HARVESTING TECHNICAL NOTE

HTN08-03

2015

Data Capture from Harvester On-Board Computers

Summary

Previous FFR studies have shown that there are many opportunities for improving forest management practices using the data captured by harvesters during felling and processing operations. This study analysed data obtained from a GNSS-enabled Ponsse Ergo 8W harvester operating in four different species of Eucalyptus in Uruguay. By recording the time taken to harvest each tree, productivity models were produced using factors such as DBH, species and operator. The analyses showed clear differences between species, and this can be valuable in predicting harvest cost differences. The data also showed significant differences in operator efficiency, which could be useful in assessing skills and training requirements. By recording the exact volume of the tree and its geospatial location, stand productivity maps were created showing different stand densities. This information could be useful for silvicultural planning. This case study demonstrated that data from GNSS-enabled harvesters can add value to plantation forest management.

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Introduction

Previous FFR work has shown that production data from forest harvesters has been used world-wide in many forestry and forest operations applications (Olivera *et al.* 2014). With the addition of an integrated Global Navigation Satellite System (GNSS) receiver, other management applications exist, such as machine productivity assessment, in-forest navigation to aid the machine operator, and reconciliation of forest inventory (Olivera and Visser, 2014). The goal of this study was to capture and analyse harvester data and assess the feasibility of using such data for applied management purposes in the New Zealand forest industry.

During 2013, numerous attempts were made to capture plantation harvesting data from grapple harvesters operating in New Zealand, but no GNSS-enabled harvesters that could provide reliable data were found to be operating. Although a few Australian operations were capturing and using harvester data, their companies were reluctant to share such data, which highlights the issues of commercial sensitivity of such information, and data ownership. Eventually, a willing collaborator for the study was found in Uruguay (Figure 1).

Figure 1: Geographic location of study sites

The forestry sector in Uruguay has grown considerably in recent years from less than 100,000 hectares in 1990 to 990,000 hectares in 2012 (40,000 ha/year). *Eucalyptus* species make up 73% of this area while pine plantations represent only 26%. It is estimated that over 60% of the annual volume of 10 million cubic metres is harvested each year using the cut-to-length (CTL) harvesting system (MGAP DGF 2014). Therefore with a lot of harvesters operating in Uruguay there is a large database of information potentially available for this study.

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Study Area

The forest plantations harvested were owned by the company Montes del Plata, located in the western part of Uruguay. The terrain had gentle slopes, mostly below 6% slope, and occasionally over 12%. Soils in the area were loam, predominantly deep, with a medium level of fertility (MGAP 2008).

Each harvested unit in the study corresponded to even-aged, single species, first rotation stands. The stands include four different species of Eucalyptus (*E. bicostata, E. dunnii, E. grandis and E. maidenii)*, two of which had two different age classes, and were harvested between March and October 2014 (Table 1).

Table 1: Description of the harvested stands

		E. bicostata [a]	*E. dunnii* [b]		*E. grandis* [c]	*E. maidenii* [d]	
Plantations caracteristics[e]	Plantation age (years)	19	16	19	16	15	19
	Average DBHOB[f] (mm)	207	206	223	204	183	200
	Average volume (m^3 ha^{-1})	273	287	546	288	240	261
	Average height (m)	21.3	21.9	29.2	22.8	20.4	21.8
	Stocking (trees ha^{-1})	952	759	1000	682	933	781
	Mean tree volume (m^3)	0.29	0.35	0.55	0.39	0.26	0.35

[a]*Eucalyptus bicostata* , Maiden, Blakely & Simmons; [b]*Eucalyptus dunnii* , Maiden; [c]*Eucalyptus grandis* , W.Hill; [d]*Eucalyptus maidenii* , F.Muell; [e]Data from Pre-harvest inventory; [f]DBHOB = Diameter at breast height over bark

Study Method

The data for the study were retrieved from a single-grip Ponsse Ergo 8W harvester equipped with a Ponsse H7euca specialised harvester head designed for processing and debarking eucalypts (Figure 2).

Figure 2: Ponsse Ergo harvesting in Eucalyptus stands.

A combined GSM-GNSS antenna was fitted on the cabin for geospatial data collection and communication. The control system was Opti4G 4.715, which complies with the StanForD standard (Arlinger *et al.*, 2012). This machine was one of a group of five harvesters and three forwarders working in the region.

The operation ran from Monday to Friday in double shifts – day shift from 7:00 to 17:30 and night shift from 20:30 to 7:00, and Saturday from 7:00 to 15:00. All harvested trees were debarked for pulpwood at a standard log length of 6.5 m, and a second grade of variable length logs between 3.0 m and 6.5 m.

During this period, three different operators operated the harvester. Two operators were considered experienced, defined as having more than 12 months' experience (Purfürst and Erler 2011), whereas the third operator had only 10 months' experience. Initially all operators were trained by Ponsse professional instructors – 60

hours of theoretical training, 60 hours of practical training in simulator and 48 hours of practical training in the field.

The training programme included instructions to identify and record downtime as it happened during the operation. On-board computer measurement calibration was performed weekly or when a new site was started (whichever happened first), or if a difference higher than 8% between inventory predictions and harvester records was detected, or when a sensor in the harvester head was fixed or replaced.

Overlaying the harvester data on a Google map provided a clear visual indication of harvester progress through the stand (Figure 3).

Figure 3: Visual indication of harvester progress through the stand (each purple dot represents a harvested tree).

To model harvester productivity, both individual tree registers and work statistics recorded under the StanForD standard as stem files (.stm files) and operational monitoring data (.drf files) respectively were used (Olivera and Visser, 2014). Stem files contain compressed data for each individual processed stem (Figure 4).

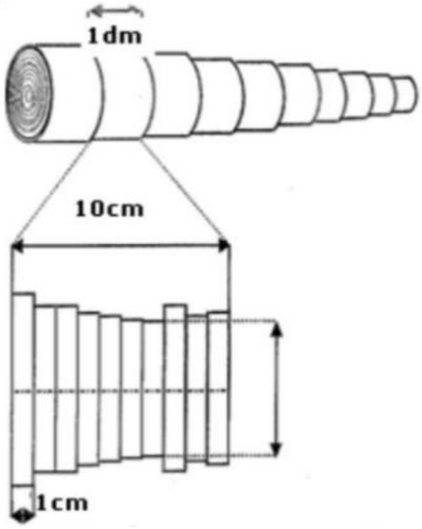

Figure 4: Stem files record diameter at 10-cm intervals for the whole stem, as well as number and grade of logs cut from each stem.

From .stm files, the following information was extracted for each recorded stem:

- stem ID,
- geographic coordinates (latitude, longitude and altitude),
- DBH, total harvested volume, merchantable volume only, merchantable height, and stem small end diameter (SED),
- time stamp (year, month, day, hour, minute and second) for when the tree was felled, and
- operator identification.

A shift (day/night) attribute was assigned to each stem according to the time stamp. The .drf are specific files for operational machine monitoring and contain detailed information on the use of time and mechanical events during the operation.

A macro-enabled spreadsheet in Microsoft Excel 2013 was created to extract and manipulate the data from original text files as downloaded by the harvester on-board-computer. From the original data set of 67,581 trees harvested, 63,717 were used.

Examples of trees discarded from the dataset were those that included a delay time element in the felling cycle, cycle times that were unusually short or long, and trees that had a DBH of less than 40 cm or were smaller than 3 metres in height. This process of 'cleaning' the raw data is both cumbersome and time consuming but necessary for the analyses not to be biased through extreme outliers. As such, approximately 6% of all stem files recorded by the harvester were removed.

Results

Machine Productivity

The average tree size harvested was only 18 cm DBH, which is very small by New Zealand standards. By dividing the tree volume from the stem file by the length of time between felling events as shown by the time stamp in the data file, machine productivity was calculated. The average productivity for all of the data was 30 m^3/hr. As expected there was a clear trend of increasing productivity with increasing DBH (Figure 5).

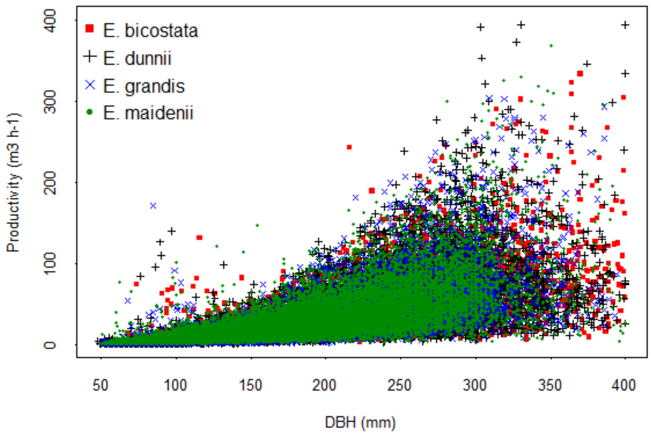

Figure 5: Graph of productivity per processing hour (all records) as a function of DBH showing distribution of points.

For example, at 30 cm DBH the average productivity was 65 m^3/hr. Results also showed that larger diameter trees increased the level of variability, as some large trees that were felled and processed quickly had very high productivity (up to 400 m^3/hr). All these results are expressed in units per processing hour, not scheduled time, which is consistent with previous studies of the effect of harvesters nearing their upper limit of capability (Visser and Spinelli, 2012).

Separating out the data by species, it was possible to create productivity curves relative to tree DBH. The data showed significant differences, with *E. dunnii* being 10% more productive to harvest compared to *E. bicostata* (Figure 6). By modelling such an effect it is possible to predict harvester productivity and cost more accurately given future stand characteristics of tree size and species.

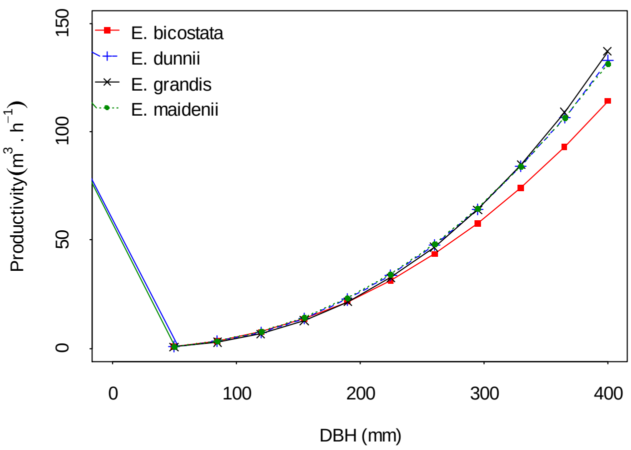

Figure 6: Productivity predictions by the model. Results expressed by species per processing hour.

Even though the three operators in the study undertook a similar training programme, they showed differences in performance for each species. Interestingly, the operator with only 10 months experience displayed average productivity, which suggests that experience does not necessarily explain performance. For example, for *E. maidenii* at DBH of 200 mm (the diameter class with the highest frequency) operator 1 outperformed operators 2 and 3 by 30% and 11% respectively (Figure 7). Such information can help identify operator skill levels, and to effectively target training.

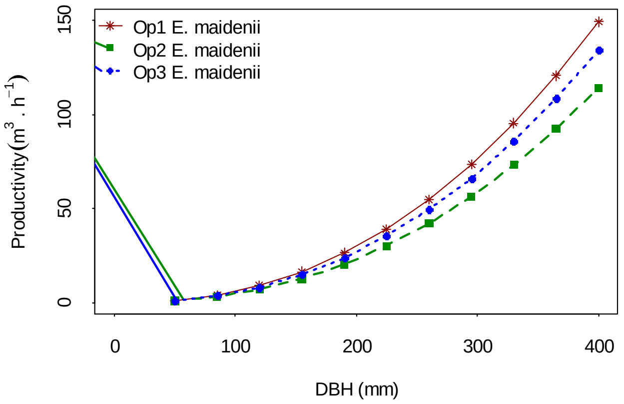

Figure 7: Operator's productivity predictions by the model for E. maidenii. Results expressed per processing hour.

It was also possible to investigate the effect of day versus night shift, but interestingly there was no significant productivity difference for any of the three operators.

Stand Productivity Mapping

Only a small percentage of the area harvested had slopes greater than 6%. By overlying the data on a digital elevation model (DEM) in ArcGIS it is also possible to analyse the effect of slope, but as slopes up to 12% are well within the capability of a Ponsse Ergo, no effect on productivity was found.

From the individual tree volumes and locations, it was also possible in ArcGIS to create a 'contour' map of stand productivity (Figure 8). This map highlights areas of high stand productivity. In Figure 8 the dark blue colour was greater than 496 m3/ha, whereas the red areas had stand productivity of less than 420m3/ha. This is important information for planning subsequent silvicultural decisions. For example, an investigation of the red area might reveal a nutrient deficiency.

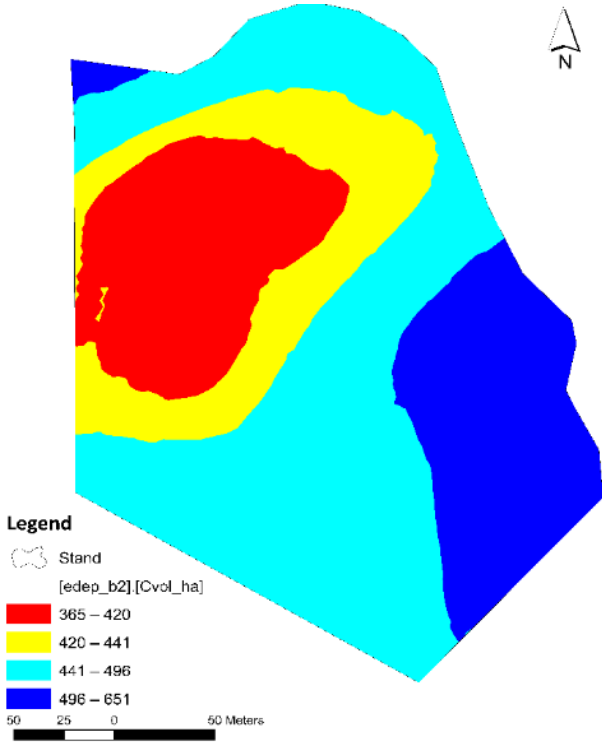

Figure 8: A stand productivity map (m^3/ha) produced from the harvester data.

Conclusions

Harvesters are not only timber processors but also powerful data recorders. This case study has shown that the data captured by the harvester can be effectively used to establish productivity models that allow for differentiation not only between species, but also between operators. However, it should be noted that significant amounts of work were involved to process the data for analysis. As such, a logical next step is to automate processes such as data extraction and data cleaning so that data can be more readily used as a management tool.

Acknowledgements

The authors would like to thank the Uruguayan company Montes del Plata for authorizing the use of the data used in the study. Special thanks to Ponsse Uruguay S.A. for their support and provision of data from the operations in Uruguay.

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