Productivity Linear Regression Models of Tree-Length Harvesting System in Natural Coastal Aleppo Pine (*Pinus halepensis* L.) Forests in the Chalkidiki Area of Greece

Christos Gallis, Gavriil Spyroglou

Abstract – Nacrtak

*Time studies of harvesting and skidding tree-length logs in Aleppo pine (*Pinus halepensis *L.) natural coastal forests of Chalkidiki area in northern Greece were carried out to formulate linear regression models and to evaluate productivity. The harvesting system consisted of a feller with chainsaw for felling, delimbing and crosscutting, and a four wheel drive farm tractor, with a 74 kW engine, equipped with a special winch attached to the tractor three point hitch for the extraction of tree length logs. Operational factors such as distance, slope, volume and the time required for harvesting and extracting tree length logs were measured and recorded. The results illustrate that the calibrated linear regression models show strong correlation between the time needed for harvesting operations and the extraction distance from the stump to the forest road.*

Keywords: tree length system; extraction; time studies; linear regression models; productivity; Aleppo pine; natural coastal forests

1. Introduction – *Uvod*

The forest biomass industry operates under severe economic pressure for lower production costs. One way to lower the pressure is the most effective cost control of raw material (Bushman and Olsen 1988, Gallis 1997, Gallis 2003). Timber cost has been a topic of continuous concern for forest managers and forest products industry. Technical and economic utilization of forest biomass depends on various factors related to terrain conditions, transportation networks and harvesting technologies, as well as systems, silviculture and forest operations management (Cavalli and Grigolato 2010, Picchio et al. 2011). Working time studies are very often used for the analysis of productivity of various forest biomass harvesting systems (Gallis 2004, Magagnotti et al. 2012, Picchio et al. 2009, Savelli et al. 2010, Spinelli and Nati 2009). Thus collected data may be used to formulate regression models for the correlation of several parameters of the harvesting system with time and productivity (Cubbage et al. 1988, Gallis 1997, Gallis 2004, Gingras 1988, Katenidis et. al. 1983). These models could be used for planning and economical analysis of forest operations (Howard 1988, Samset 1990, Gallis 2004).

The harvesting and removal of forest biomass from the natural forests of Greece requires a profitable and environmentally acceptable logging system. This system should be able to thin and remove individual trees from even aged stands with dense understory of evergreen broadleaved shrubs or uneven-aged stands, and to harvest mature trees. The most critical stage of the logging operation is forwarding logs from the forest site to the roadside landings. It may account up to 30% of the total harvesting cost and can cause some environmental damages (Fisher et al. 1980, Gallis 2003, Picchio et al. 2011, Spinelli et al. 2010).

Currently in Greece, the main system widely employed is felling, delimbing, topping and crosscutting trees with a chainsaw in the stump area and extracting medium and small-sized logs from the forest site to roadside landings by special vehicles, farm tractors and horses. The use of tree length system has been recently introduced in Greek forestry mainly in stands with terrain of low inclination. Modified farm tractors are currently used for wood extraction. In the tree length system, trees are usually extracted with a part of the load dragged along the ground with a cable winch attached to the rear system of the farm tractor (winching operation). Farm tractors may have some advantages such as increased flexibility for other types of work, and lower capital investment. The flexibility and relatively low capital input can reduce the need to maintain high productivity and annual utilization (Johansson 1997). Further research of skidding operations time studies for tree length system operations is required in Greece.

The aim of this study was to calibrate regression models through working time studies in order to define the effect of stand and operational factors such as distance, slope, and volume on time of harvesting and on extracting tree length logs from the forest site to the forest road. The study was carried out in the coastal Aleppo pine (*Pinus halepensis)* natural forests of Sithonia peninsula of Chalkidiki area in northern Greece.

2. Materials and methods – *Materijal i metode*

The working time studies were conducted in several different uneven-aged *Pinus halepsinis* stands and they examined the harvesting and extraction cycles. The harvesting system applied consisted of selecting individual trees, one by one, through high thinning positive selection. More specifically, in each stand, the plus or future trees are identified intuitively on a regular distribution pattern by the forester in charge and, according to the silvicultural descriptions of the management plan, one or two trees – competitors are marked for felling (Chatziphilippidis and Konstandinidis, 1995). The marked trees were felled, delimbed and topped by a chainsaw in the stump area. The extraction was carried out by a four wheel farm tractor, with a 74 kW engine, equipped with a special winch attached to the tractor three point hitch. The stands under study had no strip roads for extraction. Thus, the operation was performed with the farm tractor moving on the forest ground.

The system of harvesting-extraction with farm tractors consists of a driver and a feller. In several stands, time studies were performed in order to calculate the time required for the extraction of one tree length log from the stand to the roadside landing. The timing method used in this study was the *continuous method*. According to this method the watch is in continuous motion and the position of the time indicator is recorded at the beginning of each work phase or delay and at the end of the total work under study (Tsoumis and Efthymiou 1973, Barnes 1980, Niebel 1988, Tsoumis 1992, Gallis 1997, Gallis 2004).

The starting point for timing the extraction cycle was when the team departed from the roadside to the stand for loading. An operator performed the harvesting operations assisted by the driver. The time was recorded for each cycle element: travelling empty to the place of loading, felling, delimbing, waiting to be loaded, using the winch for loading, travelling with the load, arriving at the landing, waiting to be unloaded, unloading, and cross cutting. In addition to time measurements, other parameters were also recorded for each cycle such as the volume of tree length logs, the distance from the landing to the loading point, and the slope. For every full cycle of harvesting-extraction operation, the full cycle and the harvesting time productivity were calculated as cubic meters of tree volume harvested per hour. 30 complete cycles were recorded (Table 1) in total. For each numbered log, the volume was calculated using the formula of truncated cone.

Simple linear models (linear regression models) in the form Y (Time of logging operation) = f (*Slope*, *Distance*, *Log volume*) were selected. The development of model equations for each category of logging operation time was $Y = a + b \cdot \mathrm{Sl} + c \cdot \mathrm{Dist} + d \cdot \mathrm{LogVol}$, where Y is the Time needed for logging operations in minutes, Sl is the terrain slope in (%), Dist is the distance of the logging site to the forest roadside landings in meters and LogVol is the volume of the logs forwarded from the logging site to the forest roadside landings in cubic meters. The statistical analysis was performed by using the computer statistical program SPSS 12.0 (Norusis 2003).

3. Results and discussion – *Rezultati i rasprava*

The average slope of the study area was 4.6% denoting a rather flat terrain where a farm tractor can be easily used for harvesting operations without a risk of erosion on the skidding roads. The mean extraction distance was 84.17 m and the mean extracted log volume was 1.95 m^3 resulting in a mean harvesting time of 6 minutes and 9 seconds, which corresponds to 42.1% of the total time. The mean extraction time was 3 minutes and 29 seconds, meaning that almost 24% of the total time was spent for this operation. Travelling empty time was 1':17'' representing 8.7% of the total time of the harvesting operation. The total time for a complete cycle ranged from 10 minutes and 27 seconds to 28 minutes and 36 seconds with an average of 14 minutes and 36 se-

Table 1 Descriptive statistics of the slope, distance, log volume and times needed for logging operations
Tablica 1. *Deskriptivna statistika nagiba terena, udaljenosti, obujma sortimenta i utroška vremena pridobivanja drva*

Variable *Varijabla*	N *N*	Min. *Min.*	Max. *Maks.*	Mean *Arit. sred.*	Std. Dev. *St. dev.*
Slope – *Nagib*, %	30	2	8	4.60	1.45
Distance – *Udaljenost*, m	30	35	207	84,17	50.67
Log Volume – *Obujam sortimenta*, m^3	30	0.95	6.33	1.95	0.97
Preparation – *Priprema za rad*, min:sec	28	0:06	1:24	0:47	0:30
Felling – *Rušenje*, min:sec	30	0:42	2:36	1:10	0:54
Delimbing – *Kresanje grana*, min:sec	30	2:09	8:06	4:14	1:40
Skidding – *Privlačenje*, min:sec	30	1:42	6:03	3:29	1:21
Cross cutting – *Trupljenje*, min:sec	30	1:42	12:42	4:09	2:15
Travelling empty – *Neopterećena vožnja*, min:sec	30	0:36	2:30	1:17	0:51
Total time – *Ukupno vrijeme*, min:sec	30	10:27	28:36	14:36	3:54
Harvesting time – *Vrijeme sječe*, min:sec	30	3:42	11:48	6:09	2:19
Full cycle productivity – *Proizvodnost cijelokupnoga procesa*, m^3/h	30	4.9	9.9	7.5	1.3
Harvesting time productivity – *Proizvodnost sječe*, m^3/h	30	10.8	32.2	18.5	4.5

conds. Katenidis (1978) reports that the travelling empty time consumed one half (50%) of the harvesting time required when mules were used as animals for extraction and 25% of the total time used for skidding. The use of machines instead of animals, whenever feasible, reduces considerably the extraction as well as the travelling empty time. The harvesting time and the full cycle productivity ranged between 10.8 to 32.2 and 4.9 to 9.9 m^3 per hour with a mean value of 18.5 and 7.5 m^3 per hour, respectively. Descriptive statistics of the slope, distance, log volume and the necessary times used in logging operations are presented in Table 1.

After the application of linear regression procedure on the above mentioned models, the adjusted results are shown in Table 2. Model 1 is for the full cycle operation, Model 2 for travelling empty and Model 3 for travelling with the load (skidding). For travelling empty (2) and skidding (3) models, the only statistically significant independent variable was the distance, the other two variables, slope and log volume appeared non-significant because for slope, there is no much variability within the variable (2–8%) and for the log volume, the 74 kW farm tractor with its 4100 kg mass used for skidding was strong enough to carry out the logging without any delays due to log size and weight. If we suppose that the tractor was moving by a more or less constant velocity, when skidding or when travelling empty from the forest road to the logging site, then the distance was the only driving variable for the time needed for the operations.

Table 2 Linear regression model equations to predict logging time operations
Tablica 2. *Linearne regresijske jednadžbe modela za predviđanje utroška vremena pridobivanja drva*

Model *Model*	Equation *Jednadžba*
1	$T_{full} = 6.434 + 0.023 \cdot Distance + 3.082 \cdot Log\ volume$
2	$T_{empty} = 0.366 + 0.009 \cdot Distance$
3	$T_{forwarding} = 1.909 + 0.012 \cdot Distance$

For model (1), the independent variable *slope* was not statistically significant for the reason explained above, and hence it was removed from the model. The *log volume* variable plays an important role accounting for a large proportion of the observed variance (partial adj. R^2=0.64). This can be attributed to the fact that the full cycle time includes harvesting operations (felling and delimbing) that represent 42.1% of the full cycle operation, making this variable highly significant. Johansson (1997), in his study on small tree harvesting by use of farm tractors with the crane attached to the front part, when doing regression analysis of time consumption per work cycle, found that the tree volume was the only variable that accounted for a large proportion of the variation in time consumption and that there was no reason to use a more sophisticated model than that of the simple regression.

Table 3 shows that all regression models have large correlation coefficients as well as coefficients of determination. All the models performed very well, and the variance explained by the models varied from 74 percent for the full cycle model (1) to 24 percent for the forwarding (3). The Durbin-Watson statistic is between 0.81 and 2.04. For models (1) and (3), the Durbin-Watson statistic falls within the range 1.5 to 2.5 and the assumption of residuals independence is satisfied for these models. For model (2) the Durbin-Watson statistic was 0.81 indicating a positive autocorrelation.

Autocorrelation is the phenomenon that distinguishes time series from other branches of statistical analysis. For example, if we consider the tractor operator during the travelling empty time. A usual time cycle varies around one minute and seventeen seconds. The variation may be caused by machine failure; the dense understorey of evergreen broadleaves characteristic for Allepo pine stands sometimes prevents the operator from keeping a constant tractor speed, resulting in a run of increased travelling empty time cycle. This is an example of positive autocorrelation, determined by the Durbin-Watson statistic for model 2 (0.81), with data falling and staying below one minute and seventeen seconds for a few cycles especially when the understorey vegetation is very dense obliging the tractor operator to reduce a bit the moving speed, then rising above one minute and seventeen seconds and staying high for a while, then falling again, and so on.

Table 4 shows the model coefficients and their significance denoting strong models. The slope variable, represented by the (b) parameter in all models appeared non significant by the regression analysis and is not included in the table. The same holds for the log volume variable, represented by the (b) parameter for models 2 and 3. Multicollinearity is not a problem for the models because the tolerance statistic was very close to 1, much greater than 0.1, which is considered the threshold for multicollinearity problems. The variance inflation factor (VIF) was also around 1 and certainly less than the threshold value of 5 (Van Laar 1991).

In order to visualize the relationships among the dependent and independent variables of the calibrated models, three and two dimensional scatter plots were drawn. Fig. 1 shows the strong positive linear relationship that exists among the dependent variable *time* of various logging operations and the independent variables, distance and log volume.

The three models were also checked for heteroscedasticity, the third assumption of the linear regression – assumption of constant error variance. The residual analysis of the models 1 & 3 in Fig. 2 shows that there were no obvious patterns or clustering in the residuals, the residuals were homoscedastic, and the variance remained the same for every combination of values of the independent va-

Table 3 Statistical summary of the studied models
Tablica 3. *Statistički sažetak ispitivanih modela*

Model *Model*	R	R^2	Adjusted R^2 *Prilagođeni* R^2	SE of estimate *Stand. pogreška procjene*	Durbin-Watson
1	0.87	0.76	0.74	1.81	1.65
2	0.94	0.89	0.88	0.17	0.81
3	0.49	0.24	0.21	1.07	2.04

Table 4 Model coefficient estimates and collinearity diagnosis
Tablica 4. *Procjena koeficijenata i dijagnoza kolinearnosti za modele*

Model *Model*	Parameters *Parametri*	Coefficients *Koeficijenti*	SE *Stand. pogreška*	T *T*	Sig. *Razina znač.*	Tolerance *Tolerancija*	VIF *FPV*
1	*a*	6.434	0.983	6.543	0.000		
	c	0.023	0.007	3.414	0.002	0.988	1.012
	d	3.082	0,348	0.885	0.000	0.988	1.012
2	*a*	0.366	0.061	5.974	0.000		
	c	0.009	0.001	15.145	0.000	1.00	1.00
3	*a*	1.909	0.385	4.955	0.000		
	c	0.012	0.004	2.956	0.006	1.00	1.00

Sig. – 0.000 means that the coefficient of the model is highly significant; *Razina znač. – 0,000 razumijeva da su koeficijenti modela visoko značajni*

VIF – Variance Inflation Factor; *FPV – Faktor povećanja varijance*

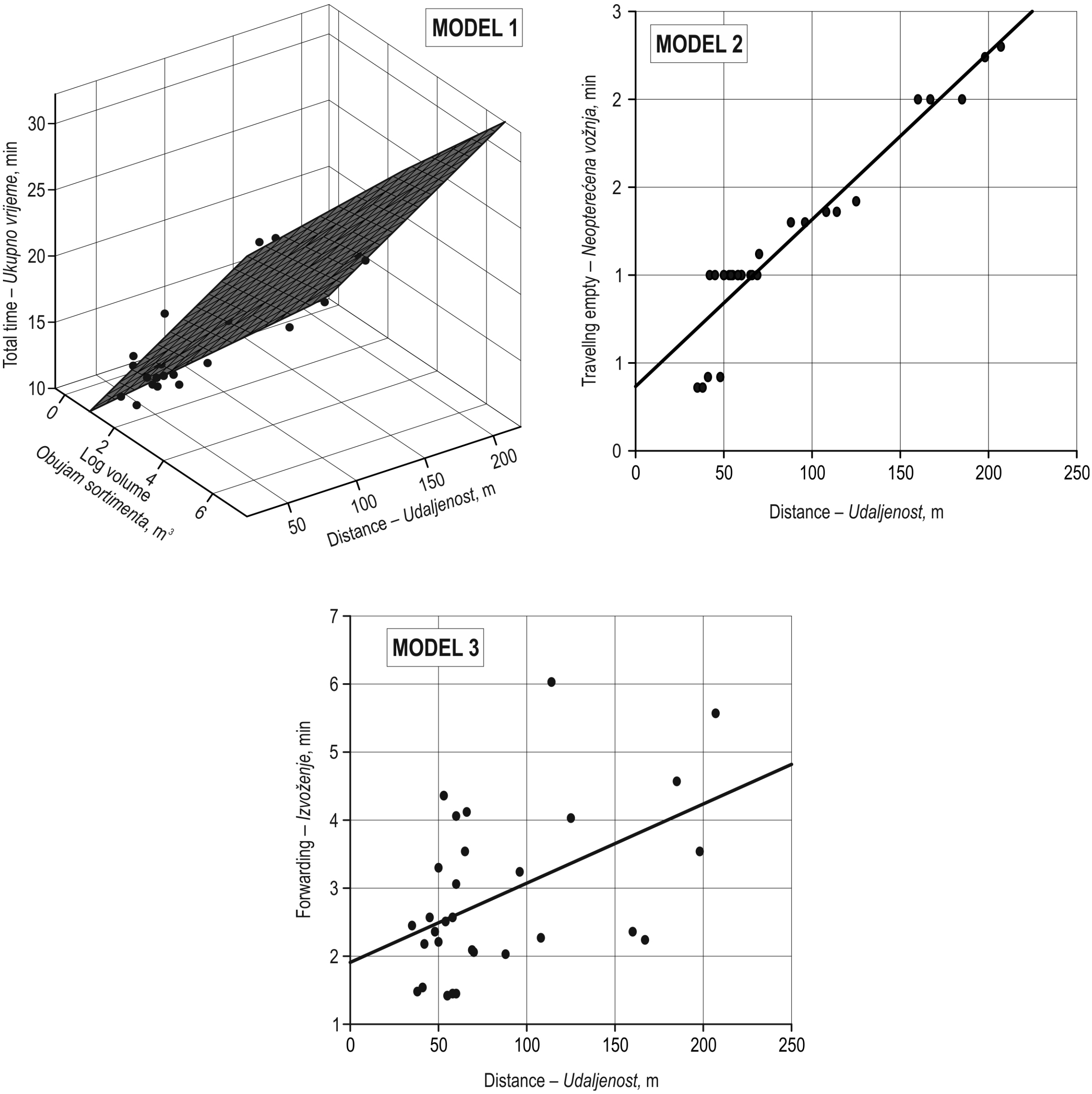

Fig. 1 Scatter plots between dependent and independent variables of the three models
Slika 1. *Točkasti grafikoni zavisnih i nezavisnih varijabli za tri modela*

riables. Model 2 shows a slight clustering and as it can be seen in Table 5, the Kolmogorov-Smirnov and Shapiro-Wilk tests for the normality of the residuals appear statistically significant, meaning that either the relationship in model 2 is not linear or that there is another variable causing more variability, which was not considered or measured during data collection. The autocorrelation exhibited by the same model might be another source of the clustering in the residuals.

The assumption of normality was another issue that had to be tested in order to secure that the calibrated models are statistically sound. The statistical criteria of Kolmogorov-Smirnov and Shapiro-Wilk shown in Table 5 appear statistically non-significant at α = 0.05 level except Model 2, for which

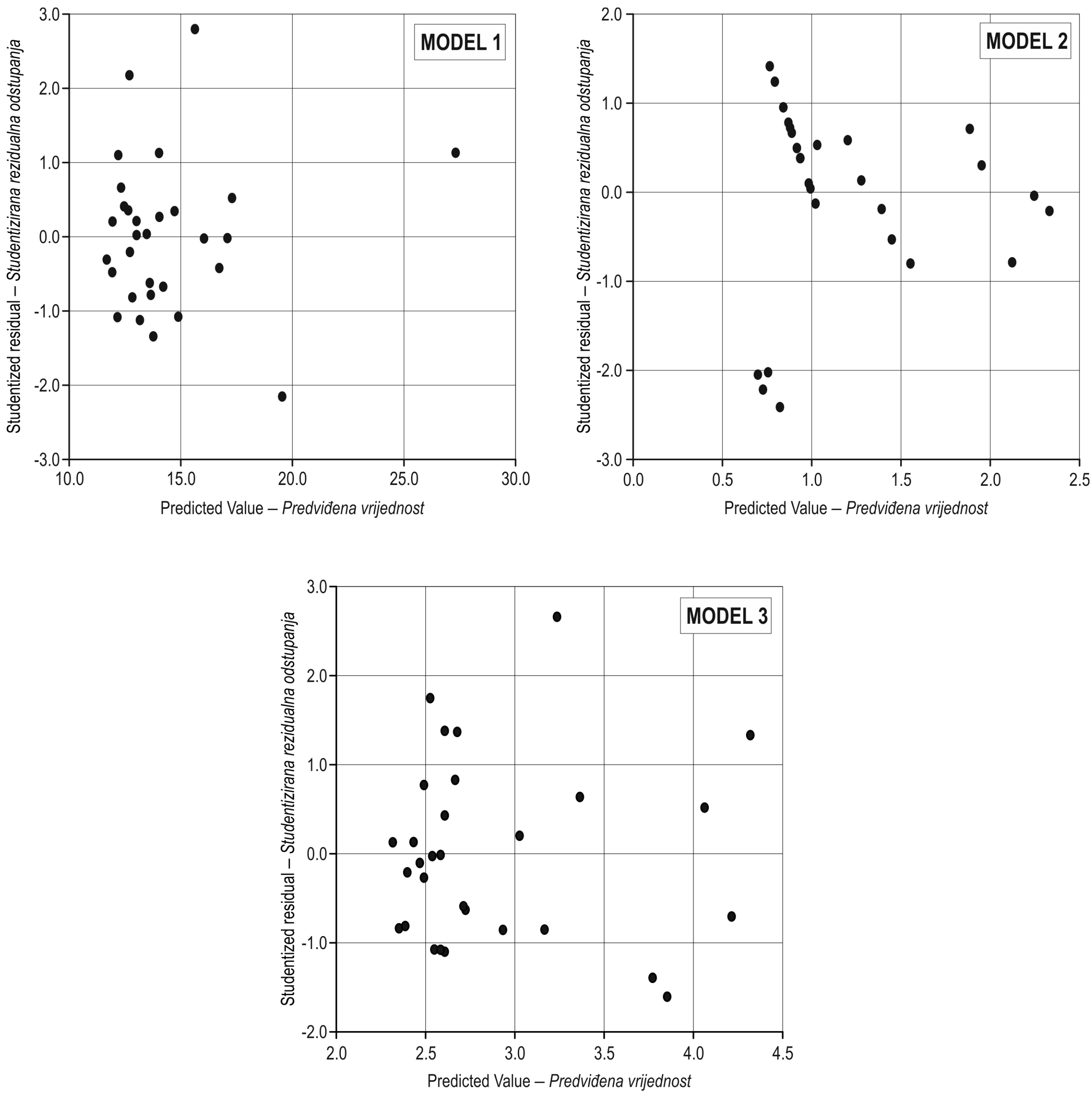

Fig. 2 Residual analysis of the three models
Slika 2. *Analiza rezidualnih odstupanja za tri modela*

the criteria appeared significant. This deviation from normality was not a big problem and hence did not interfere with the regression analysis.

4. Conclusions – *Zaključci*

From the present study, the following conclusions can be drawn:

1. The modified farm tractors can be operated in tree length harvesting with flexibility and good productivity in natural stands with low inclination and without strip roads.
2. The calibrated regression models show strong correlation between the time needed for harvesting operations and the extraction distance from the stump to the forest road.

Table 5 Tests of normality of the residuals for the studied models
Tablica 5. *Testovi normalnosti rezidualnih odstupanja ispitivanih modela*

Model *Model*	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic *Statistika*	df *St. sl.*	Sig. *Razina znač.*	Statistic *Statistika*	df *St. sl.*	Sig. *Razina znač.*
1	0.114	30	0.200 [ns]	0.964	30	0.384 [ns]
2	0.186	30	0.010*	0.866	30	0.001**
3	0.118	30	0.200 [ns]	0.958	30	0.267 [ns]

[ns] – The respective statistic is non-significant; [ns] – *nema značajne razlike*

* – Significant at alpha level (or *P-value*) = 0.05; * – *značajna je razlika za vrijednost p = 0,05*

** – Significant at alpha level (or *P-value*) = 0.001; ** – *značajna je razlika za vrijednost p = 0,001*

Further studies are needed to define the impact of site and stand conditions such as steeper slopes, mixed forests, mountain forests, stands with strip roads, as well as other related operations such as delimbing and crosscutting, for more consistent and sound time study models for tree length harvesting system covering all types of forests in Greece.

Acknowledgements – *Zahvale*

This study was financially supported through the grant for »New Researchers« of the National Agricultural Research Foundation (NAFREF) of Greece (2002).

5. References – *Literatura*

Barnes, R. M., 1980: Motion and time study: design and measurement of work. 7th ed., John Wiley and Sons, New York, 689 p.

Bushman, S., Olsen, E. D., 1988: Determining Costs of Logging-Crew Labor and Equipment. Oregon State University, College of Forestry, Forest Research Lab, research Bulletin 63, 23 p.

Cavalli, R., Grigolato, S., 2010: Influence of characteristics and extension of a forest road network on the supply cost of forest woodchips. Journal of forest research 15(3):202–209.

Chatziphilippidis, G., Konstandinidis, P., 1995: Αραιώσεις και κλαδεύσεις δασικών συστάδων (Thinning and pruning of forest stands). Πρακτικά 6ου Πανελλήνιου Δασολογικού συνεδρίου με θέμα “Δασική Ανάπτυξη, Ιδιοκτησιακό – χωροταξικό” Χανιά, 6-8 Απριλίου 1994. In: Hellenic Forestry Society (ed.) Proceedings of the 6th Pan-Hellenic silvicultural congress »Forest development, land ownership – land use planning«, Chania, Greece, 6-8 April 1994, pp. 327–336.

Cubbage, F. W., Wojtkowski, P. A., Bullard, S. H., 1988: Cross-sectional estimation of empirical southern United States pulpwood harvesting cost functions. Canadian Journal Forest Research, 19(6): 759–767.

Gallis, C., 1997: Stochastic Computer Simulation of Forest Biomass Logistics in Greece. Doctoral dissertation, Dept. of Forest Resource Management, University of Helsinki, Finland, 139 p.

Gallis, C., 2003: Probabilistic assessment of forest biomass storage time and its effect on cost: a beech wood case study. Forest products journal 53(10): 44–47.

Gallis, C., 2004: Comparative cost estimation for forwarding small-sized beech wood with horses and mini--skidder in northern Greece. Forest products journal 54(11): 84–90.

Gingras, J. F., 1988: The effect of site and stand factors on feller-buncher performance. Forest Engineering Research Institute of Canada, Technical Report No. TR-84, 18 p.

Greek Forest Service, 1994: Τιμές υλοτομιών και άλλ ων εργασιών συγκομιδής (Prices for felling and other harvesting operations). Υπουργείο Γεωργίας, Γενική Διεύθυνση Δασών και Φυσικού Περιβάλλοντος. Ministry of Agriculture, General Directorate of Forests and Natural Environment, Dept. of Forest and Natural Environment, Athens, 18 p.

Fisher, E. L., Gibson, H. G., Biller, C. J., 1980: Production and Cost of a Live Skyline Cable Yarder Tested in Appalachia. U.S. Dept. of Agriculture, Forest Service, Northeastern Forest Experimental Station, Forest Service Paper NE-465, 7 p.

Howard, A. E., 1988: Harvesting profitability as affected by classification of costs and assignment of the components scheduled time. Canadian journal forest research 18(11): 1369–1375.

Johansson, J., 1997: Small trees harvesting with farm tractor and crane attached to the front. International journal of forest engineering 8(1): 21–33.

Katenidis, K. B., 1978: Μετατόπιση ξύλου κωνοφόρων με μουλάρια στα Ελληνικά Δάση. (Soft wood skidding by mules in Greek forests). Υμουργείο Γεωργίας, Ινστιτούτο

Δασικών Ερευνών Αθηνών. Ministry of Agriculture, Athens Forest Research Institute, Research Bulletin No. 98, 38 p.

Katenidis, K. B., Efthymiou, P.Í., 1983: Μελέτη των υλοτομ ικών εργασιών στα Ελληνικά δάση οξυάς Δασική Έρευνα **3**: 165–217. (Research on Wood Felling and Conversion Operations in the Beech Forests of Greece). Forest Research 3: 165–217.

Magnagnotti, N., Pari, L., Spinelli, R., 2012: Re-engineering firewood extraction in traditional Mediterranean coppice stands. Ecological engineering 38(1): 45–50.

Niebel, B.W., 1988: Motion and time study. 8th ed., Irwin, Homewood, Illinois, 799 p.

Norusis, M., 2003: SPSS 12.0 Statistical Procedures Companion. Prentice Hall.

Picchio, R., Maesano, M., Savelli, S., Marchi, M., 2009: Productivity and Energy balance in conversion of a *Quercus cerris* L. Coppice stand into High forest in Central Italy. Croatian journal of forest engineering 30 (1): 15–26.

Picchio, R., Spina, R., Maesano, M., Carbone, F., Lo Monaco, A., Marchi, E., 2011: Stumpage value in the short wood system for the conversion into high forest of a oak coppice. Forestry studies in China 13(4): 252–262.

Picchio, R., Neri, F., Maesano, M., Savelli, S., Sirna, A., Blasi, S., Baldini, S., Marchi, E., 2011: Growth effects of thinning damage in a Corsican pine (*Pinus laricio* Poire) stand in central Italy. Forest ecology and management 262(2): 237–243.

Samset, I., 1990: Some observations on time and performance studies in forestry. Communications of the Norwegian Forest Research Institute No 43. 5, As, 80 p.

Savelli, S., Cavalli, R., Baldini, S., Picchio, R., 2010: Small scale mechanization of thinning in artificial coniferous plantation. Croatian journal of forest engineering 31(1): 11–21.

Spinelli, R., Nati, C., 2009: A low investment fully mechanized operations for pure selection thinning of pine plantations. Croatian journal of forest engineering 30(2): 89–97.

Spinelli, R., Magagnotti, N., Nati, C., 2010: Benchmarking the impact of traditional small-scale logging systems used in Mediterranean forestry. Forest ecology and management 260(11): 1997–2001.

Tsoumis, G., Efthymiou, P., 1973: Έρευνα συγκομιδής ξύλός στο Πανεπιστημιακό δάσος Ταξιάρχη Χαλκιδικής. Επιστημονική Επετηρίδα του Αριστοτέλειου Πανεπιστημίου Θεσσαλονίκης Τόμος ΙΣΤ: 273–296. (A study on harvesting oak wood in the University forest at Taxiarchis, Chalkidiki-Greece). Scientific Annals, School of Agriculture and Forestry, Aristotle University of Thessaloniki, Greece, 16: 273–296.

Tsoumis, G., 1992: Harvesting Forest Products. Stobart Davies Ltd., Hertford, England, 57 p.

Van Laar, A., 1991: Forest Biometry. University of Stellenbosch, 590 p.

Sažetak

Linearni regresijski modeli proizvodnosti pridobivanja drva deblovnom metodom iz prirodnih obalnih šuma alepskoga bora u predjelu Chalkidiki u Grčkoj

*Studij vremena pri sječi i privlačenju obloga drva uz primjenu deblovne metode u prirodnim obalnim šumama alepskoga bora (*Pinus halepensis *L.) u predjelu Chalkidiki u sjevernoj Grčkoj proveden je radi dobivanja linearnih regresijskih modela i procjene proizvodnosti.*

Sustav pridobivanja drva činili su sjekač s motornom pilom za rušenje, kresanje grana i prevršivanje, dok je za privlačenje obloga drva korišten prilagođeni poljoprivredni traktor koji je imao pogon na sva četiri kotača, snagu motora 74 kW i posebno vitlo pričvršćeno u trima točkama na stražnjem dijelu vozila. Operativni čimbenici, na primjer: udaljenost, nagib terena, obujam oblovine, utrošak vremena sječe, izradbe i privlačenja, izmjereni su i zabilježeni.

Cilj je ovoga istraživanja bio poboljšavanje regresijskih modela pomoću studija rada i vremena s namjerom definiranja utjecaja sastojinskih i operativnih čimbenika kao što su: udaljenost privlačenja, nagib terena i obujam drva na utrošak vremena sječe, izradbe i primarnoga transporta iz sječine do pomoćnoga stovarišta (šumske ceste). U istraživanom sustavu pridobivanja drva usporedno su radili vozač traktora i sjekač. U nekoliko sječina proveden je studij vremena radi izračuna vremena potrebnoga za privlačenje pojedinoga debla iz sječine do šumske prometnice.

Pri snimanju radnoga procesa primijenjena je protočna metoda kronometrije. Polazišna točka studija vremena radnoga turnusa privlačenja drva bio je trenutak kada je vozilo krenulo s pomoćnoga stovarišta u sastojinu radi utovara drva. Jedan je radnik sjekao stabla uz povremenu pomoć vozača traktora. Vrijeme je bilo zabilježeno za *svaku sastavnicu radnoga turnusa: vožnja neopterećenoga vozila do mjesta utovara, sječa stabala, kresanje grana, čekanje na utovar, skupljanje obloga drva vitlom (privitlavanje), vožnja opterećenoga vozila, dolazak na pomoćno stovarište, čekanje na odvezivanje tovara, odvezivanje tovara (istovar) i prikrajanje radi izrade drvnih sortimenata.*

Rezultati istraživanja pokazuju da su poboljšani modeli linearne regresije čvrsto povezani s vremenom potrebnim za sječu i s udaljenošću vožnje iz sječine do šumske ceste. Ovo je istraživanje pokazalo da se prilagođeni poljoprivredni traktori mogu koristiti u deblovnoj metodi izradbe drva za primarni transport uz određene prilagodbe i postizati zadovoljavajuća proizvodnost u prirodnim sastojinama gdje su manji nagibi terena i koje nisu sekundarno otvorene (nema šumskih vlaka i traktorskih putova). Također, poboljšani regresijski modeli pokazuju jaku ovisnost utroška vremena radova pridobivanja drva o udaljenosti privlačenja iz sječine do šumske ceste.

Ključne riječi: deblovna metoda, privlačenje, studij vremena, linearni regresijski modeli, proizvodnost, alepski bor, prirodne obalne šume

Authors' address – Adresa autora:

Christos Gallis, PhD
e-mail: cgalis@fri.gr
Gavriil Spyroglou, PhD
e-mail: spyroglou@fri.gr
Forest Research Institute
570 06 Vassilika, Thessaloniki,
GREECE

Received (*Primljeno*): November 25, 2011
Accepted (*Prihvaćeno*): February 8, 2012