Application of GPS and Gis to Map Main Logging Road Features in Peninsular Malaysia

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Abstract: A 9.8 km of main logging road was mapped at Perak Integrated Timber Complex (PITC) in Perak State, northern part of Peninsular Malaysia to identify of their inventories. Logging road features, length of road section, height of cut-fill slopes, longitudinal slope, steepness, length of slope factor, roadside drain, drainage structures, were located to sub-meter accuracy with differential global positioning system (DGPS) equipment and described while traversing the logging road. The DGPS data were exported into Geographic Information System (GIS) format. Road features were coupled with existed terrain data for analysis. The results of this study indicate that feasible to estimate the amount of soil loss from the main logging road and the cost-effective of detailed mapping program to characterize system variability and identifying spatial relationships. The results of this study indicate the effectiveness of a one-time detailed mapping program to characterize system and identify spatial relationships of logging roads system
Keywords: global positioning system, geographic information system, mapping, logging roads, erosion

1 Introduction

Logging roads are a necessary part for sustainable forest management. Monitoring of logging roads gives some indication of land disturbance resulting from a logging operation. Road maintenance is essential in order its originally constructed condition, protect adjacent resources, user safety and convenient to the silvicultural management. The advances of microprocessors, sensors, geographical information systems (GIS), and global positioning systems (GPS) have helped in the development of new techniques for forests engineering. The GPS and GIS technologies have been used to develop mapping logging roads systems in hill forest.

Tests of GPS efficiencies in the dense rain forests of northeaster Zaire, Africa resulted 20 minutes in area where elevations angles were less than 50 degrees, canopy closure was less than 20 percent, and there was a forest opening of >0.125 ha (Wilkie, 1989). When Kruczynski and Jasumback (1993) surveyed a block of forest three times with Trimble Pathfinder GPS, the area obtained were within 0.5% of the valued derived from a theodolite traverse. The effects of the Global Positioning System on terrain, forest canopy, number of consecutive position fixes, and PDOP were evaluated. The mean differentially corrected positional accuracy for 27 sites was 4.35 meter with 95 percent of the mean positions estimated within 10.2 meter of the true values (Deckert, 1996).

Many studies have been conducted to investigate the potential of GPS data input to GIS databases (Colwell, 1991; Slonecker & Carter, 1990). The purpose of this paper is to present the results of a study in integrating GPS and GIS in the building of a spatial database for monitoring logging roads maintenance management. A limited knowledge of the site-specific performance of these systems exists. Therefore the overall goals of this study were: (1) To explore the efficiencies, advantages and limitations of GPS and GIS technologies into the development for monitoring logging road maintenance management; and (2) To conduct a site-specific evaluation of the accuracy and performance of the developed system.

2 Study area

The study was conducted in Perak Integrated Timber Complex (PITC) at primary and secondary logging roads in Peninsular Malaysia (Latitude 5°24'40"N to 5°34'15"N and Longitude 101°33'0"E to

101°39'30"E) (Figure 1). The concession area constitutes part of Temenggor Forest Reserve within Hulu Perak district, Perak Darul Ridzuan covering a total area of 9,765 hectares of rich and pristine virgin lower and upper hill mixed dipterocarp forest. To its north is Belum State Nature Park while not far to the east is the Perak-Kelantan states border.

3 Methods

3.1 Field mapping

Primary and secondary logging roads of PITC to the concessions area were mapped by traversing the roads over one-day period in 1st December 2001. The study section included the primary and secondary located between PWD R-01 class road to the Compartment 26 (Figure 2). Logging roads features (bridges, culverts, landslides) were located using Trimble Pathfinder Pro XR GPS equipment. Discrete locations and continuous data were recorded to an accuracy of one meter. To record continuous condition, the GPS equipment was operated in continuous line mode (location recorded every five seconds) over an incremental distance and segment. Segmenting the continuous line measurements was needed to parse the data into the data into manageable unit and allow for break in data collection activities during the day. Road segment profiles were based on high and low profile in continuous road conditions. To record point features, the GPS was operated in point mode (point features in one second). The differential correction was used to remove the error caused by Selective Availability (S/A) and other factors by using Malaysian Active GPS Systems (MASS) of GPS at http://www.geodesi.jupem.gov.my/mass.htm permanent station at Ipoh, capital State of Perak (Latitude 4°35'18.54071"N and Longitude 101°07'34.19882"E at 41.322 m.asl).

All coordinates data collected were recorded using three-dimensional mode. Receivers were set to record coordinate based on the WGS-84 geodetic datum and HAE. Analysis of receiver data was performed with Pathfinder 2.51 software. Field operation include setting up the base station, taken point of commencement (PoC), a tie point at the junction of the main and the access road, entering attribute or feature information, and determining point positions. The spatial data from logging roads frequently travel through forest canopy, broken or side-slope terrain. The use of a extended up to 15 meter poles, catapult and using a Criterion™ 400 survey laser for offsets was a practical solution for the purposes of this study.

3.2 GIS analysis

GPS data were exported into a Geographic Information System (GIS) format using Pathfinder Office software. Field descriptions of the continuous segments and discrete features were added to the GPS location information to create a series of GIS coverage. A separate data layer (coverage) was made of each road feature mapped. Road radius of curvature was calculated using GIS by GPS measured.

4 Results and discussion

The longitudinal profiles of primary and secondary logging roads survey results are presented in Figures 1. It was shown that, the roads tend from distance 0.00 kilometer at 738.266 m. asl to distance 9,268 kilometer at 556.304 m. asl at the concession area.

4.1 Roads

Total 2D lengths of primary and secondary roads were 303 meter and 9,268 meter respectively (Figure 2). The total line length of 3D was 9,832 meter. The gradient of each segment were measured range from –18.15% to 17.58%. The maximum gradient of the secondary roads were 18.15% at distance 5,429 meter to distance 5,538 meter which fulfilled the “Standard Roads Specification” the gradient should less than 20%. Total length of 3D of roads was measured 9,036 meter. The most critical curve radius were 19 and 22 degrees at 2.25 km and 8.23 km respectively (Figure 2). The roads surveyed were more than 20 m/no. of curves/km which categorize as excellent classification system (FAO, 1989).

4.2 Bridges

A total of 3 steel bridges were located at surveyed road (Figure 3). As recommended for permanent positions as more than 60 positions, the two positions (upstream and downstream of the bridges) (Trimble, 1995). These first bridges was constructed using steel-trussed with length was DGPS observed as 24.25 meter (actual 24.30 meter) crossing Sungai Mangga. The second bridges were constructed using I-joist channel with DGPS observed as 12.16 meters (actual 12.10 meter). While the third bridges, using steel-trussed with DGPS observed as 24.23 meter (actual 24.30 meter) crossing Sungai Selaur. The observations for 3 superstructures within forested site with distance less than 25 meter apart were only ±0.007 meters.

4.3 Culverts

A total of road culverts were 56 numbers with different size and material (Table 1). The spiral polyethylene ResinTech ® with size 225/250 mm (internal/external diameter) was introduced at PITC due to eased of handling and installation. These resin material pipes were installed at distance 0.00 kilometers to distance 4-kilometer cutoff drain crossing. The spun-concrete culverts which size 0.3 meter diameter and 1.5 meter diameter were installed at first and second order of the streams. The attributes of the functional condition were inspected at point entity as severity of free flow, partial obstruction and total obstruction, only 6 resin culverts were not satisfactory and required immediately action.

4.4 Erosion and landslides

It was a difficulty to measure surface erosion from road surface; the existing side drained tends to formation of rill erosion. The maintenance gang of PITC almost adhered this situation as preventive maintenance. The management had provided motor grader and roller to maintain the design profile and compaction at optimal condition. The study was done during monsoon season; the major landslides (exceeded 50 meter square) ware identified 4 numbers at cut batter and 3 numbers at fill batter.

5 Application of logging road results to the forest management

Timber complex manager according to forest roads specifications geared to sustainable forest management is using results of the logging roads survey. Future management decisions will focus on using limited resources to address highly erodible soil first. Results from erosion assessment are being incorporated into a GIS-based erosion from logging roads. Roads survey results indicate that surface erosion play important role in road and stream connectivity which must be considered in development of sustainable forests.

Roads survey maps created in this study will aid in evaluation and selection of appropriate mitigation and rehabilitation measures for the PITC. Result from slope stability and road surface assessment portions this study are being incorporated into a GIS-based roads and streams connectivity for the watershed. Roads survey results indicate that erosion and landslide plays an important role in sediment transport, which must be considered in sustainable forest management. Determining accurate locations of all above entities with GPS has allowed us to easily return to evaluation, features and structures locations for preventive and corrective maintenance.

6 Conclusions

During a one-time traverse of primary and secondary of logging roads at PITC, the continuous roads conditions (profiles and alignments) and locations of discrete features (bridges, culverts and landslides) were mapped using GPS and later exported into GIS format for analysis.

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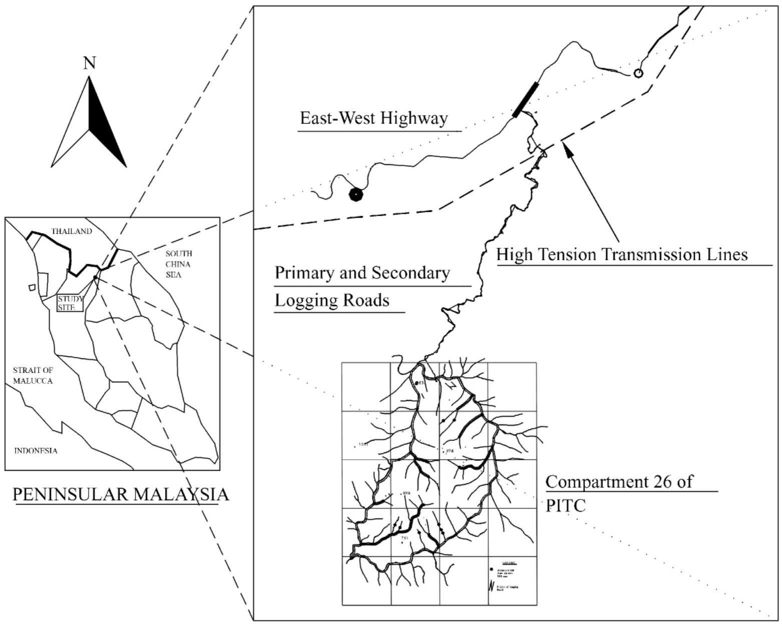

Fig. 1 Location map of study area

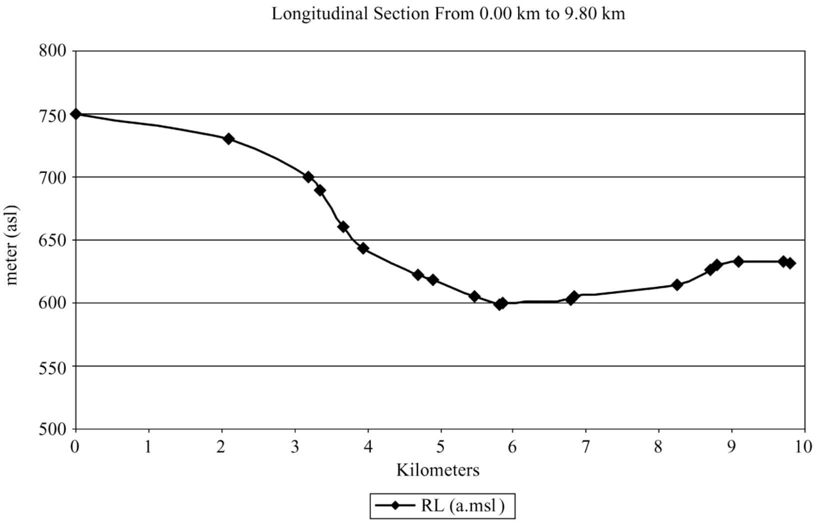

Fig. 2 Longitudinal section of primary and secondary roads

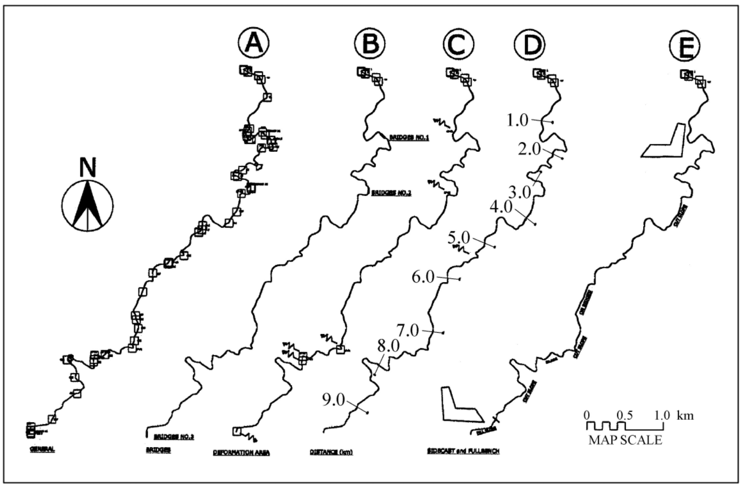

Fig. 3 Primary and Secondary Logging Roads Features at PITC

Table 1 Profiles characteristic of logging roads at PITC

Segment No.	*2D*	*3D*	*Distance* (km)	*RL* (a.msl)
1	0.076	0.085	0.000	750
3	1.345	1.364	2.094	730
5	0.599	0.608	3.190	700
7	0.025	0.025	3.342	690
9	0.003	0.003	3.664	660
11	0.024	0.024	3.942	643
13	0.166	0.166	4.686	623
15	0.029	0.042	4.900	618
16	0.568	0.578	5.478	605
18	0.169	0.172	5.816	599
19	0.029	0.042	5.858	600
21	0.625	0.637	6.786	603
22	0.017	0.049	6.835	605
24	0.011	0.014	8.255	615
26	0.047	0.048	8.708	626
27	0.083	0.084	8.792	630
28	0.287	0.29	9.082	633
30	0.387	0.389	9.696	633
31	0.015	0.019	9.715	633
32	0.083	0.087	9.802	632
Total (km)	9.598	9.802		