LOGGING ACTIVITIES IN SLOPE AREAS, HELI-LOGGING OR CABLE YARDER IN ITALY

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The aim of this paper was to compare cable yarders and helicopters during extraction activities in steep terrains.
The harvesting was carried out in two different situations:
1) clear cutting in a fir plantation;
2) thinning in a black pine plantation.
Three helicopters (Agusta Bell 412, Aérospatiale AS 332 L and Aérospatiale AS 350 Ecureuil) and two cable yarders were compared (Greifenberg TG 430 and Vallauri VS 10 Endmast) were compared.
In the first area the helicopter AS 332 L was more affordable than the Greifenberg TG 430 cable yarder for the extraction, while the Agusta Bell 412 was the most expensive.
In the second area, the extraction by Vallauri VS 10 Endmast cable yarder was the most affordable, but the costs were similar at the extraction by helicopter AS 350 Ecureuil. The extraction by Agusta Bell 412 was the most expensive.
In thinning the direct costs of helicopter and cable yarder were similar, but in a clear cutting the use of helicopter was more affordable than cable yarder. In both situations, the Agusta Bell 412 helicopter was the solution with the highest direct costs.
In difficult forest areas poorly served by roads, heli-logging can be an option in timber extraction because it reduces the need to construct new tracks. The construction of new roads can be invasive especially in mountain areas with steep slopes.

Keywords: helicopter, extraction, cable yarder, machine costs.
Parole chiave: elicottero, esbosco, gru a cavo, costi macchina.

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1. Introduction

Wood extraction in Italy are performed using traditional ground-based methods such as animals and tractors with winch. The aim of this study was to compare new different extraction systems with low soil impact such as cable logging and helicopter logging. As well as studying the economic point of view of the aerial logging, the environmental, social and operational aspects were considered. The morphology of the terrain, the characteristics of the forest and of the infrastructures and also the kind of management were considered. The comparison cable yarder vs helicopter was carried out taking into consideration three models of helicopters.

2. Materials and methods

Methodology had taken into account two different types of sites.
The first area, about 50 ha, was a silver fir (*Abies alba* Mill.) plantation 70 years old. Some circular areas of 60 m of diameter were harvested interesting the 40% of the surface. The harvesting operation aimed at releasing the advance regeneration of native hardwood, naturally established. Trees were felled and processed by chainsaw and then extracted to the landing area. An uphill single permanent road crosses the forest area and any other trail is present. The average bunching, extraction and transport distance was 7 km (average bunching-extraction distance about 750 m, average transport distance over 6 km). A service landing for the aerial logging was approximately 2 km from the felling site.
The other site, 40 ha, was a black pine (*Pinus nigra* Arnold) plantation 33 years old. Thinning was planning as the systematic elimination of one row every two and the selective cutting of the worst trees in the remaining standing rows.
The harvesting operation aimed at releasing the advance regeneration of native hardwood, naturally established under the black pine canopy. Trees were felled and processed by chainsaw and then extracted at the landing area. The skid trails used during plantation were still recognizable at the moment of our study.

The service road density was 37.4 m/ha for the forest road and 30.2 m/ha for the skid trails. The average bunching, extraction and transport distance was 4 km (average bunching-extraction distance about 250 m, average transport distance over 3.5 km). A service landing for the aerial logging was approximately 1.2 km from the felling site.
In the first area an Agusta-Bell 412 (Tab. 1) and an Aérospatiale AS 332 (Tab. 1) helicopters were used to extract the logs. An agricultural tractor SAME Iron 115DT, with a forest loader Kastle 35.56 Z (Tab. 2), was used for logs movement at the landing.
This heli-logging method was compared with a traditional mixed method (aerial and ground based). A Greifenberg TG 430 cable yarder (Tab. 3) was used to extract the logs, and an agricultural tractor SAME Iron 115DT carried with a forest loader Kastle 35.56 Z and a trailer Bernardi B 140 4WD (Tab. 3) was used for logs transport and movement.
In the other site the aerial logging operations were performed with the Agusta-Bell 412 (Tab. 1) and the Aérospatiale AS 350 Ecureuil (Tab. 1) helicopters. At landing area the logs movement were performed by agricultural tractor SAME Iron 115DT equipped with a forestry loader Kastle 35.56 Z. This heli-logging method was compared with a traditional mixed method (aerial and ground based). Vallauri VS 10 Endmast cable yarder was used to extract the logs and a HSM 208 F - 12 t (Tab. 4) forwarder was used for logs transport and movement.
Based on similar studies, productivity and working times analysis were carried out (Harstela, 1991; Picchio *et al.*, 2011; Picchio *et al.*, 2009; Verani *et al.*, 2009). The operational costs were calculated including the machinery costs, the cost of personal protective equipment (PPE), and the human work costs (Bernetti and Romano, 2007; Brun and Berruto, 2000; Iacoponi and Romiti, 2001; Hippoliti, 1997; Hippoliti and Piegai, 2000; Merlo, 1991).

3. Results

3.1. First study area

The most important productivity parameters are shown in table 5. In this first area, the best productivity was recorded for the heli-logging, compared with the cable yarder logging. However, analyzing the results in terms of utilization costs, the Aérospatiale AS 332 L (28,548.60 €/ha) for heli-logging was more affordable in comparison with the Greifenberg TG 430 cable yarder (32,842.70 €/ha). The helicopter Agusta Bell 412 was the most expensive (44,690.70 €/ha).

3.2. Second study area

Also in this case the helicopter productivities are higher than those of the cable yarder (Tab. 6). However, analyzing the costs of utilization, the Vallauri VS 10 Endmast was the most affordable (38,140.10 €/ha), but the AS 350 Ecureuil helicopter showed similar costs (38,186.60 €/ha). The heli-logging by Agusta Bell 412 (53,864.20 €/ha) was more expensive than the other logging methods.

4. Conclusion

Heli-logging is generally considered the most expensive logging method but is not always true. In some situations, heli-logging could be a good option when the load landing areas are well organized with enough space to ensure an efficient and safe movement. This study, for thinning operation, has indicated that the heli-logging cost is competitive with cable yarder. In final cutting, the cable yarder logging is the most affordable. This result was due to a large average unitary log volume (Stampfer *et al.*, 2002).
The comparison among the three helicopters used showed that the extraction by Agusta Bell 412 was more expensive. This is due to the highest purchase costs of Agusta Bell 412 in relation to payload and to low fly speed of this helicopter.
A key aspect is that the Agusta Bell 412 helicopter was designed in the early ‘70s and derived from an existing machine (Agusta Bell 212). This helicopter is an old model that over the years has undergone only continuous modifications and improvements but not enough to make up for the latest technical innovations.
The others two models were designed with greater technological contributions. A good compromise was reached with the helicopter Aerospatiale AS 332 where the large capacity in terms of passenger transport is combined with a high load capacity. The heli-copter Aerospatiale AS 350, designed after the Aèro-spatiale AS 332, probably owes its success to the development of a design that aimed at further reducing weight, cost, maintenance, with good advantage for the payload, speed and affordability.
In comparisons with the conventional ground-based extraction methods, the heli-logging provides the following environmental advantages: reducing damage to residual trees, forest vegetation and soil, reducing the needs to open new forest road for the extraction. Also the cable yarder has the same positive aspects.
The differences between the two methods are in function of the selvicultural decisions and of the stational parameters that affect work productivities and costs.
Cable yarder and more so heli-logging are a preferred alternative over conventional ground-based methods when logging are necessary in environmentally sensitive terrain, in extremely steep areas with slopes over than 40%.

Table 1. Parameters of the helicopters used in this study.
Tabella 1. Parametri degli elicotteri utilizzati in questo studio.

	Agusta Bell 412	*Aérospatiale AS 332*	*Aérospatiale AS 350*
Pilots	1-2	2	1
Length (fuselage) (m)	17.1	16.29	10.93
Rotor diameter (m)	14.0	15.6	10.7
Height (m)	4.6	4.8	3.14
Area rotor disc (m^2)	154.4		89.75
Empty weight (kg)	3079	4100	1174
Maximum (take off) weight (kg)	5397	8600	2250
No. of engines and power (kW)	2 × 671	2 × 1300	1 × 632
Maximal speed (km/h)	259	278	287
Cruise speed (km/h)	226	252	245
Flight radijus (km)	745	841	662
Service ceiling (m)	6096	6100	4600
Vertical climb rate (m/s)	6.86	8.2	8.5

Table 2. Technical data of tractor Same Iron 115 DT and the forestry loader Kastle 35.56 z.
Tabella 2. Dati tecnici del trattore Same Iron 115 DT e del caricatore forestale Kastle 35.56 z.

SAME Iron 115 DT		*Kastle 35.56 z*	
Cylinders/Displacement (no./cc)	6/6057	*Lifting capacity at 2 mt (kg)*	1700
Aspiration	Turbo intercooler	*Lifting capacity at 3 mt (kg)*	1175
Max. power (kW)	89	*Lifting capacity at 5 mt (kg)*	715
Rated speed (rpm)	2300	*Lifting capacity at 5,6 mt (kg)*	580
Max. torque (Nm)	420	*Slewing speed (U/min)*	7.2
Max. torque speed (rpm)	1200-1800	*Slewing torque (kNm)*	7.1
Max. length without link arms (mm)	4370	*Conveyning capacity (l/min)*	70
Width min.- max (mm)	1880-2480	*Weight without equipment (kg)*	890
Max. height at cab (mm)	2765		
Wheelbase (mm)	2647		
Weight with safety frame (kg)	4850		
Max. speed (km/h)	50		
Max. lifting capacity (kg)	6200		

Table 3. Technical data of cable yarder Greifenberg TG 430 and trailer Bernardi B 140 4WD.
Tabella 3. Dati tecnici della gru a cavo Greifenberg TG 430 e del rimorchio Bernardi B 140 4WD.

Greifenberg TG 430 Tractor		*Bernardi B 140 4WD*	
Mass	4000 kg	*Maximim load*	14000 kg
Carrying cable diameter	16 mm		
Pulling cable diameter	10 mm	*Weight*	3800 kg
Carrying cable length	430 m	*Axles*	n° 2
Pulling cable length	450 m		
Pulling maximum speed	5.5 m/s		
Carring cable maximum tension	67 kN		
Maximum pulling tension	31 kN		
Minimum tractor power	75 CV		

Table 4. Technical data of Vallauri VS 10 ENDMAST and Forwarder HSM 208 F - 12 t.
Tabella 4. Dati tecnici della gru a cavo Vallauri VS 10 ENDMAST e del Forwarder HSM 208 F - 12 t.

VS 10 ENDMAST VALLAURI		*Forwarder HSM 208 F - 12 t*	
Tower height	10 m	*Power engine*	171 kW
Carrying cable diameter	22 mm	*Tires*	No. 8
Carrying cable winch capacity	1100 m	*Max. speed*	28 km/h
Carrying cable traction capacity	12 t	*Max. width*	240 cm
		Max. length	465 cm
		Max. height	126 cm
		Weight	14.9 t
		Load capacity	12 t

Table 5. Productivities and costs of the first study area.
Tabella 5. Produttività e costi della prima area di studio.

	Agusta Bell 412	*Aérospatiale AS 332 L*	*Greifenberg*
Mass (t/ha)	276.5	276.5	276.5
PHS 15 (ts.f.h^{-1}op.$^{-1}$)	2.54	2.85	1.18
PHS 0 (ts.f.h^{-1}op.$^{-1}$)	3.12	3.57	1.37
Total cost (€ ts.f.$^{-1}$)	161.63	103.25	118.78
Cost (€/ha)	44690.7	28548.6	32842.7

Table 6. Productivities and costs of the second study area.
Tabella 6. Produttività e costi della seconda area di studio.

	AS 350 Ecureuil	*Agusta Bell 412*	*Vallauri*
Mass (t/ha)	273.7	273.7	273.7
PHS 15 (ts.f.h^{-1}op.$^{-1}$)	1.61	1.72	0.81
PHS 0 (ts.f.h^{-1}op.$^{-1}$)	1.9	2.03	0.95
Total cost (€ ts.f.$^{-1}$)	139.52	196.8	139.35
Cost (€/ha)	38186.6	53864.2	38140.1

RIASSUNTO

Utilizzazioni in aree acclivi, possibile impiego degli elicotteri in alternativa alle gru a cavo in Italia

La finalità di questo lavoro è confrontare gru a cavo ed elicotteri per l'esbosco di soprassuoli che si trovano su pendenze elevate. Sono state studiate le utilizzazioni in due situazioni diverse:

1) taglio a raso a buche in rimboschimento a prevalenza di abete bianco;
2) diradamento in rimboschimento di pino nero.

I raffronti sono stati fatti tra tre modelli di elicottero (Agusta Bell 412, Aérospatiale AS 332 L e Aérospatiale AS 350 Ecureuil) e tra due modelli di gru a cavo (Greifenberg TG 430 e Vallauri VS 10 Endmast).
Nella prima area il cantiere meno costoso è quello in cui viene impiegato l'AS 332 L che risulta più conveniente di quello con gru a cavo Greifenberg TG 430. L'altro cantiere con elicottero (Agusta Bell 412) ha evidenziato invece costi di utilizzazione notevolmente superiori.
Nella seconda area, il cantiere più conveniente è quello in cui viene impiegata la gru a cavo Vallauri VS 10 Endmast ma i costi sono risultati simili a quelli ottenuti con l'elicottero AS 350 Ecureuil. L'Agusta Bell 412 ha evidenziato anche in questa situazione costi superiori.
Nel caso di diradamento i costi dell'elicottero e della gru leggera si equivalgono, mentre nel taglio raso il mezzo aereo è economicamente più vantaggioso rispetto alla gru media.
Si evidenzia che l'utilizzo dell'Agusta Bell 412 non risulta mai conveniente.
Un aspetto fondamentale è che l'impiego di mezzi aerei elimina la necessità di realizzare nuovi archi viari, permettendo di evitare l'impatto di opere invasive in aree con alte pendenze.

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