FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

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Using GPS to Monitor Machine Performance

Summary

This report describes an example use of the Global Positioning System (GPS) to monitor machine performance. A GPS receiver was placed in the cab of a Volvo 150F wheeled loader, and GPS data were collected during the working shift. At the same time data from the Volvo Machine Tracking Information System (MATRIS) were collected, as well as video footage from a cab-mounted camera. Machine performance information, such as utilisation, travel speeds, distances, loading times and delays, derived from the GPS, MATRIS and video was compared. The GPS-derived data were found to closely match information from the other two sources, and it is recommended that the GPS data collection method could be applied successfully to machines in many forestry operations, such as felling and bunching, skidding and loading, to establish productivity, haul distance, and the effects of terrain on machine performance.

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Introduction

The Global Positioning System (GPS) is a global satellite-based navigation system that has the capability of locating objects (such as machines) in 3D space at a known time. GPS is already well established in areas such as personal and vehicle navigation and in monitoring truck transport. In forestry, it is widely used in New Zealand for flight path guidance and recording for aerial spraying and baiting operations.

GPS can also be useful in calculating distance travelled and average travel speed of forestry machines (Figure 1). There may also be benefit in using the system to identify time spent carrying out defined tasks at a given location as well as recording distance travelled. In the forest, tasks may include felling and bunching or skidding, or loading. Machine performance could then be described as minimising time spent or distance travelled per task, or minimising stopped or idle time. Information could be gathered on machine utilisation over time, peak usage, and downtime periods.

Previous FFR reports have examined the potential for GPS data collected by data loggers such as the MultiDat (Evanson, 2009) where GPS tracking of a skidder was described. Parker *et al*. (2010) also described the use of GPS tracking devices, in conjunction with video techniques to locate and describe the activity of rural fire fighters in fire fighting operations.

Figure 1: The QSTARZ BT-Q1000XT Travel Recorder positioned on the windscreen of the log loader.

On-board monitoring systems such as Komatsu's Komtrax and Volvo's Machine Tracking Information System (MATRIS) use data from an ECM (Electronic Control Module, also known as an EC Unit) to provide machine performance information for contractors and machine suppliers. This can include "geo-fencing" (warning when the machine exits a pre-defined area) and warnings when other machine parameters such as pressures or temperatures exceed set limits. Most of the systems offered by all the major forestry equipment suppliers also offer GPS and satellite communication as well

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as download of information *in-situ*. These packages do not usually enable detailed analysis of the machine's track since the prime consideration is the performance of the engine and associated hydraulic/electric functions (Evanson, 2010).

Figure 2. The Volvo 150F loader used in the study.

Accuracy issues and GPS performance under the tree canopy are key considerations. GPS systems without differential correction from a base station have accuracy limitations. Low cost GPS receivers don't utilise the differential correction method that enables sub-metre accuracy. Sometimes there is loss of coverage or positional accuracy as satellite alignments change. Forest canopy can reduce the quality of signal received by the GPS receiver.

Research aimed at determining forest machine productivity using GPS methods has been previously reviewed (Taylor *et al.,* 2001). The authors noted accuracy considerations and reported on GPS machine tracking studies, some of which looked at skidder tracking from a soil disturbance perspective. Other studies looked at skidder productivity and sought to identify work cycle elements. In one unpublished study, quoted by Dupre (2006), the researchers developed and used automated pattern matching to reduce the GPS data from a grapple skidder to three common elements: travel loaded; travel empty; and grapple (McDonald and Fulton, 2005).

Effective research in this area is limited to studies post-2000 because prior to that date US military requirements demanded deliberate inaccuracy ("selective availability"). One study reported position accuracy improving from 73.3m to 8.3m (Liu, 2002) with selective availability disabled.

Another study by Dupre (2006) was aimed at exploring the feasibility of using GPS for time study of a grapple skidder. The author found that GPS times were not significantly different from those of time study for travel empty and grapple time. But values for travel loaded and unload grapple were different. Recording intervals of five seconds and one second were tested and the longer interval was found to be easier and faster to analyse. This was possibly because the combination of very short time intervals and limited position accuracy suggested movement when in fact the machine was stationary. It was recommended that GPS data collection methods be linked to those recorded by an observer on the skid.

This project is part of Future Forest Research's harvesting research programme in reducing unproductive time through better monitoring systems.

Study Method and Location

This study used a low-cost GPS tracker, video recording, and the on-board computer (ECU) data of a log loader in a log yard operation to examine the potential for the GPS data collection method to be applied to other forest harvesting operations.

Key machine performance factors, such as utilisation, travel speeds, distances, loading times and delays, derived from the GPS, MATRIS and video were compared.

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The location for the study was the Central Processing Yard at Kawerau, Bay of Plenty, operated by Kajavala Forestry Ltd.

GPS

A low-cost, non-differential GPS tracking device (QSTARZ BT-Q1000XT) was used to track and record the movements of a Volvo 190F wheeled loader. The GPS unit, with low power consumption for up to 40 hours recording, was attached to the inside of the cab against the side windscreen at the beginning of the work shift. A position was recorded in the flash memory of the GPS every three seconds. Data were downloaded to the proprietary software and further processed through two additional packages: Active GPX to "play" the track in the Google Earth environment, and 3D Route Builder was used to edit the track to a usable hour-long segment.

An overlay was applied to Google Earth so that the machine's track could be monitored relative to the log stack locations in the log yard (Figure 3). The machine track icon was stopped and started in "play" mode to give elapsed time and distance values for a truck loading task.

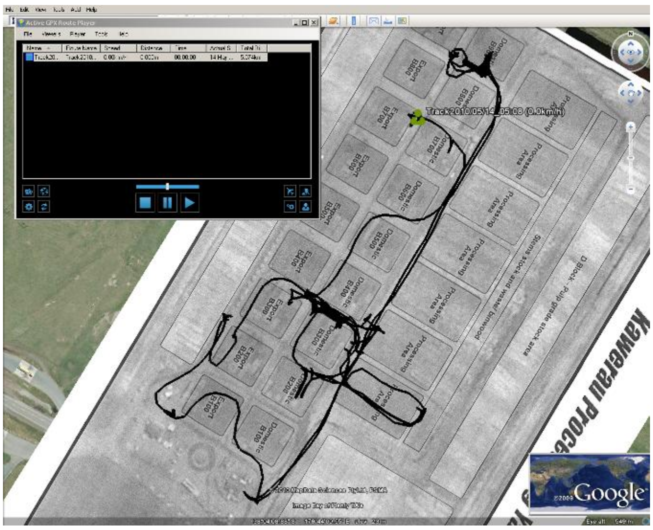

Figure 3. GPS track of study period shown on log yard layout overlaid on Google Earth.

MATRIS data

The loader's ECM was downloaded at intervals through the day by a technician from the machine supplier using a laptop and specialised cable. This enabled summaries for short time periods to be generated (at a later date by the technician in an office location). Typically ECMs are downloaded at intervals longer than a month, and relate to the machine's life history (from purchase through to the current date). The reports generated for the study are only some of the available summary graphs, which include:

- Total logged time
- Machine Utilisation – Machine in motion, Machine in work mode, Idling.
- Fuel consumption (litres)
- Average fuel consumption per hour
- Average fuel consumption per hour with gear engaged
- Average speed
- Distance travelled
- Speed distribution (%, hr)

Video

A cab-mounted video camera provided about four hours of video footage. This was used to confirm the activity or task of the loader relative to the GPS track.

Information derived from GPS track, MATRIS summary and video was integrated to enable a comparison of the various data collection methods.

Results

Machine Utilisation and Travel Speed

Data were examined from a one-hour period during which two trucks and a train wagon were loaded, and some fleeting from a processing yard carried out (Figure 4).

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MATRIS summaries define the following codes:

- *Work Mode:* in 1st gear, <0.5kph and revs higher than idle;
- *Idle*: in Neutral gear, <0.5kph and idling revs.

The GPS was not capable of determining whether a machine was in *Work Mode* or *Idle.*

Speeds derived from the GPS track were sorted into three classes to approximate the conditions of:

- Stopped <1kph
- Short, slow movements 1-4kph
- Travelling speed >4kph

GPS and MATRIS values were compared (Table 1.)

Table 1. Comparison of GPS and MATRIS values – utilisation, average speed and distance travelled.

Data Source	Utilisation (% in motion)	Work mode	Idling	Average speed (kph)	Distance travelled (km)
MATRIS	44.3	11.8	43.9	4.50	5.0
GPS	Speed 1-4kph 10.1% Speed >4kph 37.3 %	Speed<1kph 52.5%		4.15	4.51

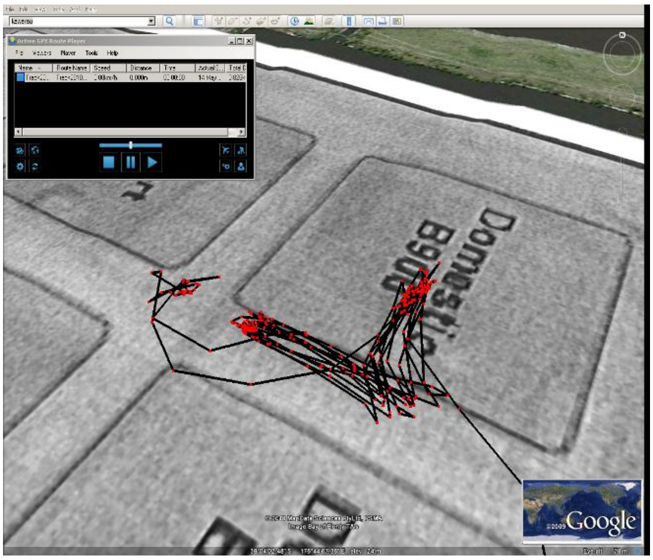

Figure 4. GPS track of loading a 2-bunk truck with random length logs.

A comparison was made between GPS and MATRIS speed distributions (Table 2).

For speeds above 4.5 kph, the two systems were in reasonable agreement, but for low speeds (less than 4.5 kph) the GPS overestimated time distribution by 2.5%.

Table 2. Comparison of MATRIS and GPS speeds (% distribution of total time).

Speed Classes	MATRIS (% time)	GPS (% time)
< 0.5 kph	42.4	39.4
0.5 - 4.5 kph	19.3	24.9
4.5 - 9.0 kph	14.1	14.3
9.0 - 13.5 kph	15.5	15.3
13.5 - 18.0 kph	7.0	5.4
18.0 - 22.5 kph	1.9	0.6
Total	100.0	100.0

Loading Times

Video footage was used for a time study of the same period. The data were used to compare truck loading time derived from GPS data and video time study.

A more detailed breakdown of the truck loading cycle is shown in Table 3.

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Table 3. Video time study result for the truck loading activity

Time Element	Time study	
	% time	Min
Run Loaded	19.3	3.3
Run Empty	17.5	3.0
Grapple	17.5	3.0
Load	14.6	2.5
Butt and pack	17.0	2.9
Write docket	12.3	2.1
Stack	0.0	0
Other	1.8	0.3
Total	100.0	17.1

Some of the time elements shown in Table 3 could be derived from the GPS track, such as the run loaded and run empty times and distances.

Table 4 shows the comparison between the video and GPS data. The GPS track showed six two-way tracks, five loads from the stacks loaded on the truck, and a return to the stack of one partial load. The small difference in the docket writing time is explained as error in interpretation of the track and estimating the start of the “Write docket” element.

Table 4. Comparison of truck loading time for a truck and trailer with 2 bunks of random length logs.

Data Source	Total time (min)	Distance (km)	Write Docket (min)	Total Loading (min)
Video	17.3	n/a	2.1	15.2
GPS	17.3	0.93 km	1.9	15.4

Delays (Stop Times)

Using the GPS dataset (as a comma-separated values file), machine speeds of less than 0.5 kph were coded as a stop. Stop times of less than 30 seconds were excluded on the basis that short stop times may have coincided with the loader actually working, but not moving. A graph (Figure 5) shows the distribution of stop times through the course of a sample 12 hour shift.

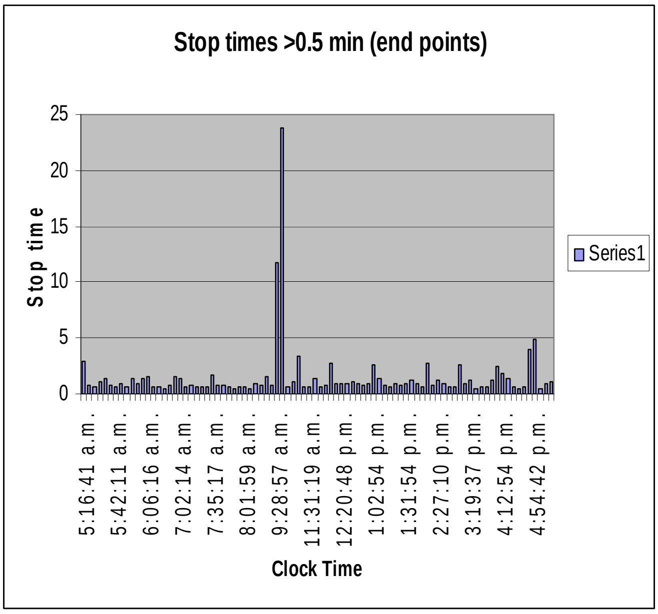

Figure 5. GPS-derived stop times, by time period, during one 12-hour shift.

This GPS-derived time data showed that stop time (>30 seconds) comprised 18% of total shift time (giving a machine utilisation estimate of 82%). Approximately 65% of stop times had durations of less than one minute. The two longer duration stop times at about 9:30am were a single stop time where the loader was undergoing maintenance. MATRIS downloads occurred at 9:00, 10:00, 11:07, 12:01 and 14:06 and these can be noted on the trace.

Applications

Use of the GPS tracking method has application in forest harvesting operations to measure skidding and forwarding times and distances on

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varying terrain. GPS tracking use on excavator loaders or feller bunchers would require fitting to the machine's dipper arm as well as cab mounting to record both machine travel and boom/arm and grapple movement. In this instance the dipper arm GPS would be used as a movement sensor.

Another possibility is the use of a GPS tracker on cable hauler rigging. Time and distance data would enable total cycle time calculations and inhaul/outhaul times for given haul distances and haul road locations.

Other cycle elements such as hooking on and unhook would be apparent, occurring as minimal movement of the tracker. Sealing the GPS unit in a ruggedized but electrically non-conducting housing presents a challenge.

Information that could be derived is given in Table 6 below.

Table 6. Applications for GPS tracking in harvesting operations

Manual Felling	• Area worked
Mechanised Felling (Boom and cab GPS)	• Area worked • Time spent in travel and positioning (speeds) • Time spent felling and bunching (Boom movement) • Delay time (exceeding average stopped time or no boom movement, no travel) • Terrain effects such as slope
Skidding	• Area worked • Time spent in travel, accumulating drags, blading on skid (haul distance and time) • Delay time (exceeding average stopped time) • Terrain effects such as slope • Number of passes (site preparation planning)
Forwarding	• Area worked • Time spent in travel, accumulating a load, (haul distance and time) • Delay time (exceeding average stopped time) • Terrain effects on travel time • Number of passes (site preparation planning)
Hauler rigging	• Haul distance • Inhaul/outhaul time • Hook on/unhook time • Hauls per corridor • Corridors per setting • Delay time (exceeding average stopped time)
Shovel Logging (Boom and cab GPS)	• Area worked • Time spent in travel (speeds) • Time spent bunching (boom movement) • Delay time (no boom movement, no travel)
Fleeting (Boom and cab GPS)	• Time spent in travel
Loading (Boom and cab GPS)	• Time spent in travel

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Conclusions

The comparison of GPS and MATRIS data recorded in this study suggests that in terms of time distribution of machine travel speeds, GPS tracking provided similar information to the MATRIS machine system.

MATRIS reporting of total distance travelled is rounded to the nearest kilometre, and elapsed time for reporting is rounded to the nearest 0.1 hour. This makes GPS tracking more accurate for estimation of these values.

For estimation of times of work cycle elements, such as truck loading, it was found that GPS tracking was reasonably accurate for total cycle time and for "run loaded" and "run empty" element times as well as for related elapsed distances.

GPS tracking information could be used by both contractor/operations manager and harvest planner to monitor machine performance in terms of time usage relative to distance and task, and to predict performance in future operations. Performance estimations would probably use a 60-minute track analysis. Movement analysis could use an eight-hour or 60-minute track.

Future research in FFR's Innovative Harvesting Solutions programme will include evaluation of GPS tracking of feller bunchers and cable rigging in steep slope harvesting operations.

Acknowledgements

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References

Dupre, R. H. (2006): The Feasibility of using GPS Technology for Continuous Time Studies of Rubber-Tyred Grapple Skidders. Master's Thesis, School of Renewable Natural Resources, Louisiana State University, May 2006.

Evanson, T. (2009): An Evaluation of the MultiDAT (Senior-model) Datalogger. Harvesting Report FFR-H001. Future Forests Research, Rotorua, New Zealand.

Evanson, T. (2010): On-board Monitoring Systems. Harvesting Technical Note Vol 2, No. 10, 2010. Future Forests Research, Rotorua, New Zealand.

Liu, C. J. (2002): Effects of selective availability ob GPS positioning accuracy. Southern Journal of Applied Forestry 26 (3).

McDonald, T.P. and Fulton, J.P. (2005): Automated Time study of Skidders using Global Positioning System Data. Computers and Electronics in Agriculture. Auburn University, Alabama. (unpublished).

Parker, R.P., Vitalis, T., Walker, R., and Marshall, H. (2010): Performance Data from Wearable Devices. Harvesting Technical Note Vol. 2, No.12, 2010. Future Forests Research, Rotorua New Zealand.

Taylor, S.E., Veal, M.W., McDonald, T.P. and Grift, T. (2001): Using GPS to evaluate productivity and performance of forest machine systems. Presentation at the First International Precision Forestry Symposium, Bell Harbor Conference Center, Seattle, Washington, USA. June 17-19 2001.