Extraction of spruce timber by Gantner cable crane from selective forests of Artvin region

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Abstract – Nacrtak

The purpose of this study is to investigate the productivity of the Gantner cable crane during extraction of Spruce timber from mixed stand of Oriental spruce, Scots pine and Oriental beech in North Eastern Turkey. Cable crane productivity is determined by using the methods of work and time study. The research results implies that some working characteristics of the Gantner cable crane such as extraction distance, speed of the carriage (loaded and unloaded), load volume, time consumption of handling operations and fuel consumption have an important impact on productivity of the cable crane.

Keywords: Gantner cable crane, carriage, productivity, Turkey, Artvin

1. Introduction – *Uvod*

Turkey has 21.2 million ha of forests, which occupies 26.6% of its total land area. Approximately 75% of the forested area is on steep terrains with slopes greater than 40%. Therefore, harvesting in mountainous regions has always posed a special difficulty. In the last 30 years, Turkey's forests have been opened by road network. Currently, there are 144,000 km of forestry roads. Also, approximately 50,000 km of public roads, which are used predominantly in forested areas, are essential routes in the road network. An average road density is 10.7 m/ha in the whole forested area.

The timber harvesting is still one of the most important forestry activities. Three types of primary transportation methods are used in Turkish forestry, and they are: human power, animal power and mechanization. Manual ground skidding (man and gravitation) is generally applied in small steep forest areas for extraction of fuelwood over short distances. Animal skidding, mainly by horses and oxen, is used for pre-skidding for bunching distance between 20 m and 100 m. Mechanical skidding is carried out by ground based forestry vehicles. Also Gantner, Koller and URUS cable systems are used for timber extraction on steep terrains.

2. Material and Methodology – *Materijal i metodologija*

In Turkey, Gantner cable cranes have been in use since the late 1950's. The actual share of cable systems is not very high in total timber extraction. However, in mountainous parts of Turkey such as the study area, this is the only possible system of timber extraction. That is the reason why the Forest General Directorate in Turkey has imported many of the URUS and Koller series mobile tower yarders, Koller carriages, Gantner cable cranes and other equipments. The Gantner cable crane is mounted on a sledge. The extraction distance of the cable crane is 1500 m (2000 m). Four workers are employed for operating the cable crane. The time of installation of the cable crane is between 20–50 hours, while the dismantling time is between 7–14 hours depending on terrain conditions.

The basic characteristics of the Gantner cable crane are as follows (Figure 3):

- Cable crane mass is 1420 kg (with winch, ropes and engine),
- Diesel engine power is 45 HP,
- Maximum pulling force is 6840 kN,
- Maximum cable speed is 7.5 m/s,
- Single drum width is 800 mm,
- Maximum payload is 2.5 t,

- Diameter/length of skyline is 24 mm/2000 m,
- Diameter/length of mainline is 16 mm/1500 m,
- Fuel consumption is 20 L/day,
- Dimensions (length, width, height): 2500x 1500x1200 mm,
- Carriage type: SKA-2.5

In order to conduct this research, the first step was to choose the harvesting area. The selected study area is situated in Artvin province (Figure 1). Gantner sledge cable crane was selected and located at the peak of the selected area. The sledge winch was placed 800 meters away from the roadside landing due to decreasing of harvesting costs and increasing the machine's performance. During the timber extraction some variables were measured and data collected.

3. Study Area – *Mjesto istraživanja*

In Turkey, the forests are managed by a state authority called »General Directorate of Forestry«. Under this Directorate 27 regional forest administrations have been established. Each of them has been authorized to administer a local Forest Offices, responsible for managing a certain part of forestlands. Nowadays there are 1238 Forest Offices, which have been managing about 21.2 million ha of forests. 15.4 million ha of forests with growing stock of 1195 million m^3 are considered as high forests and have been managed for production of technical roundwood. The remaining 5.8 million ha of forestlands are coppice forests with growing stock of 1255 million m^3 and they have been managed with the aim of producing firewood.

The study area is managed by Atila Forest Office within the Artvin Forest Administration. Atila Forest Office manages 6910 ha of forest with the growing stock of 1.4 million m^3. Road density in Atila Forest Office is 17 m/h. The most important commercial tree species are *Picea orientalis* (L.) Link, *Abies nordmanniana* (Steven) Spach, *Fagus orientalis* (Lipsky) and *Pinus sylvestris* (L.).

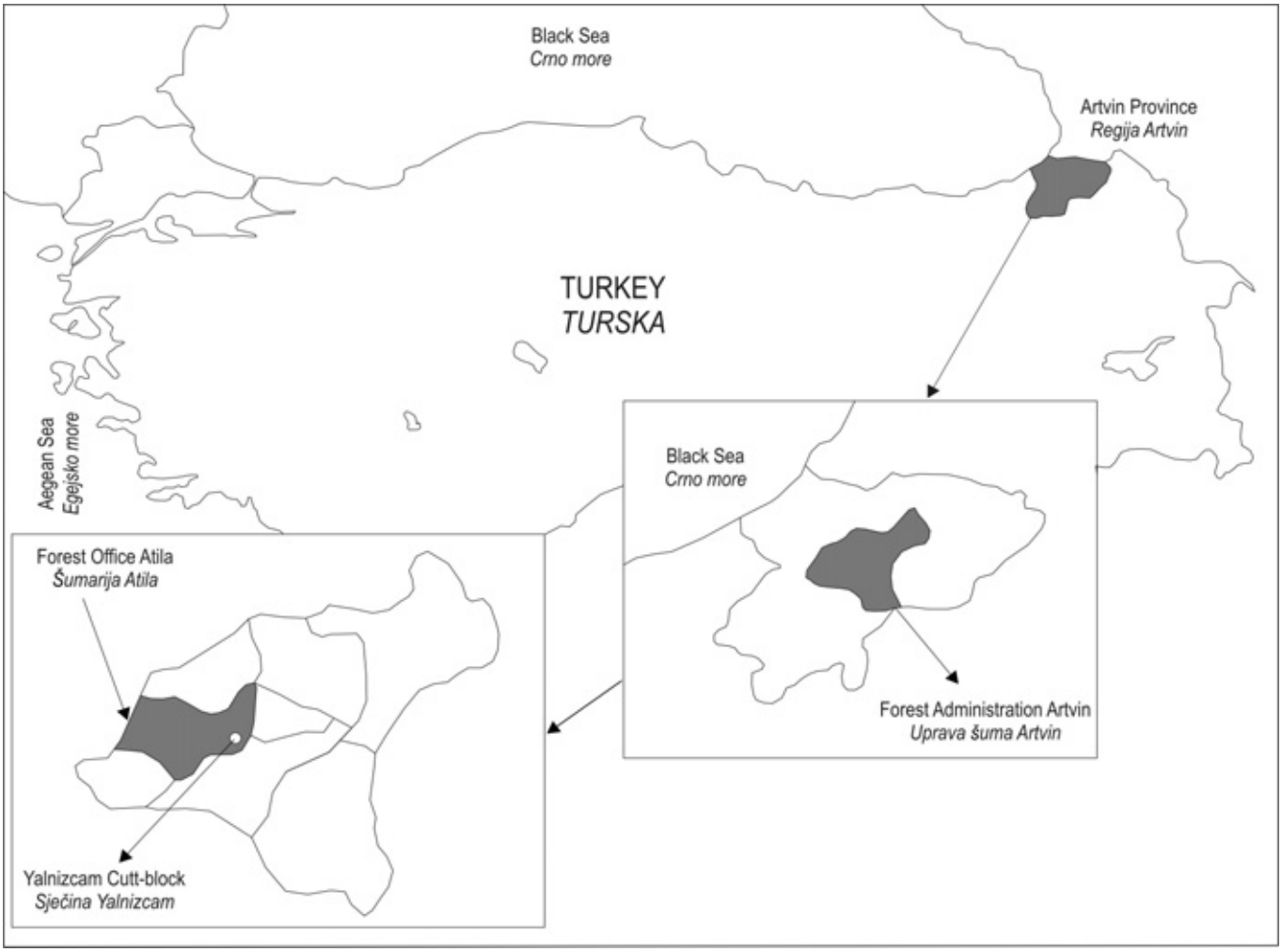

Figure 1 Artvin province and felling area – ***Slika 1.*** *Regija Artvin i položaj sječine*

Figure 2 Gantner cable crane inside the felling area
Slika 2. *Položaj žične linije u sječnoj jedinici*

Figure 3 Gantner cable crane
Slika 3. *Žičara Gantner*

The research was conducted at subcompartment 69 named Yalnizcam, in July–August 2002. The subcompartment area is 37 ha and the volume of removal is 750 m³. Length of timber assortments ranges from 4 to 6 m.

4. Variables and data collection – *Varijable i prikupljanje podataka*

This study tried to determine the impact of independent variables to »total cycle time« (total time). The total cycle time has been selected as a dependent variable whereas: »outhaul empty«, »lateral out«, »hookup«, »lateral in«, »in haul«, »unhook« and »lost time« have been selected as independent variables. Furthermore, »extraction distance«, »lateral bunching distance«, »load volume« and »timber quantity« have been selected as independent variables having impact on total cycle time.

The definitions of both dependent and independent variables are summarized below and the explanation is given of their measurement:

Dependent variable:

– ***t* – total time**, measured as time at scale level variable and the measurement unit is minute.

Independent variables:

– ***a* – outhaul empty**, starts when the operator is ready to move the carriage to the choker setter and ends when the choker setter keeps the hook.
– ***b* – lateral out**, this phase begins at the end of outhaul empty and ends when the choker setter is ready to hook a load.
– ***c* – hookup**, it begins at the end of lateral out and ends when the choke setter has completed hooking and given the signal to the operator by wireless phone to begin to drag the load.
– ***d* – lateral in**, begins at the end of hookup period and it ends when the operator is ready to move the carriage to the roadside landing.
– ***e* – in haul**, begins at the end of lateral in and ends when the carriage has reached the roadside landing, where the hook is unlocked and the log is left to the ground.
– ***f* – unhook**, begins at the end of in haul when the carriage passes over to the tripblock and ends when the hook is pulled back to the loading point.
– ***g* – lost time**, is the all work breaks.
– s_E **– extraction distance**, is described as distance between loading point and roadside landing, measured by meter-tape and marked at regular intervals.
– s_L **– lateral bunching distance**, is described as a distance between skyline and the closest log and is measured either by pacing the distance or by visual estimate.
– l_V **– load volume**, is a variable that represents the volume of all logs in the load, measured in cubic meters.

All the variables given above are considered as scale variables.

Theoretically, the mathematical function is obtained as follows:

$$t = f(a,b,c,d,e,f,g,s_E,s_L,l_V)$$

H_0 (null hypothesis) means that the proportion of variance in total cycle time (t) explained by outhaul empty, lateral out, hookup, lateral in, in haul, unhook, lost time, extraction distance, lateral bunching distance, load volume included in the regression model is equal to zero, in the population from which the sample was selected. Null hypothesis also implies that none of the independent variables has statistically significant effect on total cycle time.

Alternative hypothesis means that the proportion of variance in total cycle time that is explained by the set of ten independent variables included in the regression model is greater than zero, in the population from which the sample was selected. It also implies that at least one of these independent variables has statistically significant and linear effect on total cycle time.

5. Analysis – *Analiza*

Gantner cable crane was investigated in terms of work performance by using time and work study methods. The time periods of working components were measured by using snap back chronometry method. The extraction distance was measured by using a measuring tape, the slope gradient of the terrain was measured by clinometers, and diameter of each piece of timber under bark was measured by caliper.

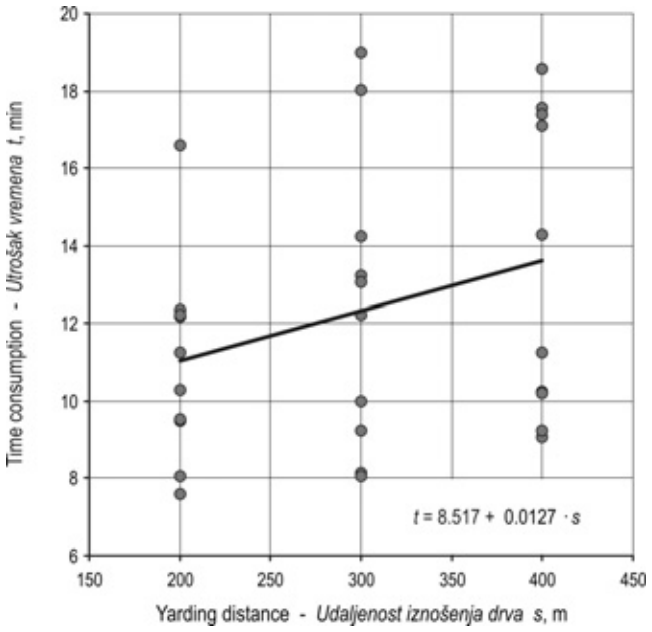

Figure 4 Dependance of total time vs. extraction distance

Slika 4. *Ovisnost utroška vremena turnusa o udaljenosti privlačenja*

SPSS Statistical Software and Excel 2000 were used for carrying out the analyses of data. A regression model was developed for the statistical analysis.

Initially a 95% significance level was set to test the null and alternative hypothesis presented above. F-test (variance analysis) was used for testing whether the data verify statistical model or not.

F-test = 160,593 and statistically based on a 0.05 significance level. Since F-test (160.593) is higher than $F_{0.005}$, (2.42) we have rejected the null hypothesis that none of these independent variables has a statistically significant effect on total cycle time.

Consequently, the data were consistent with the alternative hypothesis that the proportion of variance in total cycle time (t), explained by the set of independent variables included in the regression model, was greater than 0.0 in the population from which this sample was selected. It also implied that at least one of these independent variables had a statistically significant effect on total cycle time and that this relationship was linear.

The regression model for Yalnizcam was calculated as follows:

$$t = 1.269 + 0.900 \cdot a + 1.220 \cdot b + 0.705 \cdot c + 0.938 \cdot e + \\ + 1.311 \cdot f + 1.043 \cdot g$$

In preparing the model for the Yalnizcam cut-block, when the other variables were hold constant above the dependent variables, the coefficient of Durbin-Watson was 2.220. Since the coefficient was approximately 2 or below, this means that there was no correlation between the independent variables that form the model, and that they were completely separated from each other.

6. Results and discussion – *Rezultati i diskusija*

The first result revealed by this research is that there is a linear and positive correlation between the set of ten independent variables (**outhaul empty, lateral out, hookup, lateral in, in haul, unhook, lost time, extraction distance, lateral bunching distance, load volume**) and dependent variable (**total cycle time**). This implies that when an independent variable increases, total cycle time increases as well.

When we look at the relationship between each of these independent variables and total cycle time, some clear conclusions can be drawn.

Total cycle time (t) vs. outhaul empty (a): The unstandardized coefficient is 0.900, which means that the relationship outhaul empty and total cycle time is positive. If outhaul empty increases one min-

ute, total cycle time increases 0.900 minutes, when holding all other variables constant. Since beta (β) is 0.244, the relationship between outhaul empty and total cycle time is weak, but statistically significant. Beta coefficient means that for the increase of each standard deviation in the outhaul empty, total cycle time increases 0.244 units, when holding all other independent variables constant in the model. Since the coefficient is statistically significant, the relationship between total cycle time and outhaul empty is linear.

Total cycle time (*t*) vs. lateral out (*b*): The unstandardized coefficient is 1.220, which means that the relationship between lateral out and total cycle time is positive. If lateral out increases one-minute, total cycle time increases 1.220 minutes, when holding all other variables constant. Since beta (β) is 0.271, the relationship between lateral out and total cycle time is weak, but statistically significant. Beta coefficient means that for each increase of standard deviation in the lateral out, total cycle time increases 0.271 units, when holding all other independent variables constant in the model. Since the coefficient is statistically significant, the relationship between total cycle time and lateral out is linear.

Total cycle time (*t*) vs. hookup (*c*): The unstandardized coefficient is 0.705, which means that the relationship hookup and total cycle time is positive. If hookup increases one minute, total cycle time increases 0.705 minutes, when holding all other variables constant. Since beta (β) is 0.169, the relationship between hookup and total cycle time is weak, but statistically significant. Beta coefficient means that for the increase of each standard deviation in the hookup, total cycle time increases 0.169 units, when holding all other independent variables constant in the model. Since the coefficient is statistically significant, the relationship between total cycle time and hookup is linear.

Total cycle time (*t*) vs. in haul (*e*): The unstandardized coefficient is 0.938, which means that the relationship between outhaul empty and total cycle time is positive. If outhaul empty increases one minute, total cycle time increases 0.938 minutes, when holding all other variables constant. Since beta (β) is 0.281, the relationship between outhaul empty and total cycle time is weak, but statistically significant. Beta coefficient means that for the increase of each standard deviation in the outhaul empty, total cycle time increases 0.281 units, when holding all other independent variables constant in the model. Since the coefficient is statistically significant, the relationship between total cycle time and outhaul empty is linear.

Total cycle time (*t*) vs. unhook (*f*): The unstandardiszed coefficient is 1.311, which means that the relationship between in haul and total cycle time is positive. If in haul increases one-minute, total cycle time increases 1.311 minutes, when holding all other variables constant. Since beta (β) is 0.430, the relationship between in haul and total cycle time is moderate, but statistically significant. Beta coefficient means that for the increase of each standard deviation in the in haul, total cycle time increases 0.430 units, when holding all other independent variables constant in the model. Since the coefficient is statistically significant, the relationship between total cycle time and in haul is linear.

Total cycle time (*t*) vs. lost time (*g*): The unstandardized coefficient is 1.043, which means that the relationship between lost time and total cycle time is positive. If lost time increases one minute, total cycle time increases 1.043 minutes, when holding all other variables constant. Since beta (β) is 0.511 the relationship between lost time and total cycle time is moderate, but statistically significant. Beta coefficient means that for the increase of each standard deviation in the lost time, total cycle time increases 0.511 units, when holding all other independent variables constant in the model in the model. Since the coefficient is statistically significant, the relationship between total cycle time and lost time is linear.

The cable crane performance was being observed at the felling site for 12 working days. During that time 700 m³ of timber was extracted in 90 recorded cycles. Timber extraction was carried out at three different distances. The total cycle times of Gantner cable crane at the distances of 200, 300 and 400 m are 11.20; 12.83 and 13.83 minutes. The average total cycle time is 12.62 minutes.

The average lost time was 1.26 min/cycle. Lost times were occurred during loading and unloading and due to defect of carriage.

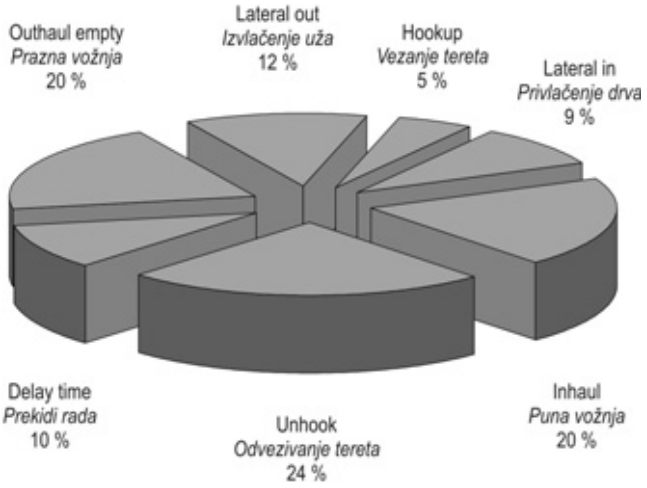

Figure 5 Structure of time consumptions

Slika 5. *Struktura utrošaka vremena*

Table 1 Results of measurements
Tablica 1. *Rezultati mjerenja*

Yarding distance *Udaljenost iznošenja drva*	Lateral bunching distance *Udaljenost sakupljanja drva*	Load volume *Obujam tovara*	Number of pieces in the load *Komada oblovine u tovaru*	Outhaul empty *Prazna vožnja*	Lateral out *Bočno izvlačenje uža*	Hookup *Vezanje tereta*	Lateral in *Bočno privlačenje drva*	In haul *Puna vožnja*	Unhook *Odvezivanje tereta*	Delay time *Prekidi rada*	Total time *Ukupno vrijeme*
s_E	s_L	l_V		*a*	*b*	*c*	*d*	*e*	*f*	*g*	*t*
m		m^3	min/cycle - *min/tura*								
200	15.0	1.25	3	1.42	1.23	0.67	1.17	1.43	3.12	2.17	11.20
300	22.5	1.30	3	2.37	1.83	0.87	0.95	2.88	2.58	1.35	12.83
400	22.5	1.35	2	3.23	1.73	1.30	1.05	3.07	3.20	0.25	13.83
Average - *Prosječno*			3	2.34	1.60	0.94	1.06	2.46	2.97	1.26	12.62

The average load volume is 1.3 m^3/cycle. The volume of an average piece of timber was 0.43 m^3 and it was 5 m long. The results of time measurements are shown in Table 1.

The average productivity at the felling site was 6.2 m^3/h. The costs of Gantner cable crane was 4.10 \$/m^3. Daily fuel consumption was measured by the volume method. The average fuel consumption per operating hour was 3.5 L/h. Fuel consumption per unit of extracted timber was 0.56 L/m^3.

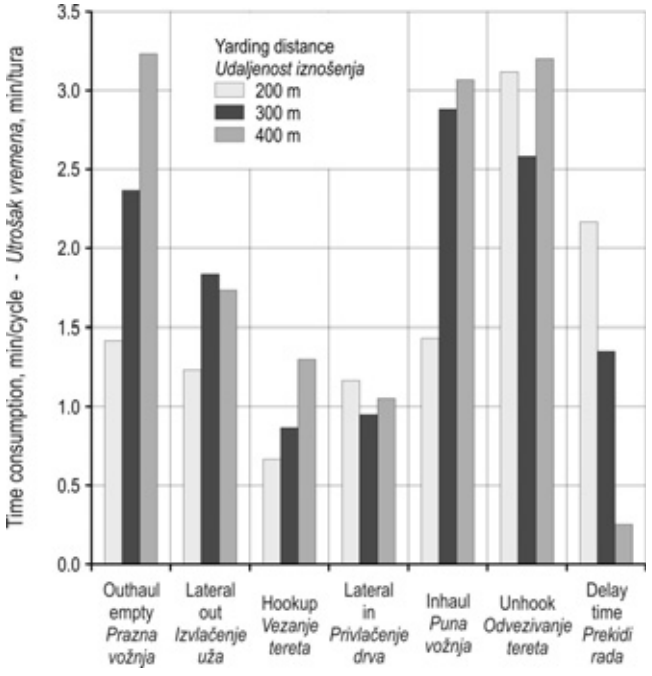

Figure 6 Time consumptions by working component
Slika 6. *Utrošci vremena radnih sastavnica*

8. Conclusions – *Zaključci*

This paper shows the results of research of yarding spruce timber by the Gantner cable crane. The cable crane with an 800 m line length was installed and four workers were engaged. Lateral dragging distance was between 20–50 m. The corridor for the main cable was not used, because the main line height was between 20–30 m. Two intermediate supports were used along the cable crane line. The height of intermediate supports was between 10–12 m. The timber extraction was carried out downhill.

When moving on the main line, the average speed of a loaded carriage (downhill) was 2.32 m/min and the average speed of unloaded carriage (uphill) was 2.74 m/min (higher by 15%).

The average total time consumption was 12.62 min/cycle. The average lost time was 1.26 min/cycle.

The average load volume was 1.3 m^3/cycle and it consisted of 3 pieces of 5 m long timber.

The average fuel consumption was 3.5 liters per operating hour of the Gantner cable crane or 0.56 L/m^3. Possible productivity of the Gantner cable crane is shown depending on the distance of timber transport and it was 6.7 m^3/h (200 m), 6.1 m^3/h (300 m) and 5.9 m^3/h (400 m), respectively, and 6.2 m^3/h on average. The costs of the Gantner cable crane was 4.10 \$/m^3.

In the areas where log transportation is performed by cable crane, after determining its route and setting the skyline line, processed logs are pre-skidded toward the skyline by human force. Thus, lateral out distance is shortened and the required time is also decreased to some extent. Consequently the hourly performance of the cable crane will be increased significantly.

The quality of forest roads which must be constructed depends on site conditions and harvesting density. Regarding to the harvesting density, it is essential to decide which cable crane is to be used.

On the other hand, regular maintenance based on technical features should also be taken into consideration. Consequently, fuel consumption and repair requirements are also decreased.

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Sažetak

Iznošenje smrekova obloga drva žičarom Gantner iz artvinskih prebornih šuma

U radu se prikazuju rezultati istraživanja proizvodnosti i statistička raščlamba utjecajnih čimbenika ukupnoga vremena turnusa pri radu užetno-žičnoga sustava za iznošenje obloga drva iz turskih državnih šuma. Istraživanje je provedeno u mješovitoj sastojini orijentalne smreke, orijentalne bukve i običnoga bora u sjeveroistočnom dijelu Turske, u regiji Artvin. Područje se odlikuje strmim razvedenim terenom i velikom biološkom raznolikošću. Izrađena se oblovina iznosila niz nagib terena, a kolica su po nosivom užetu bila pogonjena preko vučnoga užeta vitla na saonicama proizvođača „Gantner«. Nosivo je uže razapeto na visini od 20 do 30 m iznad razine tla, te su postavljena dva međuupora nosivoga užeta žične linije.

Proizvodnost ovoga sustava primarnoga transporta drva ispitana je metodama studija rada i vremena. Vrijeme radnoga turnusa podijeljeno je na sastavnice koje su mjerene povratnom metodom kronometrije. Svaki se turnus sastojao od vraćanja praznih kolica u sječinu, izvlačenja užeta za vezanje tovara, vezivanja tovara, postranoga privlačenja tovara do žične linije, iznošenja tovara do pomoćnoga stovarišta, odvezivanje tovara te nepotrebno izgubljenoga vremena. Osim tih radnih sastavnica, mjerene su još neke značajke radilišta: udaljenost iznošenja tovara po nosivom užetu, udaljenost postranoga privlačenja drva, obujam tovara te broj komada oblovine u tovaru.

Istraživanje je trajalo 12 radnih dana, tijekom kojih je snimljeno 90 turnusa. Ukupno je na pomoćno stovarište izneseno 700 m^3 obloga drva. Utvrđena proizvodnost ovoga sustava iznosila je 6,2 m^3 po pogonskom satu rada. Ovisno o udaljenosti iznošenja drva, učinak ovoga užetno-žičnoga sustava bio je za udaljenost iznošenja od 200 m jednak 6,7 m^3/h, za udaljenost iznošenja od 300 m 6,1 m^3/h, dok je najmanji bio za udaljenost iznošenja od 400 m i iznosio je 5,9 m^3/h. Trošak rada ustanovljen je u iznosu od 4,10 \$/m^3. Prosječni je turnus trajao 12,62 minuta. Kod udaljenosti iznošenja od 200 metara, uz postrano privlačenja drva do žične linije od 15 metara i obujma tovara 1,25 m^3, prosječno ukupno vrijeme radnoga ciklusa iznosilo je 12,20 minuta, dok je kod udaljenosti iznošenja od 400 metara, postranoga privlačenja od 22,5 metara i prosječnoga obujma tovara od 1,30 m^3 bio 13,83 minuta. Prosječna brzina kretanja opterećenih kolica niz nagib bila je 2,32 m/min, a neopterećenih (uz nagib) 2,74 m/min.

Radi utvrđivanja utjecaja na ukupno radno vrijeme radne su sastavnice kroz statističku raščlambu tretirane kao nezavisne varijable. Značajke radilišta (udaljenost iznošenja tovara po nosivom užetu, udaljenost postranoga privlačenja i obujam tovara) također su promatrane kao nezavisne varijable. Ukupno radno vrijeme u ovom slučaju bila je zavisna varijabla. Utvrđeno je da postoji pozitivna linearna korelacija između ukupno utrošenoga vremena turnusa i svih deset nezavisnih varijabli (7 radnih sastavnica i 3 značajke radlilišta). Navedeno potvrđuje da se povećanjem bilo koje nezavisne varijable povećava i utrošak ukupnoga vremena turnusa. F-testom ustanovljeno je da svaka radna sastavnica ima statistički značajan utjecaj na ukupno vrijeme turnusa.

Ključne riječi: žičara na saonicama Gantner, kolica, proizvodnost, Turska, Artvin

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