Analysis of Tree Damage Caused by Rockfall at Forest Road Construction Works

Selcuk Gumus, Burak Aricak, Korhan Enez, H. Hulusi Acar

Abstract – Nacrtak

Forest roads provide access for people to study, enjoy or contemplate natural ecosystems. Therefore, roads are one of the most important tools needed in forestry. Forest roads are built by excavation of soil and rock. Rockfall occurs during construction works, caused by excavated rock pieces on embankment slopes and by blasting of block rock masses. This study analyzes rockfall damage to trees during forest road construction. Injuries, branches brokenness, trunk wounds and collapse were defined as tree damages because of rockfall during road construction. These damages have been analyzed by site measurements and statistical analysis. In the study area it has been determined that 90.48% of damaged trees are in the first 10 m after the beginning of the embankment slope, and the rest of the trees are positioned between 11 m and 23 m away from the beginning of the embankment slope. The average injury area of the damaged trees was calculated as 1,081 cm^2 for the first 10 m from the embankment slope, and an injury area of 1,463 cm^2 was calculated for between 11 m and 23 m on the embankment slope. This is a very important result in terms of forest protection. Wooden obstruction or synthetic holders should be used as preventative measures in the first 10 m of the embankment slope of the road to block rockfall or slow it down.

Keywords: Forest road, construction, tree damage, rockfall, Turkey

1. Introduction – *Uvod*

The opening-up of forests enables the application of rational forestry, which is more productive and suitable for sustainable use. Therefore, forest roads are one of the most important tools needed. In Turkey, forestry work is carried out in 21 million hectares of forest land scattered in different geographical regions. A good road network is required for performing work in these forest lands with different climates and topographical conditions. Forest villagers also benefit from the road network for their transportation. So, forest roads provide economic, social and cultural benefits for all user groups (Acar and Senturk 2000, Acar and Gumus 2005).

According to the Turkish General Directorate of Forestry (GDF), technical and economical management of forests requires 210,000 km of forest roads to be constructed (SPO 2001). Up to now, approximately 150,000 km of forest roads have been constructed. GDF plans to construct 1,000 km of new forest roads per year, so they will be on the agenda for a long time to come.

Forest roads are built by excavation of soil and rock. Rockfall occurs during construction works, caused by excavated rock pieces on embankment slopes and the blasting of block rock masses. In Turkey, the traditional use of bulldozers causes loss of land and damage to trees and forest habitat (Acar and Eker 2007). The ecological balance of forests and trees is adversely affected by rockfall and road construction works (Luce and Wemple 2001, Madej 2001, Tague and Band 2001, Tunay and Melemez 2004,). It has been found that injured trees are more sensitive to insect epidemic (Lemperiere 1994, Fielding and Evans 1997, Ozcan et al. 2006). In the study area particularly, the pest *Dendroctonus micans* (Great Spruce Bark Beetle) has been a serious problem for a long time.

There have been many studies on the formation and mechanics of rockfalls (Larsen and Parks 1997, Marquinez et al. 2003, Heidenreich 2004, Segalini and Giani 2004, Perret et al. 2004, Perret et al. 2006, Dorren et al. 2005, Aydin 2007) and preventative measures have been researched (Berger and Rey 2004, Guzzetti and Reichenbach 2004, Brauner et al. 2005, Stoffel et al. 2006).

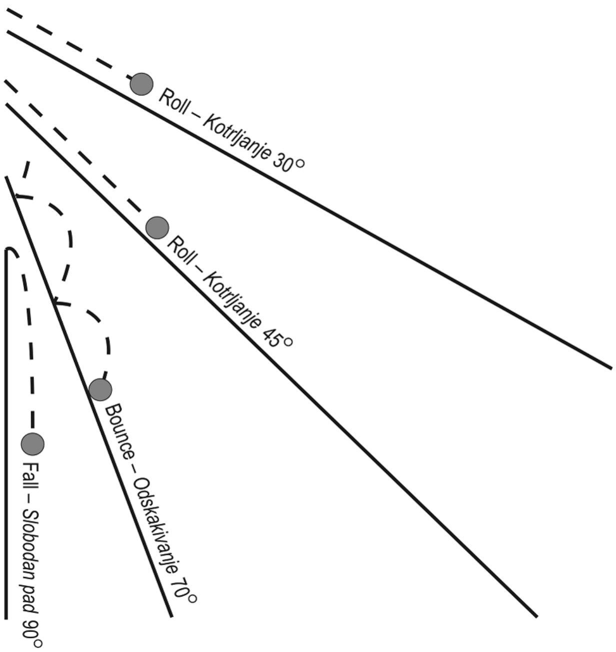

Fig. 1 General modes of motion of rocks during their descent on slopes in relation to mean slope gradients

Slika 1. *Općeniti načini kretanja stijenja pri kotrljanju niz padinu s obzirom na prosječni nagib terena*

There has been no comprehensive study about the effects of rockfall on forest trees as a result of forest road construction. Construction works have a significant adverse effect on forest trees because of the rockfall they create. This effect mostly appears in the form of tree damage. The aim of this study is to analyze tree damage occurring during forest road construction.

2. Rockfall and tree damage – *Odroni i oštećenja stabala*

After the rock has been detached and starts to move, it descends the slope in different modes of motion. These modes of motion strongly depend on the mean slope gradient (Fig.1). The three most important modes of motion are freefall through the air, bouncing on the slope surface and rolling over the slope surface. Freefall occurs if the slope gradient below the potential falling rocks exceeds 76°, but in different field situations this value varies. Fig. 1 shows that around 70° the motion of the rock gradually transforms from bouncing to falling (Dorren 2003).

Forest road constructions produce many rock pieces. If these rock pieces are not carefully placed on the embankment slope, they roll down it. This situation is unavoidable during bulldozer digging or blasting of rock mass. Stone and rockfalls cause tree damage such as torn bark, collapse, broken branches – crown – trunk. Fig. 2 shows samples of such tree damage.

3. Materials and methods – *Materijali i metode*

3.1. Materials – *Materijali*

This study has been made throughout 3,100 m of forest road construction area in the Gumushane (Kurtun region of Turkey). The road started at 510,050 m, 4,511,145 m coordinates at UTM projection system with ED 50 datum in 37 T square and ended at 510,375 m, 4,510,865 m point location. The

Fig. 2 Samples of tree damage in study area

Slika 2. *Primjeri oštećenja na stablima na istraživanom području* study area predominantly contains *Quercus petraea* (Matt.) Liebl. Subsp. *iberica* (stwen ex M.Beieb.) Krassiln, and *Picea orientalis* (L.) Link, and other species such as *Pinus sylvestris* L., *Fagus orientalis* Lipsky, and *Alnus glutinosa* (L.) Gaertn. Supsp. *barbata* (C.A.Mey.) Yalt. There is no forest cover for 0 – 100, 295–475 and 1,390–2,075 meters of the road section under consideration. According to the measurement results, the average diameter and height of trees is as follows: *Quercus petraea* 15 cm and 6 m, respectively, *Picea orientalis* 21 cm and 12 m, *Fagus orientalis* 29 cm and 18 m, *Alnus glunitosa* 26 cm and 12 m and *Pinus sylvestris* 36 cm and 20 m.

The road route has three different types of forest stand. *Quercus* forests have *Pinus* trees as well. *Quercus* forests are of low density (less than 10% canopy) and approximately 100 years of age. The main parts of the road section are covered by *Fagus* forest with *Picea* and *Abies* species in low proportions. *Fagus* forest cover has 40–70% of canopy degrees on forest lands. The forest age is approximately 100 year. Both *Quercus and Fagus* forests have not any shrubs on the floor.

The average slope gradient is 75% throughout the constructed road. The study area is classified as 5th class (>70%) very steeply sloping land according to terrain stability class (B.C. Ministry of Forests 1999). This class has been identified as high likelihood of landslides from timber harvesting or road construction area by Schwab and Geertsema (Schwab and Geertsema 2009).

Excavators and bulldozers were used during road construction. Rocks were blasted with dynamite between 1,015 and 1,182 meters.

Tape measure, caliper, height meter and GPS have been used for measurement of the area. Measurement data, standard topographic map with 1/25,000 scale, satellite image, ESRI ArcGIS software and SPSS statistical software have been used to create a database.

3.2. Methods – *Metode*

Tree and site feature measurements have been made to determine and analyze the damage caused by a rockfall. Two hundred and ninety-five damaged trees have been numbered and their type of damage has been determined. Distribution by damage type, relation to construction techniques (excavator – bulldozer, blasting) and the effect of positional values of damaged trees have been investigated by means of the data collected.

In the study area, the following features have been measured and recorded: species of damaged trees, diameter and height of trees, whether the tree has fallen or not, impact on bark or otherwise, whether the impact is on the side or front, whether there are broken branches – trunk – crown, the height of the main injury, location of injury, UTM coordinates of damaged trees.

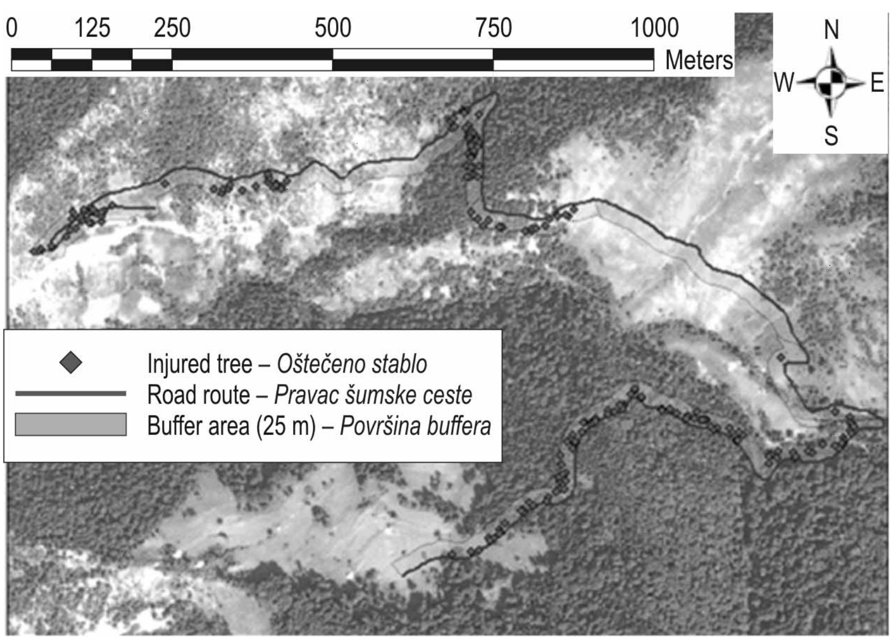

Fig. 3 Damage to trees and its geographical disturbance

Slika 3. *Zemljopisni prikaz šteta na drveću*

Geographical information systems (GIS) and remote sensing databases have been used to determine the positional values of the measured trees. While positional information of the damaged trees has been obtained by GPS, satellite images have been combined with data that have been created on GIS. Consequently, information was obtained about the distance between the road and trees, and values of slopes and width of the construction area (Fig. 3). Spot image (2.5 m resolution, May 2006) has been used to determine the construction area. A digital elevation model (DEM) was prepared in GIS database for calculating the gradient of the area.

The relation between damage to trees in stands remaining after construction and the reason for the damage has been examined with the help of this study. For this purpose, the following parameters have been determined: frequency distribution of the damage type, distance between tree and road and construction techniques.

The relationship between damaged trees' distance from road, injury status, fallen, broken branches – crown – trunk situation and the relationship diameter of trees, height of trees and side gradient were tested by independent t test. Consequently, a statistical decision was made according to the accepted hypothesis evaluation of t statistic and significance levels. The relations between rock crash type, side – front – graze, to remaining trees and height-width of main injuries were determined by the correlation analysis. The correlation displayed $p<0.05$ at significance levels (Ozdamar 2004).

4. Results – *Rezultati*

Two hundred and ninety-five damaged trees have been identified throughout the 3,100 m of forest road construction area. Table 1 shows the type of damage, the number of trees and ratio of distribution. The measurement of injury has not been made for trees, which have fallen or whose bark has been torn. Several trees have broken branches and crown.

Table 1 The distribution of tree damage

Tablica 1. *Raspodjela oštećenja na stablima*

Damage type *Vrsta štete*	Number of trees *Broj stabala*	Damage ratio in all trees *Udio štete na svim stablima,* %
Injuries (torn bark) *Ozljeda kore*	189	64.07
Collapses of tree *Izvaljeno stablo*	96	32.54
Trunk brokenness *Slomljeno deblo*	10	3.39
Branches brokenness *Slomljene grane*	76	25.76
Crown brokenness *Slomljena krošnja*	26	8.81

It has been determined that 90.48% of injured trees are in the first 10 m after the beginning of the embankment slope. Weighted average of the injured surface area on these trees has been calculated as 1,081 cm^2. Specific measurements also show as follows: the average height of the injured area is 56 cm, the average diameter of trees is 22 cm, the average tree height is 12 m, and the average slope gradient is 74% (Table 2). It has been determined that tree collapse and fractured branches – trunk – crown are effective for the first 10 m, like the injury area.

The rest of the trees are positioned between 11 m and 23 m from the beginning of the embankment slope. Weighted average of the injured surface area on these trees has been calculated as 1,463 cm^2. The average height of the injured area is 30 cm, the average diameter of trees is 24 cm, the average tree height is 15 m, and the average slope gradient is 77%.

Broken branches were determined for 16 (34%) of 47 measured trees and 6 (12%) trees had crown damage between 1,015 and 1,182 m of the road. Blasting by dynamite for rock excavation was used as a road construction technique at this section of the studied road. There is 1 (2%) tree that has two injuries. Forty-eight (19%) of 248 trees have broken branches and 20 (8%) trees have broken crowns on other parts of the road where excavator and bulldozers were used for rock and soil excavation. Twelve (5%) trees suffered both types of damage.

Variables of damage effect were obtained by statistical relationship after determination of damage frequency. When the fallen trees' diameter, height, distance to road and slope gradient were compared, according to a non-equal variance t Test (t=6.47, sd=291.30, p=0.000^{ns}), the average distance of fallen and remaining trees to roads was different, with $p<0.05$ significance level. In other words, the distances of trees to roadside are significant in felling of trees.

The diameter, height, distance to roadside and slope gradient of broken-trunk trees and remaining trees were evaluated. According to an equal variance t test (t=2.83, sd=294, p=0.005^{ns}), the average tree height of broken-trunk and remaining trees are not the same, with significance level ($p<0.05$). It is fair to say that, according to the results, small trees are more affected than larger trees. The other factors are not effective on trunk fracture at $p<0.05$ signifi-

Table 2 Frequency distribution and features of damaged trees according to distance to road

Tablica 2. *Raspodjela učestalosti i obilježja štete na stablima u ovisnosti o udaljenosti od ceste*

Distance to road (m) *Udaljenost do ceste, m*	Number of Injured trees *Broj oštećenih stabala*	Average injured surface cm^2 *Prosječna površina ozljede* (cm^2)	Average injured height (m) *Prosječna visina ozljede, m*	Number of collapsed trees *Broj izvaljenih stabala*	Number of broken trunk *Broj slomljenih debala*	Number of broken crown *Broj polomljenih krošanja*	Number of broken branches *Broj slomljenih grana*	Average tree diameter (cm) *Prosječan promjer stabala, cm*	Average tree height (m) *Prosječna visina stabala, cm*	Average slope gradient (%) *Prosječan nagib terena, %*
< 1	22	1350	1.00	2	1	1	10	27	16.33	70
1	46	1719	0.88	7		10	16	23	14.63	71
2	28	799	0.48	13		3	20	17	9.58	71
3	22	660	0.40	11	4	5	15	21	11.41	75
4	24	793	0.86	8	2	6	13	20	10.54	74
5	7	645	0.22	15		1		22	11.52	76
6	3	707	0.40	15			1	24	12.81	71
7	12	600	0.46	7				23	12.33	80
8	2	751	0.17	6	1			19	10.14	80
10	5	995	0.80	3			1	25	13.43	77
11	4	337	0.10	2				15	7.40	78
12	2	290	0.10	4				17	8.50	75
13				1				32	17.00	80
14	1	2400	1.00					32	16.00	75
17	2	1525	0.50					20	12.00	75
18	2	600	1.00					28	16.00	80
19	1	600	0.10		1			30	18.00	75
20	4	2681	0.50					26	20.75	80
22	1	4462	0.10	1				26	21.00	75
23	1	1975	0.10	1	1			23	21.33	80
Total Ukupno	189			96	10	26	76			

cance level. No correlation was obtained between trunk breaking and tree diameter, and however, it can be assumed that small trees have lower diameter than larger trees.

When trees with broken branches were examined according to the variables, the variance of average slope gradient of trees with broken branches and remaining trees was not equal (t=2.017, sd=108.17, $p=0.046^{ns}$). The average slope gradient affects branch fracture. On the other hand, there is no significant relation between tree diameter, height and distance to roadside and branch fracture at $p<0.05$ significance level.

The variance of average tree height between the broken crown and remaining trees is not equal (t=6.37, sd=52.06, $p=0.000^{ns}$). The other variables have no effect on broken crown at $p<0.05$ significance level. Small trees have a broken crown more often. This has been especially observed on road segments where dynamite blasting was used for rock excavations. Blasted rock pieces hit the crowns of small trees and damaged them.

A comparison was made between height and width of the main injury and impact of rocks and stones with grazing, side and front hit, and build-up of stones and pieces of rock. There is no statistical relation at $p>0.05$ significance level. The width and height of the main injury do not depend on the impact style of the rocks.

5. Discussion – *Rasprava*

The objective of this investigation is to define tree damage, analyze the relations between the occurrence of damage and the site and tree features, and suggest preventive measures against the damage resulting from forest road construction.

The damages were defined as injuries, broken branches, broken crown, wounded trunks and collapse of trees. Those were determined in the study area of this investigation. The results show that the main injuries occurred in the first 10 m from the road embankment slope. This is a very important result in terms of forest protection. Preventative measures such as wooden obstructions or synthetic holders to block rockfall or slow it down must be implemented to protect tree trunks especially for up to 1 m from the surface.

The slope gradient and distance of trees from the road were the factors affecting the injuries and brokenness. Rolling rock pieces are faster because of slope gradient, and rock pieces become faster and affect trees more seriously at a higher distance than those on steep slope closer to the road. Also, a rise in slope gradient increases the branches brokenness, because rock pieces bounced more at higher slopes and hit the branches. Preventive measures should be taken against rock bouncing where the slope gradient is more than 70%.

The technique of forest road construction causes different types of tree damage. Blasting with dynamite for rock excavation resulted in increased branches and crown brokenness. When this technique is used, action should be taken to block the žpopping-out' of stones and rocks. Use of dynamite for rock excavation causes approximately double damage to trees than bulldozers do. Excavator is the machine that can provide protection to trees. The excavator should be the choice for forest road construction.

6. Conclusion – *Zaključci*

Forest road construction is one of the major causes of rockfall. The rockfall resulting from forest road construction can cause damages to forest trees. These damages were determined as injuries (torn bark), collapse and broken trunk, branches and crown of trees in the Kurtun study area.

The distance of trees to road side, tree heights, slope gradients, rock excavation methods were the affecting factors in damage occurrence.

Road construction causes damage to forest trees and this can result in the decrease of growing stock as well as in insect epidemic. Forest road construction must be carried out very carefully taking adequate protective measures.

6. References – *Literatura*

Acar, H. H., Eker, M., 2007: Orman yolu yapiminda ekskavatörlerin kullanilmasi ve çevresel açidan yararlari (The use of excavators in forest road construction and their environmental benefits), Journal of Southwest Anatolia Forest Research Institute 5: 97–128.

Acar, H. H., Gumus, S., 2005: Forest roads in Turkish forestry, Mehanizacija šumarstva 26 (2): 117–120.

Acar, H. H., Senturk, N., 2000: Orman Yol Aglari, Heyelanlar ve Mühendislik Jeolojisi (Forest road network, landslides and geology of engineering), Journal of Faculty of Forestry, Istanbul University, B, 45 (3–4): 71–84.

Aydin, A., 2007: Ormanlik Alanlarda Taş ve Kaya Yuvarlanmalari (Rockfalls in forests lands), Journal of faculty of forestry, Istanbul University, 57 (2): 1–16.

B. C. Ministry of Forests, 1999: Mapping and Assessing Terrain Stability Guidebook, Second Edittion, Forest Practice Code of British Columbia, 43 p., Victoria.

Berger, F., Rey, F., 2004: Mountain Protection Forests against Natural Hazards and Risks: New French Developments by Integrating Forests in Risk Zoning, Natural Hazards 33: 395–404.

Brauner, M., Weinmeister, W., Agner, P., Vospemik, S., Hoesle, B., 2005: Forest management decision support for evaluating forest protection effects against rockfall, Forest Ecology and Management 207: 75–85.

Dorren, L. K. A., Berger, F., Hir, C., Mermin, E., Tardif, P., 2005: Mechanisms, effects and management implications of rockfall in forests, Forest Ecology and Management 215: 183–195.

Dorren, L. K. A., 2003: A review of rockfall mechanics and modeling approaches, Progress in Physical Geography 27 (1): 69–87.

Fielding, N. J., Evans, H. F., 1997: Biological control of Dendroctonus micans (Scolytidae) in Great Britain, Biocontrol News and Information 18 (2): 51–60.

Guzzetti, F., Reichenbach, P., 2004: Rockfall Hazard and Risk Assessment Along a Transportation Corridor in the Nera Valley, Central Italy, Environmental Management 34 (2): 191–208.

Heidenreich, B., 2004: Small and half scale experimental studies of rockfall impacts on sandy slopes. Ph.D.Thesis, No:3059, EPFL, Lausanne.

Larsen, M. C., Parks, J. E., 1997: How wide is a road? The association of roads and masswasting in a forested montane environment, Earth Surf. Process. Landforms 22: 835–848.

Lemperiere, G., 1994: Ecology of the Great European Spruce Bark Beetle Dendroctonus micans (Kug.), Ecologie 25 (1): 31–38.

Luce, C. H., Wemple, B. C., 2001: Introduction to special issue on hydrologic and geomorphic effects of forest roads, Earth Surf. Process. Landforms 26: 111–113.

Madej, M. A., 2001: Erosion and sediment delivery following removal of forest roads, Earth Surf. Process. Landforms 26: 175–190.

Marquinez, J., Menendez, D. R., Farias, P., Jimenez, S. M., 2003: Predictive GIS – Based Model of Rockfall Activity in Mountain Cliffs, Natural Hazards 30: 341–360.

Ozcan, G. E., Eroglu, M., Akinci, H. A., 2006: Ladin ormanlarinda *Dendroctonus micans* (Kugelann) (Coleoptera: Scolytidae)'in zarar durumu ve *Rhizophagus grandis* (Gyllenhal) (Coleoptera: Rhizophagidae)'in zararlinin populasyonuna etkisi (Pest status of Dendroctonus micans /Kugelann/ Gyllenhal/Coleoptera: Scolytidae/ and the effect of Rhizophagus grandis /Gyllenhal/ /Coleoptera: Rhizophagidae/ on the population of Dendroctonus micans in the oriental spruce forests), Turkish journal of entomology 30 (1): 11–22.

Ozdamar, K., 2004: Paket programlar ile istatistiksel veri analizi 1 (Statistical data analysis by software 1), Kaan Press. 649 p. Eskişehir 2004.

Perret, S., Dolf, F., Kienholz, H., 2004: Rockfall into forests: Analysis and simulation of rockfall trajectories –considerations with respect to mountainous forests in Switzerland, Landslides 1: 123–130.

Perret, S., Baumgartner, M., Kienholz, H., 2006: Inventory and analysis of tree injuries in a rockfall – damaged forest stand, Eur J Forest Res 125: 101–110.

Schwab, J. W., Geertsema, M., 2009: Terrain stability mapping on British Columbia forest lands: an historical perspective, Nat Hazards, DOI 10.1007/s11069–009––9410–3.

Segalini, A., Giani, G. P., 2004: Numerical Model for the Analysis of the Evolution Mechanisms of the Grossgufer Rock Slide, Rock Mechanics and Rock Engineering 37 (2): 151–168.

SPO, 2001: VIII. Five years period development reports, State Planning Organization – Turkish Republic Prime Ministry Office, SPO P.N: 2531. Forestry Specialist Community Report No: 547, Ankara, p. 158–169.

Stoffel, M., Wehrli, A., Kuhne, R., Dorren, L. K. A., Perret, S., Kienholz, H., 2006: Assessing the protective effect of mountain forests against rockfall using a 3D simulation model, Forest Ecology and Management 225: 113–122.

Tague, C., Band, L., 2001: Simulating the impact of road construction and forest harvesting on hydrologic response, Earth Surf. Process. Landforms 26: 135–151.

Tunay, M., Melemez, K., 2004: Dik egimli arazide orman yol inşaatinin çevresel etkileri (Environmental Effects of Forest Road Construction on Steep Slope), Ekoloji 13 (53): 33–37.

Sažetak

Analiza oštećenja stabala uzrokovanih odronima prilikom izgradnje šumske ceste

Šumske ceste omogućuju pristup svima koji žele istraživati ili promatrati prirodne ekosustave ili samo u njima uživati. Stoga je jedan od najvažnijih objekata u šumarstvu – cesta. Šumske se ceste grade iskopavanjem zemlje i kamena. Odroni se javljaju tijekom građevinskih radova, pri iskopavanju stjenovitih komada na strmim terenima te rušenjem većih blokova stijena.

Cilj je ovoga istraživanja definirati oštećenja stabala, analizirati odnos između pojavljivanja šteta i položaja te svojstava stabala. Nadalje, predložit će se preventivne mjere protiv štete prilikom izgradnje šumskih cesta.

Ovo je istraživanje napravljeno na gradilištu šumske ceste u Gumushane (oblast Kurtun) u Turskoj ukupne duljine 3100 metara. Uzrokovane štete, na istraživanom području, definirane su kao ozljede, slomljene grane, debla ili krošnja te izvaljena stabla. Štete su analizirane prema mjestu mjerenja različitim statističkim analizama. Na području istraživanja utvrđeno je 295 oštećenih stabala i pritom određene vrste oštećenja. Raspodjela prema vrsti oštećenja, odnos prema tehnici izgradnje (bager, miniranje) i učinak položaja oštećenih stabala bili su istraživani pomoću prikupljenih podataka.

Na istraživanom je području utvrđeno kako se 90,48 % oštećenih stabala nalazi u prvih 10 metara nasipne strane, dok je ostatak stabala smješten između 11 i 23 metra od mjesta gradnje. Prosječna izračunata površina oštećenja iznosila je 1081 cm^2 na udaljenosti od 10 metara, a 1463 cm^2 na udaljenosti od 11 do 23 metra s nasipne strane. Promatravši te podatke s područja zaštite šuma izlazi kako bi drvene prepreke ili sintetičke držače trebalo koristiti na prvih 10 metara nasipne strane kao preventivnu mjeru za sprečavanje ili usporavanje odrona.

Nagib padine i udaljenost stabala od mjesta gradnje utjecajni su čimbenici za broj oštećenja i srušenih stabala. Brzina kotrljanja kamenja proporcionalno raste s povećanjem nagiba i u tom slučaju kamenje djeluje na udaljena stabla većom snagom nego na stabla koja su bliže mjestu gradnje i koja su na manjem nagibu. Povećanje nagiba *terena također utječe na povećani broj slomljenih grana jer je i odbijanje od podloge mnogo izraženije. Preventivne bi se mjere trebale poduzimati na nagibima većim od 70 %.*

Različite tehnike gradnje uzrokuju razliku u opsegu i vrsti šteta na stablima. Miniranje pri probijanju trase ceste najviše oštećuje grane i krošnje stabala. U takvim je slučajevima potrebno poduzeti zaštitne mjere radi sprečavanja nekontroliranoga izlijetanja dijelova stijena. Upotrebu eksploziva trebalo bi svesti na najmanju moguću mjeru jer su štete otprilike dvostruko veće nego kada se koristi samo bager.

Gradnja šumskih cesta oštećuje dubeća stabla i time se smanjuje drvna zaliha i mogućnost napada štetnika na oslabljena stabla, stoga bi svi radovi na izgradnji trebali biti obavljeni što pažljivije, uz upotrebu prikladnih zaštitnih mjera.

Ključne riječi: šumska cesta, izgradnja, oštećenje stabala, odron, Turska

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