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AN INVESTIGATION ON ROUNDWOOD EXTRACTION AND DETERMINATION OF THE PHYSICAL DAMAGES ON RESIDUAL TREES AND SEEDLINGS DUE TO LOGGING OPERATION USING URUS MIII FOREST SKYLINE ON SNOW

H. Hulusi Acar[1], Habip Eroğlu[2], M. Sinan Özkaya[3]

[1]Karadeniz Technical University, Faculty of Forestry
61080, Trabzon, Turkey
e-mail: hlsacar@ktu.edu.tr

[2]Artvin Coruh University, Faculty of Forestry
08000, Artvin, Turkey

[3]Artvin Regional Forest Directorate
08000, Artvin, Turkey
e-mail: mimarsinan08@hotmail.com

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Abstract: *Forests are usually found in high and steep slopes of mountainous areas in Artvin region, which increases harvesting cost. For logging operations, Koller K 300, Urus M III mobile skylines and MB Trac 900 forest tractors are commonly used in Artvin region. In this study, productivity of roundwood extraction and the physical damages of logging activities on residual trees and seedlings due to logging by Urus M III skyline on snow in Artvin, Turkey were investigated. In order to achieve our aims, 4 representative plots were taken in the harvesting areas using Urus MIII skyline in winter season. Physical damages caused by logging to residual trees and seedling were noted. Damage classes for the residual trees were divided into 4 categories as (0:no injury, 1:light injury, 2:medium injury, 3:heavy injury) and 5 categories for the seedlings as (0:no injury, 1:light injury, 2:medium injury, 3:heavy injury, 4:dead trees). The average total time of shift was measured as 13.10 minute for uphill logging and 22.92 minute for downhill logging. Increases in number of pieces, log diameter, log length and log volume increased the total transportation time. The results also indicated that the productivity value of Urus MIII skyline varies among the sites (5.87 m^3/h in Site-1, 6.82 m^3/h in Site-2, 4.08 m^3/h in Site-3 for uphill and 1.69 m^3/h in Site-4 downhill), and uphill yarding by Urus MIII was more productive than downhill yarding on snow. Besides, it has been concluded that logging activities on snowy terrain during winter caused less damage on residual trees and seedling than that of the logging during summer season.*

1. Introduction

Several classes of extraction systems are commonly recognized, including ground-skidding systems, forwarding, cable extraction systems, aerial systems (helicopter or balloon) and animal logging, among others. Cable extraction systems are fundamentally different from other extraction systems. Cable systems are to be used, it is essential that sufficient time should be allotted to permit the necessary advance planning so that the operation can meet its environmental objectives at a reasonable cost. (Dykstra and Heinrich, 1996).

During the winter, equipment can travel off constructed roads and move logs through the forest across a frozen "pavement" of ice and snow. Unless the snow pack gets too deep, operations can continue throughout the winter. In logging operations, vegetation, including young tree seedlings, is better protected under the snow pack. Winter logging is a difficult task for the workers and the equipment, but it is really easy due to less ground friction (Trzesniowski, 1985; Murray and Buttle, 2003). In some areas with higher elevation where snow covers the ground and soils are frozen, winter logging is allowed. Root damage from equipment traveling and logs being dragged over the snow is lower compared with summer logging (Froehlich et al., 1981; Stone, 2002; Cole, 2003). Continued innovations in designing logging equipment will allow logging to become yet more versatile and less detrimental to the environment; therefore, the public can expect to see even less disruption to the visual quality of landscapes following timber harvesting operations (Whitson et al. 2003).

Cable yarding can be implemented in any weather conditions and result in less damaging to the forest ecosystem than tractor skidding (FAO, 1997; Baumgras et al., 1995; Dykstra and Heinrich, 1996). Cable yarding can be defined as the movement of logs from stump site to a landing by a machine equipped with multiple drums or winches, which operate from stationary position at the landing. Cable systems can transport logs over ground in which a tractor cannot operate. Swamps, mud, rocks, steep slopes and broken topography can be logged by a cable system designed for the terrain conditions. Besides, they are available to operate in any logging direction-upslope, down slope, or along the contour.

Timber harvesting with insufficient planning, improper operational techniques, and lack of control of operation result in severe damage to forest soil (Pinard et al., 2000; Croke et al., 2001; Demir et al., 2007; Akay et al., 2007), residual forest trees (Erdaş, 1986; Elias, 1995; Johns et al., 1996; Krzic et al., 2003), seedlings (Rushton et al., 2003; Eroğlu et al., 2007), wildlife (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).

In the most regions of Turkey, the application of mechanized harvesting equipment is currently very limited due to low labor costs and high fuel costs. In Turkey, URUS MIII cable systems have been in use since the end of 1970s. The actual usage of cable systems is not very high, but in mountainous parts of Turkey such as Artvin region, this cable system is very often the only reasonable possibility for wood extraction (Acar et al., 2000; Akay and Sessions, 2004; Öztürk and Demir, 2007).

Forests are usually found in high and steep slopes of mountainous areas in Artvin region, which increases harvesting cost. For logging operations, Koller K 300, Urus M III mobile skylines and MB Trac 900 forest tractors are commonly used in Artvin region (Acar et al., 1999; Öztürk et al., 2001; Acar and Dinç, 2001). In this study, the effectiveness of roundwood extraction by Urus M III skyline on snow was investigated in four harvesting sites in Artvin, Turkey.

2. Material and Method

This study was conducted during the year of 2007 in Artvin and Saçinka Forest Administrations in Artvin (north-eastern part of Turkey, 41° 10′ N, 41° 48′ E), Turkey (fig 1).

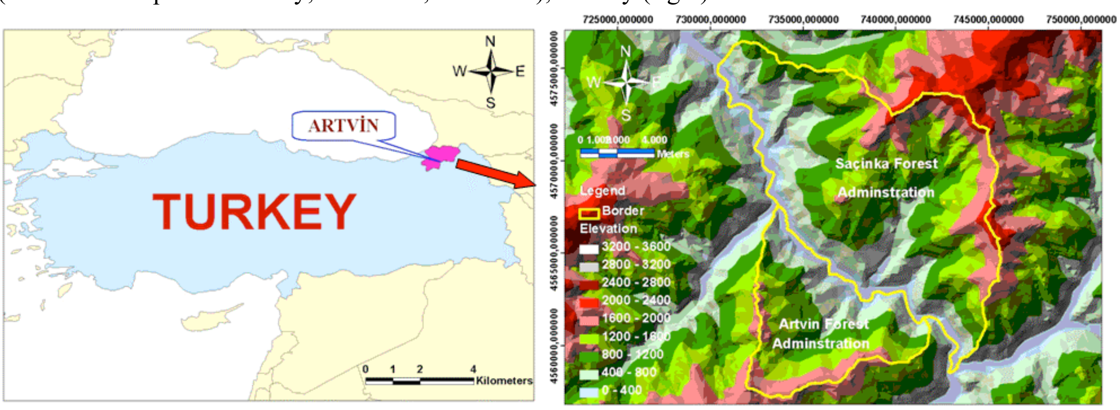

Figure 1. Location of the Artvin and Saçinka Forest Administration

Urus M III skyline was used in 4 different harvesting sites (2 in Artvin Forest Administration and 2 in Saçinka Forest Administration) (fig 2).

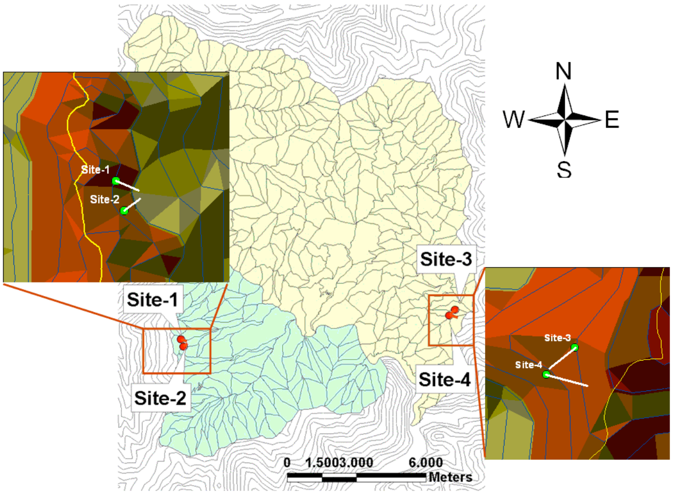

Figure 2. Location of the measurement sites in Artvin and Saçinka Forest Administration.

Urus M III forest skyline is generally used in uphill yarding operations, ranging from 500 to 600 m and combining with Mercedes Benz Unimog U1500 truck. This skyline has been used to timber harvesting on snow recently (figure 3). Four workers are employed in operating the cable system. The set up duration of cable system is between 10–16 h and pull up duration is between 4–8 h depends on terrain conditions. The number of safety ropes ranges between 2 and 4.

Figure. 3. Timber harvesting by Urus M III forest skyline on snow.

In the study sites, the ground slope and line slope range from 55 to 70% and 30 to 35%, respectively. The forest products yarded were oriental spruce, nordmann fir, and oriental beech (table 1). Transportation distance and worker number range from 200 to 400 m and 5 to 7, respectively. Uphill transportation was performed in Site-1, Site-2, and Site-3, while downhill transportation was done in Site-4.

The measurement tools such as electronic chronometer, steel meter, clinometers etc. were used during the field studies. To measure the time consumptions, digital chronometer (1 minute =100 second) was used. Also, digital camera and video camera were used to record images and videos of yarding operations. Study cards were used in time analyses to determine the productivity of the logging techniques. Cumulative time measurement technique was employed for time measurement at the study areas. Measurements were taken from the points with good visual angles to see the operations clearly.

Table 1. Properties of experimental areas for Urus M III skyline.

Type of skyline	Site no	Study area	Stand no	Ground/line Slope, %	Transport dist./ line dist., m	Number of cycle	Number of worker	Transport direction	Type of log yarded
Urus MIII	1	Artvin	30	60/30	250/500	32	6	Uphill	spruce
	2	Artvin	30	50/30	200/400	30	5	Uphill	spruce
	3	Saçinka	257	55/35	400/500	27	6	Uphill	beech-fir-spruce
	4	Saçinka	257	70/30	400/550	28	7	Downhill	beech-fir

Data obtained from the time studies in harvesting units were entered into the computer and listed in the data tables indicating work phases. Permanent time consumption technique was used during the uphill and downhill transportation by Urus M III. Measuring time consumption phases were; X_1: arrival of the empty carriage to loading area, X_2: pulling the hook and hooking the logs, X_3: pulling the load to carriage and locking, X_4: pulling the loaded carriage to unloading area, X_5: unhooking the load, and X_6: delay time. The statistical analysis was performed to investigate the effects of number of piece, log length, log diameter, and log volume on total transportation time. All statistical analyses were performed using SPSS® 15.0 for Windows® software.

The altitude of sites range 1478-1520 m, respectively, and crown closure ranges from 60 to 70%. The measured and determined some characteristics are shown in Table 2.

Table 2. Primary features of the harvesting sites.

Timber harvesting techniques	Site No	Altitude (m)	Field slope (%)	Aspect	Crown closure (%)	Number of worker	Transportation distance
Skyline	1	1478	50	South- East	70	6	450
	2	1520	40	East	60	6	700
	3	1494	70	North	70	5	550
	4	1482	50	North-West	60	5	350

In each timber harvesting site, 100 samples were measured for each damage on residual trees and seedlings. The level of damage caused by timber harvesting techniques on the residual trees and seedlings, was calculated based on injury size (table 3) as used in Elias (1998).

Table 3. The level of damage in residual trees and seedlings.

Residual trees	Seedlings
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 and stem and root and buttress injury <25%)
2 : medium injury (crown damage 30-50% / bark and stem injury 25-50% / root and buttress injury 25-50%)	2 : medium injury (crown damage / bark and stem and root and buttress injury 25-50%)
3 : heavy injury (broken stem, fallen three, crown damage-bark and stem injury-root and buttress injury > 50%)	3 : heavy injury (crown damage-bark and stem injury-root and buttress injury 50 - 75%)
	4 : dead seedling

3. Results and Discussion

The results of time measurements indicated that the most time consuming work phase was found to be "pulling the hook and hooking the log" (X_2) in Site-1, "pulling the loaded carriage to unloading area"

(X_4) in Site-2 and 3, and “pulling the load to carriage and locking” (X_3) in Site-4. Average time consumption was the highest in Site-4 for the work phases of X_1, X_2, X_3 and X_4 (fig. 4).

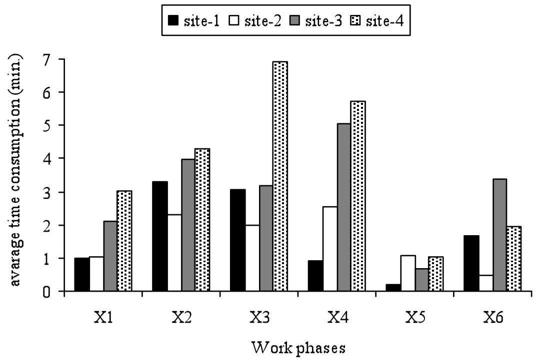

Figure 4. Distribution of time measurements for work phases in study sites.

This result showed that downhill logging by Urus M III was more difficult and took much more time than uphill logging. When the study (Öztürk and Demir, 2007) was carried out on similar condition in summer season, it was found that time consumption of “pulling to hook and hooking the log” took the most time compared with the other work phases. Average total time of cycle was founded as 17.32 min for 350 m yarding distances. In the present study, average total time of cycle was measured as 13.10 min for uphill logging and 22.92 min for downhill logging. Therefore, logging in this study by Urus M III on snow required less time than logging in dry season for uphill logging.

Number of piece, log length, and log diameter were measured in the field, and then log volume and transportation speed were calculated (table 4). The average number of piece, log length, log diameter, and log volumes range from 1.22-1.69, 2.5-12 m, 18-72 cm, and 0.226-2.278 m³, respectively. The average transportation speed was calculated as 80 m/min for uphill logging and 70 m/min for downhill logging. Transportation speed was determined as 60 m/min for uphill logging by Urus M III in summer season in similar condition (Öztürk and Demir, 2007). In addition, in the other studies, transportation speed was founded to be 61 m/min for uphill logging by Koller K 300 skyline (Erdaş and Eroğlu, 1999), 39 m/min for uphill logging by Gantner skyline (Eker et al., 2001), and 97 m/min for logging by Steyr KSK 16 skyline (Krpan et al., 2001).

Table 4 Data summary of yarding operation for study sites.

Site no	WORK PHASES, min							Average number of piece	Log length, m	Log diameter,cm	Log volume, m³	Unloaded speed, m/min	Loaded speed, m/min
	X_1	X_2	X_3	X_4	X_5	X_6	TT*						
Site-1	0.99	3.29	3.08	2.98	0.90	0.18	11.42	1.69	2.5-6	28-54	0.569-2.500	252	84
Site-2	1.04	2.29	1.99	2.56	1.09	0.49	9.48	1.63	3-6	25-56	0.502-1.584	192	78
Site-3	2.10	3.97	3.17	5.06	0.69	3.40	18.39	1.54	3-12	18-72	0.453-2.278	190	79
Site-4	3.02	4.30	6.91	5.72	1.03	1.93	22.92	1.22	4-8	24-54	0.226-1.404	133	70

* **TT: Total time**

Increases in number of pieces or product diameter increased the total transportation time when the pieces were transported either uphill or downhill. This increase was slightly higher in uphill transportation.

When product length or product volume increased, the total transportation time in both uphill and downhill transportation was increased. But this increase was higher in downhill transportation.

Increases in number of pieces, log diameter, log length and log volume did not significantly increase the total transportation time when the pieces were transported either uphill or downhill.

Productivity of Urus MIII skyline were determined in Site-1, Site-2, Site-3 and Site-4 as 5.87 m³/h, 6.82 m³/h, 4.08 m³/h, and 1.69 m³/h, respectively. The average relative productivity value was 11.23 min/m³ and 35.26 min/m³ for uphill and downhill logging, respectively (table 5). Thus, it might be stated that uphill logging by Urus MIII was more productive than downhill transportation on snow.

Table 5. Productivity values for Urus MIII on study sites

Site no	Yarding Distance, m	Line slope, %	Transportation direction	Productivity		Relative productivity	
				m^3/h	m^3/shift	min/shift	min/m^3
Site-1	250	30	Uphill	5.87	1.12	11.42	10.20
Site-2	200	30	Uphill	6.82	1.08	9.48	8.78
Site-3	400	35	Uphill	4.08	1.25	18.39	14.71
Site-4	400	30	Downhill	1.69	0.65	22.92	35.26

Productivity of Urus MIII was determined as 7.5 m³/h in summer season (Öztürk and Demir, 2007). Relative productivity value for Gantner skyline was reported as 11.74 min/m³ in Artvin (Eker et al., 2001). According to (Acar and Dinç, 2001), productivity at winter harvesting for skidding with human power was 1.15 m³/h, while it was 5.87 m³/h for an average hauling distance of 250 m in skidding by MB Trac 900. Also in the other studies in Artvin, productivity value was determined for Koller K 300 as 4.79 m³/h (Stenzel et al., 1985), 5.67 m³/h (Şentürk et al., 2007), 6.41 m³/h (Tunay and Melemez, 2001), for Urus M III as 6.73 m³/h (Eroğlu and Acar, 2007), and for Gantner skyline as 5.01 m³/h (Eker et al., 2001). The present investigation showed that although the productivity value of Urus M III skyline in uphill logging differed among the Sites 1-3 (4.08, 5.87, and 6.82), the productivity value was the least in downhill logging and decreased to 1.69 m³/h at Site-4. The results derived from this study indicated that Urus M III forest skyline should be used for logging on snow effectively and uphill logging should be preferred to downhill logging in order to increase the productivity or effectiveness of logging by Urus M III forest skyline.

It might be concluded that Urus M III can be used efficiently to extract logs on snow in Artvin forestry, Turkey. It is well known that the cost of wood extraction depends on many factors. To reduce cost and damage to remaining trees during wood extraction, Urus M III cable system can be used for logs downhill and uphill on slopes with a gradient of 30-80%. Wood extraction with Urus M III can also be economically advantageous to utilize logs produced from silvicultural activities and all tree harvesting operations.

In sites, average diameter and height of damaged residual trees and seedlings are 39.69 cm, 21.68 mm and 26.78 m, 139,74 cm respectively. Average damage level of tree and seedling are 0.23 and 0.31 respectively (Table 6).

Table 6. Data summary of yarding operation for study sites

Site No	Mean Diameter		Mean Height		Level of Damage	
	Tree (cm)	Seedling (mm)	Tree (m)	Seedling (cm)	Tree	Seedling
1	45.03	17.56	23.54	36.54	0.28	0.31
2	38.93	29.37	22.54	103.66	0.14	0.12
3	35.36	21.39	20.32	124.61	0.23	0.42
4	39.42	38.81	22.02	294.15	0.26	0.40
Average	39.69	21.68	26.78	139.74	0.23	0.31

Average degree of physical damage on residual trees is shown in Table 7. Average physical damage level of logging in winter season on residual trees has been calculated as 0.228. A study conducted by Eroğlu and Öztürk (2009) in the same area found out this degree of damage in summer season as 0.403. It was found out that 78.5% of residual trees were not injured in the logging during winter.

Table 7. The level of the damage based on the injury size of residual trees in winter season

Physical damage level (%)				Average damage level
0	1	2	3	
78.5	20.25	1.25	0.0	0.228

Average harm degrees on seedlings is given in Table 8. When this table is examined, it can be seen that the average physical damage level imposed by logging activities in winter season is determined as 0.31. The average damage level of logging activities in the same area during summer season is determined as 0.57 (Eroğlu and Öztürk, 2009). During the logging activities in winter season, 71.50 % of the seedling in stand were not damaged physically.

Table 8. The level of the damage based on the injuring size of seedlings in winter season

Physical damage level (%)					Average damage level
0	1	2	3	4	
71.50	25.75	2.75	0.00	0.00	0.313

Physical damages imposed by logging activities during summer months through overhead lines on seedlings is mostly in the form of flattening and injuring the seedling which are carried with one end on floor. Physical damage incurred by seedling is peeling of crust and cambium layers and injuries in the trunk and offshoots. These physical damages appear less during winter activities as the seedlings are under snow.

Advantages of logging on snow in winter include; 1) natural regeneration under the snow layer is not harmed, 2) soil is protected from disturbance, compaction, and erosion, 3) winter temperature and moisture protect timber quality from fungal and insect damage, 4) labor is easier to obtain because of reduced farm work during the winter, 5) local villagers are provided year-round work and 6) winter harvested timber commands a higher selling price (FAO, 1998).

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