Progress report:

A summary of current projects

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Summary

The following paper provides summaries of the work being done by Kayla Gagliardi, Marius Terblanche, and Zimbili Sibiya under the supervision of Prof. Pierre Ackerman and Mr Simon Ackerman. Each paper provides a brief over view of the study's objectives, methods, results, and conclusions.

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Multi-product forwarder based softwood timber extraction: Time consumption and productivity analysis of two forwarder models over multiple products and extraction distances

Kayla Gagliardi

1   Introduction

There is a substantial gap in forwarder productivity data for pine saw timber in South Africa at present, and as the number of product assortments being harvested increase, there is a need for more research to quantify the effects of extracting products of different dimensions. The aim of this study was to calculate the time consumption, productivity, and fuel consumption of two models of Ponsse forwarders (15-t and 20-t capacity) to compare the effects of multiple variables including machine capabilities, product assortment, load size, and extraction distance.

2   Methodology

In order to calculate and model productivity, a time study was conducted to obtain: the division of work time spent per element and per cycle, the distances travelled, and the speed of the forwarder while driving loaded and unloaded. Independent variables associated with machine productivity also recorded were product assortment, number of logs per load and approximate load volumes, speed while driving loaded and unloaded, distances travelled throughout each cycle, and fuel consumption. Machine productivity was measured according to the volume of logs (m^3) extracted per productive machine hour excluding delays longer than one minute (pmh_1), and compared between machines and products. Fuel consumption was estimated by recording the difference in diesel (l) consumed between the start and end of each shift from the machine's on-board computer. The amount of fuel consumed per shift was then divided by the length of the shift in productive machine hours ($l\ pmh^{-1}$) as well as by volume of logs extracted ($l\ m^{-3}$). From the overall litres consumed per machine it was possible to calculate logical rough estimations for the fuel consumed per product in $l\ m^{-3}$. This was done by dividing the total litres consumed per machine by the proportion of PMH_1 time spent per cycle for each of the assortments, and then by the total volumes extracted.

3   Results

Productivity averaged at 34.08 $m^3\ pmh^{-1}$ for the smaller machine, and 55.94 $m^3\ pmh^{-1}$ for the larger machine. Productivity and average log volume were strongly positively correlated. The average productivity of long saw log cycles was by far the highest for each machine, and for each machine, the long saw log productivity was more than double than for the product with the lowest productivity rate, which was Hewsaw (Figure 1).
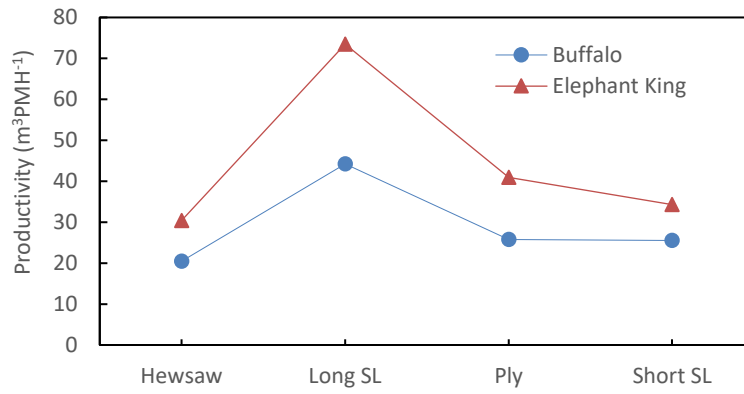
Figure 1. Comparison of mean productivities per machine and per product.

Multiple regression models were created overall for each machine where load volume and extraction distance were both significant factors for predicting productivity. Combining the overall data of the two sizes of machines allows for a more robust model (Equation 1), however, at the separate machine level, the regression equations developed accounted for more of the variation (Equations 2-3).

Overall productivity = 25.39 + 2.25 (LV) + -0.09 (ED) (1)

(n = 78, adjusted R^2 = 0.43, SE = 15.89, p < 0.01)

Buffalo productivity = 18.71 + 1.65 (LV) + -0.06 (ED) (2)

(n = 36, adjusted R^2 = 0.80, SE = 5.30, p < 0.01)

Elephant King productivity = 41.15 + 2.35 (LV) + -0.13 (ED) (3)

(n = 42, adjusted R^2 = 0.50, SE = 15.59, p < 0.01)

Where: LV = average load volume (m^3), ED = average extraction distance: the complete distance travelled while unloaded (m), Productivity = volume extracted per productive machine hour ($m^3 PMH_1^{-1}$)

Average fuel consumption of the smaller machine was 15.55 l pmh^{-1} and 0.47 l m^{-3}, and 20.57 l pmh_1^{-1} and 0.43 l m^{-3} for the larger machine. Estimates of fuel consumed per product showed that fuel consumption was lowest on average when extracting cycles of the largest product (long saw logs), compared to highest for the product with the smallest volume (Hewsaw) (Figure 2).
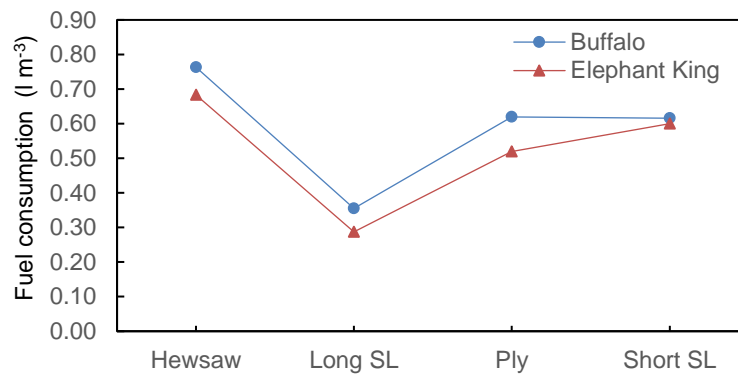
Figure 2. Comparison of mean fuel consumption L/m³ per machine and per product.

4   Discussion & Conclusion

The larger machine obtained a higher rate of productivity overall as well as for each individual product when compared to the smaller machine. Average log volume was strongly positively correlated with productivity, therefore the largest product assortment (long saw log) was significantly the most productive to extract for each machine. The smaller machine consumed less fuel per PMH_1 but the larger machine consumed less fuel per m^3, suggesting that the higher associated costs of larger machines can still be offset or surpassed based on higher rates of productivity and lower extraction costs per unit. Results obtained can contribute to the database of forwarder productivity in mechanized harvesting operations in South Africa. The models developed could aid with predicting and planning for improved system productivity and potentially reducing emissions under similar conditions and stand characteristics.

Unlocking the potential of harvester on board computer data in the South African Forestry value chain

Marius Terblanche

1   Introduction

South Africa is shifting from motor-manual and semi-mechanized to fully mechanized cut-to-length harvesting operations. There is now a marked increase of harvesters in the country, most of which are StanForD protocol compliant. This facilitates the collection of detailed tree and operational data. Through correct calibration of the on-board computing systems (OBC), it is possible to measure DBH and under bark (ub) volume quite accurately; however, this process is not fully understood or utilized in South African plantation forestry. The StanForD protocol has pre-set functions to deduct bark volume and determine ub tree and log volumes, but these pre-set functions are not adequate for South African species. The objective of this study is to develop and apply a suitable bark deduction method for South African *P. patula* on the Ponsse Opti control system running on purpose built Ponsse harvesters.

2   Methodolgy

As a first step, the change in bark thickness up the stem of P. patula was modelled using historical mensuration data. This model was then used to populate the bark deduction tables pre-set on the Ponsse Opti system for two bark deduction methods, namely: length based (Trial 2) and diameter class length-based (Trial 3). These two methods were then implemented and evaluated against a control (Trial 1 - no bark deduction method) of 40 trees each. As no bark deduction method is implemented in trial one the over bark (ob) measurements are the same as the (ub) measurements. All log assortments were physically measured for each tree with regards to small -and large end diameter, as well as length to determine the difference between machine and physical measurements.

3   Results and discussion

Table 1 shows that without the use of a bark deduction method, stem volumes can be over-estimated by as much as 13.68% and 14.59% for the length based and diameter-length based deduction methods respectively.

Table 1: Comparison of the difference in ob and ub volumes for each trial

Volumes	Trial		
	1	2	3
Total volume ob (m^3)	39.98	36.60	45.80
Total volume ub (m^3)	39.98	32.19	39.97
Volume difference (m^3)	0.00	4.40	5.83
Total number of stems	40	40	40
Average stem volume ob (m^3)	1.000	0.915	1.145
Average stem volume ub (m^3)	1.000	0.805	0.999
% ub and ob volume difference	0.00	13.68	14.59

Table 2 shows the percent difference between the manual control and harvester under bark diameter measurements at each crosscut position for the first three plywood logs cut from the stems in each trial.

Table 2: Comparison of the average manual control and harvester under bark measurements for the first three plywood logs cut from the stem.

Trial	Average Measurement height above ground (m)	Average Manual measured ub diameter (cm)	Average Harvester Diameter Measurement (cm)	% Difference measurements
1	0.17	37.31	45.90	18.72%
	2.81	31.96	33.70	5.17%
	5.45	30.80	32.12	4.11%
	8.09	28.64	30.07	4.76%
2	0.14	36.83	36.27	-1.54%
	2.78	30.08	30.89	2.64%
	5.42	28.86	30.00	3.81%
	8.06	27.36	27.90	1.94%
3	0.11	42.63	43.10	1.10%
	2.75	35.79	34.41	-4.02%
	5.39	34.42	34.29	-0.39%
	8.03	31.84	32.76	2.81%

In Table 3, the control trial, without any bark deduction method, showed a 16.36% difference between the harvester (ob) and manual control (ub) volume calculation for the first three plywood logs cut from the stem, while the two bark deduction methods achieved differences of only 3.82% and -1.48% (Table 1). Plywood log volume calculations tends to be the most affected as they are cut from the first 5.0 to 8.0 meters of the stem where *P. patula* bark is the thickest (Table 1).

Table 3: Comparison of the average log volume (m3) obtained from the manual control and harvester under bark measurements for the first three plywood logs cut from the stem.

Trial	Log number	Average Manual ub Log Volume (m³)	Avg Harvester Log volume (m³)	% Difference between manual and harvester volume
1	1	0.25	0.33	25.77%
	2	0.20	0.22	9.14%
	3	0.18	0.20	8.62%
	Total	0.63	0.75	16.36%
2	1	0.23	0.23	0.32%
	2	0.18	0.19	6.29%
	3	0.16	0.17	5.82%
	Total	0.57	0.59	3.82%
3	1	0.32	0.31	-1.77%
	2	0.25	0.24	-4.58%
	3	0.22	0.23	2.18%
	Total	0.79	0.78	-1.48%

Ergonomic risks assessment of manual and moto-manual pruning methods of Pinus patula stands in KZN Midlands in South Africa

Zimbili Sibiya

1   Introduction

The introduction of motor-manual pruning to forest operations by forestry companies in South Africa raises the question of potential related ergonomic risks in these operations. Reasons for the introduction of mechanized equipment is to improve productivity of pruning operations and quality questions. There are currently no known South African-related studies investigating the potential ergonomic impacts of either method on forestry workers to date. The research focused on comparing the effects the motor-manual pole pruner and traditional manual pruning saw has on the operator's health during 2.0 m and 3.5 m pruning lifts.

2   Research objectives

Main objective: An ergonomics risk assessment of manual and motor-manual pruning of *P. patula* stands in the KZN Midlands in South Africa.

Sub-objectives:

- Assess the physiological effects on the operator using either pruning method for the 2.0 m and 3.5 m pruning lifts by monitoring heart rates during pruning operations.
- Analyse and assess the psychophysical effects on the operator using either pruning method for the 2.0 m and 3.5 m pruning lifts based on body discomfort rating scale responses.
- Assess adverse body posture using photos taken during pruning operations.
- Determine productivity of either pruning methods for the 2.0 m and 3.5 m pruning lifts by applying time-studies..

3   Results (preliminary)

Data analysis to date indicates the following:

1. Physiological effects
   Manual 2.0 m operation are more strenuous operation for all the workers based on the high average heart rate during shifts (Figure 1).
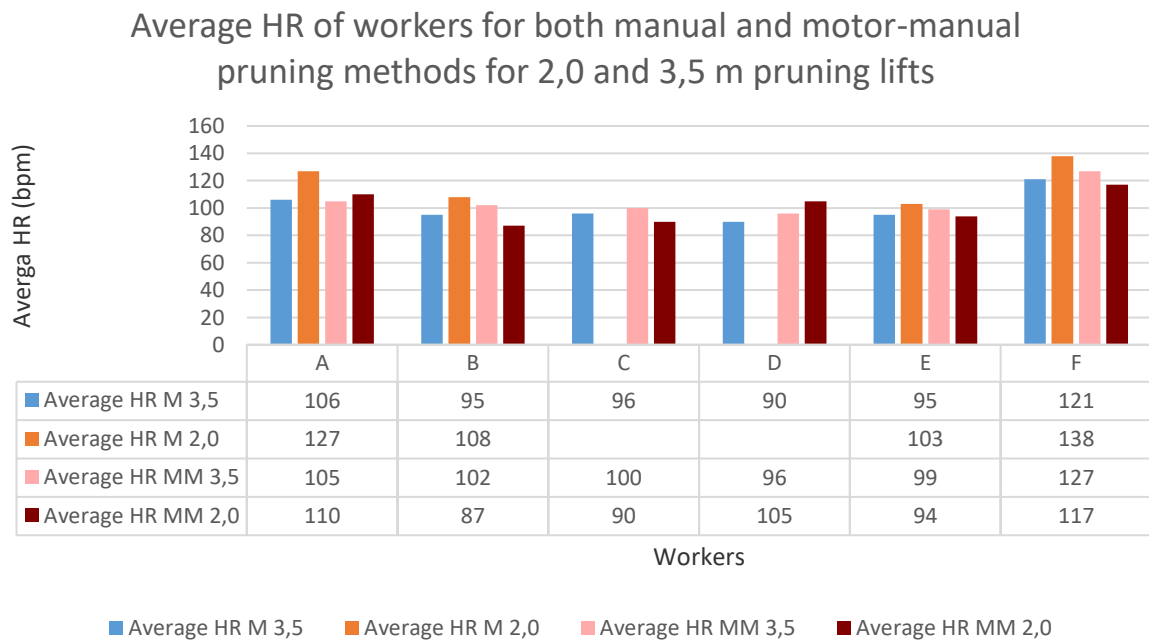
Average HR of workers for both manual and motor-manual pruning methods for 2,0 and 3,5 m pruning lifts

	A	B	C	D	E	F
■ Average HR M 3,5	106	95	96	90	95	121
■ Average HR M 2,0	127	108			103	138
■ Average HR MM 3,5	105	102	100	96	99	127
■ Average HR MM 2,0	110	87	90	105	94	117

Workers

■ Average HR M 3,5   ■ Average HR M 2,0   ■ Average HR MM 3,5   ■ Average HR MM 2,0

Figure 1: Participant's average heart rate data throughout the study which indicates the workload experienced by each of the workers with both pruning methods. (Worker C and D were not available for the manual 2.0 m operations during the data collection period and therefore, their data could not be recorded).

2. Psychophysical effects

The body discomfort map (Figure 2) had 27 body parts on which the workers could rate their discomforts. However, the results only show discomfort on the upper body, which limits it to 18 body parts (Figure 2). This gives an indication of the body parts that get most affected during these operations.
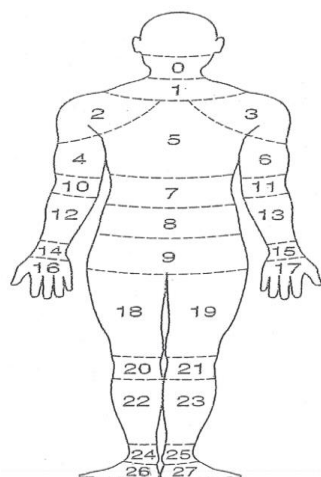

Figure 2: The Nordic musculoskeletal disorder body discomfort map indicating areas of body parts that could possibly be affected by the pruning tasks. Extracted from (Kudakwashe, et al., 2016)

The participants experienced less discomfort during manual pruning operations at both 2.0 m and 3.5 m pruning lifts compared to the motor-manual operations (Figures 3 and 4).
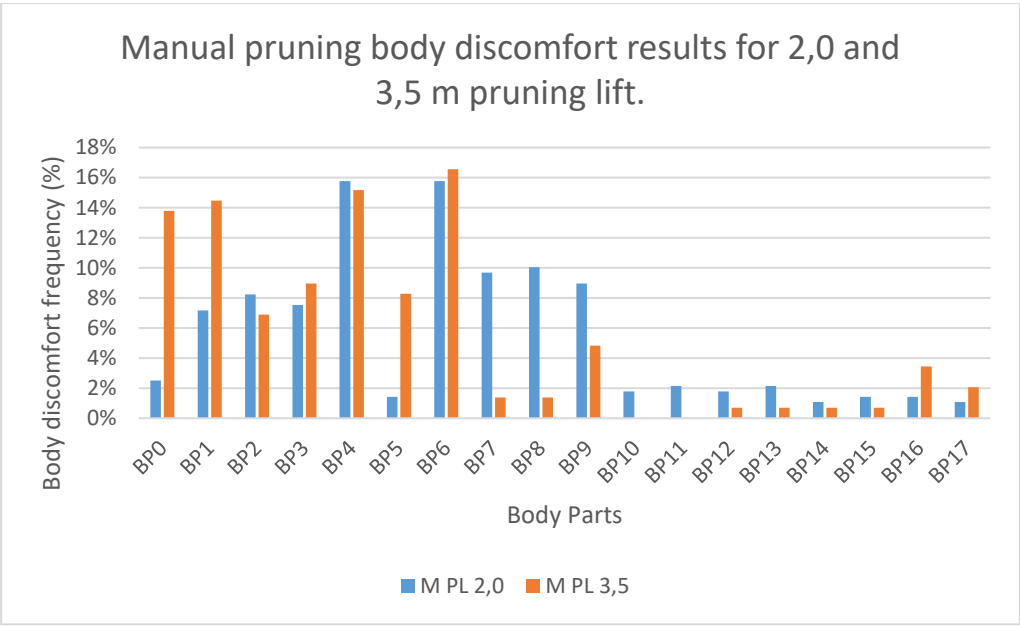

Figure 3: Overall body discomfort reported by study participants for the manual pruning operations at both pruning lifts.
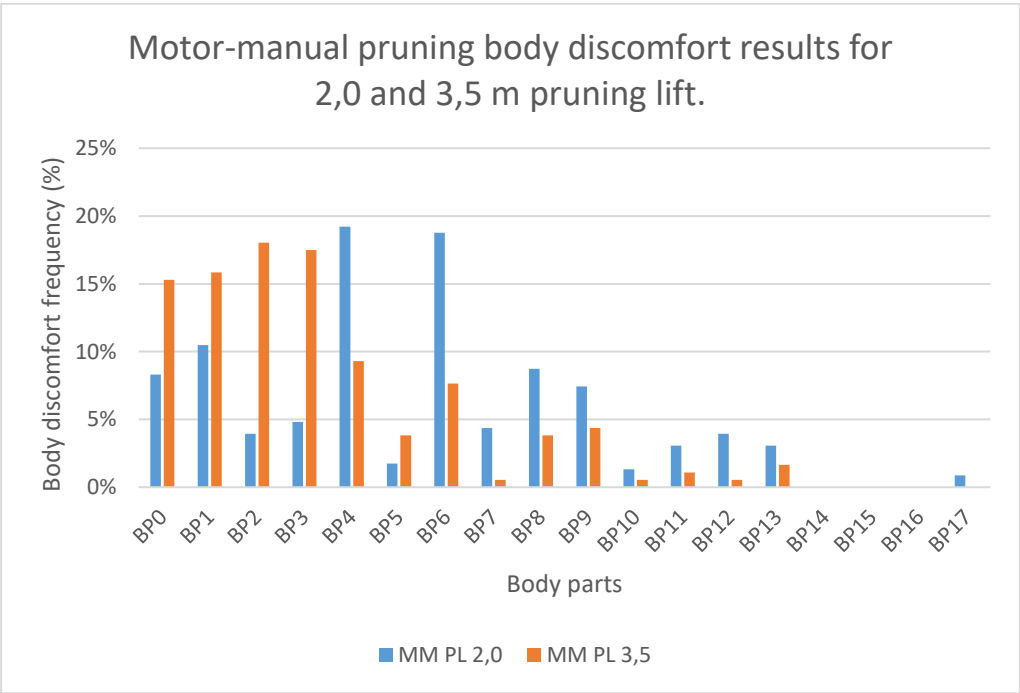

Figure 4: Overall body discomfort reported by the study participants for the motor-manual pruning operations at both pruning lifts.

3. Adverse Body Posture

- The 3.5 m pruning lift operations for both manual and motor-manual pruning methods require from operator to laterally bend and extend the neck in various directions while pruning.
- The 2.0 m pruning lifts operations for both manual and motor-manual pruning methods cause the operator to bend to reach the low branches, resulting in a lumbar flexion.

4. Productivity

- The motor-manual operations showed increased productivity compared to the manual operation at both pruning lifts regardless of the increased task target for motor-manual operations (Table 1).

Table 4: Productivity of each operator for both manual and motor-manual pruning methods for 2.0 m and 3.5 m pruning lifts. Worker C and D were not present for the 2.0 m manual pruning during the data collection period.

Method	Manual	Motor-Manual	Manual	Motor-Manual
Pruning Lift (m)	2,0	2,0	3,5	3,5
Worker A (tree pmh^{-1})	41	62	60	131
Worker B (tree pmh^{-1})	19	49	52	115
Worker C (tree pmh^{-1})		61	45	104
Worker D (tree pmh^{-1})		57	52	117
Worker E (tree pmh^{-1})	28	81	59	136
Worker F (tree pmh^{-1})	26	63	48	125

The workload (HR), monotonous and repetitive motions, and adverse postures during pruning operations indicate ergonomic risks associated with pruning operations. The study is yet to find the best practices to mitigate the identified ergonomic risks.

4   Discussion and conclusion

The findings so far in the study gives an indication of a necessity to move to mechanized operations for less strenuous workload and increased productivity. The motor-manual pruning method has its own risks of increased injuries, the effect of vibrations (motor) and noise, however, these can be avoided through safe practices and PPE (personal protective equipment). The general discomfort was experienced in the arms, and not as much on the back as expected. In the manual 2.0 m operations,

however, there was quite a high frequency of discomfort responses for the lower back. There is an indication of a high possibility of workers experiencing long term back problem with manual pruning operations specifically, as even with the 3.5 m pruning lift, there is a higher frequency of discomfort experienced.

There is still more work that needs to be done around this topic and I hope that it can be explored further with a much larger group of participants and the gender variable to be included.