The effects of *Rubus hyrcanus L.* and *Philonotis marchica* (Hedw.) Brid. on soil loss prevention from cutslopes of a forest road

A. Parsakhoo[1], M. Lotfalian[1], A. Kavian[2], S.A. Hosseini[1], M. Demir[3]

[1]*Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Iran*

[2]*Department of Watershed Management, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Iran*

[3]*Department of Forest Construction and Transportation, Faculty of Forestry, Istanbul University, Istanbul, Turkey*

ABSTRACT: The effects of *Rubus hyrcanus* L. and *Philonotis marchica* (Hedw.) Bridon on runoff generation and soil loss from cutslopes of forest roads were investigated. The study was conducted at the northern forest of Iran, about 30 km south of the city of Sari. Runoff and sedimentation after each rainfall simulation and chemical and physical soil properties were measured in 14 plots with an area of 0.48 m^2. The obtained results indicate that the vegetation dominated by *Philonotis marchica* exhibited the higher runoff coefficient and soil loss, with averages of 27.25% and 92.40 $g\cdot m^{-2}\cdot h^{-1}$(gram per square meter per hour), respectively, in comparison to *Rubus hyrcanus*. For *Philonotis marchica* (Hedw.) Brid. the sediment concentration increased quickly at the beginning of rainfall simulations and after 10–12 min there was a fast decrease in sediment concentration. The peak of sediment concentration was for the *Rubus hyrcanus* L. in the 13^{th}–15^{th} min In conclusion, *Rubus hyrcanus* L. prevented or decreased the risk of runoff and soil loss from cutslopes of forest roads in our study area.

Keywords: vegetation type; runoff; soil loss; cutslope; forest road

Vegetation plays an important role in controlling soil erosion (Zhou et al. 2006). Many studies have emphasized the importance of vegetation cover on soil loss (De Oña et al. 2009). Higher amounts of vegetation cover are associated with a generalized delay in runoff, an increase in soil infiltration capa-city and a reduction of soil erodibility (Moreno-de lasheras et al. 2009). Most of roads in Hyrcanian forest are cut through the hilly and mountainous areas (Parsakhoo et al. 2009). These mountainous roads experienced soil erosion and numerous landslides in the past. Eroded materials from cut slopes block the ditch and culverts (Coker et al. 1993; Ziegler et al. 2001). One of the most obvious signs of sedimentation in ditch is water overflowing on the road surface (Reid, Dunne 1984; Deletic 2001).

Shixiong Cao et al. (2006) indicated that vegetation cover could significantly reduce sediment yield from unpaved roads. The aboveground components of vegetation, such as leaves and stems, partially absorb the energy of the erosive agents of water and wind, so that less is directed at the soil, whilst the belowground components, comprising the rooting system, contribute to the mechanical strength of the soil (Morgan, Rickson 1995; Tague, Band 2001). Malik et al. (2000) reported that ryegrass, crimson clover, lespedeza and tall fescue controlled about 64, 61, 51 and 37% of soil erosion, respectively. Zhou, Shangguan (2007) found that both the soil erosion rate and average infiltration rate were linearly correlated with root surface area density in cm^2 root surface area per unit soil volume. In a study in China it was demonstrated that the pine woodland induced the largest water loss to surface runoff, followed by sloping cropland, lucerne, semi-natural grassland and shrubland; the poor capability of pine woodland for water conservation was due to soil compaction and poor ground coverage under the tree (Chen et al. 2007). Roads sown with *Bromusinermis*, *Elymussibiricus*, *Elymus*, *Poaannua* could bear traffic loads up to 300 vehicles per year.

Philonotis marchica (Hedw.) Brid., also known as philonotis moss, belongs to the family Bartramiaceae. It is widespread in the world. The species grows in calcareous wetlands in North, West and Central Europe, West Asia, Japan, Korea, North America, Algeria, Madeira (Šoltés 2008). *Rubus* is a large genus of flowering plants in the rose family, Rosaceae. Most of these plants have woody stems with prickles like roses; spines, bristles, and gland-tipped hairs are also common in the genus. The *Rubus* fruit, sometimes called a bramble fruit, is an aggregate of drupelets. In our study area *Rubus hyrcanus L.* had the most canopy coverage at the edge of forest road (Hosseini et al. 2001).

The objective of this study was to compare the rate of runoff and soil losses from a cutslope covered by *Rubus hyrcanus L*. and *Philonotis marchica* (Hedw.) Brid. using simulated rainfall. The final objective was to produce a series of management recommendations based on the results of the study.

MATERIAL AND METHODS

Description of the study area

Lolet and Lattalar forests within the watershed number of 71 Tejen in the Hyrcanian zone of Iran were selected as the study area. Study was conducted in August and September 2011. The research site with a total area of 3,801 ha and perimeter of 32,784 m is located approximately on the coordinates of 36°12'55'' to 36°17'45'N and 53°8'20' to 53°13'55'E. The form coefficient and compactness coefficient of the study area are 0.82 and 1.5, respectively. Minimum altitude is about 300 m and the maximum is 1,650 m. The length of the main canal or ravine in Lattalar and Lolet forests are 5,000 m and 7,000 m, respectively. The region has a very moist to mid moist and cold climate with the mean annual precipitation of 800 mm. The bedrock is typically marl, marl lime and limestone with a soil texture of loam and clay loam. Forest stands are dominated by *Fagus orientalis* Lipsky, *Carpinus betulus* and herbaceous species of *Carex silvatica*, *Buxus hyrcanus, Berachypodium silvaticum*, *Ruscus hyrcanu*s, *Phyllitis scolopendrium, Rubus hyrcanus L.* and *Polypodium auidinum*. Forest roads in the study area are used by off-road cars and off-road trucks. The traffic density is 5 vehicles per day. The mean of litter thickness on the fillslope and forest ground was 2 cm and on the cutslope and road surface it was 0.1 cm.

Research approach

14 rainfall simulations were carried out on three types of experimental plots on cutslopes (Fig.1) including plots covered by *Philonotis marchica* (Hedw.) Brid. (5 replications), *Rubus hyrcanus L*. (3 replications) and bare soil (6 replications). Each of the experimental plots was treated with the rainfall of a portable single nozzle simulator for duration of 20 minutes. The drop size was 3 mm. Water of the intensity of 32.4 mm·h^{-1} and temperature of

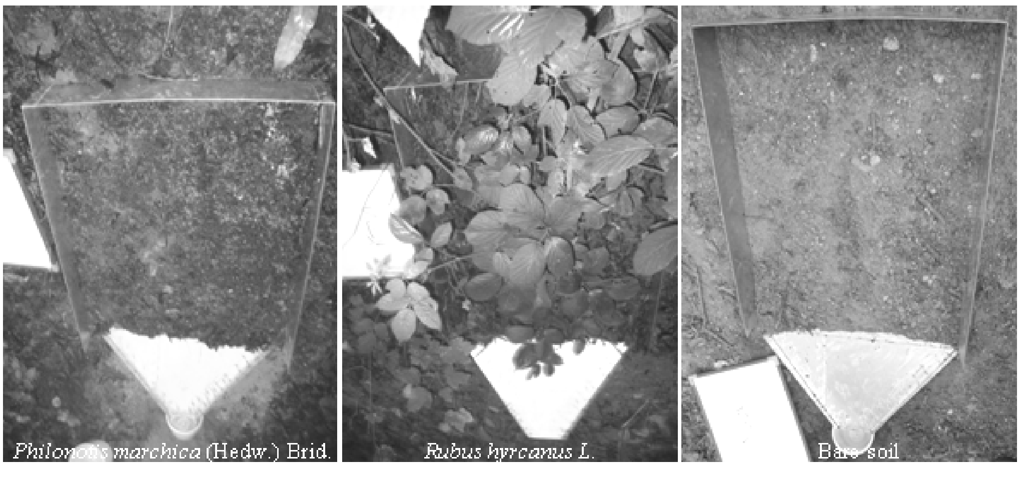

Fig. 1. Experimental plots for *Philonotis marchica* (Hedw.) Brid., *Rubus hyrcanus* L. and bare soil

23°C was falling from the Schlick r18650 nozzle at 2 m above the cutslope onto a square area of 0.48 m^2 that was limited by a steel structure. Runoff water and sediment samples were collected by a water-gauge every 4 minutes and then runoff parameters including runoff volume, infiltration, runoff coefficient and time to runoff beginning as well as sediment parameters including sediment concentration, sediment yield and total soil loss were measured in each plot. Sediment was oven-dried at 105°C for 2 hours at least. Moreover, samples of the top soil (0–10 cm deep) were collected by a cylinder (484 cm^3) for physical (soil texture, bulk density and moisture) and chemical analysis (T.N.V or $CaCO_3$ and organic matter). Soil texture was determined by the Bouyoucos hydrometer method. Lime percentage (T.N.V or $CaCO_3$) was measured using the NaOH titration method. Soil organic carbon was determined using the Walkley–Black technique.

Statistical analysis

Randomized complete block design was used to analyse the effects of independent variables on quantitative factors of runoff and soil loss. Data were statistically analysed using the GLM procedure in SAS program. The SNK (Student Newman Keuls) multiple comparison test at a probability level of 5% was used to compare means among treatments and diagram designed by Excel software. Correlation analysis was conducted using Pearson's procedures.

RESULTS AND DISCUSSION

Although the percentage of plant cover measured in the present study was relatively high on the soil beneath two vegetation types, the levels were higher on the soil beneath *Philonotis marchica* (Hedw.) Brid. compared to *Rubus hyrcanus L*. The soil beneath *Philonotis marchica* (Hedw.) Brid. has a higher content of $CaCO_3$ (28.4%) compared to *Rubus hyrcanus L*. whereas the amount of silt (27.3%) in the soil beneath the *Rubus hyrcanus L*. was higher than that in the soil beneath *Philonotis marchica* (Hedw.) Brid. The amount of organic matter reflects the percentage of plant residues and soil organisms that have lived and died in the soils (Mohammad, Adam 2010). In the present study the amount of organic matter in the soil beneath both species was higher than that in the bare soil (Table 1). Organic matter content influences soil erosion through its effect on the stability of aggregates (Guerra 1994).

Table 1. Characteristics of the experimental plots for *Rubus hyrcanus L*., *Philonotis marchica* (Hedw.) Brid. and bare soil on cutslopes

Parameters	*Rubus hyrcanus*	*Philonotis marchica*	≈Bare soil	Parameters	*Rubus hyrcanus*	*Philonotis marchica*	≈Bare soil
Slope (degree)				**sand (%)**			
Mean	49.0	51.0	41.6	mean	51.0	54.3	57.9
Standard deviation	7.6	8.3	8.8	standard deviation	12.8	9.8	7.4
Rock fragment cover (%)				**silt (%)**			
Mean	2.0	2.3	2.6	mean	27.3	21.8	21.8
Standard deviation	0.2	0.9	0.6	standard deviation	6.7	5.5	5.2
Plant cover (%)				**clay (%)**			
Mean	45.0	54.0	10.0	mean	21.7	23.9	20.3
Standard deviation	3.8	9.1	1.9	standard deviation	7.36	6.3	4.1
Litter cover (%)				**organic matter (%)**			
Mean	30.0	15.8	12.1	mean	1.5	1.4	1.0
Standard deviation	4.0	3.2	2.5	standard deviation	0.3	0.4	0.1
$CaCO_3$ (%)				**moisture (%)**			
Mean	12.3	28.4	26.1	mean	15.5	15.1	16.0
Standard deviation	2.0	4.4	3.6	standard deviation	2.5	2.9	1.8

Table 2. ANOVA for the effects of environmental parameters on runoff and soil loss from cutslopes

Parameters	Runoff coefficient	Time to runoff	Sediment concentration	Soil loss
Species	14.22***	11.31***	2.92*	2.85*
Slope	12.60***	40.41***	2.99*	2.88*
Rock fragment cover	1.17ns	1.77ns	2.54ns	1.82ns
Plant cover	15.64***	28.83***	2.33ns	2.57ns
Litter cover	5.09**	24.39***	3.43*	3.97**
Time	8.93***	0.00ns	0.26ns	0.71ns
Sand	2.01ns	8.47***	1.15ns	1.03ns
Silt	4.41**	7.94***	1.14ns	1.08ns
Clay	3.05ns	12.83***	1.28ns	1.55ns
Organic matter	3.94*	1.00ns	3.85*	3.25*
$CaCO_3$	3.77**	14.32***	2.65*	1.99ns
Moisture	0.13ns	2.62ns	1.63ns	0.85ns
Bulk density	6.41***	2.60ns	7.83***	6.47***

*,**,*** significant at a probability level of 5, 1 and 0.1 %, respectively, ns – not significant

The vegetation type had a significant effect on runoff coefficient ($P < 0.001$) and soil loss ($P < 0.05$) from the cutslope. The percentage of litter and plant cover had significant effects on runoff parameters, as shown in Table 2. The vegetation provides litter coverage on the soil surface in winter, which may not only prevent the direct raindrop impact, but also increase the soil stability due to the increased soil organic matter content (Zhang et al. 2004; Gyssels et al. 2005). There were significant differences among the different slope classes in the amount of surface runoff and sediment yield. Our results demonstrated that the time to runoff was significantly different among the different amounts of sand, silt and clay during the rainfall simulation ($P < 0.001$).

Results indicated that there were significant differences between *Philonotis marchica and Rubus hyrcanus* with respect to the runoff generation and sediment production. Vegetation dominated by *Philonotis marchica* exhibited the higher runoff coefficient and soil loss, with averages of 27.25% and 92.40 $g \cdot m^{-2} \cdot h^{-1}$, respectively, in comparison to *Rubus hyrcanus* (Table 3). Cerdà (2007) studied the road embankment erosion by means of simulated rainfall experiments (45 $mm \cdot h^{-1}$ during one hour on 0.41 m^2 plots) in Valencia province, Spain. He reported that the bare road embankments, still under construction, contributed with 30 times higher soil erosion than the vegetated ones. In a vegetated road, in 10 years old road embankments, runoff coefficient and soil erosion rates in winter were higher than those in summer. This was also observed for non-vegetated road embankments under construction. Vegetation provides a protective layer or buffer between the atmosphere and the soil by

Table 3. Comparisons between *Philonotis marchica and Rubus hyrcanus* with respect to the runoff generation and sediment production from cutslopes

Species	Runoff volume ($ml \cdot s^{-1}$)	Runoff coefficient (%)	Time to runoff (s)	Infiltration ($ml \cdot s^{-1}$)	Sediment concentration ($g \cdot l^{-1}$)	Soil loss ($g \cdot m^{-2} \cdot h^{-1}$)	Sediment yield ($g \cdot s^{-1}$)
Rubus hyrcanus	0.7c	15.2c	307.5a	3.7a	6.5c	53.2c	0.007c
Philonotis marchica	1.2b	27.2b	189.4b	3.2b	12.7b	92.4b	0.012b
≈Bare soil	2.0a	45.8a	182.7b	2.3c	16.9a	234.8a	0.031a

In the same column, values with the same superscript are not significantly different at 5% based on SNK test

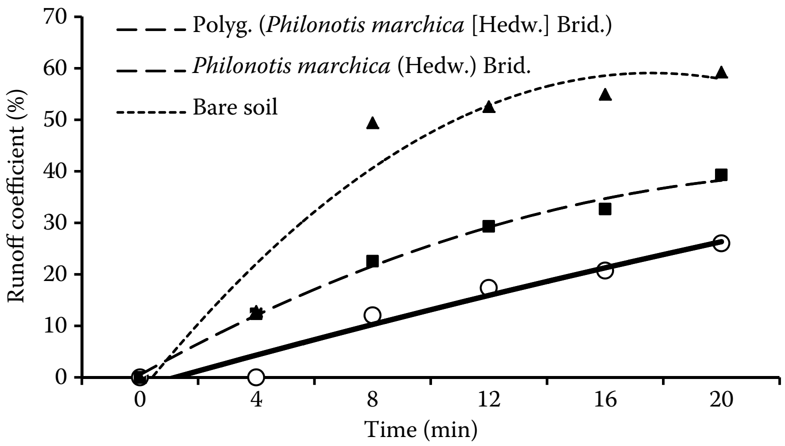

Fig. 2. Behaviour of surface runoff from rainfall simulations on plots covered by two vegetation types and bare soil

means of its canopy, roots, and litter components (Mohammad, Adam 2010).

Fig. 2 shows the behaviour of runoff during the 20 min rainfall simulation tests on road cutslopes. The runoff coefficient increased quickly during the first 8–10 min. Then it increased slowly until the end of the simulation tests probably because of the surface soil saturation with water (Vršic 2011). The runoff flow beneath the cover of *Rubus hyrcanus L.* was lower than that beneath *Philonotis marchica* (Hedw.) Brid. The runoff coefficient on bare soil was higher than that beneath both plant species. In particular the moss layer would have a large storage capacity, as Sphagnum moss can absorb up to 16 times its air-dry weight of water (Schouwenaars 1993). The litter beneath the *Rubus hyrcanus L.* was twice more than that of *Philonotis marchica*. This layer can absorb runoff and decrease the soil loss.

For *Philonotis marchica* (Hedw.) Brid. the sediment concentration increased quickly at the beginning of rainfall simulations and after 10–12 min from the beginning of the experiment, there was a fast decrease in sediment concentration. The peak of sediment concentration was for *Rubus hyrcanus L.* in the 13–15th min (Fig. 3). Fig. 4 shows the relationship between soil loss rates and runoff coefficient after rainfall simulations on different experimental plots. Soil loss from bare soil was higher than that of vegetation covered plots. Moreover, soil loss from plots covered by *Philonotis marchica* (Hedw.) Brid. was higher than that from plots covered by *Rubus hyrcanus L.*

There was a significant positive correlation between soil loss and runoff coefficient. Increases in the amount of surface runoff lead to an increase in soil loss from the cutslope. The soil loss decreased with increasing ground cover percentage (litter and plant cover) and decreasing runoff coefficient. It was proved that the amount of soil erosion decreased dramatically with the increase in vegetation coverage in the Loess Plateau of China (Wang, Wang 1999). Moreover, there was a significant negative correlation between soil loss and clay content of soil ($P < 0.05$). The soil loss decreased with increasing clay content (Table 4). This fact agrees with the findings of Forsyth et al. (2009) and

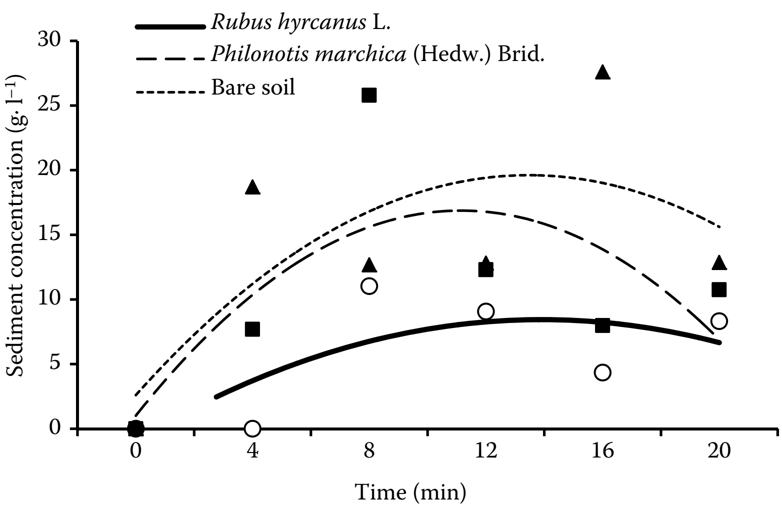

Fig. 3. Sediment concentrations on plots covered by two vegetation types and bare soil

Table 4. Pearson correlation matrix among site characteristics, runoff yield and sediment yield

No.	Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Species	1																
2	Slope	0.686***	1															
3	Rock	0.147	–0.321**	1														
4	Litter	–0.013	–0.031	0.129	1													
5	Plant	0.777***	0.831***	–0.293*	0.188	1												
6	Bulk density	0.314**	0.296*	0.370**	0.264*	0.333**	1											
7	Moisture	–0.101	–0.001	–0.601***	–0.172	0.121	–0.561***	1										
8	Organic matter	–0.505***	–0.483***	–0.347**	–0.325**	–0.525***	–0.879***	0.452***	1									
9	$CaCO_3$	0.068	–0.324**	0.588***	–0.024	–0.125	0.175	–0.094	–0.219	1								
10	Clay	0.434***	0.337**	–0.313**	0.188	0.594***	–0.158	0.499***	–0.037	–0.080	1							
11	Silt	0.043	0.363**	–0.565***	0.125	0.394**	–0.261*	0.541***	0.163	–0.492***	0.745***	1						
12	Sand	–0.258*	–0.374**	0.468***	–0.168	–0.506***	0.224	–0.556***	–0.066	0.304*	–0.936***	–0.932***	1					
13	Runoff coeffic.	–0.264*	–0.167	–0.104	–0.448***	–0.359**	–0.275*	0.089	0.381**	0.143	–0.249*	–0.073	0.173	1				
14	Time to runoff	–0.118	–0.256*	0.102	0.592***	0.014	0.083	–0.016	–0.163	–0.207	0.121	0.078	–0.107	–0.588***	1			
15	Infiltration	0.264*	0.167	0.104	0.448***	0.358**	0.275*	–0.089	–0.381**	–0.143	0.249*	0.073	–0.173	–1.000***	0.588***	1		
16	Sediment conc.	–0.042	–0.164	0.296*	–0.324**	–0.227	–0.060	–0.135	0.150	0.051	–0.228	–0.177	0.217	0.004	0.107	–0.003	1	
17	Soil loss	–0.144	–0.179	0.191	–0.374**	–0.272*	–0.104	–0.072	0.223	0.039	–0.257*	–0.145	0.216	0.262*	–0.013	–0.262*	0.903***	1

*,**,*** significant at a probability level of 5, 1 and 0.1 %, respectively

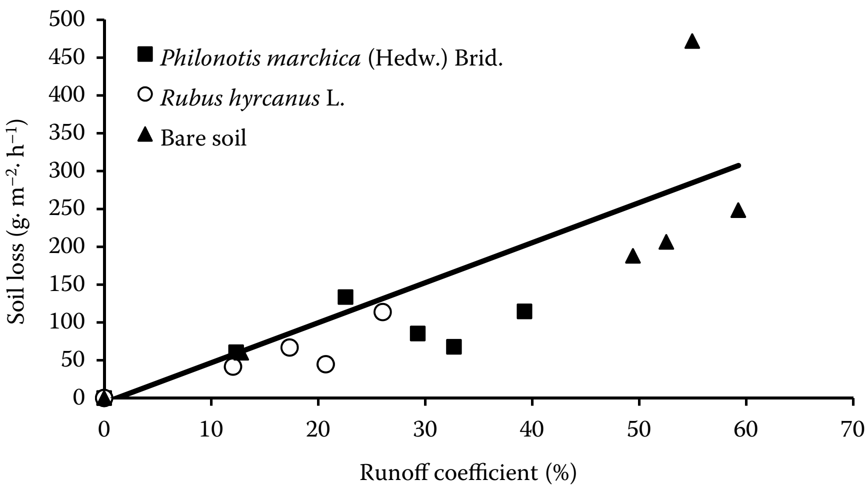

Fig. 4. Runoff coefficient and soil loss rates from rainfall simulations. R-square: *Philonotis marchica* (Hedw.) Brid

Neyshabouri et al. (2011). Besides, Duiker et al. (2001) in their erosion test found that average soil loss was negatively correlated with clay content but positively correlated with very fine sand and silt contents.

The variation in total runoff and soil erosion under different vegetation covers reflects the great importance of vegetative cover type. In conclusion, *Rubus hyrcanus L.* prevents or decreases the risk of runoff and soil loss from cutslopes of forest roads in our study area. This paper demonstrated that the majority of the sediments came from the bare soil of cutslopes. Dominant plants such as *Rubus hyrcanus L.* can be suggested to revegetate bare cutslopes, especially those species with high competitive ability and allelopathic potential to reduce soil erosion as well as the invasion of exotic species. Although, the autecological properties of this species have not been studied in the present study, it has a potential for cutslope revegetation because of its rapid vegetation growth.

References

Cerdà A. (2007): Soil water erosion on road embankments in eastern Spain. Science of the Total Environment, ***378***: 151–155.

Chen L., Huang Z., Gong J., Fu B., Huang Y. (2007): The effect of land cover/vegetation on soil water dynamic in the hilly area of the loess plateau, China. Catena, ***70***: 200–208.

Coker R.J., Fahey B.D., Payne J.J. (1993): Fine sediment production from truck traffic, Queen Charlotte forest, Marlborough sounds, New Zealand. Journal of Hydrology, ***31***: 56–64.

Deletic A. (2001): Modelling of water and sediment transport over grassed areas. Journal of Hydrology, ***248***: 168–182.

De Oña J., Osorio F., Garcia P.A. (2009): Assessing the effects of using compost–sludge mixtures to reduce erosion in road embankments. Journal of Hazardous Materials, ***164***: 1257–1265.

Duiker S.W., Flanagan D.C., Lal R. (2001): Erodibility and infiltration characteristics of five major soils of southwest Spain. Catena, ***45***: 103–121.

Forsyth A.R., Bubb K.A., Cox M.E. (2006): Runoff, sediment loss and water quality from forest roads in a southeast Queensland coastal plain Pinus plantation. Forest Ecology and Management, ***221***: 194–206.

Guerra A. (1994): The effect of organic matter content on soil erosion in simulated rainfall experiments in W. Sussex, UK. Soil Use and Management, ***10***: 60–64.

Gyssels G., Poesen J., Bochet E., Li Y. (2005): Impact of plant roots on the resistance of soils to erosion by water: a review. Progress in Physical Geography, ***29***: 198–217.

Hosseini S.A., Jalilvand H., Pourmajidian M.R., Parsakhoo A. (2011): Effects of forest road clearings on understory diversity beneath *Alnus subcordata* L. stands in Iran. Maejo International Journal of Science and Technology, ***5***: 241–251.

Malik R.K., Green T.H., Brown G.F., Mays D. (2000): Use of cover crops in short rotation hardwood plantations to control erosion. Biomass and Bioenergy, ***18***: 479–487.

Morgan R.P.C., Rickson R.J. (1995): Slope Stabilization and Erosion Control: A Bioengineering Approach. Chapan & Hall, London: 293.

Moreno-de las Heras M., Merino-Martín L., Nicolau J.M. (2009): Effect of vegetation cover on the hydrology of reclaimed mining soils under Mediterranean-Continental climate. Catena, ***77***: 39–47.

Mohammad A.G., Adam M.A. (2010): The impact of vegetative cover type on runoff and soil erosion under different land uses. Catena, ***81***: 97–103.

Neyshabouri M.R., Ahmadi A., Rouhipour H., Asadi H., Irannajad M. (2011): Soil texture fractions and fractal dimension of particle size distribution as predictors of interrill erodibility. Turkish Journal of Agriculture and Forestry, ***35***: 95–102.

Parsakhoo A., Hosseini S.A., Lotfalian M., Jalilvand H. (2009): Soil loss and displacement by heavy equipment in forest road subgrading project. International Journal of Sediment Research, ***24***: 227–235.

Reid L.M., Dunne T. (1984): Sediment production from forest road surfaces. Water Resources Research, ***20***:1753–1761.

Shixiong Cao C., Chen L., Gao W., Chen Y., Yan M. (2006): Impact of planting grass on terrene roads to avoid soil erosion. Landscape and Urban Planning, ***78***: 205–216.

Schouwenaars J.M. (1993): Hydrological difference between bogs and bog-relicts and consequences for bog restoration. Hydrobiologia, ***265***: 217–224.

Šoltés R. (2008): *Philonotis marchica* (Bryophyta), new record in Slovakia (exhausted fen Krivýkút, Poprad Basin). Thaiszia Journal of Botany, ***18***: 51–54.

Tague C., Band L. (2001): Simulating the impact of road construction and forest harvesting on hydrological response. Earth Surface Process and Landform, ***26***: 131–51.

Vršic S. (2011): Soil erosion and earthworm population responses to soilmanagement systems in steep-slope vineyards. Plant, Soil end Environment, ***57***: 258–263.

Wang X.D., Wang Z.Y. (1999): Effect of land use change on runoff and sediment yield. International Journal of Sediment Research, ***14***: 37–44.

Zhang B., Yang Y., Zepp H. (2004): Effect of vegetation restoration on soil and water erosion and nutrient losses of a severely eroded clayey Plinthudult in southeastern China. Catena, ***57***: 77–90.

Zhou Z.C., Shangguan Z.P., Zhao D. (2006): Modeling vegetation coverage and soil erosion in the Loess Plateau Area of China. Ecological Modelling, ***198***: 263–268.

Zhou Z.C., Shangguan Z.P. (2007): The effects of ryegrass roots and shoots on loess erosion under simulated rainfall, Catena, ***70***: 350 –355.

Ziegler A.D., Sutherland R.A., Giambelluca T.W. (2001): Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads. Earth Surface Process and Landform, ***26***: 235–50.

Received for publication March 6, 2012
Accepted after corrections June 28, 2012

Corresponding author:
Aidin Parsakhoo, M.Sc., Sari Agricultural Sciences and Natural Resources University, Faculty of Natural Resources, Department of Forestry, Mazandaran province, P.O. Box: 737, Sari, Iran
e-mail: aidinparsakhoo@yahoo.com