Using the harvester on-board computer capability to move towards precision forestry

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Abstract

Modern forest harvesters and processors have the capacity to generate and record a lot of data using on-board sensors and computers. Outputs contain detailed data for stems, logs cut and time. When the Global Navigation Satellite System (GNSS) function is available geospatial coordinates and time stamps can also be included. Not only does it offer a navigation tool to aid the machine operator, it also generates opportunities for detailed production reports, machine productivity assessment and forest inventory reconciliation.

A possible further application of such technology is the generation of forest productivity maps that can help us to predict, with a high level of detail, the characteristics of the forest across the terrain. Having a detailed forest productivity map could serve as a means of understanding variations across sites and exploring the possibility of site-specific management for future rotations, a concept also known as precision forestry.

Future Forests Research supported this project as part of their harvesting research programme goal to realise gains in productivity and reduce the cost of harvesting by introducing improved harvesting technologies. Innovation is not only finding and developing new technologies, but also taking full advantage of what is already available.

Modern harvesters and StanForD

Modern harvesters are equipped with computers capable of collecting and storing a great deal of data on stem measures, harvesting production and machine parameters. This data is automatically collected by the measurement system in the harvesting head, GNSS receiver, harvesting directives and records of operators' decisions (Möller et al., 2011). The information is recorded using a de facto standard called StanForD (Standard for Forest Data and communication), which is used by all major manufacturers of cut-to-length (CTL) machines across the world (Arlinger and Möller, 2007).

There are about 25 file types generated by StanForD (Skogforsk, 2007). For forest and harvesting operation data management, the most commonly used are prd, apt, pri, drf and stm files. Note that apt files are produced by the user, whereas the others are produced by the machine computer.

- *prd*

  production files, primarily harvesting production data, which contain the summary of volume and number of pieces per sort for a given period (e.g. a shift, a day or a week) or harvest unit

- *apt*

  cross-cutting instructions, including price matrices per sort that the harvester uses to maximise the value of each stem or fill a production order

- *pri*

  production-individual file of harvesting data (length, diameter and volume) for each individual log and stem

- *drf*

  operational monitoring data, which covers both work time and repair time monitoring

- *stm*

  stem files, which are compressed data for each individual processed stem (tree), including all diameter sections measured at 10 cm intervals.

StanForD uses two codes ('variable' and 'type') to standardise data capture for specific parameters, followed by the actual data that is being recorded. A StanForD data record for an individual tree, along with an explanation of the data, is shown in Table 1.

While StanForD files contain useful data, the process of extracting, storing and analysing it is complex. Software, for example SilviA, is used by both John Deere and Waratah to make reading, creating and editing StanForD files easier. Advanced software, such as TimberOffice from John Deere and Ponsse Opti from Ponsse, can be used to manage operations and fleet control.

An obvious use of harvester data is reporting daily (or shift-level) production, which is readily available in the prd summary files. Data collected in the stm and pri files can be useful for assessing the real volume harvested within a stand, and to reconcile with inventory predictions and check or validate the accuracy of the prediction models.

Table 1: Part of a stm file for a single harvested stem and explanation of the data

110 2 1~270 1 27~270 2 0~270 3 27~38 1 J Cabrera~38 4 0~38 5 0~523 1 3257956~523 2 2~523 3 5740183~523 4 2~523 5 101~523 6 20140522212527~		
Register	**Explanation**	**Information contained**
110 2 1~	Variable 110 type 2	Species code, e.g. 1 = Eucalyptus
270 1 27~	Variable 270 type 1	Stem identity = 27th tree harvested for the harvesting unit
270 2 0~	Variable 270 type 2	0 means no information contained
38 1 J Cabrera~	Variable 38 type 1	Machine operator = J Cabrera
523 1 3257956~	Variable 523 type 1	GNSS latitude = 32.579560
523 2 2~	Variable 523 type 2	Latitude 2 = southern hemisphere
523 3 5740183~	Variable 523 type 3	GNSS longitude = 57.401830
523 4 2~	Variable 523 type 4	Longitude 2 = western hemisphere
523 5 101~	Variable 523 type 5	GNSS altitude = 101 m above sea level
523 6 20140522212527~	Variable 523 type 6	Felling date and time: year 2014, month 05, day 22, hour 21, minutes 25, seconds 27

Note: The first row shows the form the data is displayed in the original text file. The body of the table explains the meaning of the information contained. Source: adapted from Olivera (2015)

When machines are calibrated properly and frequently it is likely that this data will be more accurate than traditional plot sample inventories (Gordon, 2005; Murphy et al., 2006), because it is a full enumeration (a census) of all trees and their correspondent measures of quality. An example of its application is shown in Figure 1, where data from about 2,000 stems harvested in a *Eucalyptus dunnii* plantation in Uruguay are used to determine best fit regression for both merchantable height and diameter at breast height (DBH) distributions (Olivera and Visser, 2014).

If the GNSS function is available and enabled, machine position at the time of felling and machine tracks can be recorded and displayed in real time on the machine's computer screen. The advantages of having an on-board navigation system capable of displaying geospatial information have been described by Marshall (2012). Several harvester control systems have a navigation system capable of displaying a range of base layer maps, which can include raster and vector data such as digital elevation models (raster feature), stand maps (polygon feature) and power lines (line feature).

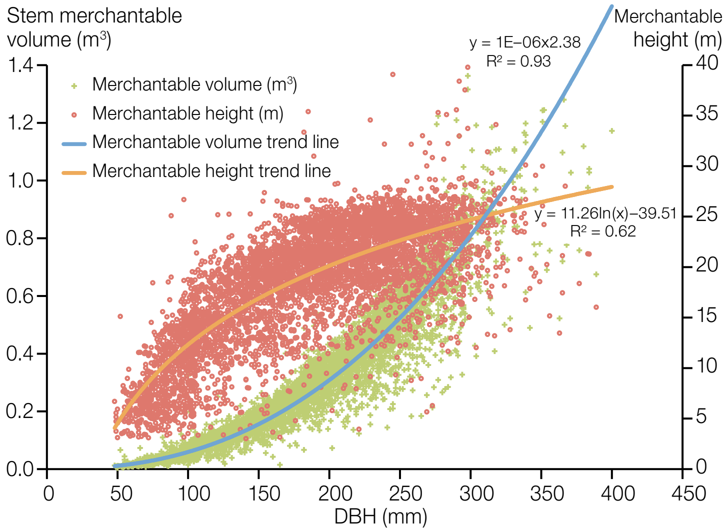

Figure 1: Volume and merchantable height as a function of DBH. Source: data from stem files

The operator can navigate with a map displaying stand boundaries as well as restricted or dangerous areas based on the outputs presented on the machine's computer screen. Additional functions such as recording points (e.g. features of interest) and calculating areas are available in some of the systems. Figure 2 overlays the harvester data on a Google map, providing a clear visual indication of harvester progress through the stand.

The GNSS allows the on-board computer to record longitude, latitude and altitude coordinates and (in some machines) time stamp in stm files when a tree is felled or starting to be processed. The work statistics function builds a record of all 'sub-activities' (e.g. working, travelling, idling etc) performed by the machine (Figure 3), recording the data as drf files (Table 2). A number of studies have shown this system to be accurate, reliable and effective in evaluating machine productivity (CRC for Forestry, 2010; Gerasimov et al., 2012; Linhares et al., 2012).

Tracking machine travel across the terrain with GNSS allows the establishment of machine productivity patterns related to both terrain characteristics (relief, soil attributes) and forest characteristics (stocking, individual volume). Several studies based on ground methods have established significant differences in harvester productivity (expressed in m^3/hour) and hence cost related to slopes (Fernandes et al., 2013; Simões and Fenner, 2010), soil type (Malinovski et al., 2006), and individual tree volume (Bramucci and Seixas, 2002; Burla, 2008; Heinimann, 2001).

GNSS machine tracks have also served as a source of data to study the environmental impacts of forest operations such as soil compaction (McDonald et al., 2002; Seixas et al., 2003), and the delivery of sediment to streams from forest harvest operations on steep terrain (Bowker et al., 2010). In combination with digital accelerometers, Berkett (2012) assessed machine slope relative to terrain slope.

Figure 2: Visual indication of harvester progress through the stand – each purple dot represents a harvested tree

Precision forestry: creating a silvicultural feedback loop

While the previously mentioned applications are useful, significant further opportunities still exist. The use of geospatial technologies in forest machinery for research or management purposes is included under the term 'precision forestry'. Precision refers to the use of computers, sensing technologies and other state-of-the-art electronics to coordinate and control processes at spatial scale, and to manage temporal variability (Heinimann, 2007; IUFRO, 2006).

Even though there is not a unique definition for precision forestry as a discipline, all those who have provided definitions agree that it is the use of modern technology and data processing for sustainable site-specific management throughout all forestry activities. The precision management concept should be applied to all planning, control and operations, including processing and merchandising, whether for forest products, forest and environmental services and/or ecological values (Bare, 2001; Dyck, 2003; Heinimann, 2007; Kovacsova and Antalova, 2010; Sarre, 2001; Taylor et al., 2011), and it is already widely applied within agriculture.

A forest yield map with information of volumes and quality at a detailed level would be a useful tool for research and decision-making for the next rotations.

Table 2: Information extracted from drf files showing work statistics and productivity information

Start time	End time	Volume (m³)	Number of logs	Fuel consumption (l)	Distance driven (m)	Work type	Number of stems cut
05–22 20:25:44	05–22 20:39:11	0	0	3	1882	Road travel	0
05–22 20:39:11	05–22 20:55:58	5.33	28	6	80	Harvesting	8
05–22 20:55:58	05–22 20:58:31	0	0	2	47	Terrain travel	0
05–22 20:58:31	05–22 21:54:24	23.8	162	20	83	Harvesting	49
05–22 21:54:24	05–22 21:55:32	0	0	0	7	Terrain travel	0

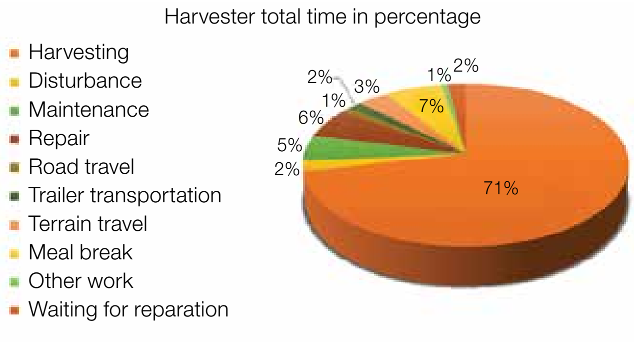

Figure 3: Proportion of time for the various activities performed by the harvester

Assessing the micro-level forest productivity variations can help forest managers and forestry researchers make the best decisions and define the most sustainable and profitable practices for the next rotation (such as fertilisation, plantation density and the most suitable progeny species to be planted).

Additionally, with that information it is possible to define, update and improve site index analysis, productivity models and volume functions. Based on this information the variation in volume across the terrain (the site) can be evaluated and the more productive areas determined according to final stocking, geographical position and seed origin (Ortiz et al., 2006; Vergara, 2004). These spatial variations can also serve as a basis for site stratification according to productivity. Having high-resolution stratification evaluations, activities such as soil sampling to further better understand how forest productivity is correlated to soil attributes can be determined.

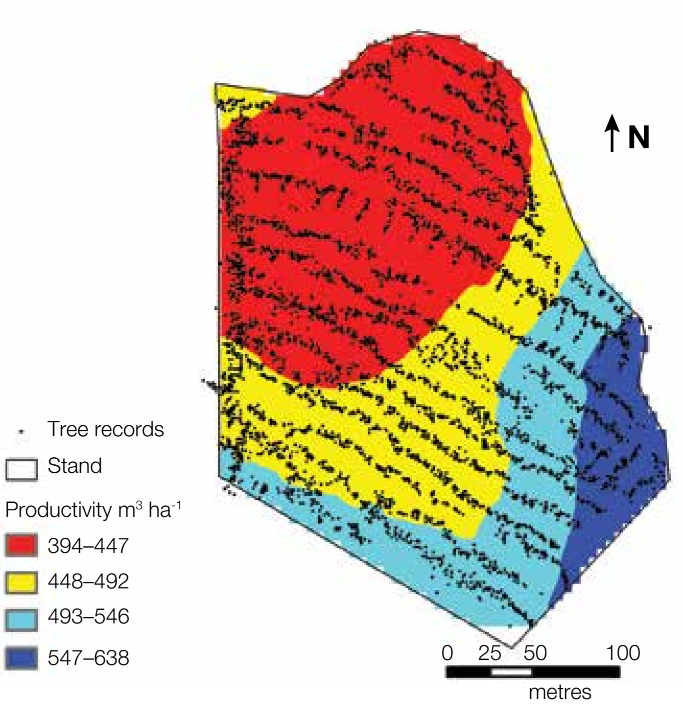

Figure 4: A stand productivity map (m³/ha) produced from the harvester data. Source: adapted from Olivera (2015)

Using a sample data set created in Geographic Information System (GIS) software using GNSS-enabled StanForD files, specifically the stm files (Olivera, 2015), the total number of trees harvested and their spatial distribution, and by combining the tree volumes in a GIS, it is possible to generate a stand volume density map (Figure 4). It can show that specific areas in the stand have outperformed others in terms of total growth.

Conclusions

Harvesters are not only timber processors, but also powerful data recorders. Several opportunities arise from both the use of StanForD files and the navigation tools from GNSS-enabled harvesters. Taking advantage of these opportunities helps not only the harvesting operation itself, but also the whole forest process. Integrating harvester head software and GNSS provides a reliable and low cost source of information for forest productivity mapping.

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