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The Role of Logging Operation on Rut Development in Hyrcanian Forest Roads

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Abstract

In this study a road without maintenance and repairing operation on pavement layer was selected to investigate the effects of forest logging on development of ruts. For this purpose, the rate of rut area and depth on pavement layer was determined before the passage of timber trucks. After the logging operations (7 months later) the area and depth of marked ruts were measured again. Results showed that there was significant difference between the before and after logging operations for depth and area of ruts on pavement layer. The rut depth and area increased with decreasing horizontal curve radius. We found significant difference between rut depth in horizontal curve with radius more than 30m and other classes ($P<0.05$). Also there was significant difference between rut area in horizontal curves with radius less than 22m and other classes ($P<0.05$). Central tire inflation (CTI) system and radial tires with low tire pressure compacts can be used in secondary transportation of wood to avoiding pavement rutting and compaction.

Keywords : logging operation, rut development, tire pressure, pavement, timber trucks

INTRODUCTION

The Hyrcanian zone is a humid zone in North of Iran [7]. The average annual rainfall ranges between 530 mm in the east and 1350 mm in the west reaching up to an occasional record of 2000 mm in the west. Based on the climatic data from meteorological stations, the maximum annual rainfall is experienced during spring and late fall and winter. Relative humidity is also constantly high with an average value fluctuating from 74.6% in the east to 84.6% in the west, rarely dropping below 60% at the hottest hours. There is an increasing trend towards higher traffic volume and traffic load demands on existing road and/or pavement network systems worldwide. The importance of road transportation has also grown worldwide, not only as a result of the development of the infrastructure, but also as in terms of the technical development of transportation trucks. Modern trucks are heavier and their load carrying capacity is greater, hence, the increased traffic and heavier vehicles have potential to cause much more distress to roads than ever before [16]. In Hyrcanian forest roads in order to reduce environmental damage the radius for horizontal curves is determined 16 meter. The horizontal curve radius depend on several factors involving design speed, topographic conditions, super elevation, the length of timber and timber truck, financial resources and environmental conservation [23].

Bearing capacity of a pavement system refers to the number of wheel passages of a specified type that it can support before it reaches an unacceptable level of functional or structural distress [17]. A road should therefore support the applied traffic loading within acceptable limits of ride quality and deterioration over its design life. Primarily, the pavement system must reduce its surface strains and stresses on the subgrade, such that its surface does not crack or deform excessively under peak and cumulative traffic loads [12]. Hauling trucks often induce permanent wheel impressions, or ruts [9, 13]. Rutting occurs when soil strength is not sufficient to support the applied load from vehicle traffic. Rutting affects aesthetics, biology, hydrology, site productivity and vehicle safety [13, 22]. A maximum permissible rut depth of between 40 mm and 75 mm is commonly used to classify pavement failure [8].

In an attempt to minimize the damage and wear to the forest access roads, hence reducing the cost of entire logging operations, several potentially beneficial investigations have been undertaken. These include; the establishment of safe axle load limits as the basis for designing an envirogentle trailer [18], establishment of optimal haulage vehicle combination [4], and the adaptation of trucks to impart lower ground contact pressures [19]. Tyre pressure is determinative for the contact pressure between wheel and road, and consequently for the state of stress in the upper part of the pavement structure [11, 25]. This pressure between the tyre and surface is not uniform and the tyre-pavement interface depends on the location and relative magnitude of critical zones inside the tyre under different loads [15]. As the contact pressure from a tyre is mainly supported by the completion layer, the load from the tyre can increase the pore water pressure in the road material when drainage is restricted. This pore water pressure increase can make unsuitable completion material unstable and may result in permanent deformation of the road surface [21]. This paper describes a study undertaken to assess the role of logging operation and horizontal curve radius on the rate of pavement rutting in Hyrcanian forest road.

MATERIALS AND METHODS

Description of the Study Area

Pashakola forest is located south of the city of Savadkooh in Mazandaran province, Iran. The latitude, longitude and elevation ranges of this forest are 36° 23′ to 36° 26′ N, 52° 09′ to 52° 19 ″ E and 1040 -1720 meter at sea level, respectively.

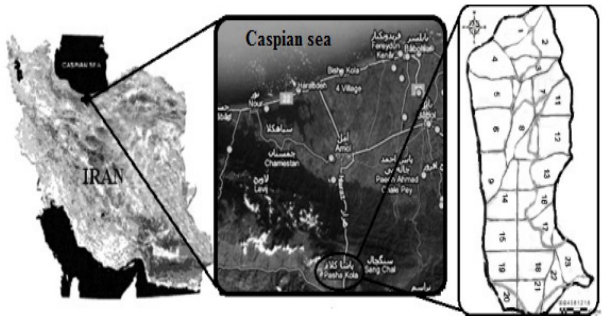

Figure 1. Map and geographical location of study area

Table 1. The rate of rut area and depth Rut Area (M2)

Station (Distance)	Rut depth (CM) (A)	Rut Area (M2) (A)	Rut depth (CM) (B)	Rut Area (M2) (B)
S1	8.6	0.182	7.2	0.145
S2	6	0,165	5,9	0,152
S3	4,2	0,174	3.8	0.148
S4	10.3	0.289	7.6	0.21
S5	6.4	0.321	6.3	0.178
S6	8.2	0.210	6.1	0.205
S7	4.6	0.162	4.6	0.154
S8	4	0.182	3.1	0.175
S9	8.1	0.152	8.2	0.148
S10	7.3	0.2	5.9	0.202
S11	8.5	0.175	8.7	0.164
S12	9.1	0.12	8.3	0.095
S13	8.5	0.152	8.4	0.136
S14	3.2	0.184	1.5	0.148
S15	6	0.176	6.9	0.152
S16	3.6	0.145	3.5	0.126
S17	5	0.192	4.9	0.157
S18	9.5	0.14	9.6	0.136
S19	9.4	0.145	9.3	0.145
S20	9.6	0.153	9.7	0.116
S21	8.7	0.186	6.3	0.174
S22	6.3	0.12	5.4	0.085
S23	2.9	0.14	3.4	0.142
S24	7	0.132	7.2	0.118
S25	8.4	0.158	7.9	0.154
S26	10.5	0.146	10.3	0.135
S27	9	0.192	9.3	0.185
S28	8.6	0.185	8.3	0.132
S29	8.4	0.132	8.6	0.124
S30	7.6	0.148	7.5	0.13
S31	3.4	0.185	3.1	0.156

Note: (A) = After logging; (B) = Before logging

Table 2. The rate of pavement rutting on horizontal curve

Station (Distance)	Horizental Curveradus (M)	Rut depth (CM) (A)	Rut Area (M2) (A)	Rut depth (CM) (B)	Rut Area (M2) (B)
C1	50	5.5	0.112	5.4	0.09
C2	32	6.1	0.126	5.2	0.08
C3	28	6.3	0.222	5.3	0.143
C4	22	12.6	0.335	12.1	0.185
C5	18	9.2	0.43	6.1	0.192
C6	16	12.3	0.52	8.4	0.36
C7	24	9.6	0.235	9.5	0.192
C8	18	12.8	0.389	12.3	0.258
C9	20	8.4	0.28	4.1	0.18
C10	18	13.5	0.43	12.9	0.28
C11	22	7.6	0.232	5.2	0.178
C12	26	9.1	0.12	7.4	0.08
C13	18	14	0.64	13.4	0.48
C14	29	9.3	0.33	9.3	0.29
C15	55	5.2	0.295	4.1	0.28
C16	19	13.2	0.32	11.7	0.18

Note : (A) = After logging ; (B) = Before logging

Data collection

In this study a road without maintenance and repairing operation on pavement layer was selected to investigate the effects of forest logging. Timber logging had been conducted in previous year. In first step, the ruts on pavement layer were determined before the passage of timber trucks and then their locations were marked on edge trees of ruts. Besides, the area and depth of ruts were measured. After the logging operations (7 months later) the area and depth of marked ruts were measured again. The graduate metal ruler and mathematical equations of calculation of shape area was used to measure the depth and area of ruts. From the start point to end point of curve were surveyed and the radius of horizontal curve were measured by meter. The type of roads in study area was secondary forest road. The three axle trucks carry the logs on this road.

Data Analysis

Completely Randomized Block (CRB) Design was used as for the analysis of the experiments in this study and the data were analyzed using SPSS (Sciences Statistical Package for the Social) computer program. The means were compared using *ANOVA* (the effect of logging operation) and *Univariate Linear Analysis* (the effect of horizontal curve).

RESULTS AND DISCUSSION

Effect of logging operation on development of ruts

There was significant difference between the before and after logging operations for depth and area of ruts on pavement layer (Table 3). According to the box plot (Fig .2), the rut depth and area after the logging operation were more than that of before logging. Moreover, variations limit of rut depth and area after the logging operation was less than that of before the logging. The mean of rut depth and area after the logging operation was 1 (cm) and 0.05 (m2) respectively, more than that of before logging. Haulage of large loads of timber and the movement of other heavy machinery peculiar to mechanized

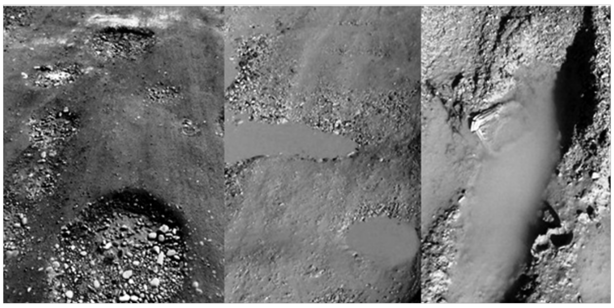

Figure 2. Pavement rutting in forest road

Table 3. ANOVA for statically comparison of the rate of pavement rutting among before and after logging

Treatment	SS	MS	DF	F
Rut depth	1	15.54	15.54	1.5*
Rut area	1	0.77	0.77	4.7*

Note: DF = Degree of freedom; SS = Sum of squares of error; MS = Mean square; F = Value calculated by dividing MS source with MS error in SAS software; * = Significant in probability level of 5 %

forestry operations accelerate their deterioration. This imposes expensive repair and maintenance costs, hence, makes transportation a costly factor in the overall timber production process [1]. Development in truck axles, tyres and suspension systems have attempted to address the road damage potential issues [5, 24], the regulations of weights and dimensions are even more important in the wake of substantial pressure from the transportation industry to allow the heavier and larger vehicles on the roads [10].

In Iran the trucks with high capacity of loading are used to decrease the logging and timber transportation costs. Besides, sometimes the unallowable loads are added to these trucks. Heavy machines such as HSM are used for loading collected logs along the forest roads. HSM is not a suitable machine for trucks loading because the pavement layer of forest roads are often cracked and rutted with entry of this machine. A road should support the applied traffic loading within acceptable limits of ride quality and deterioration over its design life. Primarily, the pavement system must reduce its surface strains and stresses on the subgrade, such that its surface does not crack or deform excessively under peak and cumulative traffic loads [12].

In suitable times the roads didn't damage with traffic of trucks, forwarders and skidders. These times are including dry days of summer and icy days of winter. If the road surface isn't maintained suitability the erosion would occur in ruts of road with passage of vehicles and then the pavement layer would damage [2]. The road surface drainage especially in moisture season is effective to prevent ruts development. High load of truck causes to crack the upper layer of pavement and the conditions are provided to penetrate water into roadbed. With penetrating water into the base and sub-base layers the lower layer subsided and the rutting increased. It is better that the mentioned road be blocked to repair, maintenance and fill ruts after the logging operations.

Effect of horizontal curve radius on development of ruts

We found significant difference between rut depth in horizontal curve with radius more than 30m and other classes (P<0.05). Also there was significant difference between rut area in horizontal curves with radius less than 22m and other classes (P<0.05). The rut depth and area increased with decreasing horizontal curve radius. The rut depth and area on curves with radius of 16 to 22 m was the most. In addition, histograms showed that in all horizontal curve classes the rate of rutting after the logging operation was more than that of before the logging (Fig.No.3). When the speed plan assumes steady the centrifugal of moving trucks increased with decreasing radius of horizontal curve [20]. This can distribute the uneven load on the road surface. Besides, the drainage network is damaged by increasing radius of the horizontal curves of forest roads [26]. If the specific slope is not considered on horizontal curves the water would collect on road surface and then the rutting would occur severity. Moreover, the pavement layer of road is damaged by increasing brake on horizontal curves and high longitudinal slopes [14]. In order to prevent rutting on road surface, it is better that the longitudinal slope on horizontal curve decreased to 5 degree [23]. The destructions on road surface are divided to deep and shallow destructions. The deep destructions are occurred when the loading of pavement layer is low. The destructions increases with increasing loads but in shallow destructions the pavement layer is damaged (problems

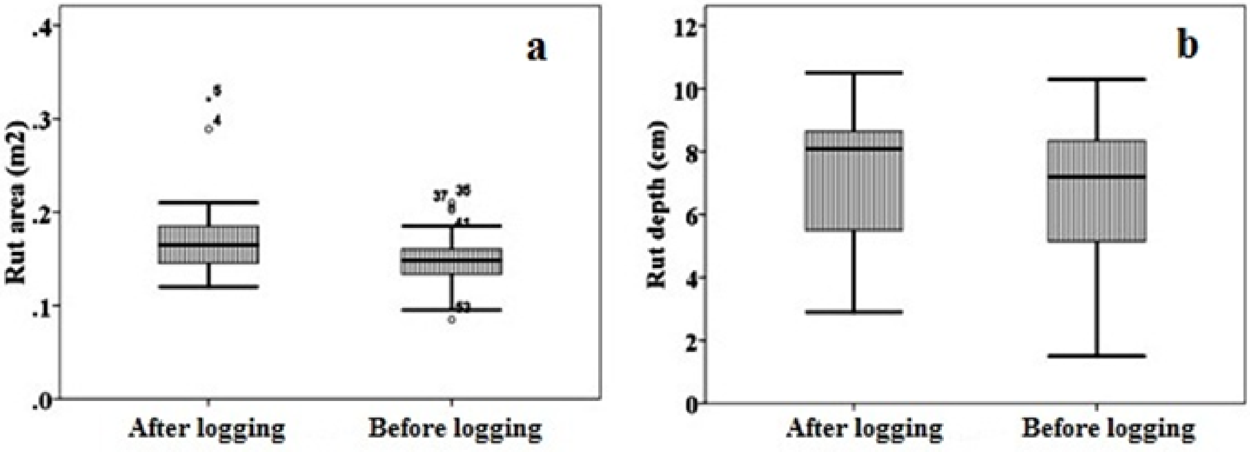

Figure 3. Comparison of the development of rut area (a) and depth (b) on road surface after and before the logging operations

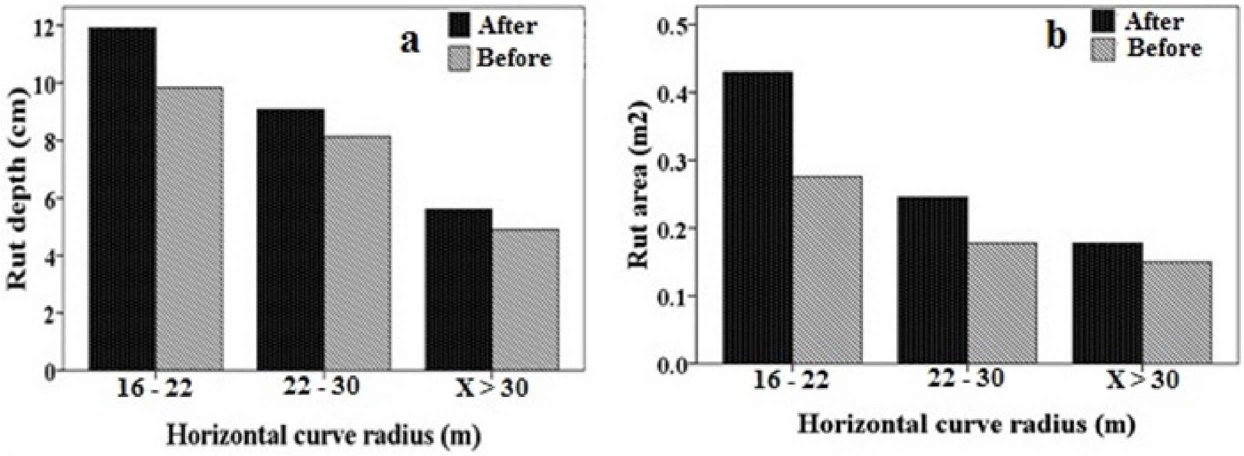

Figure 4. Comparative histogram of the effects of horizontal curve radius on the development of rut depth and area according to forest logging

Table 4. Effect of curve radius on the rate of pavement rutting

Curve radius (m) / Treatment	16 – 22	22 – 30	X > 30
Rut depth (A)	11.9 a*	9.1 a	5.6 b
Rut depth (B)	9.8 a*	8.1 a	4.9 b
Rut area (A)	0.43 a*	0.25 b	0.18 b
Rut area (B)	0.28 a*	0.18 b	0.15 b

Note: * Different letters indicate significantly differences ($p<0.05$) among curve radius; (A) = After logging ; (B) = Before logging

in traffic) due to the high ragged of pavement. Therefore, limitation of pavement damage by control of vehicle operation parameters such as axle load characteristics [6], adoption of permanently reduced and variable tyre pressure technologies [3], and routeing based on seasonal road strength, provide some alternatives for forestry operations including timber haulage [17].

CONCLUSION

Forest roads are the most important foundation for sustainable forestry operations. Variable tyre pressure control systems, or ‘tyre pressure control systems, have been gaining acceptance internationally as useful mechanisms for optimizing load, speed and air pressure in tyres, especially on those vehicles involved in heavy haulage operations that travel over a range of road types in their daily journeys, such as in timber transport. Central tire inflation (CTI) system that optimize tire pressures to match the tire’s working conditions are used extensively by many forestry companies in Canada. This system and radial tires with low tire pressure compacts can be used in secondary transportation of wood to avoiding pavement rutting and compaction.

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