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ACCURACY OF GPS FOR UPDATING FOREST MAPS: THE MARLBOROUGH SOUNDS EXPERIENCE

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Figure 1 - Surveying data point No. 6 with a GPS. Rahotia Forest is in the background

ABSTRACT

A study was carried out in a forest in the Marlborough Sounds to assess the value of a medium accuracy Global Positioning System (GPS) for updating forest stand maps. A number of forest tracks and point objects were mapped using the system, and their coordinates compared with those obtained from conventional aerial photography and a stereoplotter. It was found that the GPS could provide XY coordinates to within 5m of those obtained from the stereoplotter. However, it was also found that the system had limitations where steep hillsides and tree crowns interrupted the signal from the satellites.

INTRODUCTION

Accurate maps are a necessity for sound forest management and most forestry companies have a regular programme for keeping them up-to-date. The task is frequently carried out using small format aerial photography and a simple transfer instrument such as a Zeiss Sketchmaster. However, because the weather conditions in New Zealand restrict the number of days suitable for aerial photography, and because of the subjective nature of the mapping revision process, there is a need for a speedier and more objective method for carrying out this task.

One tool which is under consideration is the radio navigation Global Positioning System (GPS) operated by the United States Department of Defence (DoD). It comprises a network of Navstar satellites in 12-hour orbits which can provide all-weather, worldwide positioning capability to centimetre accuracy.

Equipment capable of this accuracy costs from $25,000 and is designed for specialist surveying organisations. However, cheaper and less sophisticated equipment is now available and, for an outlay of about $7,000 to $15,000, it is possible to restrict most errors to less than 5m[1], which is the order of accuracy of most forest map updating. Because the system is relatively easy to use and is available 24 hours a day, it is creating considerable interest in the forest industry as a possible way to increase the efficiency of the map maintenance process. This report outlines the authors' experience using equipment having an accuracy range in the order of 2 to 5m to update a forest map.

Eggleston (1992) examined the role of GPS in forestry and concluded that aerial photography is likely to continue to be the most efficient data source for the production of the majority of forest maps for some time to come. However, he felt that GPS would become a useful method for updating maps as more sophisticated equipment became affordable. Montgomery (1993) acknowledged that GPS has some limitations in forest mapping but believed that most problems could be overcome if the appropriate technique was used. He also believed that the advantages of GPS outweighed any disadvantages. Kruczynski and Jasumback (1993) reported on an evaluation of a Pathfinder GPS receiver to measure the area of a portion of forest for sale purposes. The areas obtained from three GPS surveys were between 0.035 and 0.5% different from the value derived from a theodolite survey. The small size of these differences show that it is possible to obtain data from a GPS survey which would be acceptable for many forestry purposes. Gerlach and Jasumback (1989) noted that map plotting accuracies, which are usually in the order of 0.5mm, represent a larger error at a typical forest map scale of 1:24,000 than that obtained from a 2 to 5m accuracy GPS unit. At the usual New Zealand forest map scale of 1:10,000 the same mapping accuracy represents 5m. This figure would be at the upper accuracy level of a similar GPS. August et al. (1994) studied the accuracy and precision of an inexpensive GPS used for environmental applications. They found that, under ideal conditions (good PDOP[2] values, few signal obstructions, post-processing of the data and using multi-recordings per site) mean errors of under 6m could be expected.

OBJECTIVE

The objective of this study was to investigate the role of a medium accuracy (2 to 5m) GPS unit for updating planimetric forest maps by comparing the positional accuracy of:

- roads plotted from aerial photographs using an analytical stereoplotter with those plotted using GPS sourced data.

[1] Provided the data had been differentially corrected by a base station which is within ~300km of the receiver.

[2] PDOP, or Position Dilution Of Precision, is a number related to the likely accuracy of the coordinates derived from the GPS. It is based upon the geometric location of the satellites being tracked by the receiver. Values of five or less are regarded as being satisfactory. Values of eight or over are usually unsatisfactory.

- XY coordinates of point objects measured with a stereoplotter with those obtained using GPS.

STUDY AREA

The area selected for the study was Rahotia Forest overlooking Onepua Bay in the Marlborough Sounds. The site comprised 210ha of radiata pine planted in 1969. The trees were being clearfelled and a number of new roads and tracks running from sea level to 610m had recently been constructed to facilitate extraction. The variable forest cover and the changeable, but mostly steep topography of the site, provided a suitable environment for evaluating the capabilities of a GPS.

METHOD

Data Derived From Aerial Photography

A run of 1:22,000 panchromatic aerial photographs were taken of the study area, and the roading network visible on them was mapped using an AP190 analytical stereoplotter (Brownlie, 1989). The plotting instrument had a measurement accuracy of better than 20 microns at photo-scale and provided an exact solution to the photogrammetric restitution problem. Although the map produced was not without some error resulting from the photo-interpretation and ground control, the stereoplotter had the inherent capability to produce object coordinates to use as a standard for comparing the accuracy of other methods of obtaining spatial information such as a GPS.

As well as measuring the XY coordinates of the roading network, the stereoplotter was used to determine the XY coordinates of 15 point objects distributed over the site. These points comprised houses (roof corners), jetties and other clearly defined features (Figure 1). The points were measured twice and the mean of the measurements used in subsequent calculations.

Data Derived From The GPS

A GPS was used to measure the XY coordinates of the same roads and 15 point objects that were measured with the stereoplotter. The unit employed was a Pathfinder Basic Plus manufactured by Trimble Navigation and hired from the Department of Survey and Land Information (DOSLI). The equipment consisted of a receiver, antenna and a surveyor's pole. DOSLI also provided training, access to their mission planning software and carried out post-processing of the data. Post-processing is a procedure for reducing the effect of errors caused by atmospheric anomalies and DoD's strategic degradation of the Navstar satellite signal. Without post-processing, the 2 to 5m error may increase to about 100m. A laptop PC was required during the survey so that the GPS data could be down-loaded at the end of each day's measurements.

Where possible, each track was surveyed at least twice, either in the morning and again in the afternoon, or on different days. This approach was taken in order to obtain data based upon different satellite configurations. The GPS antenna was mounted on the rear of a 4WD farm bike and the receiver set to give a sampling frequency of two seconds. This rate effectively provided one data point every 1 to 2m.

In surveying the location of the point sites, the antenna was positioned over the object (Figure 1) and 180 readings taken at a rate of one every two seconds. This was repeated later the same day or the next day. The mean value of the 360 readings was used for subsequent calculations.

Mission planning software, produced by Ashtec Inc., was consulted each day to ascertain the times when four or more satellites were located above the horizon (with an elevation mask set at 15^{o}) and their geometry resulted in a satisfactory PDOP. Apart from a few short time slots when this was not the case and the GPS was therefore not used, no serious problems were encountered, and the predicted PDOP values were under three most of the time. However, due to the local topography, the effective elevation mask sometimes exceeded 15°. This resulted in the GPS receiver having to select, on occasions, satellites which had a less than optimum geometry and therefore a higher than predicted PDOP value. It was, therefore, necessary to check this value every few minutes while measurements were being collected and postpone the survey if need be.

After the GPS survey had been completed, the coordinates were given to DOSLI for differential correction. This was carried out with the aid of their Christchurch base station and included conversion of the data from WGS-84 (the standard used by the DoD) to New Zealand Geodetic Datum 1949 and then to the New Zealand Map Grid projection. The resulting coordinates were then in the same reference system as those obtained from the stereoplotter.

RESULTS

Line Data

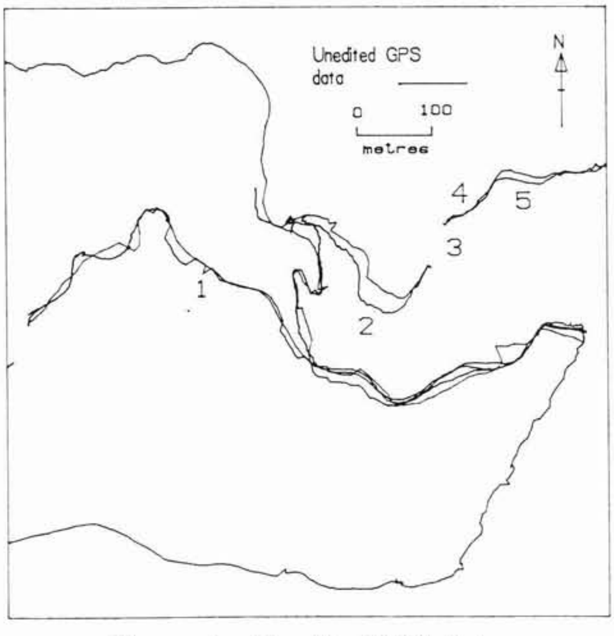

Figure 2 - Unedited GPS data

Figure 2 shows a plot of the forest tracks derived from the GPS survey. When the line-work on this map was examined closely, it was noticed that a number of problems existed in the data. These consisted of spikes (location 1), poor correlation between the lines where the roads had been surveyed more than once (location 2), and missing data (location 3).

The spikes were attributed to brief anomalies in the system and were deleted without further consideration.

Where a road had been surveyed more than once, the PDOP values of the line segments were later calculated using the GPS software. Segments associated with an unacceptably high PDOP value (over eight) were then deleted. Where more than one line remained, each of an acceptable PDOP value, a new line was manually drawn through their average position and the original data deleted. Sometimes the original lines were less than a pen width apart at map scale (location 4) and this averaging could be carried out easily and with confidence. In the instances where the lines were further apart, (location 5), intelligent guesswork was required for this operation.

When the GPS linework shown in Figure 2 was visually compared with the stereo aerial photographs of Onepua Bay, it was noticed that, where there were gaps in the data, or where two survey lines were some distance apart, these were invariably associated with the presence of mature trees or nearby steep banks and cuttings. It was, therefore, concluded that the tree crowns and local topography had interfered with the satellites' signals and had either caused multipath errors and signal loss or caused the receiver to use a constellation with a poor geometry. Luepke (1991) had a similar problem with signal loss when he used a GPS to carry out a survey under a hardwood tree canopy.

Evidence for the poor geometry problem came from an examination of the GPS data files. These showed that the satellite constellation used to determine the coordinates of the tracks on the ridges rarely changed during the survey. Where the tracks were located on the hillside, however, the constellation changed frequently, sometimes every minute or so. This was attributed to satellites "disappearing" and "reappearing" while the receiver was moved around the hillside.

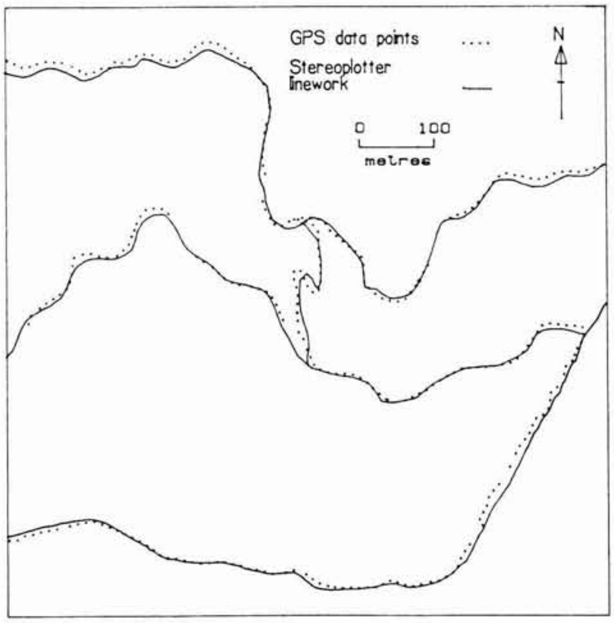

Figure 3 - Edited GPS data with steroplotter linework superimposed

Figure 3 shows the GPS linework that resulted from the editing procedures described above. The figure also shows the linework derived from the stereoplotter. By comparing the two sets of lines, it can be seen that, in most instances, they are within one or two drawing pen thicknesses of each other (about 5 to 10m at a map scale of 1:10,000).

Point Data

While a visual evaluation of the differences between the GPS and stereoplotter sets of linework has its value, it is a somewhat subjective exercise. A more objective comparison can be obtained by comparing the absolute distance between the stereoplotter and GPS measurement of the point data. Table 1 shows these distances for the 15 points. Each distance is derived from the mean of two sets of 180 GPS observations and two stereoplotter readings.

Table 1 - Absolute distance between the mean GPS and stereoplotter coordinates for 15 points

Point number	Distance (m)
1	5.86
2	2.10
3	5.11
4	4.73
5	6.83
6	7.68
7	5.31
8	7.24
9	6.38
10	1.61
11	7.84
12	4.33
13	1.64
14	1.99
15	6.51
Mean	**5.01**
Standard error of the mean	**0.58**

The mean difference between the stereoplotter and GPS coordinates was 5.01m with a standard error of 0.58m. If one assumes that the error in the stereoplotter coordinates was negligible, then this figure is at the lower limit of the accuracy claimed by the manufacturers of the Pathfinder GPS instrument (2 to 5m).

DISCUSSION AND CONCLUSIONS

Hurn (1989) described GPS as the next utility, and when one considers its potential and looks at the growing versatility of the equipment now available on the market, one can see that his prediction is coming true. However, while GPS will certainly play an increasing role in forest management in the future, experience in the Marlborough Sounds has indicated that it has limitations for updating maps if the country is very steep and dense overhead vegetation is present. This is because these features may obstruct the satellites' signals resulting in a high position error or even no position data at all.

The hillside problem can sometimes be alleviated through mission planning, that is, determining beforehand when the satellites will be in a suitable configuration for the site. The vegetation problem can be overcome by raising the antenna, but this is only practical where the trees are under about 10m tall. In any case, it is good practice to regularly check the PDOP values as the data is being collected although when one is in "roving" mode, this is not always possible.

Where the problems mentioned above do not occur, it has been shown that a GPS unit of the type used in this study, is capable of providing line and point feature coordinates that are, most of the time, within about 5m of those produced by a photogrammetric plotter. This error approximates the plotting accuracy for most 1:10,000 scale forest maps.

Since this study was carried out, further Navstar satellites have been launched by the DoD and there is now a complete network of 24 in orbit. This has led to a significant increase in the number visible in New Zealand at any one time. It is possible, therefore, that this study may have produced more accurate positions if it had been carried out a few months later when lower PDOP values would have been more generally available.

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