Research Journal of

Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 3 (6): 631-639, 2009
ISSN 1819-3412

Forest Damage Caused by Earth Working Operations in Uneven Aged Deciduous Stands

A. Parsakhoo and S.A. Hosseini
Department of Forestry, Faculty of Natural Resources,
Sari Agricultural Sciences and Natural Resources University, Sari, Iran

Abstract: In this study the regeneration and trees damages caused by bulldozer earth working operations were examined for a road construction project in the Lolet Forest, Mazandaran Province, Iran. Damages were assessed within the 10000 m^2 plot along 400 m roads in each of slope classes 30-40, 40-50, 50-60 and 60-70%. Damaged regeneration were classified into stem wounds, broken stems, leaning and interment and uprooted. Damaged trees were classified into crown injury; stem wounds, felled and uprooted trees. The wounds areas were also classified into 0-300, 300-600 and more than 600 cm^2. Results showed that the most common type of damage to regeneration was leaning and the majority of this damage occurred in diameter classes of 0-2.5 and 2.5-7.5 cm. In higher slope classes a greater number of regeneration and trees were damaged. Totally, 87% of regenerations were damaged by bulldozer earth working. Fifty percent of trees were damaged in each of slope classes: 7% were wounded (bark removed), 13% were crown injured and 30% were felled or uprooted. The wounded trees percentage in class 0-300 cm^2 was more than other wound classes. Minimizing regeneration and trees damages during earth working appears to allow a more rapid recovery of vegetation on bulldozed soil.

Key words: Regeneration damage, trees damage, earth working, road construction, Hyrcanian forests

INTRODUCTION

Forest road construction is often the most environmental trauma to adjacent ecosystems because earth movement and other activities can disturb whole watersheds (Kašková, 2004; Demir, 2007). In Hyrcanian forests of Iran, the crawler bulldozers are the most important machines which are used in earth working operation of road construction. Approximately, 80% of forest roads are constructed by bulldozer in this region (Parsakhoo *et al*., 2008a). The extent and degree of forest damage associated with bulldozer earth working are variable and appear to be related to slope, site characteristics, earth working method, soil texture and moisture content at the time of earth working and size of bulldozer blade (Pinard *et al*., 2000).

The direct damages to forest during earth working operations for forest road construction (>51% gradient) with bulldozer and excavator were determined by Tunay and Melemez (2004) in Turkey. The opening forest area with excavator was estimated 26.54% less than bulldozer. Visual disturbance strip of the area at road construction with bulldozer was determined twofold larger than road construction with excavator. Furthermore, excess material wasted downhill during the construction cause damage to trees below roadway 55% with bulldozer and 31% with excavator. The results of this

Corresponding Author: Aidin Parsakhoo, Department of Forestry, Faculty of Natural Resources, Sari Agricultural Sciences and Natural Resources University, Sari, Mazandaran Province, P.O. Box 737, Islamic Republic of Iran Tel: +98 152 4222984-5 Fax: +98 152 4222982

research showed that the environmentally sensitive techniques applied for the road construction projects are considerably superior to the traditional use of bulldozers on steep slopes (Tunay and Melemez, 2004).

The forest soil is a habitat for trees and regeneration roots and numerous viruses, bacteria, fungi, algae and other soil organisms (Arocena, 2000). Bulldozer earth working carried out in the forests has negative impacts on the variety of the soil's biological communities and conditions (Bengtsson *et al*., 1998; Demir *et al*., 2007). According to USDA NRCS soil quality institute the soil bulk density in bulldozer construction area is in the restrictive range of root growth (Hosseini and Jalilvand, 2007; Parsakhoo *et al*., 2008a).

Earth working activities on road removed large diameter trees as timber, damaged intermediate and killed smaller trees. When building roads, bulldozer operators avoid large trees (>60 cm DBH) and plow down intermediate and smaller trees. Skid operators dragging logs to consolidation decks have more autonomy than bulldozer operators, with fewer restrictions on where they move, a more maneuverable machine that allows them to avoid larger trees and rubber tires that substantially reduce soil perturbations. In tree-fall gaps, the smaller individuals were crushed prone (mean 18 cm DBH), while larger, more robust trees suffered slight or moderate damage (Feldpausch *et al*., 2005). Tree damage after earth working operations decrease the value of forest yields in future and stability of stands. The stand damage intensity is defined as the proportion between damaged trees after operations and all remaining trees (Košir, 2008).

The aim of this study was to examine the impacts of earth working operations, which have been carried out for forest road construction, on regeneration and trees damage in a mixed uneven aged hardwood stand in Mazandaran Lolet forest, Iran.

MATERIALS AND METHODS

Study Area

Lolet forest is located in Mazandaran Province in the Hyrcanian geographical region between 36° 13' 40" to 36° 17' 45" N latitude and 53° 8' 20" to 53° 12' 50: E longitude in Iran (Fig. 1). The Lolet Forest covers 1781 ha. The research area is in the 400 ×25 m boundaries (1 ha) of four secondary forest road which was under earth working by bulldozer in slope classes of 30-40, 40-50, 50-60 and

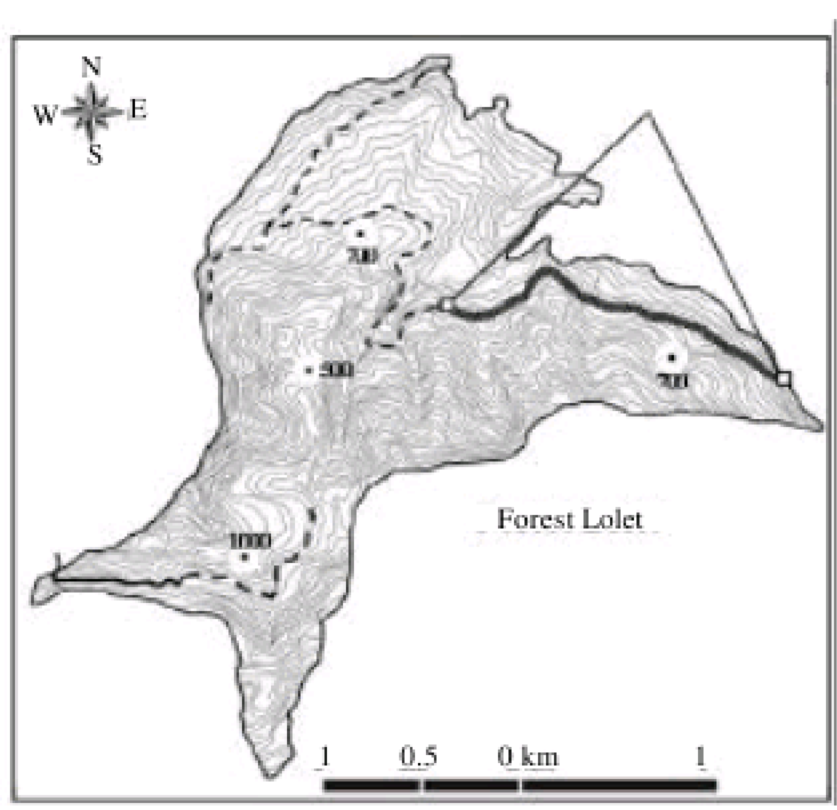

Fig. 1: The map of study area

60-70% (Fig. 2). The undamaged area where there is not any earth working impact is at least 25 m away from the road (at least 1 tree length far away from road edge to reduce side effects).

According to the 25 year, term data given by Soleiman Tangeh Meteorology Station, the nearest meteorology station to the research area, average annual precipitation is 635 mm. The climate of Mazandaran Lolet Forest is mid moist and cold. General texture type of soil in research area is loam. Vegetation period maintains for 8 months in average. Research area is a *Fageto carpinetum* stand. Altitude is 400-900 m, slope is 30-70% and it is in the NE aspect. The road passes through the stand in west-east direction. Earth working operations in the research area have been carried out by crawler bulldozer komatsu D60. The weight of this bulldozer is 17 t, the bucket volume is 5 m^3 and the engine power is 220 hp (Fig. 3).

Earth Working Damage Assessment

Damage to regeneration and trees from earth working operations was assessed along 1600 m forest road (within 10000 m^2 of each 400 m), in slope classes of 30-40, 40-50, 50-60 and 60-70 %. All injured regeneration <12.5 cm dbh were measured and classified into: (1) stem wounds (2) broken stems (3) leaning (4) covered by soil (interment) (5) uprooted (Iskandar *et al*., 2006). To inventory damaged trees by earth working operations, injured trees >12.5 cm dbh were measured and recorded, and classified according to three main classes of damage: (1) crown injury (2) stem wounds (3) felled and uprooted trees. The wounds were also classified according to area: (1) 0-300 cm^2 (2) 300-600 cm^2

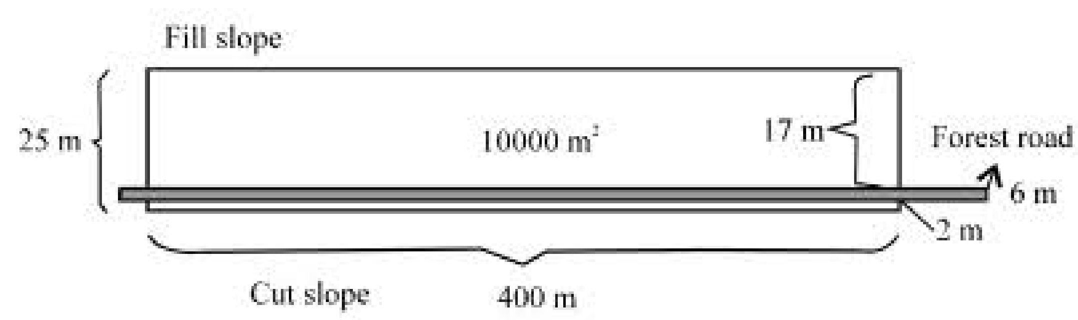

Fig. 2: Schematic of sampling area along road

Fig. 3: Bulldozer earth working operation in study area

(3) more than 600 cm^2. To compare injured regeneration density for different types of damage, all data were analyzed in Excel software.

Statistical Analysis

Analysis of variance was conducted using GLM procedures in SAS software. Mean values were compared using Tukey's multiple group mean comparison test. Significance level used in results was p<0.05.

RESULTS AND DISCUSSION

The share of damaged trees and saplings during the bulldozer earth working operations depends on the trees or saplings being near to road edge. Obviously, some them will be damaged once, twice or more times at the end of the earth working operation (Košir, 2008). The most common type of damage to regeneration was leaning stem (Fig. 4). The majority of leaning damage occurred in diameter classes of 0-2.5 and 2.5-7.5 cm (Fig. 5). Damage to regeneration following earth working disturbance varies among species (Fig. 6). In some cases, disturbance from earth working was more than in one species as compared with another species (Fig. 7). The Lolet Forest structure is uneven aged deciduous stands.

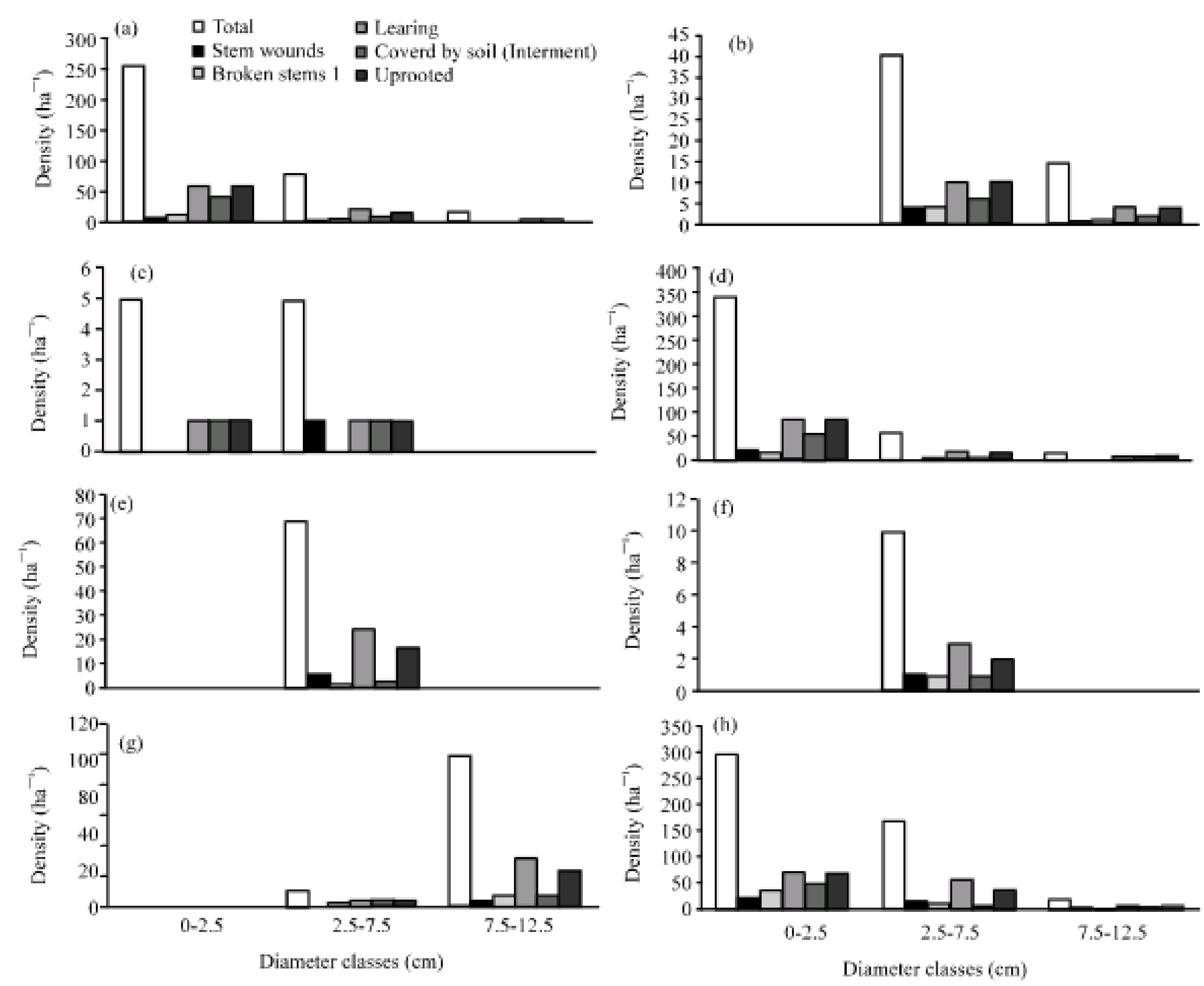

Fig. 4: Numbers of regeneration damage in slope class of 30-40%. (a) *Fagus orientalis Lipsky*, (b) *Acer insigin*, (c) *Carpinas betuluse* L., (d) *Diospyros lotus* L., (e) *Qurecus castaneigolia* C. A. Mey., (f) *Jugans regia*, (g) *Alnus sabcordata* and (h) *Parrotia persica* C.A.M

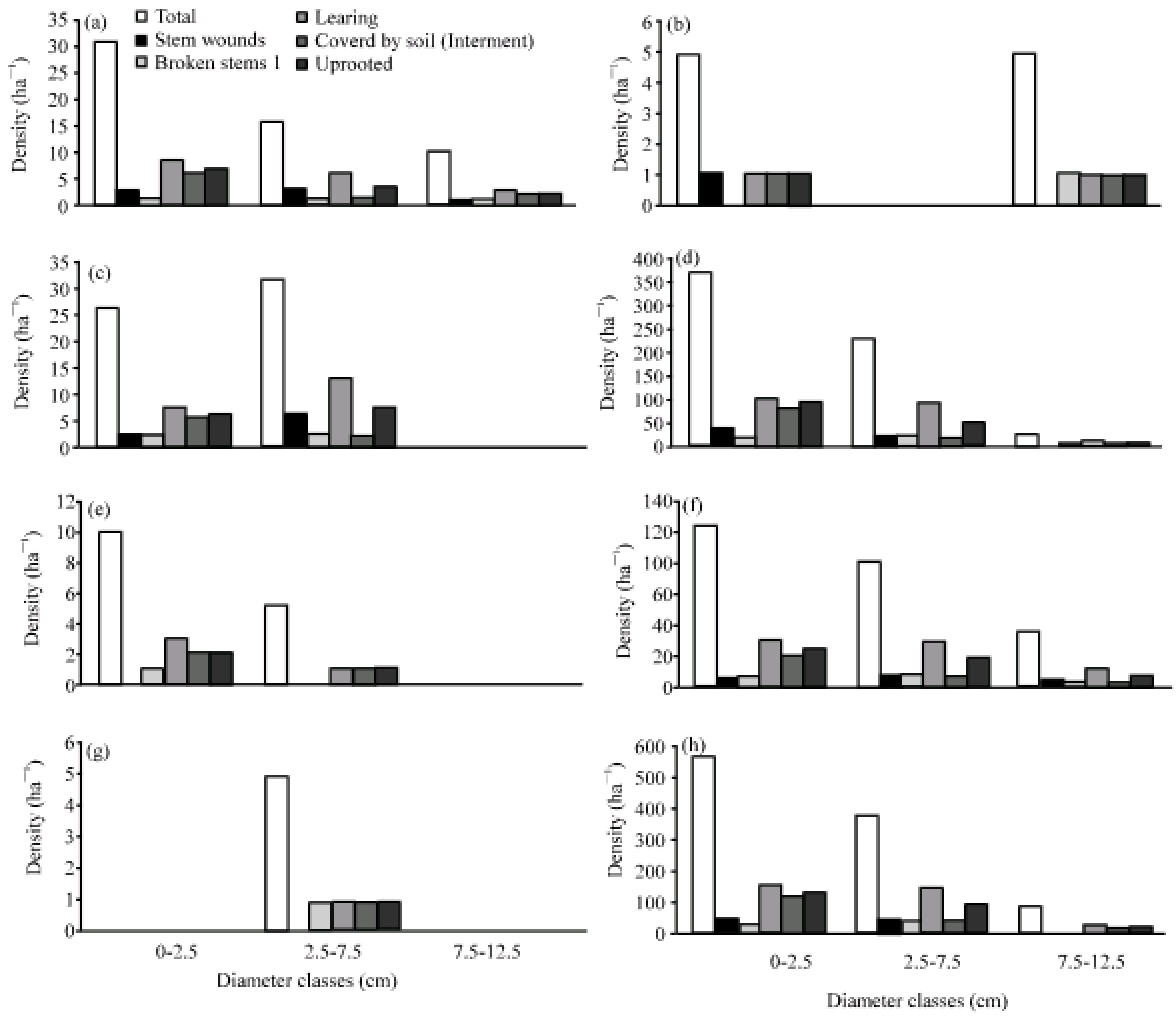

Fig. 5: Numbers of regeneration damage in slope class of 40-50%. (a) *Fagus orientalis Lipsky*, (b) *Zelkova carpinifolla*, (c) *Carpinus betulus* L., (d) *Diospyros lotus* L., (e) *Acer insign*, (f) *Parrotia persica* C.A.M., (g) *Acer laetum*, (h) Total species

Dominant trees mixture are *Fagus orientalis* Lipsky, *Carpinus betulus* L., *Parrotia persica* C.A.M., *Diospyros lotus* L. and *Acer* sp. The under story (0-4 m height) is dominated by *Ruscus hyrcanus* Woron., *Oplismenus* sp., *Carex silvatica* L., ferns and tree saplings.

The number of regeneration and trees damaged (all species) and the number of trees sustaining severe injury along forest roads appeared to be influenced by hillside gradient (slope classes). In higher slope classes a greater number of regeneration and trees were damaged. Totally, 87% of regenerations were damaged by crawler bulldozer earth working operations along forest roads. Most of these damages were occurred in diameter classes of 2.5-7.5 cm (Table 1).

Some species are inherently tolerant of damage. This may be related to rooting habits or to the trees inherent capacity to withstand stress (Parsakhoo *et al*., 2008b). Species which tolerate root damage include willow and water oak, most conifers, sweet gum, red maple and sycamore. Species which are sensitive to construction include beech, tulip tree, dogwood and sugar maple (Quesnel and Curran, 2000). Damage to the remaining stand is understood as injured trees with visible scares on stem, butt, roots or branches (Scar area >10 cm^2), broken branches in canopy and bent trees (Košir, 2008).

Approximately 50% of trees were damaged in each of slope classes: 7% were wounded (bark removed), 13% were crown injured and 30% were felled or uprooted within the earth working limit especially on 6 meter of road bed (Table 2). Damage to trees may have important negative implications

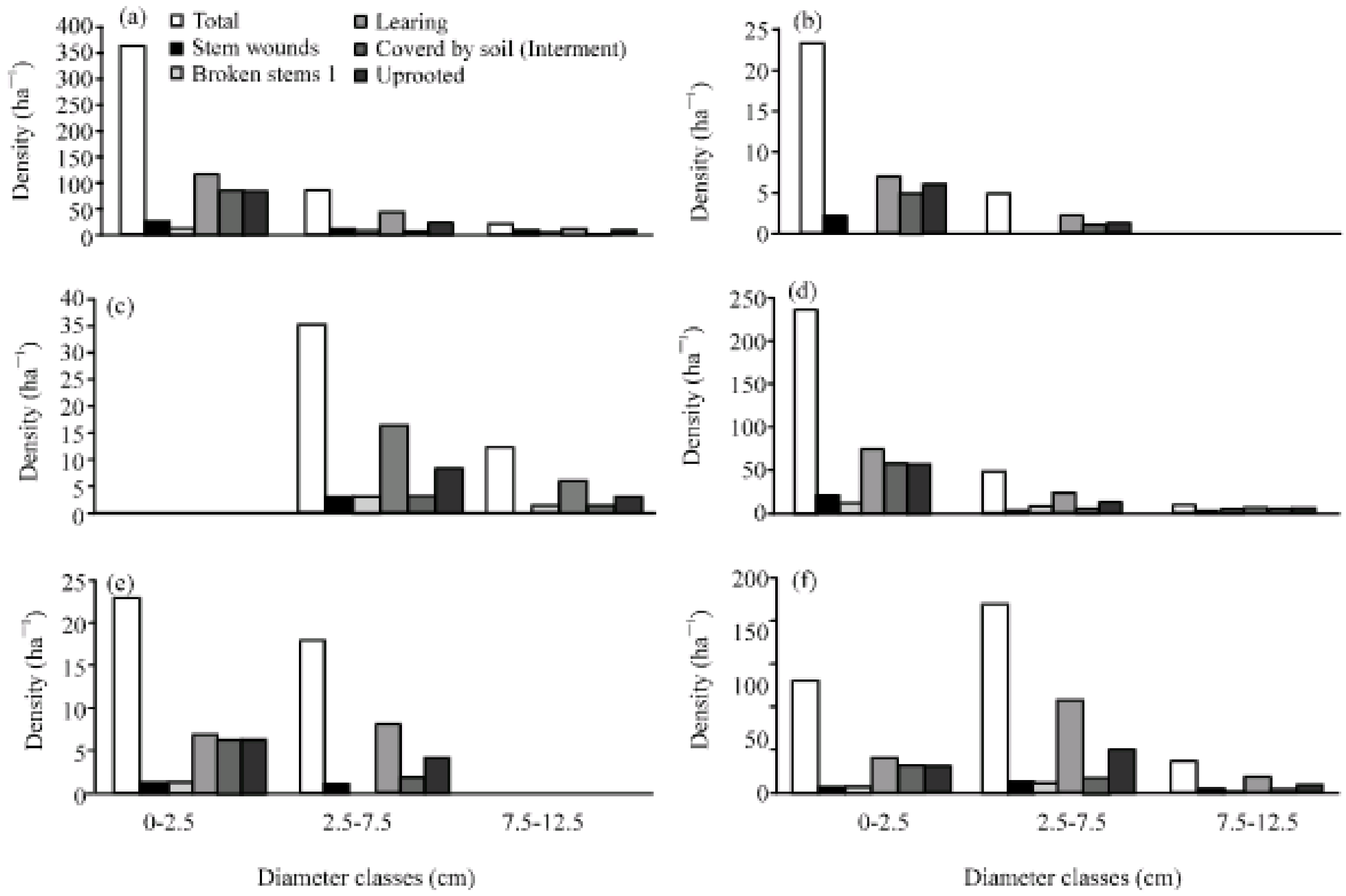

Fig. 6: Numbers of regeneration damage in slope class of 50-60%. (a) *Fagus orientalis Lipsky*, (b) *Tillia carpinifolla*, (c) *Carpinus betulus* L., (d) *Diospyros lotus* L., (e) *Acer laetun*, (f) *Parrotia persica* C. A. M

Table 1: Percentage of damaged regeneration in different slope and diameter classes after earth working

	Diameter classes (cm)			
Slope classes (%)	0-2.5	2.5-7.5	7.5-12.5	Mean
30-40	76	77	77	77^{c}
40-50	84	90	86	87^{b}
50-60	89	90	88	89^{b}
60-70	98	95	90	94^{a}
Mean	87^{a}	88^{a}	85^{a}	87

In a row or column, values with same superscript are not significantly different (Tukey test at $p<0.05$)

Table 2: Percentage of damaged trees in different slope and damage classes after earth working

Slope classes (%)	Types of tree damage			
	Stem wounds	Crown injury	Felled and uprooted	Total
30-40	8	19	24	51
40-50	8	14	28	50
50-60	7	11	32	50
60-70	5	10	36	51
Mean	7^{c}	13^{b}	30^{a}	50

In a row, values with same superscript are not significantly different (Tukey test at $p<0.05$)

for future harvests in the forest of Lolet. For example, most important commercial species (*Fagus orientalis* Lipsky.) may by attacked by fungi that drastically decrease timber value (Jackson *et al*., 2002). The damage levels caused by the earth working operation were about twice as high in the regeneration stages (diameter <12.5cm) as compared to damages levels to the trees (diameter >12.5cm). The percentage of wounded trees in wound class of 0-300 cm^2 was more than other wound area classes (Table 3).

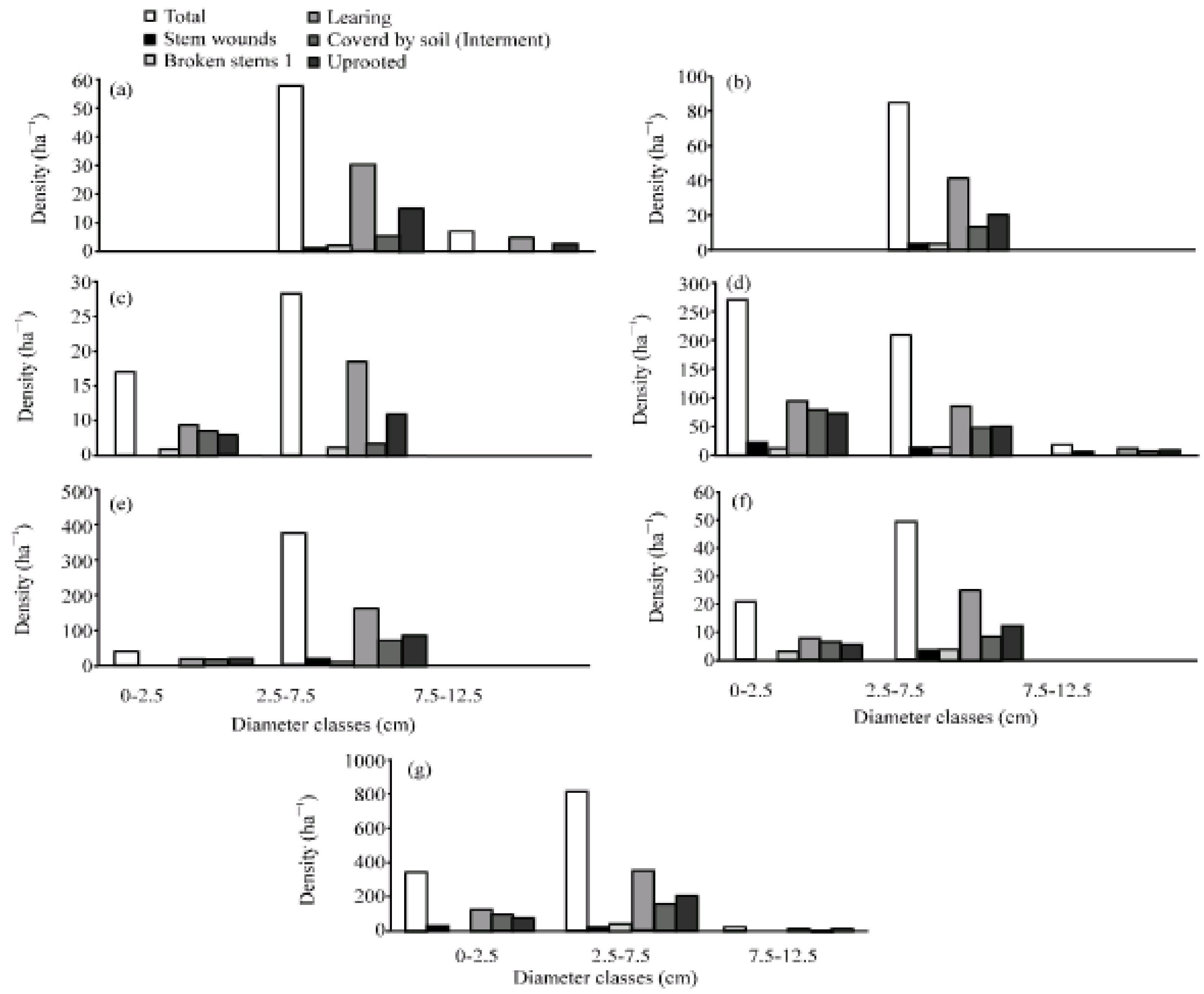

Fig. 7: Numbers of regeneration damage in slope class of 60-70%. (a) *Carpinus betulus* L., (b) *Diospyros lotus* L., (c) *Acer insign*, (d) *Parrotia persica* C.A.M., (e) *Zelkova carpinifolia*, (f) *Acer latum*, (g) Total species

Table 3: Percentage of wounded trees in different slope and wound classes after earth working

	Wound classes (cm^2)		
Slope classes (%)	0-300	300-600	>600
30-40	43	36	21
40-50	54	33	13
50-60	38	54	8
60-70	63	12	25
Mean	50^a	34^b	17^c

In a row, values with same superscript are not significantly different (Tukey test at p<0.05)

Gullison and Hardner (1993) showed that most trees with crown injury and broken trunk-dead were in small diameter classes (<50 cm), which reflects the higher level of secondary damage to residual trees during road construction. Secondary damage due to road construction is typically greater than secondary damage caused by the felling of commercial trees.

There is potential to reduce damage to the residual stand and to the ground area disturbance by the GIS methods of Hosseini and Solaymani (2006). The forest road alignment and information provides an initial foundation on which GIS can be used for this kind of analysis in forest road planning (Mohd Hasmadi and Taylor, 2008). In addition, it is necessary qualified workers, to work with best machines such as hydraulic excavators and using methods to construct forest road and forest harvesting for minimizing environmental damages (Košir, 2008). Košir (2008) reported that the models of trees damages in the remaining stand are a valuable tool for analyzing the consequences of forest operations. Košir (2008) noticed that tree damages are greater when the machine operator is working in a dark environment.

CONCLUSIONS

Forest road construction by bulldozers in Hyrcanian forests on mountainous terrain of Iran causes considerable damage to the environment and the forest standing alongside the road. The most important role the equipment operator plays during the earth working project is to determine the safest and most efficient use of equipment. Road removal jobs are often complex and difficult and it is the operator's responsibility to decide the best way to maneuver and position equipment. Forest road managers should consider not only the total road cost but also environmental impacts caused by the road construction and use. Minimizing regeneration and trees damages during earth working appears to allow a more rapid recovery of vegetation on bulldozed soil. The suggestion of this research is that the heavy equipment environmental performance should be studied in order to select the best one. For example, hydraulic excavator usage for forest roads construction in steep slopes is major step towards environmental sound. Also, bulldozers with low dimensions and high engine power such as D6 and D7 Komatsu models can be replaced with larger bulldozers for reducing forest damages during earth working operations in hillsides with high slope percent. In present study, the most common type of damage to regeneration was leaning and the majority of this damage occurred in diameter classes of 0-2.5 and 2.5-7.5 cm. In higher slope classes a greater number of regeneration and trees were damaged. Totally, 87% of regenerations were damaged by crawler bulldozer earth working. Approximately 50% of trees were damaged in each of slope classes: 7% were wounded (bark removed), 13% were crown injured and 30% were felled or uprooted. The wounded trees percentage in class 0-300 cm^2 was more than other wound classes.

REFERENCES

Arocena, J.M., 2000. Cations in solution from forest soils subjected to forest floor removal and compaction treatments. Forest Ecol. Manage., 133: 71-80.

Bengtsson, J., H. Lundkvist, P. Saetre, B. Sohlenius and B. Solbreck, 1998. Effects of organic matter removal on the soil food web: Forestry practices meet ecological theory. Applied Soil Ecol., 9: 137-143.

Demir, M., 2007. Impacts, management and functional planning criterion of forest road network system in Turkey. Transport. Res. Part A, 41: 56-68.

Demir, M., E. Makineci and E. Yilmaz, 2007. Investigation of timber harvesting impacts on herbaceous cover, forest floor and surface soil properties on skid road in an oak (*Quercus petrea* L.) stand. Build Environ., 42: 1194-1199.

Feldpausch, T.R., S. Jirka, A.M. Passos, F. Jasper and S.J. Riha, 2005. When big trees fall: Damage and carbon export by reduced impact logging in Southern Amazonia. Forest Ecol. Manage., 219: 199-215.

Gullison, R.E. and J.J. Hardner, 1993. The effect of road design and harvest intensity on forest damage caused by selective logging: Empirical results and simulation model from the bosque chimanes, Bolivia. Forest Ecol. Manage., 59: 1-14.

Hosseini, S.A. and H. Jalilvand, 2007. Marginal effect of forest road on alder trees (case study: Darab kola forest, Mazandaran Province, Iran). Pak. J. Biol. Sci., 10: 1766-1771.

Hosseini, S.A. and K. Solaymani, 2006. Investigation of effective factors for path tracing using GIS in Kheyroud forest (Iran-Mazandaran Province). Pak. J. Biol. Sci., 9: 2055-2061.

Iskandar, H., L.K. Snook, T. Toma, K.G. MacDicken and M. Kanninen, 2006. A comparison of damage due to logging under different forms of resource access in East Kalimantan, Indonesia. Forest Ecol. Manage., 237: 83-93.

Jackson, S.M., T.S. Fredericksen and J.R. Malcolm, 2002. Area disturbed and residual stand damage following logging in a Bolivian tropical forest. Forest Ecol. Manage., 166: 271-283.

Kašková, M., 2004. Design of forest road network in relation to all-society functions of forests. J. For. Sci., 2004: 243-247.

Košir, B., 2008. Modelling stand damages and comparison of two harvesting methods. Croatian J. For. Eng., 29: 5-14.

Mohd Hasmadi, I. and J.C. Taylor, 2008. Sensitivity analysis of an optimal access road location in hilly forest area: A GIS approach. Am. J. Applied Sci., 5: 1686-1692.

Parsakhoo, A., S.A. Hosseini, H. Jalilvand and M. Lotfalian, 2008a. Physical soil properties and slope treatments effects on hydraulic excavator productivity for forest road construction. Pak. J. Biol. Sci., 11: 1422-1428.

Parsakhoo, A., S.A. Hosseini, M. Lotfalian and H. Jalilvand, 2008b. Bulldozer and hydraulic excavator traffic effect on soil bulk density, rolling project and tree root response. Int. J. Natural Eng. Sci., 3: 139-142.

Pinard, M.A., M.G. Barker and J. Tay, 2000. Soil disturbance and post-logging forest recovery on bulldozer paths in Sabah, Malaysia. For. Ecol. Manage., 130: 213-225.

Quesnel, H.J. and M.P. Curran, 2000. Shelterwood harvesting in root-disease infected stands-post-harvest soil disturbance and compaction. Forest Ecol. Manage., 133: 89-113.

Tunay, M. and K. Melemez, 2004. Environmental effects of forest road construction on steep slope. Ekoloji, 13: 33-37.