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Small Scale Mechanization of Thinning in Artificial Coniferous Plantation

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Abstract – Nacrtak

In Italy, where conventional forests have a protective rather than productive purpose, some silvicultural operations as first and second thinning could be carried out in an economic way adopting systems based on small scale mechanization. Authors tested a system based on small scale mechanization for bunching and skidding operations, using an All Terrain Vehicle (ATV), a compact, agile and versatile vehicle that adapts well to dense and rather inaccessible forests, such as forests of artificial origin where no kind of intervention, particularly thinning, had ever been carried out. The vehicle was used for bunching, using an electric winch, and for skidding whole trees. The use of the ATV showed that it is a competitive vehicle with both traditional and cutting edge vehicles, performing a traction power average of 313 daN and PHS_0 *productivity variable from 1.20 to 3.05* $t_{d.m.}h^{-1}$*. Such figures confirm how in first thinning, on level ground but also on slopes (max 50%), over distances not exceeding 200 m, the ATV is a perfectly suitable vehicle. Furthermore, the impact of the vehicle on the ground and especially on the shallow soil horizons was negligible and had no effect on tree roots.*

Key words: Small scale forestry, All Terrain Vehicle, Thinning, Bunching, Skidding, Winch, Forest utilization

1. Introduction – *Uvod*

First thinning yields low quantities of timber that are often of limited commercial value, making it difficult to get economic revenue (Malinen et al. 2001, Yeo B. J. and Stewart M. 2001, Heikkila et al. 2007). This explains the worrying tendency to avoid thinning, especially in artificial coniferous forests, and the consequent rise of degradation and instability problems in many forests (Bergström et al. 2007).

Resorting to advanced mechanization would involve substantial investment and above all accurate planning of intervention, not justified by the resulting low productivity in first thinning (Mederski 2006). Conventional forest mechanization is more suitable for third thinning and final cutting and in general it proves to be too demanding or too cumbersome to be applied efficiently in first and second thinning, often causing considerable damage to the trees and to the ground (Heikkila et al. 2007).

According to the latest researches on forest utilization in Italy, especially in coniferous forests, there is a tendency to avoid thinning, mainly for economic reasons. In fact thinning interventions show high operational costs, in particular when bunching and skidding are concerned, and this is not balanced by the revenue obtained from selling the wood material. The amount of harvested trees in thinning is about 20–40% of the total number of individuals in the forest, which corresponds to 10–25% of the total wood mass. Therefore felling, bunching and skidding operations, in particular during first thinning in high density vegetation, with a shortage of permanent skid roads and where it is quite difficult and/or economically onerous to open temporary skid roads, often present various problems that could be solved in a difficult and expensive way.

Under such forestry circumstances, a test was carried out, featuring an All Terrain Vehicle (ATV), easy to maneuver and highly versatile, that adapts well to the dense and inaccessible woods like most artificial coniferous forests. The vehicle was used for bunching, using an electric winch, and for skidding.

Full Tree System (FTS) was adopted as working method since it guarantees levels of productivity that justify the economics of the intervention, even if it causes a greater loss of organic substance from the forest (Heikkila et al. 2007).

The main objectives of the test were:

- setting-up of suitable operating methods, with a low environmental impact, for a proper use of the ATV,
- measuring ATV productivity under different operative conditions,
- testing possible mechanical and technological improvements in vehicle and working methods.

2. Materials and methods – *Materijal i metode*

The ATV is a multipurpose, versatile vehicle that can be used for moving on trails that are mostly inaccessible to agricultural and forest tractors in various silvicultural operations, from plantation to complementary operations for the final cutting.

The model supplied was suitably adapted to use in operations of bunching and skidding (Fig. 1). The adaptations carried out in collaboration with KL Italia concerned:

- installation of a Warn electric winch with a pulling force of 12 kN and rope winding speed varying from 2.1 to 7.6 m/min. In ATV for general purpose the winch is mounted on a special plate positioned in front of the vehicle; for the test the winch was applied at the rear of the ATV with the roller fairlead positioned 0.5 m from the ground (as low as possible, to avoid or to limit the vehicle overturning during the winching operation). The winch was equipped with a steel rope with a fiber core, 5 mm diameter, 30 m long and with a minimum breaking strength of 24 kN. The ATV's electrical system was made powerful by supplying it with a double battery to guarantee energy supply in case of prolonged use of the winch. Winch controls were positioned both on the handlebar and on the rear of the machine, provided with safety switch,
- mounting a ROPS on the ATV's frame,
- mounting two tool boxes in the front and in the rear of the machine, provided with elastic bands for the secure fastening of the tools,
- equipping the wheels rim with tire valves protections,
- assembling a special ballast-holder with the capacity for two ballast, each one with a mass of 20 kg. The rear ballast was due to the extra weight of the rear winch, the double battery and the ROPS.

Fig. 1 ATV adapted for forest use

Slika 1. *Adaptirani ATV za rad u šumi*

The adapted vehicle overall dimensions were 1.2 m width, 1.9 m length and 1.5 m height, with a total mass (including the ballast) close to 340 kg. The total mass in working conditions, including the driver, a chainsaw, four skidding chains, a hookaroon, a felling lever, a tank for refueling the chainsaw and a toolbox, was up to 445 kg.

The instruments used to acquire the data were: an analogical chronometric table »Minerva« provided with three centesimal chronometers; a tree caliper; an automatic logger's tape; a clinometer; a laser gauge; a HBM Wägezelle load cell mod. Z7-2 connected to a »CR10C Campbell« data-logger.

A preliminary test was carried out in order to measure the traction features of the ATV.

The procedure adopted during the test included:

- determining the main characteristics of the terrain on which the test was carried out (granulometry, soil type and moisture content) (Table 1), on samples taken with the aid of a corer,
- carrying out traction tests (OECD, 2007) with two different gears, using »fast« first gear (F) and »slow« first gear (S) (3 replications), with maximum wheel slip of 30%,

Table 1 Characteristics of the soil in Blera area, where the traction tests were carried out

Tablica 1. *Svojstva tla u području Blera u kojem su testirane trakcije tla*

Soil type *Tipovi tala*	Granulometry *Granulometrijski sastav*			Moisture, % *Vlaga, %*
Clayey *Glinovito tlo*	Sand, % *Pijesak, %*	Silt, % *Prah, %*	Clay, % *Glina, %*	
	5	39	56	23

Table 2 Work components of the skidding cycle of the ATV in the two experimental areas

Tablica 2. *Sastavnice radnoga procesa privlačenja ATV-om u istraživanim područjima*

Site *Područje*	Method *Metode*	Work component – *Sastavnice radnoga procesa*			
Casalotti	Uphill *Uzbrdo*	Approaching and manoeuvring *Zauzimanje položaja*	Tree hooking *Vezanje drva*	Skidding *Privlačenje*	Tree releasing *Otpuštanje drva*
Casalotti	Downhill *Nizbrdo*	Approaching and manoeuvring *Zauzimanje položaja*	Tree hooking *Vezanje drva*	Skidding *Privlačenje*	Tree releasing *Otpuštanje drva*
Blera	With winch *S vitlom*	Approaching and manoeuvring *Zauzimanje položaja*	Tree hooking *Vezanje drva*	Winching and skidding *Privitlavanje i privlačenje*	Tree releasing *Otpuštanje drva*
Blera	Without winch *Bez vitla*	Approaching and manoeuvring *Zauzimanje položaja*	Tree hooking *Vezanje drva*	Skidding *Privlačenje*	Tree releasing *Otpuštanje drva*

carrying out traction tests using the »slow« first gear and equipping the vehicle with different ballast: without ballast (W), with front ballast (40 kg) (F), and with front and back ballast (40+53 kg) (FB) (3 replications).

The data related to the pulling force, measured using the load cell and the data-logger, were statistically processed using Kruskal-Wallis non parametric test in so far as data were not distributed normally and with insufficient homogeneity variance.

As observation unit skidding cycle (from the vehicle's approach to the felling trees and necessary maneuvers to the trees release at the landing) was considered, the working time of each individual work component was recorded using the analogical chronometric table (Kanawaty 1992; Harstela 1991; Berti et al. 1989) (Table 2).

The distances covered by the vehicle to approach the trees and skidding distances were measured by the laser gauge; gradient of the terrain was measured by means of the clinometer.

Wood moisture (w, %) was determined using the thermo-gravimetric method applied on trunk samples. The wood density (ρ) was calculated as following:

$$\rho_{w\%} = \frac{m_{w\%}}{v_{w\%}}$$

$\rho_{w\%}$ wood density at a moisture content equal to w, g cm^{-3}

$m_{w\%}$ wood mass at a moisture content equal to w, g

$v_{w\%}$ wood volume at a moisture content equal to w, cm^3

Volume of the trunk was calculated from the measurement of the trunk length, using the automatic logger's tape, and a single diameter measurement on the outside of the bark from the middle of the trunk, using the tree caliper, and applying the Huber's formula:

$$V = L \times (DOB)^2 \times 0{,}000000786025$$

V volume of the trunk, m^3

L length of the trunk, cm

DOB diameter over bark, cm

Mass of the trunk was calculated as following:

$$M_{w\%} = V \times \rho_{w\%}$$

$M_{w\%}$ mass of the trunk at a moisture content equal to w, t

V volume of the trunk, m^3

$\rho_{w\%}$ wood density at a moisture content equal to w, t m^{-3}

Fresh branches and tops were taken from 30 trees randomly chosen at the landing; and their mass was determined by weighting them; their volume was measured by water displacement in a xylometer. The total mass and volume of the trees were calculated adding the mass and volume of the branches and top to those of the trunk.

Mean gross productivity was calculated based on PHS_{15} (Productive Hour System$_{15}$) while the mean net productivity was calculated based on PHS_0 (Productive Hour System$_0$).

2.1 Characteristics of site and methodology *Karakteristike područja istraživanja i metode pridobivanja drva*

Casalotti experimental area – *Područje istraživanja Casalotti*

The area is situated within the municipality of Rome; it is covered by a plantation of *Pinus eldarica* Medw. and the soil is tuffaceous sand (sand 60%; silt 20%; clay 20%). The test plot subjected to thinning extended over 3 ha situated at 40 m a.s.l. and the terrain was characterized by a light roughness and an

Fig.2 ATV in uphill skidding

Slika 2. *ATV tijekom privlačenja drva uzbrdo*

average gradient of 29% (with maximum value of 47% and a minimum of 19%).

The test plot had an uphill and a downhill landing site with a main road uphill and a secondary road downhill. About half way through its range a firebreak road crosses the area, parallel to the gradient, offering a strip of land 12 m wide and about 120 m long, without trees, used as a further skid road.

Plantation was carried out along the contour according to a planting space of 3x3 m (Fusaro 2003). No silvicultural treatment was performed before the thinning intervention. The area presented its original density, with bifurcate trees and small clearings due to natural windthrows, which allowed light to penetrate within the branches of standing trees and ensure natural renewal of spontaneous species characteristic of the Mediterranean belt.

The thinning aimed at eliminating dried trees, bifurcated trees, badly formed trees and others by now irrecoverable of the undergrowth. A total of 65 trees were marked and felled using a Stihl MS 260 chainsaw (Table 3). The ATV reared near the butt of the felled trees to hook them with the chain and skid them to the landing where the load was released. Two skidding directions were adopted according to the tree dimension: large trees were skidded downhill while the smaller ones were skidded uphill (Fig. 2).

Blera experimental area – *Područje istraživanja Blera*

The experimental area is situated in Pian del Pero, within the municipality of Blera; it is covered by plantation of *Pinus laricio* Poir. over 8 ha, divided into several plots by bare zones or areas covered by thinly scattered vegetation of broadleaf in tree and shrub form, intensely pastured. The soil is clayey (sand 5%; silt 39%; clay 56%). The test plot is located about 200 m a.s.l. and the terrain is characterized by a gradient ranging from 0 to 20%, with stony ground packed by excessive bovine pasture. It is supplied with a secondary trail and a service clearing useful for pasture, used as a landing during the test.

The plantation is 35 years old, developed on degraded pastures; the vegetative condition of the plantation was deteriorated by parasitic attacks extending over the entire surface, which have caused blight and death of numerous trees that remained withered and standing or prostrate on the ground.

The thinning aimed at removal of dried and unwell trees susceptible to becoming hotbeds for the spread of parasites of weakness and easy triggers for fires. Felling and skidding procedures were the same as in the previous experimental area. A total of 185 trees were marked and felled (Table 3).

Using the data obtained from both experimental areas (for Blera area only data from skidding without winch were considered) a regression analysis was applied in order to calculate the equations, which can describe the relations between skidding time and skidding distance and between skidding time and skidding mass.

3. Results and discussion – *Rezultati i rasprava*

3.1 ATV pulling force – *Vučna sila ATV-a*

It can be concluded from the statistical analysis that there were significant differences in the values found using the two gear ratios, obtaining the best performance with the »slow« first gear, which revealed an average pulling force of 295.2 daN (Table 4).

Table 3 Mean dendrometric characteristics of trees subjected to thinning

Tablica 3. *Srednje dimenzije stabala u proredama*

Parameter *Parametri*	Casalotti		Blera	
	n.	Av. ± SD.	n.	Av. ± SD.
Dbh, cm *Prsni promjer*, cm	65	18.4 ± 4.6	185	19.1 ± 5.4
Height, m *Visina*, m	65	10.1 ± 1.6	185	8.5 ± 2.8
Volume, m^3 *Volumen*, m^3	65	0.090 ± 0.006	185	0.159 ± 0.011
Mass, $t_{w98\%}$ *Masa*, $t_{w98\%}$	65	0.10 ± 0.005	185	0.14 ± 0.01
Mass, $t_{d.m.}$ *Masa*, $t_{d.m.}$	65	0.0 5 ± 0.003	185	0.12 ± 0.01

Table 4 Statistical data of pulling force, differences between »fast« (F) and »slow« (S) first gear

Tablica 4. *Statistički podaci o sili privlačenja, razlike između »brzohodne« (F) i »sporohodne« (S) prve brzine*

Parameter – *Parametri*	F *Prva sporohodna brzina*	S *Prva brzohodna brzina*
n	120	120
Mean ± SD., daN *Aritmetička sredina ± Sd.*, daN	228.6 ± 63.6 ^{A}	295.2 ± 68.0 ^{B}
St. Err., daN *Standardna pogreška*, daN	5.8	6.2
Kruskal-Wallis *p*-value *Kruskal-Wallis test, p-vrijednost*	0.9861	0.3179

A, B: P<0.05

Considered the statistical analysis of the data obtained from the pulling test with different ballast applications (Table 5) significant difference was obtained only considering the C ballast assembly while no significant difference was recorded between A and B ballast assembly (Table 5).

The ATV was used in subsequent tests using the »slow« first gear and the C ballast assembly.

3.2 Casalotti experimental area – *Područje istraživanja Casalotti*

The high slope of the ground (in some areas over 40%) and the pulling force performed by the vehicle sometimes required crosscutting of trees with large dimensions, to make skidding easier. Crosscutting was performed by the operator, equipped with chainsaw, both after felling and during skidding, when after the first pulling attempt he realized that the vehicle was unable to pull the load. Crosscutting was necessary in both skidding directions. Despite substantial differences between the average uphill distances compared to downhill distances, average times for performing the operations were similar (Table 6). In fact the ATV speed when moving downhill was reduced by increasing the load applied.

The larger load skidded in downhill direction affected the productivity, which resulted greater than the one measured in uphill direction (Table 7).

Among the delay times in the work cycle, in both skidding directions there were two salient entries which together stand for over 20% of the total working time (923 min):

- obstruction at the landing, independent of the vehicle capacity and operator's ability, but due to inadequate organization of the site (over 15%);
- jamming of the load during pulling, mainly due to extremely close planting spaces (about 5%).

3.3 Blera experimental area – *Područje istraživanja Blera*

One of the tests in the Blera area was carried out using the winch for bunching the trees before skidding. The experiment gave good results from the point of view of winch functioning, its correct positioning on the vehicle rear end, operator's skills in using winch controls. Anyway in the specific context, bunching with the winch could be considered superfluous. In fact due to light load almost exclusively made up of a reduced number of trees that can be pulled by the winch and to the ATV's agility and maneuverability in positioning at the butt of the trees, the use of the winch was not warranted. Moreover, the time used for winching could be spent in-

Table 5 Statistical data of pulling force, differences between ATV without ballast (W), ATV with front ballast (40 kg) (F) and ATV with front and back ballast (40+53 kg) (FB)

Tablica 5. *Statistički podaci o vučnoj sili, razlike između ATV-a bez utega (W), s prednjim utegom (40 kg) (F) i s prednjim i stražnjim utegom (40 + 53 kg) (FB)*

Parameter *Parametri*	W *Bez utega*	F *S prednjim utegom*	FB *S prednjim i stražnjim utegom*
n	117	159	183
Mean ± SD., daN *Aritmetička sredina ± Sd.*, daN	299.8 ± 64.9 ^{A}	299.7 ± 48.6 ^{A}	313.1 ± 42.0 ^{B}
St. Err., daN *Standardna pogreška*, daN	6.0	3.9	3.1
Kruskal-Wallis, *p*-value *Kruskal-Wallisov test, p-vrijednost*	0.3951	0.1343	0.4709

A, B: P<0.05

Table 6 Mean values of time, distances and loads during skidding cycles of the ATV in the two experimental areas

Tablica 6. *Srednje vrijednosti vremena, udaljenosti tovara tijekom turnusa privlačenja ATV-om na istraživanim područjima*

Work component *Sastavnice radnoga procesa*	Casalotti						Blera					
	Time, min *Vrijeme*, min		Distance, m *Udaljenost*, m		Load, $t_{d.m.}$ *Tovar*, $t_{d.m.}$		Time, min *Vrijeme*, min		Distance, m *Udaljenost*, m		Load, $t_{d.m.}$ *Tovar*, $t_{d.m.}$	
	Uphill *Uzbrdo*	Downhill *Nizbrdo*	Uphill *Uzbrdo*	Downhill *Nizbrdo*	Uphill *Uzbrdo*	Downhill *Nizbrdo*	With winch *S vitlom*	Without winch *Bez vitla*	With winch *S vitlom*	Without winch *Bez vitla*	With winch *S vitlom*	Without winch *Bez vitla*
Approaching and manoeuvring *Zauzimanje položaja*	1.17	0.91	92.4	44.7	–	–	1.63	1.50	94.9	77.9	–	–
Tree hooking – *Vezanje drva*	0.30	0.31	–	–	–	–	3.35	–	5.3	–	0.30	–
Skidding – *Privlačenje drva*	1.15	0.86	85.4	47.3	0.05	0.06	1.41	3.49	94.9	77.9	0.30	0.29
Tree releasing *Otpuštenje drva*	0.32	0.31	–	–	–	–	0.69	0.70	–	–	–	–

Table 7 Mean values of PHS_{15} and PHS_0 productivity of skidding in the two experimental areas

Tablica 7. *Srednje vrijednosti PHS15 i PHS0 produktivnosti privlačenja na istraživanim područjima*

Description *Prikaz*	Casalotti	Blera		
	Uphill skidding *Privlačenje uzbrdo*	Downhill skidding *Privlačenje nizbrdo*	With winch *S vitlom*	Without winch *Bez vitla*
PHS_{15} productivity, $t_{d.m.}h^{-1}$ *PHS_{15} produktivnost*, $t_{d.m.}h^{-1}$	0.98	1.28	2.18	2.79
PHS_0 productivity, $t_{d.m.}h^{-1}$ *PHS_0 produktivnost*, $t_{d.m.}h^{-1}$	1.09	1.52	2.60	3.05

creasing the number of skidding trips. Therefore, in such conditions of soil and vegetation, it was better to operate without bunching the trees with the winch, achieving an average PHS_0 productivity of 3.05 $t_{d.m.}$ h^{-1}, rather than bunching first and then skidding, achieving a PHS_0 productivity of 2.79 $t_{d.m.}$ h^{-1} (Table 7). The experiment thus highlighted the fact that using the winch is advisable only when trees of small or medium dimensions are available, and they are, however, difficult to be reached by the ATV.

As regards the entries of delay times in the work routine, equal to about 8% of the total working time (501 min), there are no substantial differences between those recorded for skidding with ATV and those when bunching was also carried out by winching with the winch. Very high values were nevertheless recorded due to problems with the load and with the loss or jamming of trees during pulling. The reasons are independent of the characteristics of the vehicle and its accessories but they should be traced back rather to the poor technological quality of the trees that were skidded, which gave the load a certain incoherence.

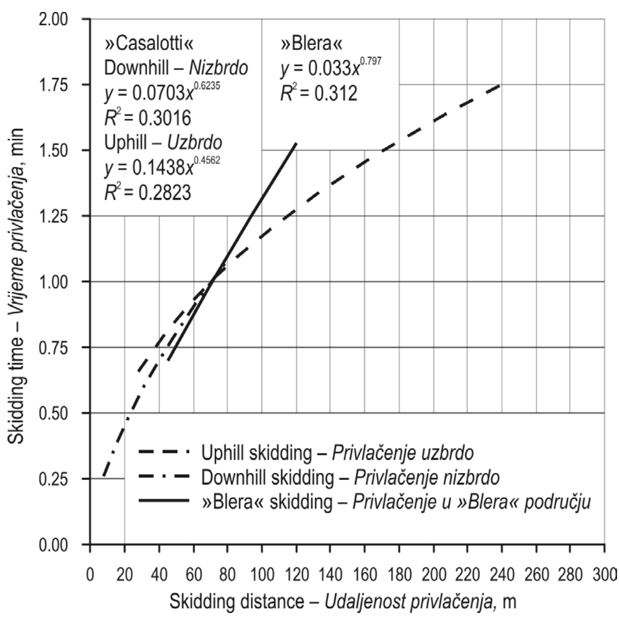

Figure 3 Skidding time as function of skidding distance in the two experimental areas

Slika 3. *Vrijeme privlačenja kao funkcija udaljenosti privlačenja na istraživanim područjima*

3.4 Regression analysis – *Regresijska analiza*

The regression analysis calculated the equations which can describe the relations between skidding time and skidding distance (Fig. 3). The regression equations were not characterized by a high determination coefficient (R^2) so the skidding distance did not seem to influence the skidding time even when the traveling direction was considered.

For such reason skidded mass was considered in relation to skidding time and for describing the relations among these variables regression equations were calculated (Fig. 4). The regression equations were characterized by a fairly high determination coefficient (R^2) that was able to point out the dependence degree between the variables. In fact, increasing the skidded mass of the load, the skidding time tended to increase. In Casalotti test the dependence between the variables was proved in both traveling directions.

It can be concluded that in order to achieve high productivity in skidding with the ATV, it is convenient to skid medium sized loads, increasing the characteristics of versatility, easiness of handling and speed of the vehicle in forest, independently of the traveling direction (uphill or downhill).

Comparing the mean value of productivity registered at the two sites (Table 7) it must be taken into consideration that the greater productivity registered in Blera test plot, in particular when skidding was carried out without using the winch, was mainly influenced by the gradient of the ground and the

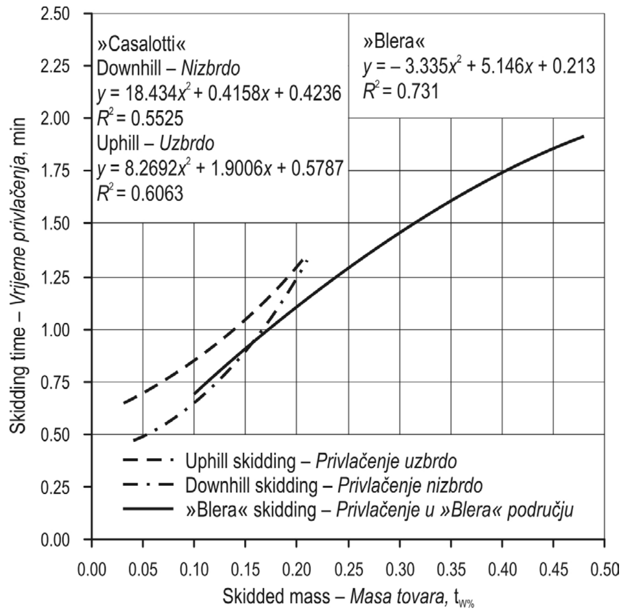

Fig. 4 Skidding time as function of mass skidded per cycle in the two experimental areas (in Casalotti experimental area the wood moisture was 98%, while in Blera the wood moisture was 45%)

Slika 4. *Vrijeme privlačenja kao funkcija mase skidera (na području Casalotti vlaga u drvu bila je 98 %, dok je na području Blera bila 45 %)*

Table 8 Comparison between the average data collected in the present study and those found in the national scientific literature

Tablica 8. *Usporedba između prikupljenih podataka i podataka pronađenih u znanstvenoj literaturi*

Machines – *Vrsta stroja*	Distance, m *Udaljenost*, m	Productivity, $t_{d.m.}$ h^{-1} *Produktivnost*, $t_{d.m.}$ h^{-1}	Trees *Vrsta stabala*	Ref. *Literatura*
Mini skidder – *Laki skider*	110–125	0.65–1.39	*Pinus pinaster, Pinus laricio*	Baldini et al. 1989 Baldini and Spinelli 1990 Avolio et al. 1989
Mini tractor – *Laki traktor*, 24 kW	100–300	0.90–1.60	–	Baldini, Donati 1974b
Skidder – *Skider*, 38 kW	200	1.30	–	Baldini, Donati 1974a
Farm tractor 48 kW and forestry winch *Poljoprivredni traktor sa šumskim vitlom*, 48 kW	130	1.00	*Pinus pinaster*	Baldini et al. 1993
Farm tractor 51.5 kW and forestry winch *Poljoprivredni traktor sa šumskim vitlom*, 51.5 kW	544	0.90–1.10	*Pinus nigra*	Neri 2004
Forestry tractor – Šumski traktor, 44 kW	205	1.51–1.93	*Pseudotsuga menziesii, Pinus nigra*	Fabiano and Piegai 2007
Mini tractor – *Laki traktor*, 15 kW	105	0.70–0.77	*Pinus laricio*	Baldini, Picchio 2001
Farm tractor 60 kW and forestry winch *Poljoprivredni traktor sa šumskim vitlom*, 60 kW	62–87	1.18	*Pinus laricio*	Verani, Sperandio 2005
ATV – *ATV*, 14 kW	47–95	1.20–3.05	*Pinus laricio, Pinus eldarica*	Present study

characteristics of the harvested trees. In fact in Blera the maximum gradient was 20%, lower than the average gradient in Casalotti (29%). Furthermore in Blera the harvested trees had higher mass and volume, with little dry branches that reduced obstruction during maneuvers between standing trees, while those in Casalotti were green individuals with many, green, persistent branches.

4. Conclusions – *Zaključci*

From the national scientific literature referring exclusively to interventions of first thinning in artificial coniferous plantations, it is possible to assess and compare some of the data recorded in the present study with those reported at similar sites according to type of plantation, type of intervention and utilization systems, where however different systems and levels of mechanization were used (Table 8). The ATV gave such results as to make it competitive with both more traditional and cutting edge vehicles in the agricultural and forestry sector, leading to PHS_0 productivity variable from 1.20 to 3.05 $t_{d.m.}h^{-1}$.

The values of productivity confirm that the ATV, in a context of first thinning on level ground but also on sloping ground, over distances not exceeding 200 m, is an ideal vehicle for working in forests where high density does not prevent it from easily entering, hooking up and skidding a load made up of trees of small and medium dimensions.

Based on the data acquired from the test, it can be concluded that:

ATV proved to be a suitable vehicle in operations of first thinning in artificial coniferous plantations. Firstly due to its limited size but also to its features of agility and maneuverability which allow the vehicle to move inside the forest, arriving close to the butt of the trees to be hooked, without causing damage neither to the standing trees nor to the ground. Furthermore no wounds at trees butt were registered because the ATV maneuverability allowed the operator to move even with a full load among trees without causing damage.

ATV achieved higher productivity in skidding if compared with the one obtained by other vehicles as shown in literature;

ATV abilities in skidding over distances shorter than 200 m were superior to those of an agricultural tractor equipped with a forest winch, due to the ease of maneuvering and the higher speed when traveling both unloaded and fully loaded;

ATV pulling force made it particularly suitable to operate with trees of small or medium dimensions such as those obtained in first thinning;

ATV impact on the ground and especially on the shallow horizons was negligible and did

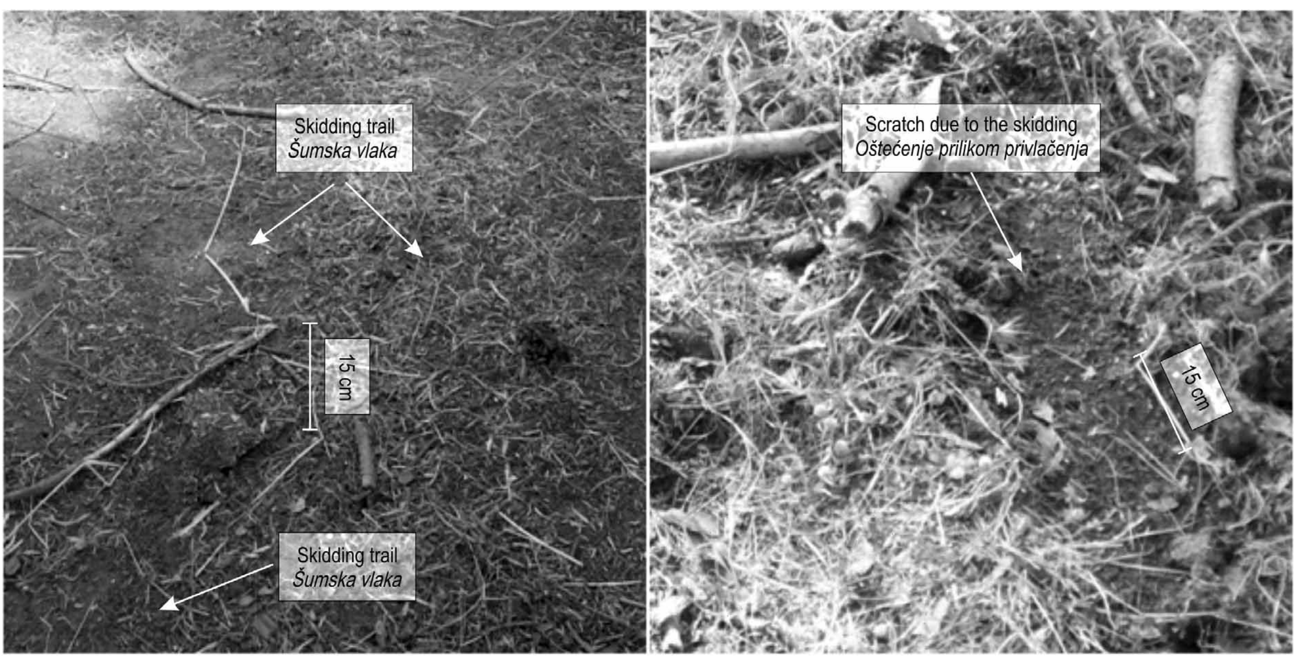

Fig. 5 Impacts on the soil produced by the ATV during skidding

Slika 5. *Utjecaji na tlo tijekom privlačenja drva ATV-om* not affect the tree roots (Fig. 5). The reduced weight and tire characteristics make the vehicle particularly ideal for moving inside the forest.

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5. References – *Literatura*

Avolio, S., Baldini, S., Spinelli, R., 1989: Prove di meccanizzazione in diradamenti di pinete artificiali di pino laricio nella Presila di Cosenza. Annali Istituto Sperimentale per la Selvicoltora, 20: 501–547.

Baldini, S., Berti, S., Cutini, A., Mannucci, M., Mercurio, R., Spinelli, R., 1989: Prove sperimentali di primo diradamento in un soprassuolo di pino marittimo (*Pinus pinaster* Ait.) originato da incendio: aspetti selvicolturali, di utilizzazione e caratteristiche della biomassa. Annali Istituto Sperimentale per la Selvicoltora 20: 385–436.

Baldini, S., Donati, R. 1974a: Rapporto sul trattore da esbosco TA 45. Istituto del Legno, Consiglio Nazionale delle Ricerche, Firenze. Contributi Scientifico Pratici – IRL, XVIII 42: 15–27.

Baldini, S., Donati, R., 1974b: Prove preliminari di esbosco con il trattore leggero Cast 435 L. Istituto del Legno, Consiglio Nazionale delle Ricerche, Firenze. Contributi Scientifico Pratici – IRL, XVIII 44: 39–42.

Baldini, S., Picchio, R., 2001: Primo diradamento con messa a punto di nuove metodologie di lavoro in una pineta dei Cimini. Economia Montana: Linea Ecologica 33 (6): 47–54.

Baldini, S., Pollini, C., Spinelli R., 1993: Agricultural tractor use in wood harvesting. Proceedings of 5th AIGR National Conference. Italian Association of Agricultural Engineering, Maratea, Italy: 213–217.

Baldini, S., Spinelli, R., 1990: Miniskidder in Italy. Small Scale Forestry 1: 23–27.

Baldini, S., Spinelli, R., 1993: Mini-tractor development for forest utilization. Proceedings of 5th AIGR National Conference. Italian Association of Agricultural Engineering, Maratea, Italy: 87–92.

Bergström, D., Bergsten, U., Nordfjell, T., Lundmark, T., 2007: Simulation of Geometric Thinning Systems and Their Time Requirements for Young Forests. Silva Fennica 41(1): 137–147.

Berti, S., Piegai, F.,Verani, S., 1989: Manuale d'istruzione per il rilievo dei tempi di lavoro e delle produttività nei lavori forestali. Quaderni dell'Istituto di Tecnologia ed Assestamento Forestale, Università degli Studi di Firenze Fascicolo IV: 65.

Cantiani, P., Iorio, G., Pelleri, F., 2005: Effetti di diradamenti in soprassuoli di pino nero (Pettenaio, Perugia). Forest 2(2): 207–216.

Fabiano, F., Piegai, F., 2007: Diradamenti in impianti artificiali di conifere. Sherwood – Foreste ed Alberi Oggi 136: 23–29.

Fusaro, E., 2003: Per la gestione di impiati sperimentali di conifere in ambiente medietarraneo. Prove per l'introduzione di Pinus eldarica in Italia. Economia Montana: Linea Ecologica 35(2): 51–59.

Harstela, P., 1991: Work studies in forestry. Silva Carelica 18: 1–41.

Heikkila, J., Sirén, M., Aijala, J. O., 2007: Management alternatives of energy wood thinning stands. Biomass and Bioenergy 31(5): 255–266.

Jäghagen, K., Lageson, H., 1996: Timber quality after thinning from above and below in stands of Pinus sylvestris. Scandinavian Journal of Forest Research 11(1–4): 336–342.

Kanawaty, G., 1992: Introduction to work study. Fourth (revised) Edition, International Labour Office, Geneva: 1–494.

Malinen, J., Pesonen, M., Maatta, T., Kajanus, M., 2001: Potential harvest for wood fuels (energy wood) from logging residues and first thinnings in Southern Finland. Biomass and Bioenergy 20(3): 189–196.

Mederski, P. S., 2006: A comparison of harvesting productivity and costs in thinning operations with and without midfield. Forest Ecology and Management 224(3): 286–296.

Neri, F., 2004: Tempi di lavoro e produttività nelle operazioni di abbattimento, allestimento ed esbosco in diradamenti di pino nero nel complesso forestale »Alpe di Catenaria«. Sherwood – Foreste ed Alberi Oggi 100: 5–9.

Niemela, J. 1984: Development of off-road motorcycles and their possibilities in field experiments. Proceeding of the 6th International Mechanization Conference, Rutherford, I. R. Ministry of Agriculture, Fisheries and Food (MAFF), London (United Kingdom). Agricultural Development and Advisory Service Dublin (Ireland): 35–44.

Nordfjell, T., 1990: Small off road vehicles for thinning (mini-forwarders, mini-skidders, SKOGIS, ATV, snow mobiles). Small Scale Forestry 1: 13–22.

OECD, 2007: Agricultural Codes and Schemes, Standard code for the official testing of agricultural and forestry tractor performance. Code 2: pp. 61.

Picchio, R., Savelli, S., Di Fulvio, F., 2005: Sviluppi nei lavori forestali di ATV e minitrattori. Alberi e Territorio, 2 (10–11): 26–30.

Piegai, F., 1987: Le tecniche di lavoro nei primi diradamenti. Quaderni di Monti e Boschi 3: 33–42.

Spiik, E., 1992: Salvaging wind felled trees with all terrain vehicles. Small Scale Forestry 1: 18–21.

Spinelli, R., 1995: Sviluppo di un trattore per i diradamenti. Mondo Macchina 2: 22–25.

Spinelli, R., Spinelli, R., 2001: Meccanizzazione in miniatura per i primi diradamenti. L'esperienza svedese. Mondo Macchina 10: 20–22.

Verani, S., Sperandio, G., 2005: Prove di diradamento selettivo meccanizzato su Pino laricio in Calabria. Economia Montana: Linea Ecologica 37(4): 53–57.

Wayman, R. B., North, M., 2007: Initial response of a mixed-conifer understory plant community to burning and thinning restoration treatments. Forest Ecology and Management 239(1–3): 32–44.

Yeo, B. J., Stewart, M., 2001: Thinning Pinus radiata plantations by operator selection: 2. Effect on harvesting productivity. Australian Forestry 64(4): 220–225.

Sažetak

Privlačenje drva lakom mehanizacijom u proredama crnogoričnih kultura

Prve su prorede obilježene u prvom redu malom količinom posječena drvna te niskom komercijalnom vrijednosti drva, s vrlo niskim novčanim prihodima ili bez njih, što objašnjava zabrinjavajuću težnju za izbjegavanjem proreda, posebno u crnogoričnim kulturama. Izostavljanje proreda može biti uzrok degradacije i nestabilnosti mnogih šumskih sastojina. Polazeći od takvih okolnosti, provedeno je ovo istraživanje radi pronalaska novoga, jeftinijega i jednostavnijega rješenja za pridobivanja drva u proredama. Vozilo ATV (All Terrain Vehicle), koje je jednostavno za upravljanje i vrlo prilagodljivo na terenu, testirano je u proredama kultura bora. Glavni su ciljevi ovoga istraživanja bili: razvoj prikladnih operativnih metoda, određivanje produktivnosti ATV-a u različitim uvjetima rada, ispitivanje mogućih mehaničkih i tehnoloških poboljšanja vozila i metoda rada.

Istraživanje je provedeno uz pomoć modela Kawasaki KLF 300 ATV koji je proizveden za teške terenske uvjete, ali nema sportsku namjenu. Glavne su značajke ATV-a visoka vučna sila, dobra stabilnost i snaga. Karakteristike su motora: obujam od 300 cm^3, snaga od 14 kW, okretni moment od 23,5 Nm na 5500 o/min. Prijenosne su karakteristike: poluautomatski mjenjač s brzim sustavom prijenosa 5 + natraške i sporim sustavom prijenosa 5 + natraške, najmanja je brzina oko 1 km/h, a najveća je brzina oko 90 km/h. Na vozilima ATV u suradnji s uvoznikom Kawasaki off-road motocikala za Italiju, KL Italija, izrađene su odgovarajuće preinake radi poboljšanja njihovih karakteristika za skupljanje i privlačenje drva. Preinake su vozila bile sljedeće: ugradnja električnoga vitla Warn, ugradnja zaštite od prevrtanja ROPS na okvir ATV-a, ugradnja dviju kutija za alat na prednjem i na stražnjem dijelu vozila, opremanje vijenca kotača sa zaštitnim ventilima za gume, ugradnja posebnoga držača balasta na prednjem dijelu vozila.

Vozilo se koristilo za skupljanje i privlačenje drva stablovnom metodom na područjima:

- *sastojine bora Pinus eldarica Medw. na području Casalotti (Rim, središnja Italija) na površini od oko 3 ha, prosječna nagiba od 29 % i blagih površinskih prepreka,*
- *sastojine crnoga bora Pinus laricio Poir. na području Blera (Viterbo, središnja Italija), na površini većoj od 8 ha, prosječna nagiba od 5 % i blagih površinskih prepreka.*

Statistička analiza vrijednosti vučnih sila ATV-a pokazala je značajne razlike u odnosu vučne sile s različitim sustavima prijenosa i primijenjenim balastom. Najbolju izvedbu od 313,1 daN (prosječna vučna sila) dobivena je u sporohodnoj prvoj brzini i pri balastu od 40 kg na prednjem dijelu vozila i od 53 kg na stražnjem dijelu vozila. Studijom su rada i vremena utvrđena kašnjenja u radnom ciklusu od oko 15 % na području Casalotti pri privlačenju drva uz nagib i niz nagib i oko 16 % pri privitlavanju i privlačenju drva na području Blera te 8 % pri privlačenju drva na području Blera. Privučeno je drvo uzeto u obzir u odnosu na vrijeme privlačenja drva te su za opisivanje odnosa među ovim varijablama izračunate i regresijske jednadžbe. Regresijske je jednadžbe obilježio prilično visok koeficijent determinacije R^2 i značajni koeficijent R, koji ističe stupanj ovisnosti između varijabli, pa je tako s povećanjem privučena drva i vrijeme privlačenja veće. Analiza podataka pokazuje da je najveća produktivnost privlačenja ATV-om pri srednjem opterećenju vozila, bez razlike u smjeru privlačenja uz nagib ili niz nagib. Opterećenje vozila također utječe na pokretljivost vozila po terenu, lakoću rukovanja i brzinu vozila u šumi. Znanstvena je literatura omogućila usporedbu dobivenih rezultata ovoga istraživanja s rezultatima drugih istraživanja u sličnim uvjetima, ali pri različitim sustavima rada i razinama mehaniziranosti (produktivnost se vozila kretala od 0,65 $t_{d.m.}$/h do 2,20 $t_{d.m.}$/h). Ovom je usporedbom ustanovljeno da je ATV konkurentno vozilo i tradicionalnim i suvremenijim vozilima u šumarstvu. Produktivnost se ATV-a kretala u rasponu od 1,20 do

3,05 $t_{d.m.}$/h. Dobivene vrijednosti produktivnosti ATV-a potvrđuju da je ovo vozilo dobar izbor u prvim proredama gustih sastojina na ravnom i blago nagnutom terenu, na udaljenostima ne većim od 250 m (udaljenost i podaci prikupljeni u istraživanju) jer mjere vozila olakšavaju ulazak u sastojinu, privitlavanje i privlačenje stabala.

Ključne riječi: šumarstvo malih razmjera, vozilo ATV, prorede, skupljanje drva, privlačenje drva, vitlo, iskorištavanje šuma

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