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Full Length Research Paper

Evaluation of drainage system of forest roads in Iran: Darabkola forest roads

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It is necessary that forest roads be constructed according to standards considering the importance of forest roads in the forestry plans and sustainable management. The Standard Drainage system is one of the most important technical buildings in the forest road construction. Darabkola forests have been located in the central part of the northern margin of Alborz Mountains in watershed basin 74 which have been established in 1.5 km distance of sari. Darabkola forest's area is 2612 ha. The effective factors on road drainage such as road width, cross and longitudinal slopes of road, slope of excavation and embankment ranges, longitudinal slope of ditch and basal area of ditch were measured in each 40 m of 1.5 km of forest road length. Then the sample point's locations were recoded using GPS (Global Position System) and the related map was prepared. The Culverts diameter and the Culverts distance of each other was measured in the current drainage system and the culverts location was also recorded using GPS. In addition, road route was tracked and recorded using GPS to obtain more accuracy. Finally, the drainage system of study forest road was compared with accepted standards. Results showed that there is significant difference between the current drainage system of Darabkola forest roads and accepted standards in some cases and the drainage system of these roads was evaluated in the medium situation.

Key words: Culvert, drainage system, forest roads, global position system (GPS), Iran.

INTRODUCTION

Forest roads network provide accessibility to different parts of forest for management activities such as protection against fire and pest invasion, plantation and logging operation (Pouya et al., 2009). In addition to positive effects, forest road construction has negative environmental impacts including destruction of natural drainage, soil degradation and increase in river sediments (Egan et al., 1985; FAO, 1992). Water is the biggest enemy of forest roads and most experts believe that at least 80% of erosion sediments in the forest environment are due to forest roads construction. According to obtained data of developed countries, about25% of the total costs of forest roads construction is spent for drainage system construction (Sarikhani, 2005).

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Most forest roads are constructed in rainy and humid areas and water is one of the most important factors in their destruction (Majnounian et al., 2005). Therefore, the proper drainage system for a forest road is very important and vital. The improper drainage can cause erosion, landslide and buoyancy in the forest roads (Sarikhani, 2005). Existence of any landslide and buoyancy region in the excavation and embankment ranges is a strong reason for improper drainage system (Anon, 1995). On the other hand, the proper designing of drainage system of forest roads can reduce the maintenance costs of forest roads (Swift, 1985). Based on Anon's research (1995), watershed basin characteristics such as public slope percentage, public slope aspect, natural drainage situation and plant cover status of excavation and embankment ranges are very effective factors on the drainage system designing.

Brake and Molanau (2001) believe that situation of the excavation and embankment ranges and their plant cover

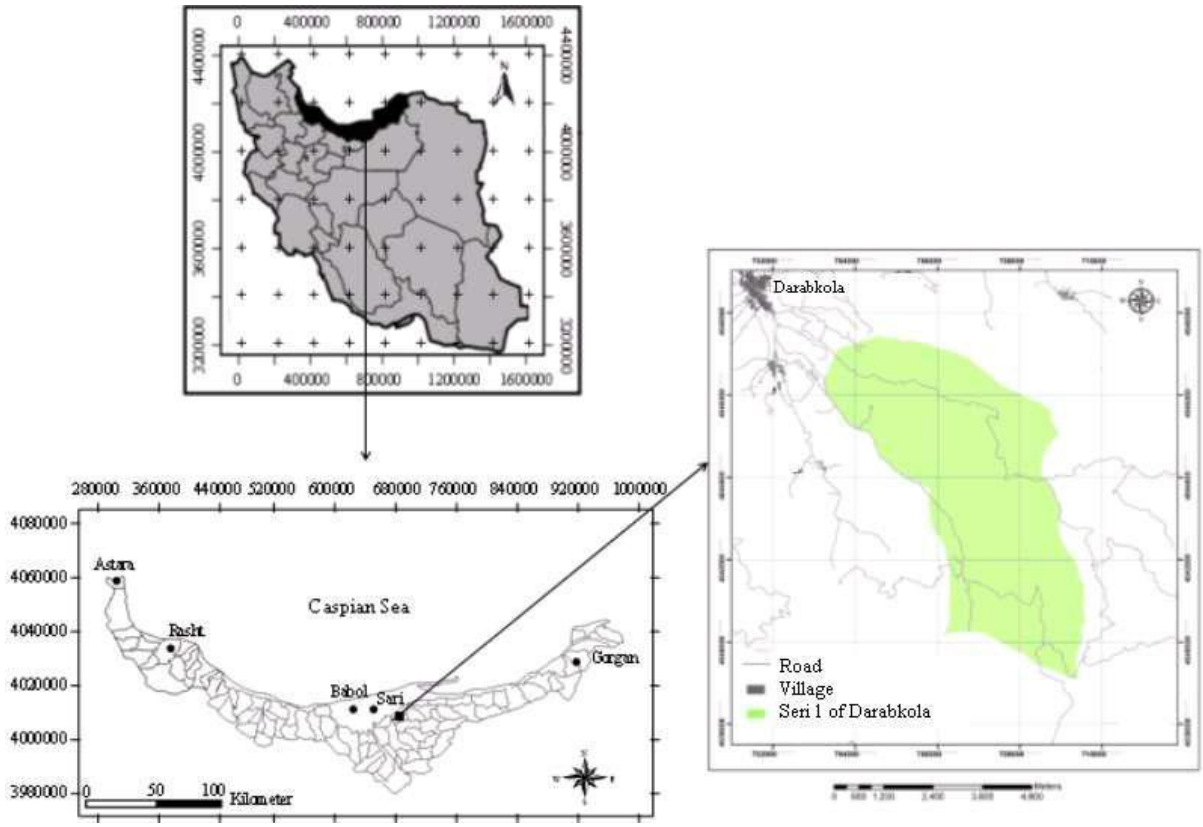

Figure 1. Position of Seri 1 of Darabkola forests and access ways to it.

are more effective than other effective factors in road drainage. Brinker's research results (1995) showed that the drainage culvert diameter, culverts distance from each other and their slope toward road are the most important factors in the forest roads drainage. Khalilpour (2007) evaluated the drainage situation of forest roads in Estakhrposht - Neka using GIS. His research results showed that the current drainage system is not according to water volume and mechanical characteristics of the soil in Estakhrposht - Neka. In Khalilpour (2007) research, the cross slope of road was measured 2 to 3%, the side slope of ditch was measured 1 to 1.5, the longitudinal slope of ditch was measured 2 to 3%, the basal area of ditch was measured 0.5 m^2 and the maximum diameter of culverts was measured 40 cm. Akbari (2007) evaluated the culverts proper diameter of forest roads in Nekachoob forests. His Results showed that the culverts proper diameter is 27 to 158 cm using curve number method. Also, he concluded that distance between culverts should be 419 to 480 m. Thus, it is essential that the drainage system of forest roads be in accordance to standards considering the importance of drainage system in forest roads to prevent the destruction of roads technical buildings, erosion and sediment production. Therefore, the purpose of the research is evaluation of drainage system of Darabkola forest roads using GIS and comparison of current drainage system with the accepted standards, so that the strengths and weaknesses points of the current drainage systems can be investigated and the solutions would be introduced to provide the applied patterns in the present and to give the applied proposals in the future.

MATERIALS AND METHODS

Description of the study area

Darabkola forests have been located in the central part of northern margin of Alborz mountains and low and girdle heights of basin 74 which have been established in 15 km distance of sari east and 36° 23′ to 36° 33′ northern latitude and 52° 20′ to 52° 31′ eastern length. The area of the Darabkola forests is 2612 ha (Figure 1). Its minimum height of sea level is160 m and maximum height of sea level is 710 m. There are 24 km roads in the region and road density is 9 m per ha (Office of Educational and Research Forest of Department of Natural Resources of Sari, 2004).

Data collection

In this study, GPS, clinometers and meter were used to pick up the ground data**.** Drainage system standards were used to evaluate the drainage system of second degree forest roads (Sarikhani and Majnounian, 2005). The effective factors on road drainage such as

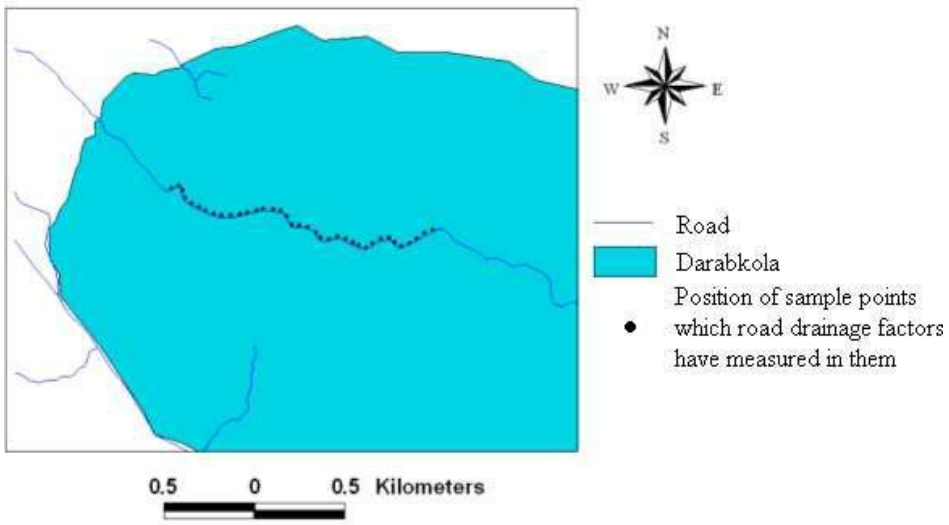

Figure 2. Position of sample points which the effective factors on road drainage have measured.

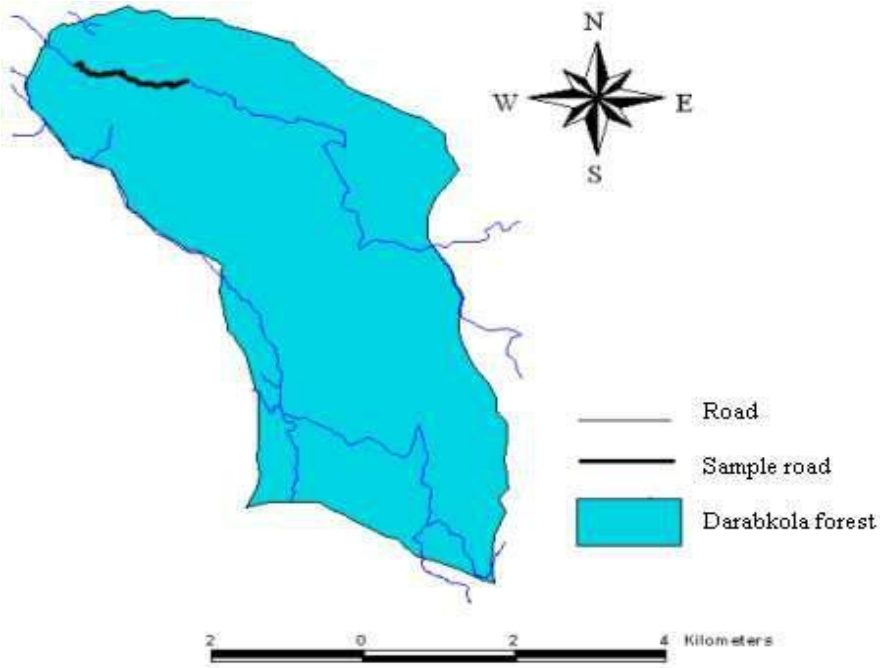

Figure 3. Location of sample forest road for the study.

road width, cross and longitudinal slopes of road, slope of excavation and embankment ranges, longitudinal slope of ditch, basal area of ditch (little width, large width and depth of ditch) was measured in about 1.5 km of secondary forest roads and in each 40 m to evaluate the drainage system of second degree of forest roads (every 40 m was considered a station).

Then was recorded a sample point location using GPS (Global Position System) and prepared related map in *Arcview* 3.1 software (Figure 2). Culverts diameter and their distance of each other in existence drainage system was measured. Culverts location was also recorded using GPS. Position of any landslide and buoyancy region in the excavation and embankment ranges was also recorded using GPS. In addition, road route was tracked and recorded using GPS for obtaining to desirable accuracy. Figure 3 shows the location of sample forest road for the study.

RESULTS

Evaluation of drainage system was done in 1.5 km of Darabkola forest roads (Figure 3). Tables 3 and 4 shows

Table 1. Standard values of width, cross and longitudinal slope of grade 2 forest roads (Sarikhani 2005).

Factors	Cross slope (%)		Longitudinal slope (%)	Road width (m)	
	Maximum longitudinal slope is 8	The longitudinal slope is 3 or 4 or less		With shoulders	Without Shoulders
Standard value	2	4	3 - 4 to 6	8.5	5.5

Table 2. Standard values of drainage factors in grade 2 forest roads (Sarikhani 2005)

Factors	Longitudinal slope of ditch (%)	Side slope of ditch (%)	Sizes of ditch (cm)			Culvert diameter (cm)	Distance of between culvert (m)
			Width of ditch floor	Depth of ditch	Average width		
Standard value	Appropriate with longitudinal slope of road (3 - 4 to 6)	1 to 4	30	At least 35	100	100-65	50 to 70

Table 3. Comparison of width, cross and longitudinal slope of grade 2 forest roads in Darabkola with slope standards of forest roads.

Factors	Cross slope (%)		Longitudinal slope (%)	Road width (m)	
	Maximum longitudinal slope is 8	The longitudinal slope is 3 or 4 or less		With shoulders	Without Shoulders
Standard value	2	4	3 - 4 to 6	8.5	5.5
Achieved Average in Darabkola forest road	6.14		3.72	7.94	4.9

Table 4. Comparison of drainage system of grade 2 forest road in Darabkola with drainage system standards of forest roads.

Factors	Longitudinal slope of ditch (%)	Side slope of ditch (%)	Sizes of ditch (cm)			Culvert diameter (cm)	Distance of between culvert (m)
			Width of ditch floor	Depth of ditch	Average width		
Standard value	Appropriate with longitudinal slope of road (3 - 4% to 6%)	1 to 4	30	At least 35	100	100-65	50 to 70
Achieved Average in Darabkola forest road	4.02	1 to 1.31	32.24	31.86	106.13	64.44	165

comparison of the existing drainage system in secondary forest roads in Darabkola (mean of picked drainage data at each sampling point) with drainage system standards in forest roads. The standards are presented in Tables 1 and 2. Average of road width with shoulders was measured 7.94 m and without shoulders was measured 9.4 m. The average of road longitudinal slope was measured as 3.72%. Average of the cross slope of road was measured 6.14%. The average the cross slope of road is the mean of cross slopes averages towards excavation range (8.32%) and embankment range (3.79%). Average of Excavation range slope was measured 26.27% and average of embankment range slope was measured as 27.70%. Average of Longitudinal slope of ditch was measured as 4.02%. Average of longitudinal slope of ditch was measured 1 to 1.31. Road ditch is trapezoidal in shape. Average of large side (width) of ditch was measured as 73.89 cm and Average of little side (width) of ditch was measured 32.24 cm. Thus average of ditch width is 106.13 cm. In addition, the

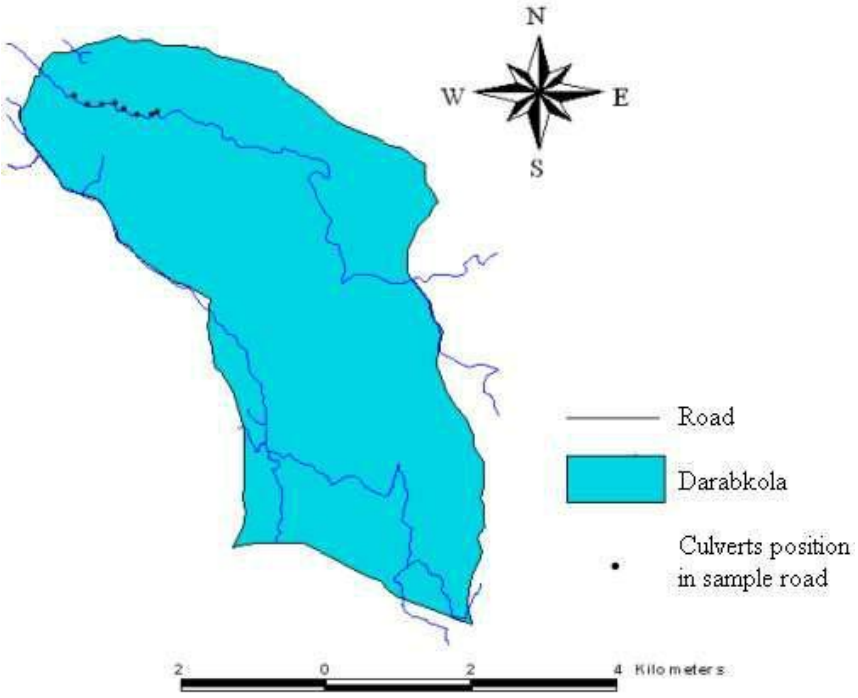

Figure 4**.** Culvert positions in sample road.

Table 5. Culverts data in grade 2 forest road in Darabkola.

Culvert number	Diameter (cm)	Distance (m)
1	60	230
2	60	185
3	60	137
4	60	148
5	60	172
6	60	213
7	60	60
8	100	175
9	60	-
Average	64.44	165

average of ditch depth was obtained as 31.86 cm. Average of ditch basal area was also obtained 0 / 16 m^2. There were eight cement culverts in the sample forest road (1.5 km) (Figure 4). Table 5 shows culverts data in grade 2 forest road in Darabkola. Average of culverts diameter was obtained as 64.44 cm. Average of culverts distance was obtained 165 m. Wholly, two Landslide and buoyancy regions were observed in sample forest road (1.5 km) (Figure 5).

DISCUSSION

Considering the results, average of road width with shoulders was measured as 7.94 m and without shoulders was measured as 9.4 m. While the standard values of road width with shoulders is 8.5 to 9 m and without shoulders is 5.5 m. Thus, the existing road width is lower than the standard value. The road width may be decreased due to the passage of time, but it can be said that it is in accordance with the standards wholly. With attention to Table 3, the average of longitudinal slope of Darabkola forest Road (3.72%) is in accordance with standards value (3 to 6%) but it is about the minimum of standard value. So sediment accumulation in ditch is because of low longitudinal slope of forest roads. The average of the cross slope of road was measured as 6.14%. The slope is the mean of cross slopes averages

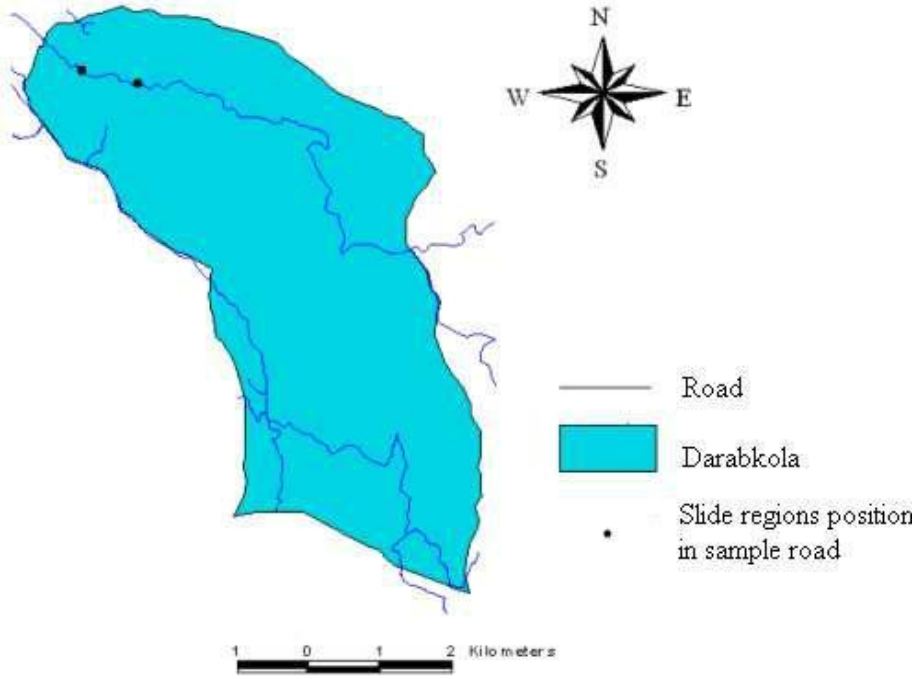

Figure 5**.** Position of landslide and buoyancy region in sample road.

towards excavation range (8.32%) and embankment range (3.79%). This cross slope is more than the standard value of cross slope of forest road but it is suitable because of more cross slope toward the excavation range (from road center toward ditch) and lack of water accumulation in road surface. In addition, cross slope of forest roads should be further when longitudinal slope of forest roads is low (such as Darabkola forest roads) (Sarikhani, 2005). The result is different from Khalilpour research result (2007) that he has estimated the cross slope of Estakhrposht forest roads 2 to 3%. The reason is the suitable and exact longitudinal slope of Estakhrposht forest roads. Slope of excavation range (26.27%) and embankment range (27.70%) is suitable because of their harmony with the common slope of the study area.

Longitudinal slope of ditch (4.02%) is suitable because of its harmony with longitudinal slope of forest road (3.72%), its harmony with standards (3-4% to 6%) and lack of water accumulation in ditch according to FAO standards (2006), longitudinal slope of ditch in standard situation is 2 to 8% for water collection without extra sediments. Average of side slope of ditch was measured 1 to 1.31 which it should be lower because of non-cement ditch in most of Darabkola forest roads. In addition, in low-slope ranges, side slope of ditch is considered lower (1 to 4). These results are different from Khalilpour research result (2007) that has estimated the side slope of ditch 1 to 1.5, that its reason is the cement ditch in Estakhrposht forest roads. Forest road ditch is trapezoidal in shape. The average of large side (width) of ditch was measured as 73.89 cm and the average of the little side (width) of ditch was measured as 32.24 cm. Thus, average of ditch width is 106.13 cm. Although average of ditch width is near to standard value (100 cm), but it is unsuitable because of plenty changes in the ditch width in some of the regions. Of course the average of ditch floor width (average of little side) (32.24 cm) has been in accordance with the standard value (30 cm).

On the other hand, the average of ditch depth was obtained as 31.86 cm that it is different from the standard value (at least 35 cm). Also, the average ditch basal area was obtained as 0 / 16 m^2 because the low basal area and depth of ditch hardened the water movement in the ditch. Khalilpour (2007) also believe that ditch basal area (0.5 m^2) is low in his study area because of barricade in ditch. Thus, important result of these researches is that the maintenance of forest roads especially drainage building is not considered in Iran. The ditch of Darabkola forest roads had been deformed in most of the regions and had been transformed from trapezoidal shape to triangle shape. In addition, ditch floor had been filled of sediments, grass and little branches. Ditches that do not allow the flow of water in canals and are not useful. Therefore, cleaning operation of ditch must be set in priority of maintenance programs of forest roads for desirable function of drainage system. There were eight cement culverts in sample forest road of which seven of them have 60 cm diameter and one of them has 100 cm diameter with attention to Table 5. The average of

culverts diameter is 64.44 cm, that it is approximately according to the standard values (65 to 100 cm) (Sarikhani, 2005). In addition, this result has harmony with Akbari's research result (2007) which has obtained culverts diameter 43 to 49 cm in his study area. Brinker (1995) has also determined the minimum of culverts diameter to be 45.7 cm. Wholly required culverts diameter in forest roads which depend on watershed basin and its characteristics such as shape, slope, topography, climate, soil type, plant cover and number and frequency of torrent which flow in region (FAO, 2007). Average of culverts distance has been obtained as 165 m, which is far more than the standard value (50 to 70 m) (Sarikhani, 2005). Thus, more construction of culverts is essential in Darabkola forest roads. Of course, Brinker (1995) has presented a formula for maximum culvert distance as follows:

Culvert distance (m) = (400/ slope road) + 100 (Brinker, 1995)

With attention to the formula, maximum culverts distance in Darabkola forest roads is 207.52 cm, of which culverts distance (165 m) is proper in Darabkola forest roads with attention to the aforementioned formula. In addition, Akbari (2007) estimated culverts distance 419 to 480 m in his study area (Nekachoob forest). Thus, culverts distance in Darabkola forest roads is better than those in Nekachoob. Wholly, the culverts in Darabkola forest roads against the ditches were completely clean from little branches and sediment. Wholly, two landslide and buoyancy regions were observed in sample forest road (1.5 km). According to Anon (1995), existence of any landslide and buoyancy region in the excavation and embankment ranges is a strong reason for improper drainage system. Thus, the drainage system of Darabkola forest roads can be evaluated in a moderate level considering the low landslide and buoyancy regions in Darabkola forest.

Conclusion

Finally, we can conclude that the situation of physical characteristics and engineering of Darabkola forest roads is proper and it is according to standards of forest roads in Iran. But the results of the research showed that the current drainage system in Darabkola forest roads is different from drainage system standards in some cases. Thus, the using of new drainage system and biologic constancy is essential in the region. Of course the existence of required economic resources is very essential for forest roads maintenance. However, these should not be done based on the destruction and barricade in culverts and ditches and other drainage buildings. Wholly, current research evaluates that the road planning and drainage system of Darabkola forest roads in comparison with standards, is in the moderate level. Thus, maintenance operation of forest roads and drainage system is essential in Darabkola forest roads. So, other references in the world emphasizes that the drainage system of forest roads should be considered with periodic maintenance operation and after torrent, logging and skidding (FAO, 2006). Thus, it is suggested that the consideration given to ditches and culverts and other drainage buildings be increased. In addition, creation of further culverts is essential in Darabkola forest roads.

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