African Journal of Biotechnology Vol. 8 (6), pp. 1082-1089, 20 March, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

An investigation on roundwood extraction of *Fagus orientalis* lipsky, *Abies nordmanniana* (Stew.) Spach. and *Picea orientalis* (L.) Link. by Urus M III forest skyline on snow

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Accepted 5 January, 2009

Harvesting and transportation of woods from forest are extremely difficult, expensive and time-consuming operations. In the most regions of Turkey, the application of mechanized harvesting equipment is currently very limited due to low labor cost and high fuel cost. In Turkish forestry, the most common harvesting method is cut-to-length system, which is carried out intensively during the late spring and summer, as well as during the winter with a limited extent. In this study, productivity of roundwood extraction (*Fagus orientalis* Lipsky., *Abies nordmanniana* (Stew.) Spach. and *Picea orientalis* (L.) Link.) by Urus M III skyline on snow in Artvin, Turkey was investigated. The average total time of shift was measured as 13.10 min for uphill logging and 22.92 min 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.

Key words: Artvin, skyline, roundwood logging on snow, oriental spruce, oriental beech, nordmann fir.

INTRODUCTION

Timber extraction is the process of moving trees or logs from the cutting site to a landing or roadside where they will be processed into logs or consolidated into larger loads before transporting them to the processing facility or other final destination. 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 fundametally different from other extraction systems. If 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 eco-

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system than tractor skidding (Stenzel et al., 1985; FAO, 1997; Fairweather, 1991; 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.

The most common harvesting method applied in Turkish forestry is cut-to-length where the trees are cut, felled, delimbed, topped, and bucked into the various lengths by using chainsaw at the stump area. Then, debarking is handled by hand tools such as axes (Erdaş, 1986; Eroğlu and Acar, 2007). 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. Although, the equipment has been increasingly used in the regions with intensively managed forests (Akay et al., 2004), over 80% of the logging operations in Turkish forestry are still practiced by using man power as skidding or sliding, which are subject to technical, ergonomic, and environmental problems (Hasdemir et al., 2000; Eroğlu et al., 2007). 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).

The haulage of timber produced as well as other forest operations, depends very closely on the weather conditions. Forest harvesting operation in Turkey is carried out intensively during the late spring and summer months, and during the winter months with limited extent. The rendering of time studies and the planning of operations on the basis of such studies bear great importance in order to perform the operations in winter months in a more productive manner within the desired time.

Winter months are often characterized by high precipitation and snow accumulation. Therefore, either soil moisture is already fully recharged and excess rainfall is converted almost entirely to surface and subsurface runoff for both forested and harvested catchments, or snow accumulates and little runoff is generated until spring snow melt season (Hubbart and Matlock, 2006). Overall, winter harvesting of boreal mixed wood sites did not have a major impact on the majority of soil properties evaluated or on the species composition of the under story vegetation community (Bock et al., 2002). The best way to avoid soil compaction is to log in the winter when soil is frozen or in a dry period when soil moisture is low.

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.

MATERIALS AND METHODS

This study was conducted during the year 2007 in natural oriental spruce (*Picea orientalis* (L.) Link.), oriental beech (*Fagus orientalis* Lipsky) and nordmann fir (*Abies nordmanniana* (Stew.) Spach.) stands of Artvin and Saçinka Forest Administrations in Artvin (north-eastern part of Turkey, 41° 10′ N, 41° 48′ E), Turkey (Figure 1). The climate in Artvin is mild with humid summers. Annual precipitation and temperature averages approximately 700 mm and 13°C, respectively (Akman, 1990). Urus M III skyline was used in 4 different harvesting sites (2 in Artvin Forest Administration and 2 in Saçinka Forest Administration) (Figure 2).

Artvin Forest Administration manages a forest area of 5225 ha with the growing stock of 4 million m^3 in a mountainous region with steep slopes (range from 30 to 65%) and high elevations (up to 3000 m, average 2500 m). In this area, *P. orientalis* (L.) Link, *F. orientalis* Lipsky, *A. nordmanniana* (Stew.) Matt., *Pinus silvestris* L. *Castanea sativa* Mill. and *Quercus* spp. are generally dominant species in either pure or mixed forms. The climate is generally characterized by cold winters and semi-arid summers. Mean annual precipitation is 690 mm and average monthly temperature ranges from 32°C in August to -2.5°C in January (Sarıyıldız et al., 2005).

Saçinka Forest Administration located in Artvin is characterized by a dominantly steep and rough terrain with an average slope of 57.23% and an altitude of 185 to 2469 m above sea level. The total area is 13314 ha. The vegetation type is forest vegetation and the dominant tree species of the vegetation are *P. orientalis*, *F. orientalis*, *Quercus petraea subsp. Iberica, P. sylvestris, A. nordmanniana subsp. nordmanniana, Carpinus betulus,* and *Alnus glutinosa subsp. barbata*. Although no comprehensive study in the area about plant sociology has been done, 12 various tree species such as *Quercu pontica, Q. petraea and Ostrya carpinifolia*as as well as 19 different shrubs and brushes and 35 plant types taking into the group sporadically that are not standing on their own have been detected and recorded. Mean annual temperature of the study area is 12.7°C, and mean annual precipitation is 644.9 mm. Main soil types are sandy clay loam, clay loam and sandy loam (DIE, 2007; Anonymous, 2006).

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. The basic characteristics of the URUS MIII were given in Table 1 (Öztürk and Demir, 2007). The carriage used was made by Koller and had a self-locking mechanism.

The coordinate of the sites was determined by Magellan GPS receiver with a free static measure. Digital maps of Artvin and Saçinka Forest Administrations (F47c_1, F47c_2, F47b_3, and F47b_4) were generated by with the ArcGIS 9.1 software package program. Then, the joined digital maps were converted to TIN theme in ArcGIS to acquire 3D digital map. The coordinates of the sites were handled on a separate layer. Then, the map shown in Figure 2 was generated by overlaying the two layers (digital map and coordinate layer).

In the study sites, the ground slope and line slope range from 55

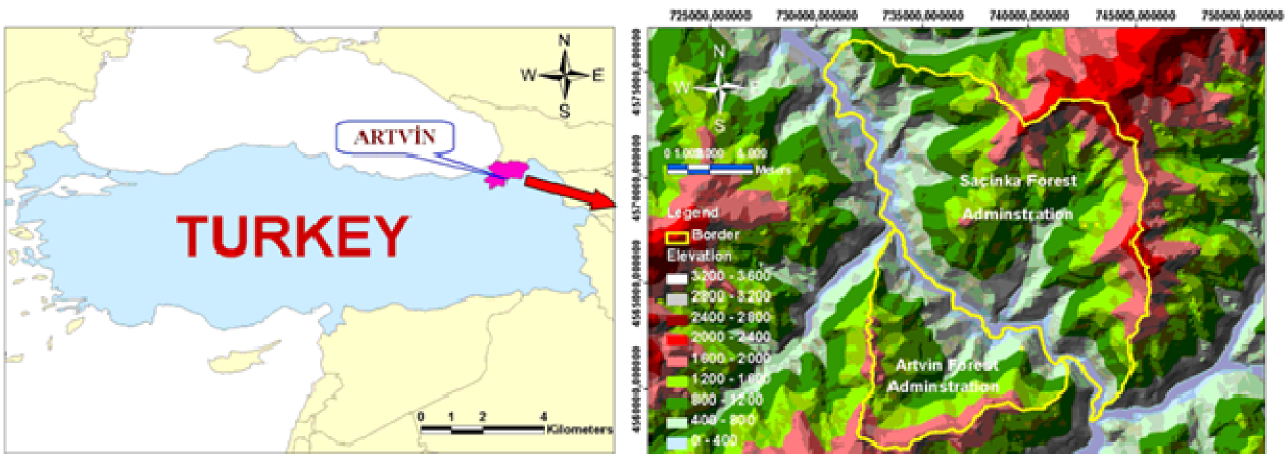

Figure 1. Location of the Artvin and Saçinka Forest Administration.

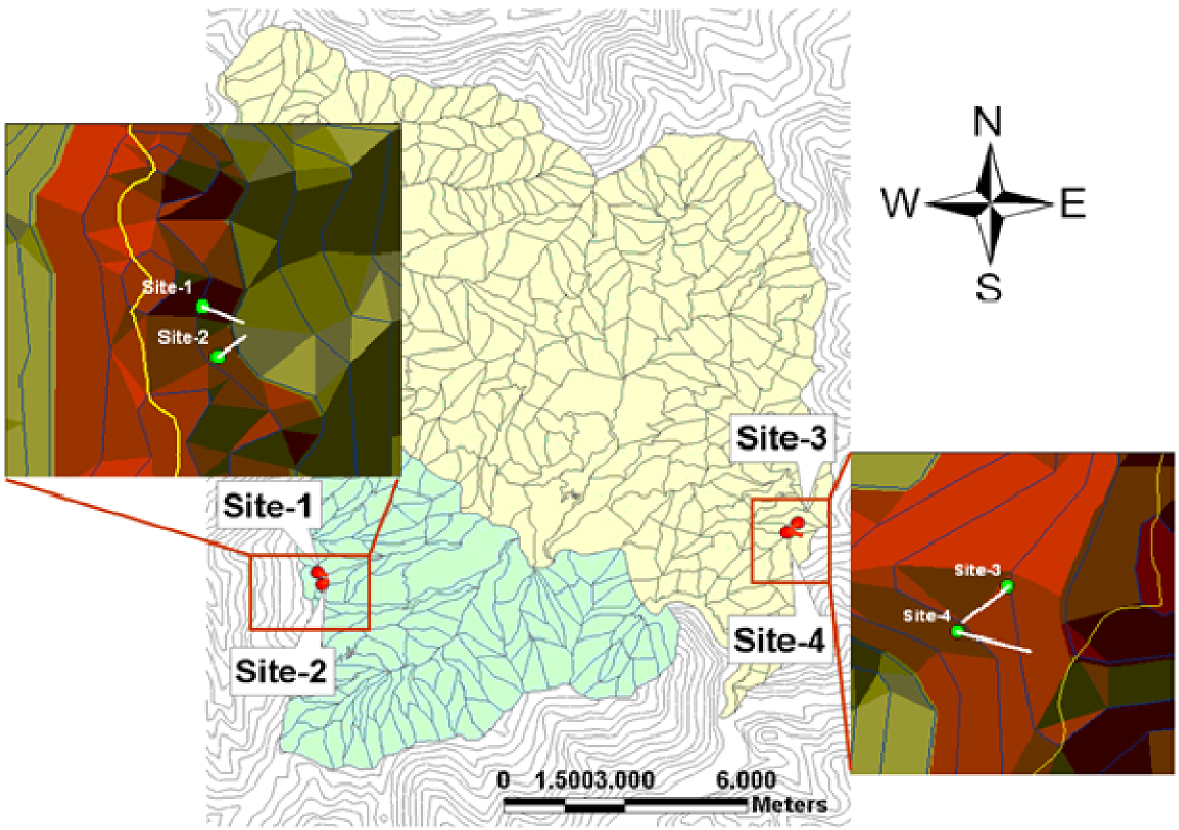

Figure 2. Location of the measurement sites in Artvin and Saçinka Forest Administration.

to 70% and 30 to 35%, respectively. The forest products yarded were oriental spruce, nordmann fir, and oriental beech (Table 2). Transportation distance and worker number range from 200 to 400 m and 5 to 7, respectively. Uphill transportation was performed in Site-1, 2, and 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 min =100 s) 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.

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

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

Table 1. The basic characteristic of the URUS MIII.

Feature	Value
Base Truck	Mercedes 1500 T
The mass of cable system	8500 kg
Engine power	160 hp, diesel engine
Fuel tank	180 l
Maximum cable speed	210 m/mm
Maximum load weight transporting of cable crane	2000 kg
Diameter/length of main line	18 mm/600 m
Diameter/length of haul line	10 mm/600 m
Diameter/length of haul-back line	12 mm/1200 m
Diameter/ length of hoist line	8 mm/600 m

Table 2. 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

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.

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 (Figure 4). 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

Table 3. 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 (m^3)	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.

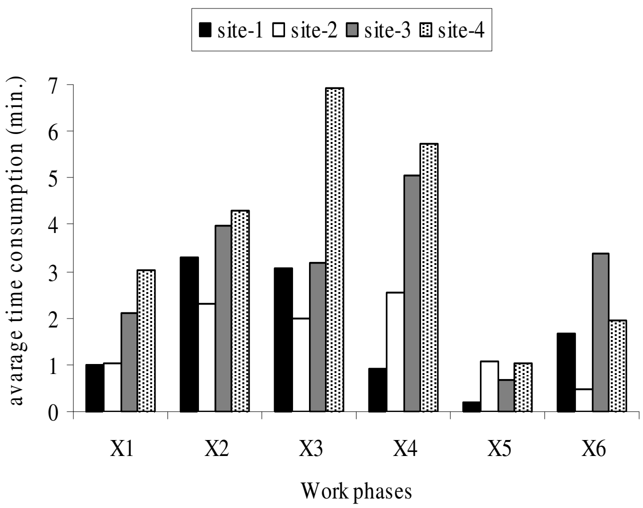

Figure 4. Distribution of time measurements for work phases in study sites.

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 3). 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).

Increases in number of pieces or product diameter increased the total transportation time when the pieces were transported either uphill or downhill (Figures 5 and 6). 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 (Figures 7 and 8).

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

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 (Stenzel et al., 1985), 5.67 (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.

During the construction of forest roads, depending on the length of road, 1.0–2.0 ha is cleared from trees and plants. Road constructions in rocky lands and mountain-

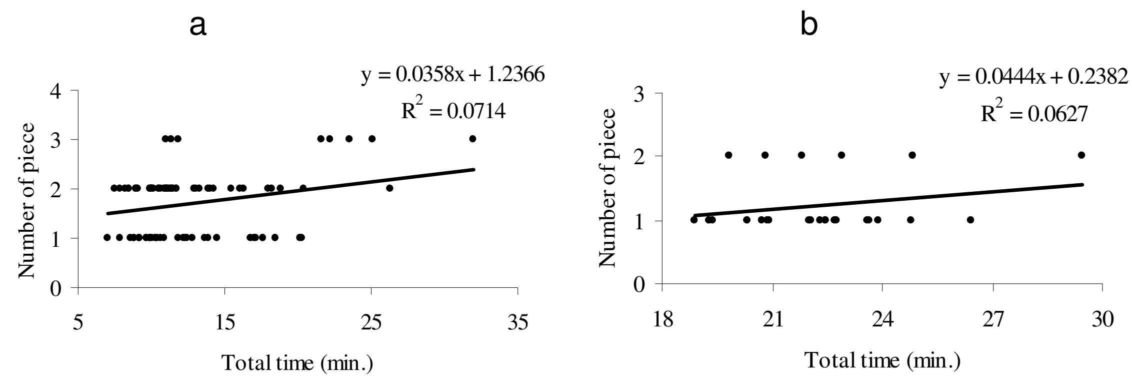

Figure 5. Relation between number of piece and total transportation time in uphill (a) downhill (b) transportation.

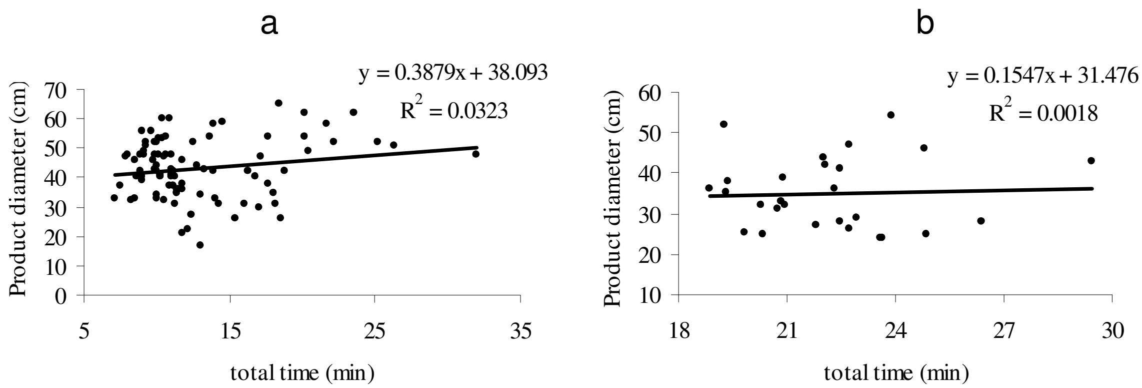

Figure 6. Relation between product diameter and total transportation time in uphill (a) and downhill (b) transportation.

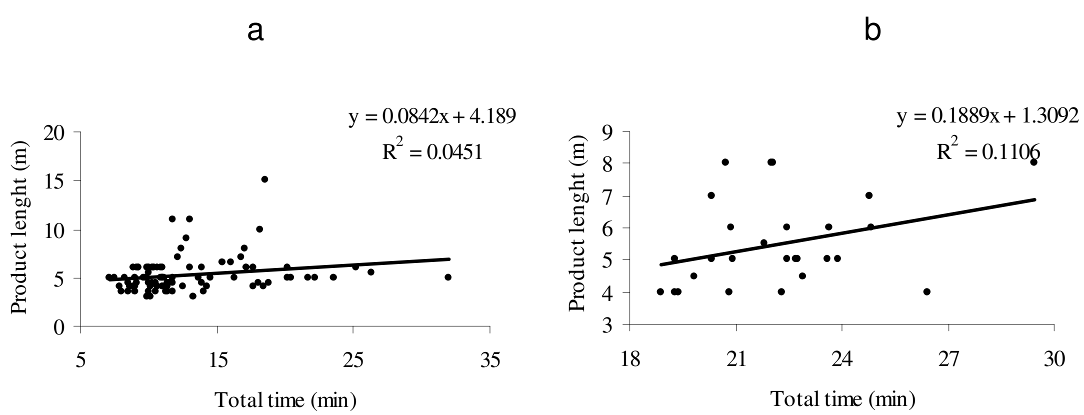

Figure 7. Relation between product length and total transportation time in uphill (a) and downhill (b) transportation.

ous lands as in the region of Artvin, huge damages are seen to occur in stands below the road. During the construction studies, rolled stones and rocks damage the trees and plants that are below the road. Because of this, it is better to approach these lands with skylines, instead of roads (Öztürk and Demir, 2007).

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

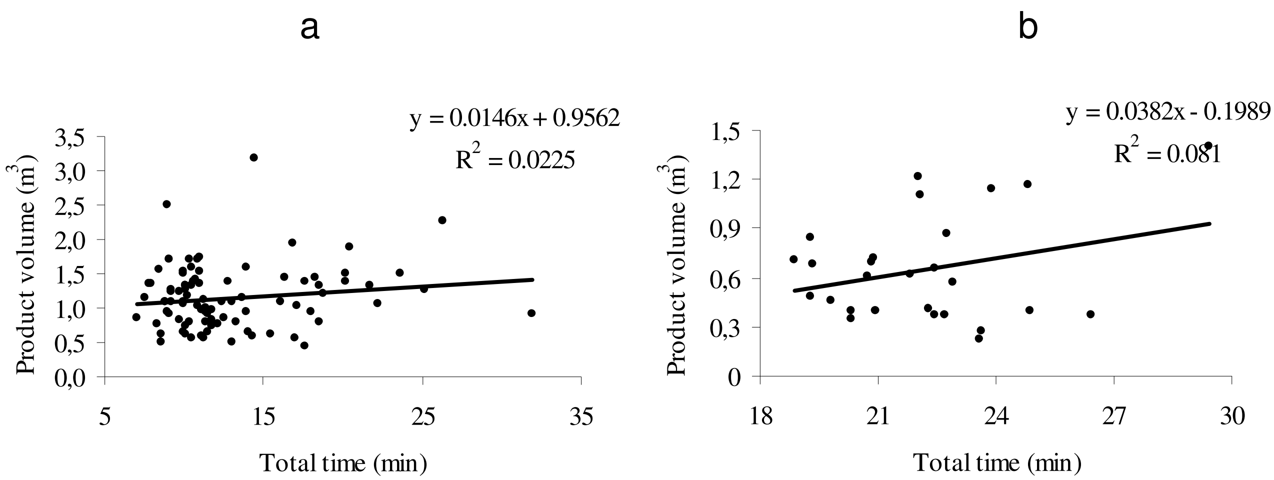

Figure 8. Relation between product volume and total transportation time in uphill (a) and downhill (b) transportation.

Table 4. 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

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.

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).

To increase the productivity of Urus M III mobile skylines, carriage maintenance must be supplied and chokers and cables should be done at the beginning of the work and damages caused by logging can be minimized by means of better timber harvesting planning and proper, well controlled timber harvesting operation techniques.

ACKNOWLEDGEMENTS

This study is funded by The Scientific and Technological Research Council of Turkey (TUBITAK) with the project number 106O054.

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