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Mechanized harvesting operation in windthrow damaged stands: a case study in the Northeast Italy

Alberto Cadei [1]. Omar Mologni [2]. Raffaele Cavalli [1]. Stefano Grigolato [1]
[1] Department of Land. Environment. Agriculture and Forestry. Università degli Studi di Padova
[2] Department of Forest Resources Management. University of British Columbia

Background

The critical aspects to be addressed in salvage logging are different from the ordinary logging operation conditions, with an increment of the risk for the safety of the forest operators. Furthermore, as in the case of the Vaia storm in the eastern Alps, the high presence of damaged wood material in steep and very roughness terrain determines a really complex operation condition. This condition is a key factor for many Italian forest enterprises, which, due to the need to reduce the safety risk and to increase the logging productivity in salvage logging operations. are moving to full mechanized system with the introduction of harvester and forwarder machines.

Objectives

The objectives of the present study are to analyze time consumption, productivity and machine tilt of full mechanized Cut-to-Length system using wheeled harvester and forwarder in windthrow conditions in the Italian Alps.

Research methodology

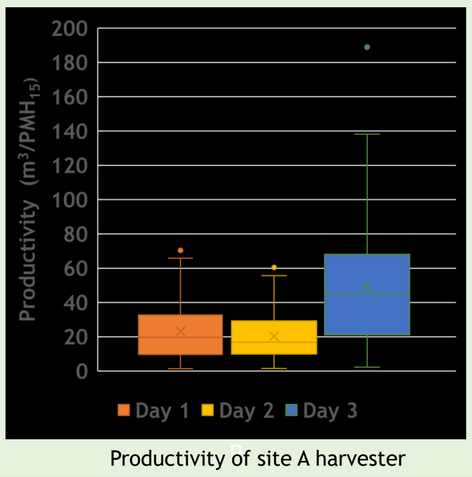
Field activities were conducted during spring 2019 in two sites (A and B).
Global Navigation Satellite System (*GNSS*) was installed in forwarder and harvester in order to collect the position of the machines. The landing points were market using the app *AvenzaMap*®. Hight frequency accelerometer was mounted on the chassis of harvester and forwarder. Action cameras were installed in the harvester and forwarder cabs and collected video in micro SD memory. Three power banks of 20000 mAh insured the power of *GNSS* devices and action cameras. Both cameras were set to at 720 ppm and time stamp function active. During any loading phases, high-quality photos were taken orthogonally to the machine in order to reduce perspective distortions. StanForD data (.hpr and .pri) were thus downloaded from on-board computer at the end of the field activities.
Significant variables in forwarder productivity were investigated using a random intercept to the adoption of linear mixed-effect models. The significance of the single variables was evaluated through the application of the Likelihood Ratio Test, testing the difference in two nested models using the Chi-square distribution. The significance level of the statistical analysis was set to 0.05. Statistical assumptions were checked analysing the residual plot distributions. In case of non-normal distribution of the residuals, logarithm and square root transformations were used, as appropriate, on both response variables and explanatory continuous variables.
The goodness-of-fit of linear mixed-models was tested through the coefficient of determination (R^2_{LR}).

Results

Harvester

832 harvester cycles were monitored in 33.73 hours (PMH_{15}), 785 total stems were processed into 2330 logs, total harvester volume was 518.78 m^3. Maximum average machine inclination was 18.1 % (St. dev. 0.67 %) measured during felling in site A and 12.6 % (St. dev. 1.16 %) during moving in site B. Highest maximum machine inclination was 41.8 % was measured during processing in site A and 32.8 % during processing in site B.

	Day	Total time	Delay	Stem number	Logs number	Average stem volume	Total volume	Productivity	
	-	min	min	n°	n°	m^3	m^3	m^3/PMH_0	m^3/PMH_{15}
Site A	1	260.62	6.97	98	377	0.71	69.79	16.51	16.07
	2	163.52	12.72	53	232	0.61	32.29	12.85	11.85
	3	344.95	17.78	101	428	1.34	135.41	24.83	23.55
Site B	4	521.58	39.12	332	831	0.58	191.38	23.80	22.02
	5	353.67	29.65	59	136	0.34	20.24	3.75	3.43
	6	241.82	47.75	140	326	0.50	69.67	21.54	17.29



Productivity of site A harvester

Forwarder

50 forwarder cycles were monitored in 34.27 hours (PMH_{15}), 647 m^3 of timbers were extracted. Maximum average machine inclination measured was 12.9 % (St. dev. 0.91 %) measured during travel loaded in site A, and 18.7 % (St. dev. 2.27 %) during travel while loading in site B. Highest maximum machine inclination measured was 30.4% measured during loading in site A and 42.1% during loading in site B.

	Day	Total time	Delay	Number of logs	Average log volume	Total extracted volume	Productivity	
	-	min	min	n°	m^3	m^3	m^3/PMH_0	m^3/PMH_{15}
Site A	1	138.98	15.8	183	0.23	41.49	20.21	17.91
	2	222.45	14.9	248	0.27	67.17	19.41	18.12
	3	263.47	9.1	453	0.25	114.23	26.95	26.01
Site B	4	419.17	37.6	436	0.26	113.46	17.84	16.24
	5	510.78	59.5	472	0.28	132.03	17.55	15.51
	6	501.30	58.6	498	0.36	178.92	24.25	21.42

N	Random intercept		R^2_{LR}
	variance	St.dev.	
50	0.0146	0.1207	0.771

N: number of observations; R^2_{LR}: coefficient of determination

Response variable	Explanatory variables						
	Coefficient	Unit	Estimate	SE	t-value	χ^2	p-value
Productivity (m^3 /PMH_{15})	Distance	m	$-4.452\ 10^{-4}$	$6.355\ 10^{-5}$	-7.004	28.42	<0.001
	Volume	m^3	$9.183\ 10^{-2}$	$7.613\ 10^{-3}$	12.062	67.09	<0.001
	Average machine inclination	%	$-2.493\ 10^{-2}$	$7.845\ 10^{-3}$	-3.177	8.77	0.003

References

Kärhä, K., Anttonen, T., Poikela, A., Palander, T., Laur, A. (2018). Evaluation of Salvage Logging Productivity and Costs in Windthrown Norway Spruce-Dominated Forests. *Forests*, *9*, 280. https://doi.org/10.3390/f9050280