature between one and three (Talhuyi 2002). Also to determine the percentage of sand, Eq. 1 was used.

$$F_S = \frac{\text{gravel percentage}}{\text{coarse-grained percentage}} \times 100 = \frac{\text{percentage passing through sieve 4} - \text{percentage passing through sieve 200}}{100 \text{ percentage passing through sieve 200}} \times 100 = \frac{PP\,\#4 - PP\,\#200}{100 - PP200} \times 100 = \quad (1)$$

The mean percentage passing through each sieve in different slope classes and mine was identified using one-way ANOVA test. The presence or absence of pits and ruts were examined by Fisher's test by STATISTICA (SPSS, Version 16). MS Excel (MS Office, Version 2013) was used for analysing all the data.

RESULTS

Table 1 shows results of average sifting through various sieves in relation with each slope class and studied mine. In the slope class more than 7%, the lowest percentage is related to sieve number 1.5, and there were no significant differences between the other treatments. In sieve 1 there was a significant difference between control treatment sample and the slope of more than 7%, while between the slope of less than 4% and 4%–7% no significant difference was observed. In sieve ¾ there was a significant difference between control treatment and the slope of more than 7%. In sieve ½ between control treatments, less than 4% slope and more than 7% slope a significant difference was also observed. In sieve 3/8 results were the same as in sieve 1/2. In sieve 4 and 10 no significant difference was observed in any treatment either, but in sieve 40 the highest passing percentage was for slope of 4–7%. So it showed a significant difference compared to control treatment and slope of more than 7%.

Using gradation curves, coefficient of uniformity for each treatment was calculated. Comparison of the average coefficient of uniformity between the treatments showed that there was a significant difference between slope 4–7% and slope more than 7%. Also, there was a significant difference between slopes less than 4% compared to slope 4–7% and slope more than 7% (Table 2, Figs 2 and 3).

Comparing the coefficient of curvature showed significant differences between the studied treat-

Table1. Average percentage passing through each sieve in slope classes and studied mine

Slope classes	Sieve number							
	1.5	1	3.4	1.2	3.8	4	10	40
Less than 4%	97.57[a]	88.89[ac]	83.19[b]	70.24[b]	60.91[b]	39.51[a]	20.12[a]	7.41[ab]
4–7%	98.51[a]	91.967[ab]	84.56[ab]	73.50[ab]	64.59[ab]	45.16[a]	25.19[a]	10.82[a]
More than 7%	94.38[b]	86.00[c]	78.26[ab]	69.34[b]	60.39[b]	37.09[a]	19.77[a]	7.67[ab]
Control	99.68[a]	94.24[a]	89.75[a]	81.97	73.68[a]	49.28[a]	21.30[a]	6.27[b]

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Table 2. Comparison of the average coefficient of uniformity between the treatments studied

Coefficient of uniformity	Sum of Squares	df	Mean Square	F	Sig
Between Groups	1940.77	3	646.92	5.66	.00
Within Groups	2970.15	26	114.23		
Total	4910.92	29			

Table 3. Comparison of the coefficient of curvature between slope classes

Coefficient of curvature	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.688	3	3.563	2.202	.0412
Within Groups	42.056	26	1.618		
Total	52.744	29			

ments (Table 3 and Fig. 4). Duncan's test for differences between treatments showed that the ratio between control and slope above 7 percent showed a significant difference while there was no significant difference between the other slope classes.

Comparison of the presence and absence of pits and ruts in each group using Fisher's test showed that there is no significant relation between the two characteristics of road pavement destruction in slope class of less than 4% and 4–7% (α = 0.574), less than 4% and more than 7% (α = 0.675) and 4–7% with more than 7% (α = 0.675). We can conclude that in this area pits and ruts are independent and are influenced by other factors (Tables 4, 5, 6).

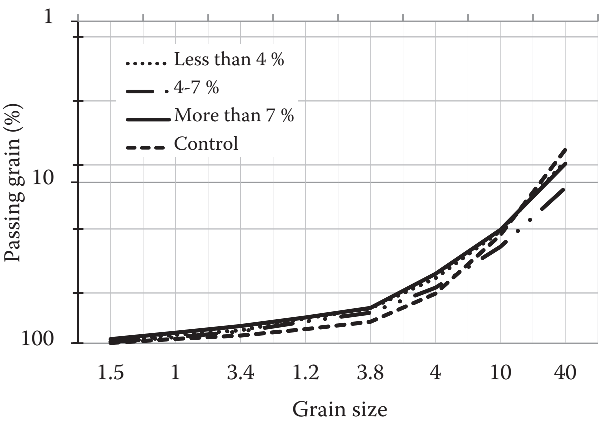

Fig. 2. Soil grading curve of the slope classes

DISCUSSION

One of the main problems in the pavement of forest roads is the correct choice of building materials (Ozturk et al. 2013). Considering the materials available in the area is very important (FAO 1998). So the use of appropriate building materials could reduce maintenance periods in forest roads (Akay 2006). It could prevent the emergence of signs of damage to road pavement such as pit, rutting and rill erosion (Ceratti 2000). According to results of passing through various sieves it can be observed that in high slope classes, as a result of runoff, fine-grained soil is washed away and so the percentage

Fig. 3. Comparison of the coefficient of uniformity between treatments

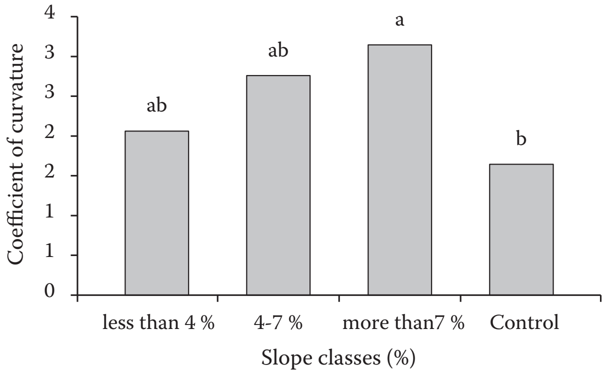

Fig. 4. Comparison of the coefficient of curvature between treatments

https://doi.org/10.17221/68/2018-JFS

Table 4. Comparison of the presence and absence of pits and ruts in slope class less than 4%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson's Chi-Square	0.087[a]	1	0.769		
Continuity Correction[b]	0.000	1	1.000		
Likelihood Ratio	0.086	1	0.769		
Fisher's Exact Test				1.000	0.574
Linear-by-Linear Association	0.082	1	0.774		
N of Valid Cases[b]	20				

Table 5. Comparison of the presence and absence of pits and ruts in slope class 4–7%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson's Chi-Square	0.000[a]	1	1.000		
Continuity Correction[b]	0.000	1	1.000		
Likelihood Ratio	0.000	1	1.000		
Fisher's Exact Test				1.000	0.675
Linear-by-Linear Association	0.000	1	1.000		
N of Valid Cases[b]	20				

Table 6. Comparison of the presence and absence of pits and ruts in slope class more than 7%

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson's Chi-Square	0.002[a]	1	0.964		
Continuity Correction[b]	0.000	1	1.000		
Likelihood Ratio	0.002	1	0.964		
Fisher's Exact Test				1.000	0.658
Linear-by-Linear Association	0.002	1	0.965		
N of Valid Cases[b]	20				

passing through sieves with larger dimensions is reduced. The appropriate amount of fine soil in the pavement of forest roads is very important because a decrease or an increase in its amount could lead to negative impacts (Dawson 2007). Lack of fine particles in pavement materials might result in crashing larger particles with each other, compaction change, in an increase in soil permeability and vulnerability to freezing. If compressibility is high, it will result in high stability. On the other hand, the lack of proper compressibility could result in lower stability. In this study, the percentage passing through sieve 1.5 was the lowest. This means that after the fine fraction was washed away, the coarse fraction was left. There is a significant difference in the slope class above 7 percent in sieve number 1, 3.4, 1.2 and 3.8 between slope class above 7% and control treatment (mine). The percentage passing through sieve 40 in class 4–7% is the highest due to the lower slope. According to the gradation curves, coefficient of uniformity was calculated for each treatment and the results showed that between control treatment and slope classes 4–7% and above 7% there is a significant difference, and the coefficient of uniformity is not appropriate. This indicates that after a year, the coefficient of soil uniformity changed and this change in slope class more than 7% was greater. The coefficient of uniformity on slopes of less than 4% with slope treatments more than 4–7% and more than 7% slope was significant. Regarding the accurate diagnosis of soil gradation and using the coefficient of curvature, the coefficients for treatments were calculated and the result showed a significant difference between treatments. Treatments did not have an appropriate coefficient of curvature. All this evidence shows that the bed soil changed after a year. Among the signs of the road surface destruction are pits and ruts that in this study all of them were explored in the mentioned road. Comparison of the presence and absence of pits and ruts in each group using Fisher's test showed that there was not a significant correlation between these two indices in the various slope classes. We can stat that in this area

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pits and ruts are independent and are influenced by other factors. Generally, regarding slight changes in the other slope classes we can conclude that slope class of 4–7% is more suitable for the road construction.

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