Three forestry applications of the Global Positioning System (GPS) in New Zealand

Murray Lawrence, John Firth and Rod Brownlie[1]

Abstract
The authors' experience using a medium-accuracy GPS receiver for locating sample plots in the forest, navigating for an aerial survey, and delineating forest roads is described. The system worked well, provided the satellite's signals were not attenuated by overhead vegetation or the topography, in which case the accuracy dropped and, in some cases, no data was collected at all.

Keywords
Aerial navigation, forest inventory, forest maps, GPS.

Introduction
Widely promoted for marine navigation and hailed as "the next public utility" (Hurn, 1989), the Global Positioning System (GPS) has aroused considerable interest amongst forest managers and researchers in New Zealand.

The GPS is a very accurate radio navigation aid designed for military purposes and operated by the US Department of Defence. It uses the signals from a constellation of 24 satellites in high (20,000 km) orbit to enable positions on the Earth to be fixed 24 hours a day, anywhere in the world. The GPS signals accessible to civilians are deliberately degraded, with the result that positions may be in error by 100 m or more. However, by matching the signals received by a roving receiver with those obtained by one located at a station whose coordinates are accurately known, it is possible to cancel the effect of the degradation and, with suitable equipment, to calculate positions to sub-metre accuracy.

Eggleston (1992) examined the role of GPS for a range of forestry activities including determination of the position of kauri trees and mapping of roads. He concluded that the technology had significant potential but the accuracy of the result was strongly dependent on factors such as the type of equipment used and the absence of overhead vegetation. When Kruczynski and Jasumback (1993) surveyed a block of forest three times with a Trimble Pathfinder GPS, the areas obtained were within 0.5% of the value derived from a theodolite traverse.

Researchers at the NZ Forest Research Institute have conducted tests with GPS in a number of forestry applications, and three of these have been selected to illustrate the potential of the system for forest surveys.

In all three examples the GPS unit used was a Trimble Pathfinder Basic Plus, a 6-channel receiver capable of 2-5 m accuracy with differential correction. The Basic Plus can track up to eight satellites simultaneously and at the time of these studies (1993/94) was typical of the medium accuracy units being considered for general forestry applications.

Locating of sample plots in forest stands
The precision of geographical positions obtained with the GPS can be influenced by a number of factors. These include the technical capability of the receiver unit, the number of satellites 'visible' to the receiver at any one time, their position relative to each other, and in forests, signal interference by tree canopies. Earlier tests of GPS units (Eggleston, 1992) indicated difficulties in obtaining accurate positions in tree stands taller than 15-20 m, though with patience satisfactory readings could sometimes be obtained.

In this application, the GPS receiver was used to determine the locations of inventory plots as part of a study linking conventional ground-based forest inventory with stand volume estimates derived from satellite imagery. The study area was on flat to rolling terrain, and was stocked with approximately 200 stems/ha of 30-year-old radiata pine. The average tree height was 40 metres.

Computer software, made available through the Department of Survey and Land Information, was used to enable the field work to be carried out when the geometric position of the satellites was most favourable. In addition, in order to minimise the attenuating effect of the tree canopy on the satellites' signals, the GPS aerial was mounted on a 12 m pole (see Figure 1) and, wherever possible, advantage was taken of small gaps in the tree canopy. Despite these precautions, it was not possible to obtain useful readings for many of the plots. Similarly, only poor and imprecise positions could be obtained for internal roads and tracks approximately four metres wide.

These problems were overcome by obtaining GPS readings

Figure 1. Evaluating a GPS unit to record the location of a sample plot in a forest stand.

---
[1] *Researchers, NZ Forest Research Institute, Rotorua.*

on external stand boundaries not surrounded by trees, or on large internal skid sites. Once accurate reference points had been obtained, it was possible to survey offsets from these points to the plot centres. This was done using a Criterion™ survey laser, but could also have been achieved using rangefinders and stadia or a compass and chain.

Forest inventory frequently requires travel through dense undergrowth or over broken terrain. The use of a 12 m pole for the antenna is often impractical because of its size and weight. The time involved surveying offsets precludes their use in routine practice. Despite this, the combination of the GPS and survey offsets was a practical solution for the purposes of this study.

Navigating for aerial surveys

Drake and Luepke (1991) found that a GPS mounted in a helicopter was an effective tool for mapping the boundaries of a forest fire. When Bergstrom (1990) mounted a GPS in a helicopter, he was able to use it to locate and record the position of dead trees that were suitable for salvaging.

A Pathfinder Basic Plus was used to aid navigation during an aerial survey of 194 forest compartments for a tree canopy condition known as upper-mid-crown yellowing. The requirement for very large-scale aerial photographs dictated a flying height of only 100 m above the canopy. At this altitude, roads and tracks normally used for navigation are often obscured by trees. So that the helicopter pilot did not have to repeatedly climb several hundred metres to obtain a bearing to the next site to be photographed, the GPS was used to guide him directly there (see Figure 2).

Figure 2. Using a GPS unit as a navigation aid for low-altitude aerial photography.

Map coordinates were obtained for each photographic location and a plan prepared showing the shortest route between them. The coordinates were entered into the GPS as waypoints (predetermined positions) in the order determined by the flightplan. The GPS antenna was fixed to the roof of the helicopter and the first waypoint selected. The GPS unit displayed the distance and heading to the first compartment and the pilot was able to fly directly to the site, using the GPS to update the course every few seconds, and to make corrections to the flight path when necessary.

The average time required to photograph each compartment, including ferry times to and from the forest, was 3.3 minutes. If the GPS had not been available, the time required for the job would have more than doubled. With helicopter flying charged at rates over $1000/hr, this time-saving resulted in a considerable reduction in the cost of the project.

Updating forest maps

As the management of New Zealand's forests becomes more intensive, there is a growing need to keep stand maps up-to-date. Some cartographers are considering the use of GPS for this purpose because it can provide data in almost all weathers. Aerial photography, traditionally used for map updating, usually requires cloud-free skies to obtain acceptable imagery. For this type of application, the antenna is usually hand-held or attached to the roof of a vehicle (see Figure 3) and the GPS records map coordinates of the boundaries or roads and tracks as they are followed.

Figure 3. Configuring a GPS unit to map forest roads.

In a study reported by Firth and Brownlie (1994), a GPS was used to survey the internal logging roads in a recently harvested area in the Marlborough Sounds. Results showed that the GPS was able to provide coordinates within 5 m of those obtained from aerial photography and a stereoplotter but only where hillsides, road cuttings or overhead vegetation did not interfere with the satellites' signals. No data were recorded at all for about 10% of the road length because of these restrictions. Although satellite positional information, provided by the GPS unit, was used in the field to try to identify occasions when the topography or vegetation cover was likely to cause unacceptable errors, this method was not always reliable.

Conclusions

It is clear from the three applications of GPS outlined above that the Trimble Pathfinder Basic Plus receiver was of value for aerial navigation work. The system was sufficiently accurate for updating forest maps, except where the topography and overhead vegetation interfered with the satellites' signals. Its value for locating field plots under tree canopies was limited.

References

Bergstrom, G.C. (1990). "GPS in forest management". GPS World, Vol. 1, No. 7. Pp. 46-49.

Eggleston, N. 1992. "Satellite navigation in forestry". NZFRI What's New in Forest Research No. 222. 4p.

Firth, J. and R. Brownlie. 1994: "Accuracy of GPS for updating forest maps – the Marlborough Sounds experience". New Zealand Logging Industry Research Organisation Report 19(13). 6p.

Kruczynski, L. and A. Jasumback. (1993): "Forestry Management Applications: Forest Service Experience with GPS". J. of Forestry, Vol. 91, No. 8. Pp. 20-24.

Hurn, J. 1989: "GPS – a guide to the next utility". Trimble Navigation Ltd, Sunnyvale, CA, 94088-3642, USA. 76p.