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Full Length Research Paper

The impacts of timber harvesting techniques on residual trees, seedlings, and timber products in natural oriental spruce forests

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The impacts of three timber harvesting techniques (manpower, skidder, and skyline) on residual trees, seedlings, and timber products were investigated in natural oriental spruce stands in Artvin, Turkey. Each of timber harvesting techniques was used in 5 different harvesting sites. The degree of damage caused by timber harvesting techniques in the residual trees, seedlings and timber products was calculated as based on injuring size. The results showed that timber harvesting techniques resulted in damages to residual trees, seedlings, and timber products, but the degree of damages caused by the harvesting techniques was significantly different. The highest level of damage was caused by manpower, followed by skidder and skyline harvesting technique. These results suggest that the damages caused by logging can be minimized by using proper timber harvesting techniques.

Key words: Logging, manpower, skidder, skyline, harvesting damage.

INTRODUCTION

Timber harvesting is extremely difficult, expensive, and time – consuming operation. The logging operation was traditionally done by using animal and human power in Turkey. However, mechanized harvesting techniques have been increasingly implemented to improve productivity and reduce logging costs. Therefore, eventual environmental damages caused by harvesting techniques are now gaining increasing importance in the decision-making process when determining what actions to take and what machinery to use in forest harvesting. Once the mechanized harvesting techniques were introduced, damages especially on residual trees and seedlings were recognized.

Timber harvesting with insufficient planning, improper operational techniques, and lack of control of operation result in severe damage to forest soil (Bettinger and Kellogg, 1993; Smidt and Blinn, 1995; Marshall, 2000; Pinard et al., 2000; Quesnel and Curan, 2000; Croke et al., 2001; Demir et al., 2007; Akay et al., 2007a,b; Makineci et al., 2007), residual forest trees (Froehlich et al., 1981; Erdaş, 1986; Elias, 1995; Baumgras et al., 1995; Johns et al., 1996; Karaman, 1997; Krzic et al., 2003), seedlings (Steege et al., 2002; Rushton et al., 2003; Eroğlu et al., 2007), wildlife (LeDoux, 1997; Scrimgeour et al., 2000; Mangan and Bertolo, 2003), and wood products (Holmes et al., 2002; Eroğlu, 2007). This damage can lead to such environmental degradation as damaged forest, compacted and infertile soil, erosion and turbid water (FAO, 1997). Thus, proper forest harvesting, especially well planned logging techniques should be applied to maintain site productivity and to ensure sustainable management of forest resources (Dykstra and Heinrich, 1992).

Several projects and investigations have been concentrated on reducing the impact of negative effects of harvesting operations, and reduced impact logging (RIL) regarding technical and economic aspects has been implemented effectively in some countries (Elias, 1995, 1998; FAO, 1997; Pinard et al., 2000; Steege et al., 2002).

Forests are usually located in high and steep mountainous areas in Turkey and especially in Artvin region, which increases the cost of harvesting. In harvesting operations, manpower, skidders, and skylines are commonly used in Artvin region (Eroğlu and Acar, 2007). However, there have been no studies about the impact of harvesting techniques on the forest environment. Thus, the aim of this research was to investigate the damage levels to

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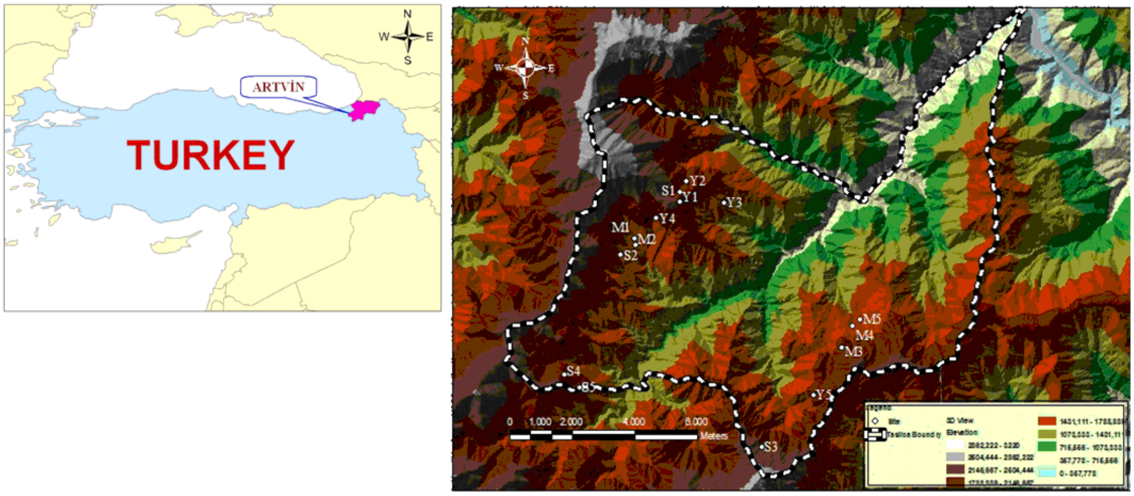

Figure 1. Location of the measurement sites in Taşlıca Forest Administration in Artvin.

Table 1. Primary features of the harvesting sites.

Timber harvesting techniques	Site No	Mean Diameter			Mean Height			Field slope (%)	Aspect	Crown closure (%)	Number of worker	Transportation Distance (m)
		Tree (cm)	Seedling (mm)	Product (cm)	Tree (m)	Seedling (cm)	Product (m)					
Manpower	M1	38.0	19.3	39.4	20.6	43.6	4.5	55	East	75	6	500
	M2	42.6	15.2	39.6	18.6	32.1	4.3	60	East	70	6	400
	M3	38.1	17.6	38.4	20.2	39.5	5.2	70	North	70	5	550
	M4	33.9	16.3	34.3	20.7	33.7	4.9	65	North	40	5	650
	M5	45.8	14.6	48.8	25.0	30.9	4.9	50	West	50	5	500
Skidder	S1	35.7	17.1	46.6	25.7	35.1	3.8	70	East	60	4	120
	S2	35.1	18.4	38.6	20.5	38.9	4.6	55	East	70	5	90
	S3	35.8	18.9	39.0	25.6	43.3	4.3	70	East	70	5	110
	S4	42.3	20.2	51.2	23.2	43.2	4.7	65	North	70	5	100
	S5	40.8	22.7	46.2	20.6	53.9	3.9	65	North	70	5	110
Skyline	Y1	33.8	17.4	39.8	23.8	39.9	3.9	70	East	70	6	450
	Y2	46.9	19.0	56.8	26.5	44.9	4.3	65	East	60	6	700
	Y3	61.5	16.9	72.8	28.2	37.0	3.5	70	East	70	5	550
	Y4	43.0	17.4	34.7	20.6	37.8	4.1	60	North	60	5	350
	Y5	40.8	25.4	46.0	23.1	59.2	4.5	60	West	70	6	400

residual trees, seedlings, and timber products due to three harvesting techniques (manpower, skidder, and skyline) used in natural oriental spruce forests in Artvin, Turkey.

MATERIALS AND METHODS

This study was conducted during the year of 2007 in natural oriental spruce stands of Taşlıca Forest Administration in Artvin Forest Enterprise, Turkey (Figure 1). The dominant oriental spruce trees in the study area were 91 - 103 years old (Akkuzu and Güner, 2008). The coordinate of the sites was determined by Magellan GPS receiver with a free static measure. Digital maps of Taşlıca Forest Administration ($F47d_1$, $F47d_2$, $F47d_3$ and $F47d_4$) were generated with the ArcGIS 9.1 software package program. The joined digital maps were converted to TIN theme in ArcGIS format to acquire 3D digital map. The coordinates of the sites was handled on a separate layer. Then, the map shown in Figure 1 was generated by overlaying the two layers (digital map and coordinate layer).

Each of timber harvesting techniques, which are Manpower-M (gravity method-downhill), skidder-S (MB Trac 900-uphill) and skyline-Y (Urus MIII-uphill), was used in 5 different harvesting sites (Figure 1).

The altitude of sites range 1510 - 2102 m, respectively, and crown closure ranges from 55 to 70%. The measurement and determination of some characteristics are shown in Table 1.

In each timber harvesting site, 100 samples were measured for each damage on residual trees, seedlings and timber products. The

Table 2. The level of damage in residual trees, seedlings, and timber products.

Residual trees	Seedlings	Timber products
0: no injury	0: no injury	0: no injury
1: light injury (crown damage < 30% / bark and stem injury < 25% / root and buttress injury < 25%)	1: light injury (crown damage-bark, stem, root and buttress injury <25%)	1: light injury (product injury < 10%)
2: Medium injury (crown damage 30 - 50% / barks and stems injury 25 - 50% / root and buttress injury 25 -50%)	2: medium injury (crown damage -bark, stem, root and buttress injury 25-50%)	2: medium injury (product injury 10-30%)
3: heavy injury (broken stem, fallen three, crown damage-bark and stem injury-root and buttress injury > 50%)	3: heavy injury (crown damage-bark, stem, root and buttress injury 50 - 75%)	3: heavy injury (product injury >30%)
	4: dead seedling	

Table 3. ANOVA results testing the effects of three timber harvesting techniques on damage levels.

Source	df	Mean square	F	Sig.
One-way ANOVA on residual trees				
Between groups	2	216.515	472.091	0.000
Within groups	1497	0.459		
One-way ANOVA on seedlings				
Between groups	2	230.328	352.065	0.000
Within groups	1497	0.654		
One-way ANOVA on timber products				
Between groups	2	246.403	399.300	0.000
Within groups	1497	0.617		

Table 4. The level of the damage based on the injury size of residual trees.

Timber harvesting techniques	Damage level (%)				Average damage level
	0	1	2	3	
Manpower	6.0	21.2	66.8	6.0	1.728a
Skidder	19.4	61.8	12.8	6.0	1.054b
Skyline	65.6	27.8	6.6	0.0	0.410c

Values not followed by the same letter differ significantly at $p \leq 0.05$.

level of damage caused by timber harvesting techniques on the residual trees, seedlings, and timber products was calculated based on injury size (Table 2) as used by Elias (1998).

All statistical analyses were performed using SPSS® 15.0 for Windows® software. The effects of timber harvesting techniques on damage levels of residual trees, seedlings, and timber products were analyzed by using one-way analysis of variance (ANOVA). When significant differences were found, the Duncan's New Multiple Range Test was also performed to show the differences between the means ($P \leq 0.05$).

RESULTS AND DISCUSSION

In sites, average diameter and height of damaged residual trees, seedlings and timber products are 38.96, 1.84, 41.82 cm and 22.89, 0.41 and 4.14 m respectively.

One-way ANOVA showed that the level of damage in residual trees, seedlings and timber products was significantly affected by the timber harvesting techniques (Table 3). The level of damage caused by manpower timber harvesting technique on the residual trees was the highest (1.73), followed by skidder (1.05) and skyline harvesting technique (0.41) (Table 4). Although more than 80% of the residual trees were damaged by manpower and skidder harvesting techniques, less than 35% of the residual trees were damaged by skyline method. More than 65% of residual trees were injured heavily when using manpower harvesting method.

The level of damage caused by manpower timber har-

Table 5. The level of the damage based on the injuring size of seedlings.

Timber harvesting techniques	Damage level (%)					Average damage level
	0	1	2	3	4	
Manpower	5.4	28.0	41.6	19.0	6.0	1.922a
Skidder	13.2	60.6	20.0	6.2	0.0	1.192b
Skyline	55.6	32.0	12.4	0.0	0.0	0.568c

Values not followed by the same letter differ significantly at $p \le 0.05$.

Table 6. Degree of the damage based on the injuring size of timber products.

Timber harvesting techniques	Damage level (%)				Average damage level
	0	1	2	3	
Manpower	6.0	22.0	52.0	20.0	1.918a
Skidder	14.6	55.0	24.2	6.2	1.220b
Skyline	57.6	33.4	9.0	0.0	0.514c

Values not followed by the same letter differ significantly at $p \le 0.05$.

vesting technique in seedlings was the highest (1.92), while the lowest damage level was caused by skyline harvesting technique (0.57) (Table 5). About 55.6% of seedlings were not damaged in skyline harvesting technique, but undamaged seedlings were less than 15% in the other harvesting technique. Skyline and skidder harvesting techniques did not result in fatal injury to seedlings, and skyline did not even caused heavy injury.

The level of damage caused by manpower timber harvesting technique in timber products was the highest (1.92), followed by skidder (1.22) and skyline harvesting techniques (0.51) (Table 6). About 57.6% of seedlings timber products were not damaged in skyline harvesting, but undamaged timber products were less than 15% in the other harvesting technique. The percentage of timber products injured heavily was 0.0, 6.0 and 20% in skyline, skidder, and manpower harvesting techniques, respectively.

Each harvesting system can cause distinctive damage to remaining crop trees during thinning operations. Most scars from cut-to-length thinning systems are relatively small injuries (Bettinger and Kellog, 1993). Damage to residual trees was less severe with skyline thinning than with conventional skidding or tractor-based operations (Aulerich et al., 1976; Fairweather, 1991; Flatten, 1991). Tractor logging caused relatively more severe scarring to crop trees than did skyline, helicopter and cut-to-length system (Aulerich et al., 1976; Fairweather, 1991; Han and Kellogg, 2000). However, it was found that damage to residual trees was higher using tractors than using skylines. The present study indicated that logging with manpower in natural forests in Artvin, Turkey caused heavier damage on seedlings, residual trees, and timber products when compared with skyline and tractor system. Stand damage (scaring, crown and root damage) was the lowest in skyline and about 6% of the residual trees were affected moderately or heavily.

Although damages on residual trees, seedlings, and timber products caused by skidder and manpower show similarity, medium injury were the highest in skidder and heavy injury was the highest in manpower. Using skyline technique can reduce damage on seedlings and timber products up to 50% and on residual trees up to 60% when compared to skidder and manpower. Reduced impact timber harvesting can reduce damage on soil and residual stand up to 50% when compared with conventional timber harvesting in tropical natural forest in Indonesia (Elias, 1992).

It might be concluded that the damages caused by logging can be reduced by means of better timber harvesting planning and well controlled harvesting techniques. Thus, using of skyline harvesting technique should be preferred to manpower and skidder harvesting techniques on the steep terrain conditions as studied and described in this research.

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