Giuseppe Pellizzi Prize

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Optimizing the wood supply chain in Calabria: from harvest site to the mill of wood process

Activity: Factors affecting forwarder productivity

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Objectives

This study was carried out by PhD thesis and it aims to analyze operational time consumption for estimating the productivity of two different models of forwarders (John Deere 1910E and 1110E), in three different sites (two in New Zealand and one in Southern Italy) and show general trends of productivity in relation to common factors in harvesting operations and to determine the operation cost for harvesting for different forwarders.

Summary

Modern forwarders are an efficient extraction option for timber harvesting operations. Three case studies were carried out; (1) a selective cut in Calabria, Italy with a smaller 12 t capacity John Deere 1110E, (2) a clearcut on the West Coast of New Zealand with a larger 19 t capacity John Deere 1910E, and (3) a larger clearcut operation in Canterbury with two John Deere 1910E. The studies used an elemental time and motion study approach resulting in 73.4 hours of detailed data, with 159 cycles extracting 2,241 m^3 of timber. Distance and payload were significant factors for all productivity. Cycle time was the fastest, and consequently productivity the highest, at the Canterbury site where the terrain roughness was low, overcoming any effect of the average small piece size (0.59 m^3). Travel speed was slowest at the West Coast site showing the effect of wet and difficult terrain, with travel empty speed being just 3.8 km/hr compared to 6.7 km/hr at the other two sites. Productivity at the two clear-cut operations was significantly higher than the selective cut, compounded by the use of the larger capacity forwarders at the clearcut sites. The unit cost of forwarder extraction ranged from €2.55 to €3.60 /m^3, showing that forwarders are very cost effective.

Materials and methods

Site	A	B	C
Country	Italy	New Zealand	New Zealand
Place	San Giovanni in Fiore	Paparoa Forest	Balmoral Forest
Species	Calabrian Pine	Pinus radiata	Pinus radiata
Stand Type	High forest	Plantation	Plantation
Operation Type	Selective cut	Clearcut	Clearcut
Total area (ha)	22	25	27
Density (trees /ha)	870	148	700
Site volume (m³/ha)	630	300	405
Removal (trees/ha)	158	all	all
Average tree volume (m^3)	1.2	1.9	0.57
Average Slope (%)	25	5	5
Roughness	Medium	Medium (muddy/ wet)	Low (clear, dry ground)

- Cost -

The machine's costs were calculated as described by Miyata (1980) and by using the COST model proposed by Ackerman et al. (2014). The purchase prices and operator wages required for the cost calculations were obtained from catalogues and accounting records (FORME 2015). A salvage value of 20% of the purchase price was assumed, with an economic life of 8 years. Cost calculations were based on the assumption that companies worked the whole year except the rainy season when the harvest areas in Southern Italy are not normally accessible. As reported in others study (Spinelli et al 2011) were considered a total 180 working days in the year, at an average of 8 scheduled working hours per day (equals 1440 hr /year).

- Productivity -

In order to determine the productivity of the forwarder, the operating cycle of the machine has been divided in several elements: ***Travel empty, Loading, Travel loaded, Unloading, Complementary work times, Refuel time and Delay time and others***.

Also recorded: ***number of logs, total volume payloads, slope, distance of loading and forwarding distance***.

Variables	Work sites								
	Site A			Site B			Site C		
	Min	Average	Max	Min	Average	Max	Min	Average	Max
Total travel distance (m)	290	729	1560	100	650	1400	240	665	1640
Loading distance (m)	25	54	90	10	10	10	30	83	270
Number of logs (n°)	20	20	39	25	35	43	52	77	119
Average log volume (m^3)	0,27	0,36	0,53	0,35	0,42	0,54	0,15	0,25	0,47
Total pay load volume (m^3)	8,3	10,1	10,8	11,4	14,3	17,6	8,4	14,8	18

Table 3. Calculation of hourly costs for the two John Deere forwarders used in the case study for forwarding in Southern Italy and New Zealand.

Parameter	Value	
	1110E	1910E
Purchase price (€)	265,000	432,000
Salvage value (€)	86,400	86,000
Economic Life (y)	8	8
Scheduled operating time (h/yr)	1,440	1,440
Annual depreciation (€)	26,500	43,200
Interest cost (€)	12,058	19,656
Taxes and insurance (€)	13,780	22,464
Total fixed cost (€ h^{-1})	36.35	59.25
Total variable cost (€ h^{-1})	50.7	47.5
Total labour cost (€ h^{-1})	20	13
Total cost (€ h^{-1})	87.1	106.7

Results and discussion

The time studies covered in total 73.4 hr; of which 29.2 were recorded at site A, 28.5 at site B, and 15.7 at site C. Within this time, the forwarders completed 159 forwarding cycles (50 for site A, 69 for B and 40 for C, respectively) and extracted 6,884 logs with a total volume of about 2,078 m^3. Only short delays were measured during all three different studies, giving 97, 93 and 93% utilization rates, for sites A, B and C, respectively. The average cycle time was 33.2 min at site A, 24.2 at B and 22.8 at C. Figure 1 shows the ratio of the time elements for the total work time at each site.

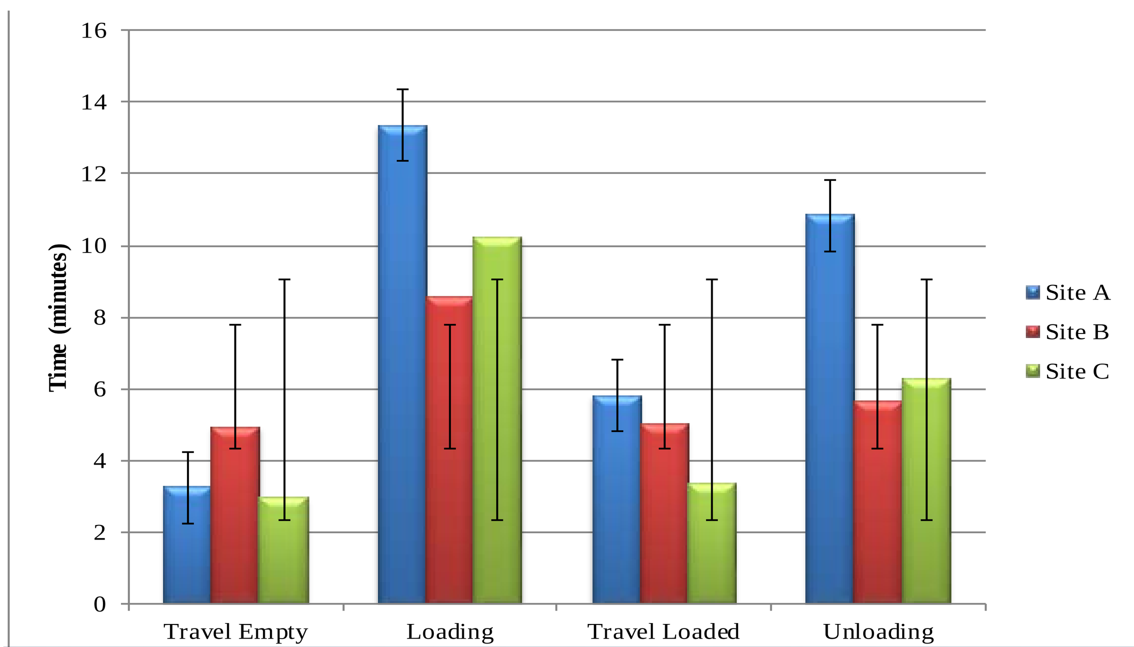

Figure 1. Share of operations under analysis within work time.

A travel time equation was developed (Eq. 1), whereby travel time includes both unloaded and loaded travel. This is because a forwarder might travel a shorter distance and load over an extended distance and then travel back from the furthest point. The equation shows the effect of poor ground conditions at the West Coast (site B) slowed the machine significantly; whereby the travel time at the Canterbury (site C) was similar to that in Calabria.

While the model is significant for the data from the three sites, one surprising component is the negative effect of load size (Vol). It would suggest that the larger machines loading at sites B and C were faster than the smaller machine at site A. However, the other factor is that the logs were more spread out at site A; the bunched logs at site B reduced the average cycle time by almost 3 min. The equation for unloading shows a very similar effect as for loading. It does show that the larger machines at both sites B and C unloading onto a large landing were much faster than unloading the smaller forwarder in the more constrained site in Calabria (site A). A separate equation provides a regression model for the total cycle time. Overall it shows that the larger scale clear-cut operations in New Zealand (sites B and C) are faster than the smaller-scale operation in Calabria, despite having to load approximately 50% more volume. A final equation was developed to model the productivity (m^3/PMH). For this model, all parameters are logical with a reduction in productivity with distance (Dist), increase with payload volume (Vol), a decrease with poor track conditions at site B and the highest productivity on the good dry flat terrain at site C. The average productivity of forwarding at site A was 18.9 m^3/PMH, at site B 37.1 m^3/PMH and 42.7 m^3/PMH at site C.

Table 4. Regression equations for each individual

Work Elements	Equation
Travel (min)	3.64+0.007* Dist + 2.89 * Wc -2.24 * Ca
Loading (min)	18.02 - 0.457 * Vol - 2.90 * WC -0.98 *CA
Unloading	13.43 - 0.25 * Vol - 4.17 * WC - 3.39 * CA
Total cycle time (min)	36.09 + 0.012 * Dist - 1.10 * Vol - 2.75 * Wc - 4.23 * CA
Prod (m^3/PMH)	-11.2 - 0.015 * Dist + 3.95 * Vol + 0.47 * WC + 3.71 * CA

Figure 2 shows the relationship and variability between average forwarding distance and productivity. While the cycle time models already show a difference, when factoring in the larger payloads, productivity at sites B and C are considerably higher. Within this study there was no significant difference identified between log assortments. Fixed and hourly operating costs for productive machine time of the forwarder are reported in Table 3. The calculated costs were consistent with Jirošek et al. (2007) who showed forwarder extraction cost depends on the type of the vehicle used (i.e., its nominal carrying capacity) and that forwarders of higher carrying capacity achieve lower costs per product unit and higher productivity.

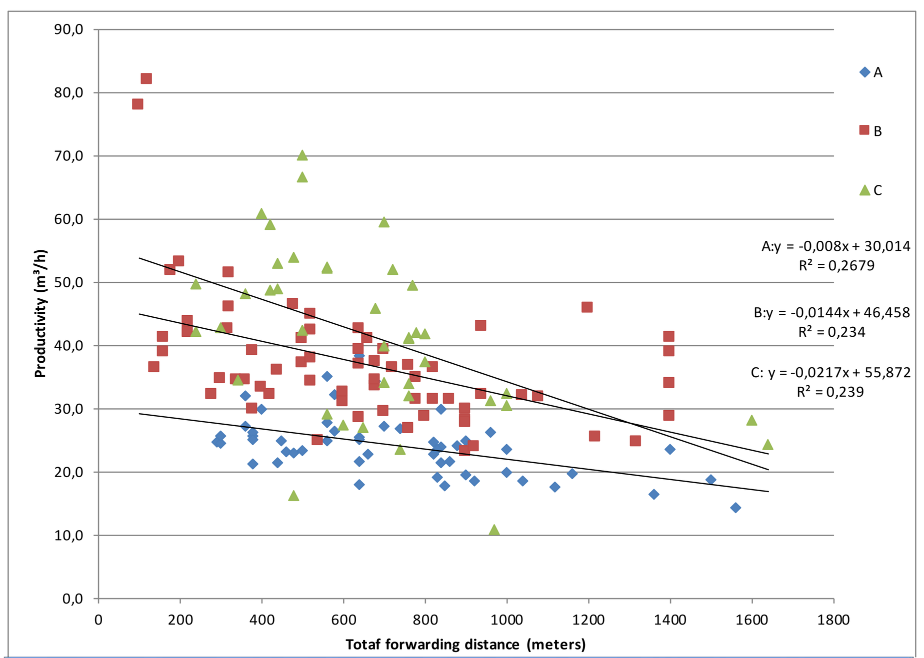

Figure 2. Relationship between average distance and productivity for forwarding at the three study sites.

Conclusion

Time consumption, productivity and costs of forwarding were calculated for two different models of forwarder, a John Deere 1110E and a John Deere 1910E based on data collected at three different sites. Forwarder productivity in cut-to-length forest harvesting systems is strongly positively correlated with the volume of payload and negatively with the average extraction distance. Even when considering the higher operating cost of the larger machines, the much higher productivity rates at the plantation clear-cut New Zealand sites resulted in significantly lower unit cost for extraction. The data provided show a clear opportunity for southern Italian sites adopting higher levels of mechanization, even if conditions such as steeper terrain, limited infrastructure or longer forwarding distance will negatively impact productivity. The data provided should help facilitate improved logging planning and consequently achieving cost competitiveness of the system for harvesting Calabrian pine.

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