Original Research

Assessment of Drainage System Standards of Forest Roads in Iran Using GIS

Saeedeh Eskandari*, Seyed Ataollah Hosseini

Department of Forestry, Sari Agricultural Science and Natural Resources University, I. R. Iran

Received: 19 January 2012
Accepted: 2 October 2012

Abstract

Forest roads should be constructed according to standards and particular attention needs to be given to forest roads in planning and management schemes to develop sustainable forest infrastructure. The creation of standards for drainage systems is one of the most important technical developments in forest road construction. Seri 1 of Darabkola forest has been located in the central part of the northern Alborz Mountains in basin 74 and in 15-kilometer distance of Sari in Iran and covers an area of 2,612 hectares. In this research slope and aspect maps of the Seri 1 of Darabkola forest were prepared using *Arcview 3.1* and *ArcGIS 9.1* to evaluate drainage. In addition, factors effecting road drainage were measured and evaluated: road width, cross and longitudinal slopes of roads, ranges of excavation and embankment slopes, longitudinal slope of ditches, and basal area of ditches at intervals of 1.5 kilometers of forest road and for each 40 meters of each section. Sample points of locations were taken using global positioning system (GPS) and a related map was prepared. Measurements of culverts were taken for diameter and distances apart from each other in the existing drainage system as well as locations that were also recorded using GPS. In addition, road routes were tracked and recorded using GPS to obtain the desired accuracy. Finally, the drainage system of the forest road was compared to the accepted standards. Results showed that there was significant difference between the current drainage system of Seri 1 of Darabkola forest roads and accepted standards, but in some cases evaluation of the existing drainage systems on these roads demonstrated that they were in accordance with accepted standards.

Keywords: culvert, drainage system, forest roads, GIS, Global Positioning System, Iran, standards

Introduction

A forest road network provides access to different parts of a forest for management activities such as protection against fire, pest invasion, markup, plantation, and logging operations [1]. Forest road construction, in addition to these positive aspects, has a negative environmental impact that specifically includes destruction of natural drainage, soil degradation, and increased river sediment [2, 3]. So, during normal conditions only a few sources within a limited area are exposed to erosion as a result of discharge from rivers. Consequently, stream sediment may reflect only limited parts of a drainage area. Over bank deposits (floodplain sediments) are another drainage sample type [4].

Water is the biggest enemy of forest roads and most experts believe that at least 80 percent of erosion sediment in a forest environment is due to the creation of forest roads. About 25 percent of the total cost of forest road construction is spent on drainage [5]. Most forest roads are constructed in rainy and humid areas, and water is one of the most important factors affecting their destruction [6]. In addition, roadside soil receives at least twice as much rainfall water as other areas and the interception of subsurface flow from the construction of roads further increases volumes of water in road side areas [7, 8]. Land areas at deep strata have poor permeability, and percolating water seeps into valleys and ditches

*e-mail: saeedeheskandari119@yahoo.com

or main drainage canals. In depressions and endoaquolls, soil has poor drainage and collected water is discharged as runoff, in a surface drainage system [9].

Therefore having a proper drainage system in place for forest roads is of vital importance. Improper drainage can cause erosion, landslides, and buoyancy [5]. Improper systems of drainage in embankments and excavation sites can contribute to landslide and buoyancy in a region [10]. However, maintenance costs can be reduced by properly designed drainage networks for forest roads [11]. Based on Anon's research [10], basin characteristics such as public slope percentage, public slope aspect, natural drainage situation, and constructed drainage situation, covering excavation, and embankment ranges are effective factors that need to be considered in the design of drainage networks. Brake and Molanau [12] recommend that plant cover on excavation sites and embankment ranges are more effective against landslides than other factors in road drainage. The research results of Brinker [13] showed that drainage culvert diameter, separation distances, and degree of slope toward a road are the most important factors affecting forest road drainage. Khalilpour Amiri [14] evaluated the drainage situation of forest roads in Estakhrposht in Neka using GIS. The research results showed that the current drainage system was not consistent with water volume and public and mechanical characteristics of the soil. The road cross slope was measured at 2 to 3 percent, side slope of the ditch was measured at 1 to 1.5, longitudinal slope of the ditch was measured at 2 to 3 percent, basal area of the ditch was measured at 0.5 m^2, and maximum diameter of the culvert was measured at 40 centimeters and determined as appropriate dimensions. Akbari Fardi [15] evaluated culverts in forest roads in the Nekachoob forest. Results showed that the appropriate dimension for culverts was 27 to 158 centimeters using the curve number method. It also was concluded that distances between culverts should be within a range of 419 meters to 480 meters. Osma et al. [16] concluded from research that drain clearing should be done whenever necessary, and mechanical clearance of roadside scrub is preferable to the use of herbicides.

With attention the importance of appropriate drainage systems for forest roads to prevent the destruction of roads, buildings, and technical infrastructure, and erosion and sediment production, it is essential that drainage systems meet standards. Therefore, the purpose of this research was to evaluate the system of drainage in the Seri 1 of Darabkola forest roads using GIS and compare it with accepted standards in order to evaluate the strengths and weaknesses of the existing drainage system. Furthermore, the study aimed to make recommendations for future development planning.

Materials and Methods

Study Area

Seri 1 of Darabkola forest has been located in the central part of the northern Alborz Mountains in basin 74 and in 15-kilometer distance of Sari in Iran at N latitude 36º33’ 20” to 36º33’30” and E longitude 52º14’40” to 52º31’55”. Seri 1 of Darabkola forest area covers 2,612 hectares (Fig. 1). The minimum and maximum elevation of study area is 180 m and 800 m, respectively. The minimum and maximum rainfall of study area also is 36.1 and 119.8 mm in July and November, respectively [8]. There are 24 kilometers roads in this forest and road density is about 9 meters per hectare [17].

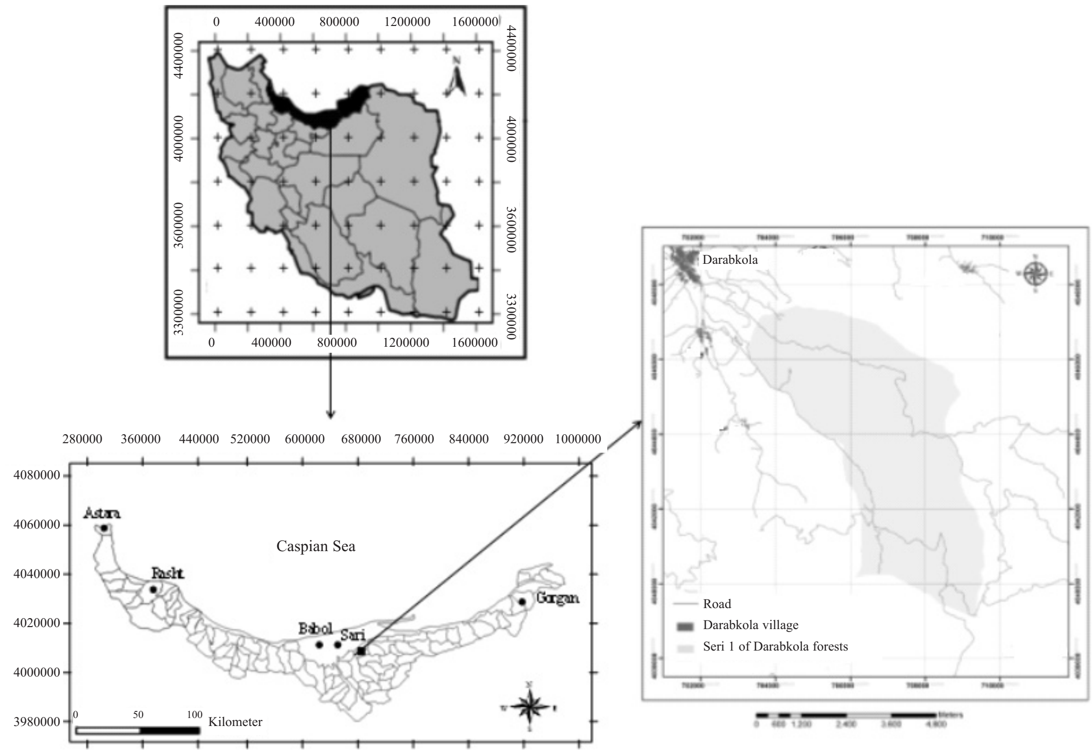

Fig. 1. Position of Seri 1 of Darabkola forests and access ways to it.

Maps Preparation Method

Firstly, the 1:25,000 digital topographic map was georeferenced with *ArcGIS* 9.1 software to prepare slope and aspect maps. A digital elevation model (DEM) of the area was prepared with 5 m pixel size using *Arcview* 3.1 software. Then slope and aspect maps were prepared with DEM in *Arcview* 3.1 software and were separated at the regions' border. The slope map was prepared in 5 classes (0-10%, 10-18%, 18-28%, 28-41%, and >41%) and the aspect map was prepared in 5 classes (east, north, south, west, and flat).

Data Collection Method

In this study, GPS, clinometers and meter were used to pick up ground data. Drainage system standards were used to evaluate the drainage system of second degree forest roads [13]. The factors affecting 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 (little width, large width, and depth of ditch) were measured from about 1.5 km of secondary forest roads at 40 m intervals to evaluate the drainage system of second degree forest roads (every 40 m was considered as a station). Then sample point locations were recorded using GPS and a related map was prepared with *Arcview* 3.1 software (Fig. 2). Culverts in the drainage system were measured for diameter and their distances from each other. Locations of the culverts also were recorded using GPS. Positions of any landslide and buoyancy in the region from excavation and embankment ranges was also recorded using GPS. In addition, road routes were tracked and recorded using GPS for obtaining desirable accuracy. Fig. 3 shows the location of sample forest roads for the study.

Results

Result of the Maps

The slope map of the Seri 1 of Darabkola forest area was prepared in 5 classes. Fig. 4 shows the sample road

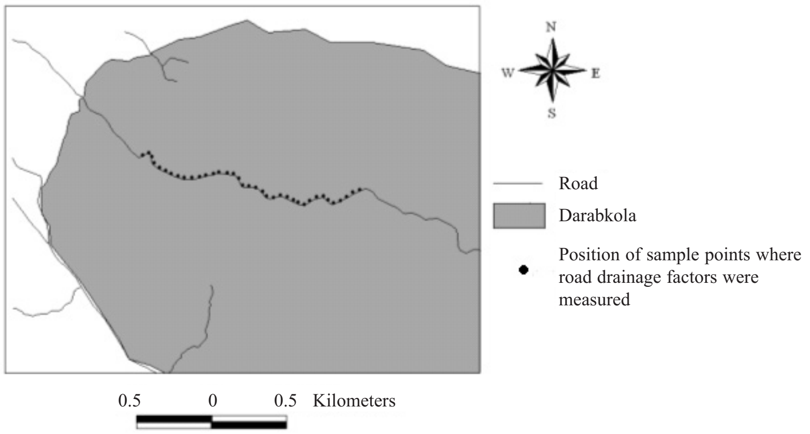

Fig. 2. Position of sampling points which the effective factors in road drainage were measured in them.

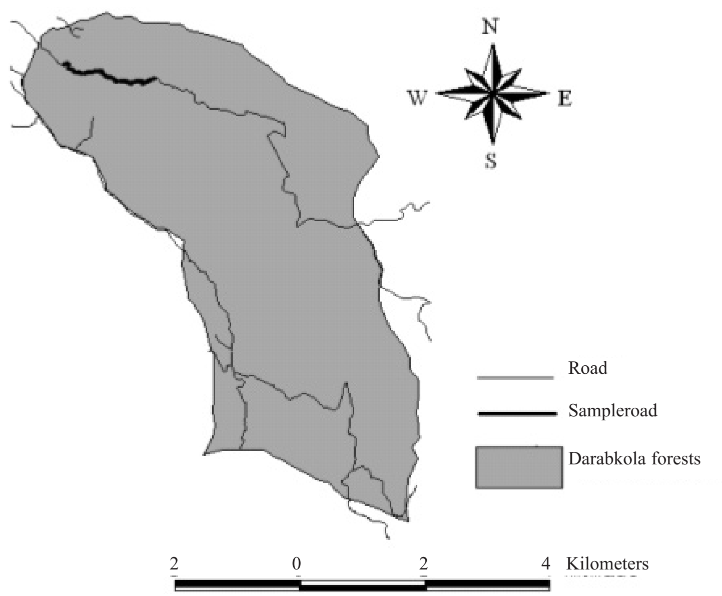

Fig. 3. Location of sample forest road for this study.

Table 1. Standard values of width, cross, and longitudinal slope of grade 2 forest roads [5].

Factors	Cross slope (%)		Longitudinal slope (%)	Road width (meter)	
	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 [5].

Factors	Longitudinal slope of ditch (%)	Side slope of ditch (%)	Sizes of ditch (cm)			Culvert diameter (cm)	Distance 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

position on the slope map. With attention to Fig. 4, most of the sample road sets were in 10-18 and 18-28 classes. An aspect map of the area also was prepared in 5 classes (Fig. 5). With attention to the aspect map, most of the sample road sets were in the northern aspect (N) class.

Result of Field Operation (Data Collection)

Evaluation of the drainage system was done for 1.5 kilometers of the Seri 1 of Darabkola forest roads (Fig. 3). Tables 3 and 4 show comparisons of existing drainage systems in secondary forest roads in Seri 1 of 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.

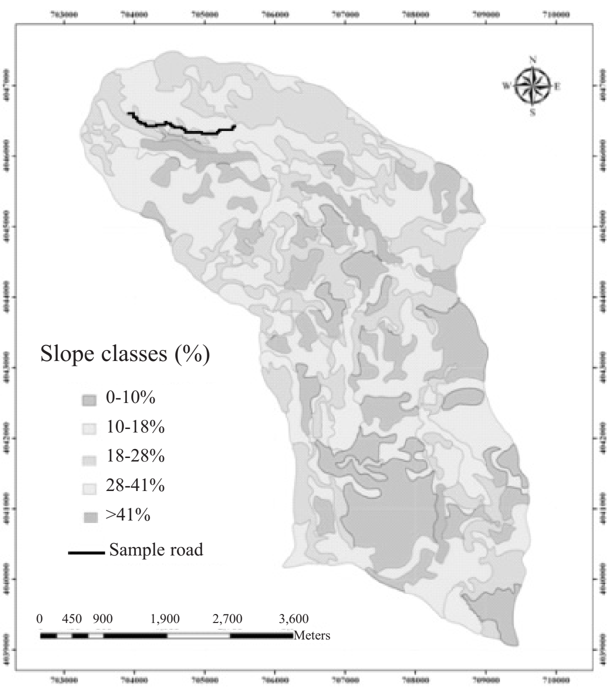

Fig. 4. Slope map of Seri 1 of Darabkola forest and position of sample road on it.

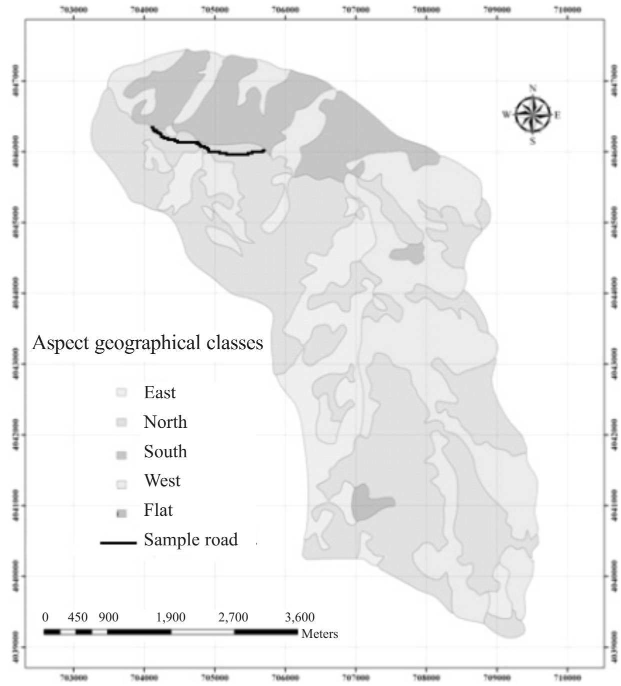

Fig. 5. Aspect map of Seri 1 of Darabkola forest and position of sample road on it.

The average road width with shoulders was measured at 7.94 m and without shoulders it averaged 9.4 m. The average of road longitudinal slopes was 3.72 percent. The average cross slope of roads was 6.14 percent. Average of the cross slope of roads is the mean of cross slope averages toward an excavation range (8.32%) and an embankment range (3.79%). The Average of excavation range slope was 26.27% and average of embankment range slope was 27.70%. Average of longitudinal slope of ditch was 4.02%. Average of longitudinal slope of ditch was in the range of 1 to 1.31. Road ditches are trapezoidal in shape. The average of the large side (width) of a ditch was 73.89 cm and average of the little side (width) was 32.24 cm. Thus the average ditch width was 106.13 cm. In addition, average ditch depth was 31.86 cm. The average ditch basal area was 0/16 m^2.

Table 3. Comparison of width, cross, and longitudinal slope of grade 2 forest roads in Seri 1 of 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 Seri 1 of Darabkola forest road	6.14		3.72	7.94	4.9

Table 4. Comparison of drainage system of grade 2 forest road in Seri 1 of 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 between culverts (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 Seri 1 of Darabkola forest road	4.02	1 to 1.31	32.24	31.86	106.13	64.44	165

There were eight cement culverts in the sample forest road (1.5 km) (Fig. 6). Table 5 shows data for the culverts in a grade 2 forest road in the Seri 1 of Darabkola area. The average diameter of culverts was 64.44 cm. Average distance of culverts was 165 m. In total, two landslide and buoyancy regions were observed in the sampled forest road (1.5 km) (Fig. 7).

Discussion and Conclusion

The slope map shows that most of the sample road sets fell into categories of 10-18% and 18-28% classes of slope map. This shows that road construction incurred a lot of embankment and excavation. Since excavation and embankment cause an unbalancing of the soil, high levels of erosion can be predicted along the road together with the formation of a lot of sediment under the road. So results of Hosseini et al. [8] in the Seri 1 of Darabkola forest area showed that percentage of bare soil on cut slopes was more than that on filled slopes. This indicates the necessity of having a strong drainage system for forest roads. In addition, with regard to attention to the aspect map, most of the sample road sets had a northern aspect (N) class. Since the regions on the northern range (aspect) usually have more moisture, higher amounts of runoff can be expected on the road at this aspect. This information can be used to design an effective drainage system.

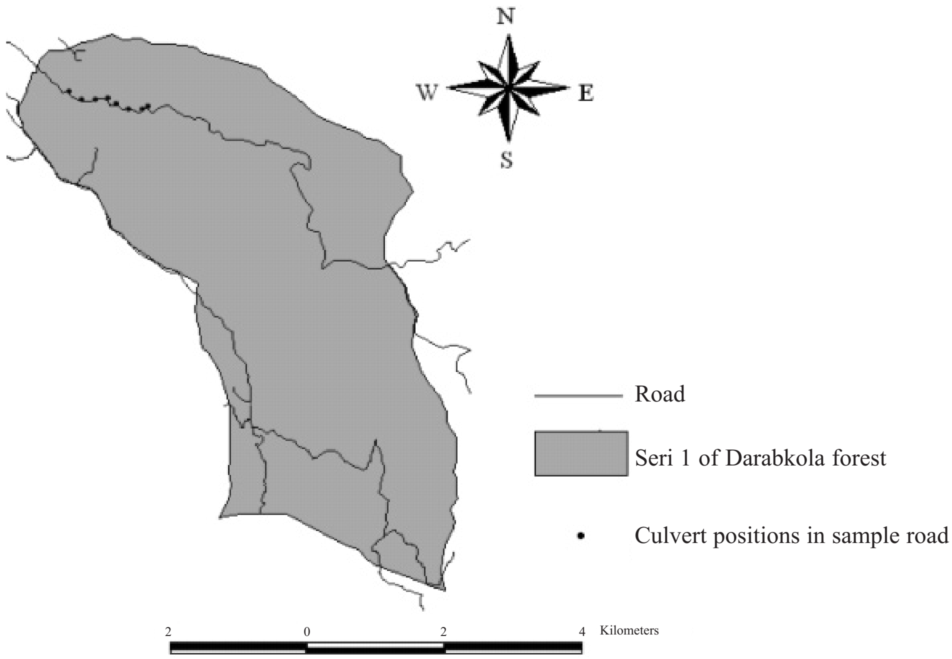

Fig. 6. Position of culverts in sample road.

Considering these results, average road width (including shoulders) was 7.94 meters; without shoulders width averaged 9.4 meters. The standard measurement for road width with shoulders is 8.5-9 meters, and without shoulders the standard is 5.5 meters. Thus, the existing road width is lower than the standard. Road width may be decreased due to the passage of time, but it can be said that it is in accordance with standards. With attention to Table 3, the average of longitudinal slopes of the Seri 1 of Darabkola forest Road (3.72%) was in accordance with standards of (3 to 6 percent), but it only met the minimum requirement level of the standard. So sediment accumulation in the ditches was because of the low longitudinal slope of the forest roads. The average cross slope of the road was 6.14 percent. The slope is the mean of the cross slopes average towards the excavation range (8.32%) and embankment range (3.79%). This cross slope was more than the standard for 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 on the road's surface. In addition, the cross slopes of forest roads should be more when the longitudinal slope of a forest road is low (such as on the Seri 1 of Darabkola forest roads) [5]. The result is different from the results of Khalilpour [14], in that the cross slope of Estakhrposht forest roads was estimated at 2-3%. The reason is the suitability of the longitudinal slope of Estakhrposht forest roads; the slope of excavation range (26.27%) and embankment range (27.70%) were determined as suitable because of their harmony with the common slope of the study area.

Longitudinal slope of ditch (4.02%) was suitable because of its harmony with the longitudinal slope of the forest road (3.72%), its harmony with standards (3-4% to 6%), and lack of water accumulation in the ditch according to FAO standards [18]; the standard longitudinal slope of a ditch is 2-8% for water collection without extra sediment. The average of side slope of ditch measured 1 to 1.31, which should be lower because of non-cemented ditches in most of the Seri 1 of Darabkola forest roads. Furthermore, in low-slope ranges, side slope of ditch was considered lower (1 to 4). These results are different from the research results of Khalilpour [14], in that the side slope of ditch was estimated within a range of 1 to 1.5, the reason being that ditches in the Estakhrposht Forest roads were cemented.

A forest road ditch is trapezoidal in shape. The average of the large side (width) of the ditches was 73.89 centimeters and the average of the little side (width) of the ditches was 32.24 centimeters. Thus the average width of ditches was 106.13 centimeters. Although the average width of ditches was close to the standard of (100 centimeters), it was unsuitable because of the wide range of ditch widths in some regions. Of course the average ditch floor width (average of little side) (32.24 centimeters) is in accordance with the standard (30 centimeters). However, the average ditch depth of 31.86 centimeters is different from the standard (at least 35 centimeters). Average of ditch basal area was 0/16 m^2, and this should be a larger area. Because low basal area and depth of ditch make it harder for water flow in the ditch. Khalilpour [14] also recommended that ditch basal area (0.5 m^2) was low in his study area because of a barricade in the ditch. Thus an important result of this research is that the maintenance of forest roads, especially drainage construction, is not always well considered in Iran. The ditches of the Seri 1 of Darabkola forest roads have been malformed in most regions and have been transformed from trapezoidal shapes to triangular. In addition, ditch floors have been filled with sediment, grass and small branches. These ditches allow water to flow into the canals and are not useful. Osma et al. [16] also concluded that clearing drainage channels should be done whenever necessary and that the mechanical clearance of roadside scrub should be done for the purpose of safety and that this would be preferable to the use of herbicides. Therefore, cleaning operations for ditches must be set as a high priority in main-

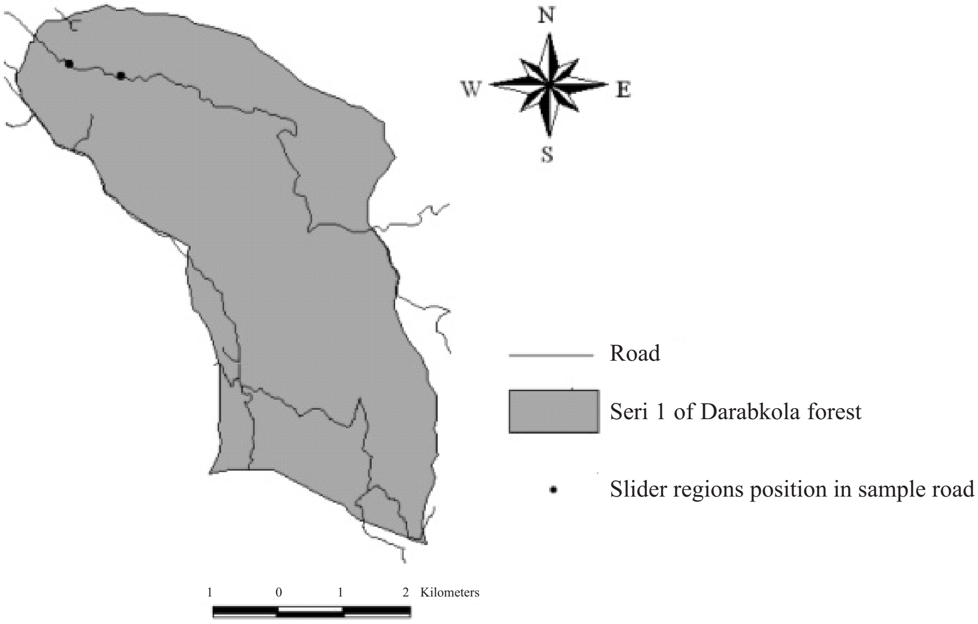

Fig. 7. Position of slider regions in sample road.

Table 5. Culvert data for grade 2 forest road in Seri 1 of Darabkola forest.

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

tenance programs of forest roads to facilitate properly functioning drainage.

There were eight cement culverts in the sample forest road, of which seven were 60 cm in diameter and one was 100 cm in diameter (Table 5). The average culvert diameter was 64.44 cm, approximately that of the standard (65-100 cm) [5]. In addition, this result is in harmony with that of Akbari Fardi [15], which recorded culvert diameter of 43-49 cm in his study area. Brinker also determined a minimum culvert diameter of 45.7 cm. In summary, a recommended culvert diameter in forest roads depends on the watershed basin and its characteristics such as shape, slope, topography, climate, soil type, plant cover, and number and frequency of torrent to flow a region [19]. Average length of culverts was 165 m, which is far more than the standard (50-70 m) [5]. Thus construction of more culverts is essential for Seri 1 of Darabkola forest roads. Brinker [13] has presented the following formula for a recommened maximum for culvert distance.

$$\text{Culvert distance (m)} = (400/\text{slope road}) + 100$$

With attention to the formula above, the maximum distance of culverts in Seri 1 of Darabkola forest roads is 207.52 cm, of which culverts cover a distance of 165 meters, and this is appropriate for the Seri 1 of Darabkola forest roads. In addition, Akbari Fardi [15] estimated a culvert distance covering 419-480 m for his study area (Nekachoob forest). Thus culvert distance of the Seri 1 of Darabkola forest roads is preferable to that of Nekachoob. Furthermore, the culverts in the Seri 1 of Darabkola forest roads were completely clear from little branches and sediment. Two landslide and buoyancy regions were observed in the sample forest road (1.5 kilometer). According to Anon [10], the existence of any landslide and buoyancy in sites of excavation and embankment is a strong contributing factor to improper drainage. Thus drainage in the Seri 1 of Darabkola forest roads can be determined as moderate, considering low incidences of landslide and buoyancy in the region.

Finally, it can be concluded that the situation of physical characteristics and engineering of Seri 1 of Darabkola forest roads is appropriate and in accordance with standards for forest roads in Iran. But the results of the research showed that the current drainage system in Seri 1 of Darabkola forest roads in some cases is different from the standard for a drainage system. Thus, construction of a new drainage system with biological consistency is essential in the region. Of course this would require the use of economic resources, but this is essential for the maintenance of forest roads. The focus should not only be based on unblocking culverts and ditches, but should include construction of more drainage channels. This current research has evaluated the road planning and drainage system of Seri 1 of Darabkola forest roads and established the fact that, in comparison with standards, it is moderately effective. Thus maintenance operation of forest roads and drainage systems is essential to sustain Seri 1 of Darabkola forest roads. References to other drainage systems should be considered with periodic maintenance operations and after torrents, logging, and skidding [18]. Thus, it is suggested that consideration for ditches and culverts and other drainage infrastructure be increased. In addition, the creation of further culverts is essential for Seri 1 of Darabkola forest roads.

References

1. POUA K., MAJNOUNIAN B., FEGHHI J., LOTFALIAN M., ABDI A. Application of Beckmound method in evaluating of forest roads network in ground skidding method with Skidder, case study: Namkhane Seri of Kheiroud Kenar forest. Iran Forest journal, **1**, 35, **2009**.
2. EGAN A., JENKINS A., ROWE J. Forest road in west Virgina, USA: Virgina University Morgan, Town, WV, USA. pp. 8, **1985**.
3. FAO, Irrigation and Drainage Paper No. 46, CROPWAT: A Computer Program for Irrigation Planning and Management, pp. 48, **1992**.
4. GOSAR M. Mercury in River Sediments, Floodplains and Plants Growing thereon in Drainage Area of Idrija Mine, Slovenia. Pol. J. Environ. Stud. **17**, (2), 227, **2008**.
5. SARIKHANI N., MAJNOUNIAN B. Guide of plan, perform and exploitation of forest roads. journal of number 131, program and budget organization press, pp. 170, **2005**.
6. MAJNOUNIAN B., MAHDAVI M., NIKOUYI M. Cross drainage designing of forest roads in Siyahbil Seri in Asalam watershed Basin, Iran Natural Resources Journal, **58**, (2), 339, **2005**.
7. AREVALO J. R., DELGADO J. D., OTTO R., NARANJO A., SALAS M., ANDES-PALACIOS J. Exotic species in the roadside plant communities through an altitudinal gradient in Tenerife and Gran Canarina (Canary Islands). Plant Ecol. Evol. Syst. **7**, 185, **2005**.
8. HOSSEINI S. A., JALILVAND H., POURMAJIDIAN M. R., PARSAKHOO A. Effects of forest road clearings on understory diversity beneath *Alnus subcordata* L. stands in Iran. Maejo Int. J. Sci. Technol. **5**, (02), 241, **2011**.
9. JUSZCZAK R., KĘDZIORA A., OLEJNIK J. Assessment of Water Retention Capacity of Small Ponds in Wyskoć Agricultural-Forest Catchment in Western Poland. Pol. J. Environ. Stud. **16**, (5), 685, **2007**.

10. ANON E. How to install corrugated steel culverts. Nova Scotia. Dep. Environment, 9- 27, **1995**.
11. SWIFT LW. Forest Road design to minimize Erosion in the Southern Appalachian Proceedings of forestry and water quality: a mid-south symposium. Monticello, AR: University of Arkansas, 141-151, **1985**.
12. BRAKE D., MOLNAU M. Sediment transport distances culvert spacing on logging roads with in the Oregon cost mountain range. USA. pp. 21, **2001**.
13. BRINKER RW. Forest Road and Construction Associated Water Diverson Devises. Alaban Cooperatives Extension System, ANR 916, pp. 27, **1995**.
14. KHALILPOUR AMIRI H. investigation of drainage factors in Estakhrposht forest in Neka. MS thesis, Mazandaran University, Iran, pp. 73, **2007**.
15. AKBARI FARDI R. Determination of culvert diameter in forest road. MS thesis, Mazandaran University, Iran, pp. 108, **2007**.
16. OSMA E., ÖZYIĞIT İ. İ., ALTAY V., SERIN M. Urban vascular flora and ecological characteristics of Kadıköy district, Istanbul, Turkey, Maejo Int. J. Sci. Technol. **4**, 64, **2010**.
17. Office of Educational and Research Forest of Department of Natural Resources of Sari, Seri 1 of Darabkola forestry plan, pp. 550, **2004**.
18. FAO, Description of the environmentally sound road construction technique in steep terrain. Forestry department, pp. 22, **2006**.
19. FAO, drainage systems and protection works for forest roads. Forestry department, pp. 10, **2007**.