Chapter 10: Evaluation of Laser Light Detection and Ranging Measurements in a Forested Area[1]

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Introduction

Airborne laser scanning technology is a remote sensing technology that is increasingly being used to map terrain surfaces. This measurement technology uses a laser light detection and ranging (LIDAR) system to compute distances from the airborne sensor to surfaces below the aircraft. As the aircraft flies over an area, the LIDAR system emits laser pulses that are reflected by vegetation, buildings, or the ground surface. A detector in the LIDAR sensor records the time it takes for each laser pulse to travel from the sensor to the ground and back to the sensor. This time is then used to compute the distance from the sensor to the reflecting surface. In open areas with hard surfaces, LIDAR systems often achieve vertical accuracies of 6 inches or better. However, in forested environments covered with dense canopy, the accuracy of LIDAR measurements has not been thoroughly examined.

A LIDAR system was used to scan the surface of the 2 square miles that encompass the Blue Ridge study site (fig.10-1). The forest canopy within the study area is primarily coniferous and highly variable. It included recent clearcuts and forest plantations ranging from recently planted to 70-year-old mature forests. In addition, 108 fixed-radius plots (1/5 acre) were located throughout the study site (fig. 3-1 in chapter 3). The location of each plot was established with either global positioning system (GPS) receivers or ground survey methods (Reutebuch et al. 2000). On each plot all trees were measured, and a subsample of groundcover vegetation was collected both prior to and after harvesting operations (chapter 3). These georeferenced vegetation samples provided an excellent opportunity to investigate the following questions:

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[1] A summary of *A test of Airborne Laser Mapping Under Varying Forest Canopy* (Reutebuch et al. 2000).

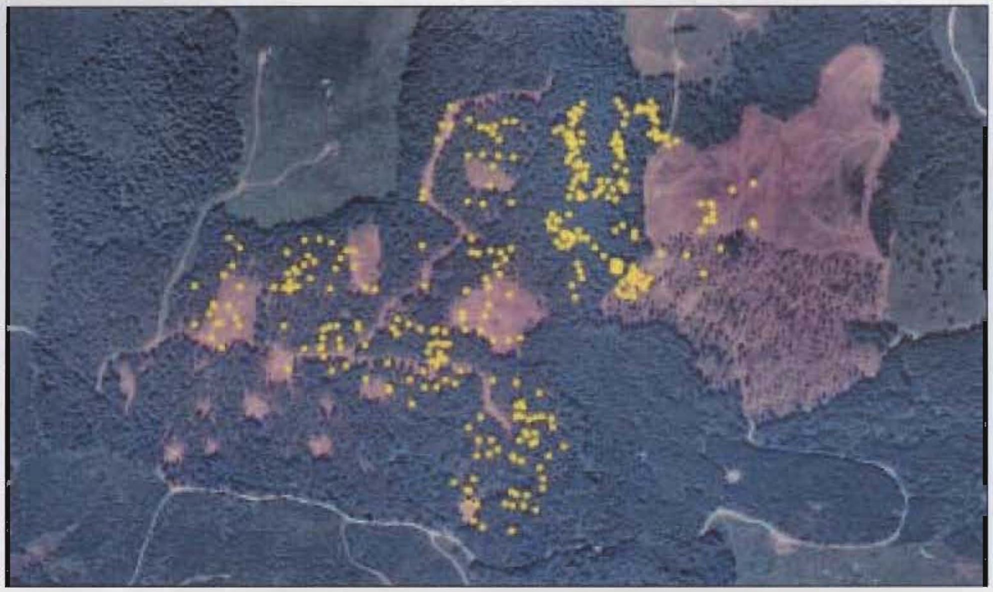

Figure 10-1—1999 orthophotograph of the LIDAR study area, after harvest. Yellow dots indicate the location of 350 ground survey checkpoints. (Washington State DNR, Resource Mapping Section.)

1. How accurately can LIDAR map the ground surface under varying canopy densities?

2. Can LIDAR data be used to measure stand and individual tree characteristics?

To investigate these questions, a LIDAR system was flown over the study area both prior to harvesting in 1998 and after harvesting in 1999. The instrument was a Saab Topeye[2] LIDAR system that was mounted in a helicopter and operated by Aerotec of Bessemer, Alabama. The LIDAR coverage area is mountainous with elevation varying from approximately 500 to 1,300 ft and ground slopes from 0 to 45 degrees.

Accuracy of LIDAR-Derived Digital Terrain Models Under Forest Canopy

The accuracy of two digital terrain models (DTMs) derived from the two LIDAR data sets was assessed (Reutebuch et al. 2000). Ground elevations from the airborne laser DTMs were compared to 350 ground survey points distributed throughout the Blue Ridge harvesting treatment units (fig. 10-1). The root mean square error of the 1999 DTM was 2.4 ft with an average error of 0.0 ft. The root mean square error of the 1998 DTM was 3.8 ft with an average error of +1.3 ft. This work is discussed in more detail by Reutebuch et al. (2003).

The 1999 airborne laser DTM also was compared to spot heights measured photogrammetrically from 1:12,000 aerial photos. In all, 992 photogrammetric heights were measured throughout the study area (fig. 10-2). The average difference from the 1999 LIDAR DTM was 0.0 ft, with a standard deviation of 6.0 ft. In relatively open areas, the photogrammetric heights compared very well with the LIDAR DTM elevations. Eighty-seven percent of the photogrammetric heights were within 10 ft of the corresponding LIDAR DTM elevations. In areas with very tall, dense canopy, the photogrammetric heights occasionally had large errors.

[2] The use of trade or firm names is for the convenience of the reader and does not imply endorsement by the USDA Forest Service of any product or service.

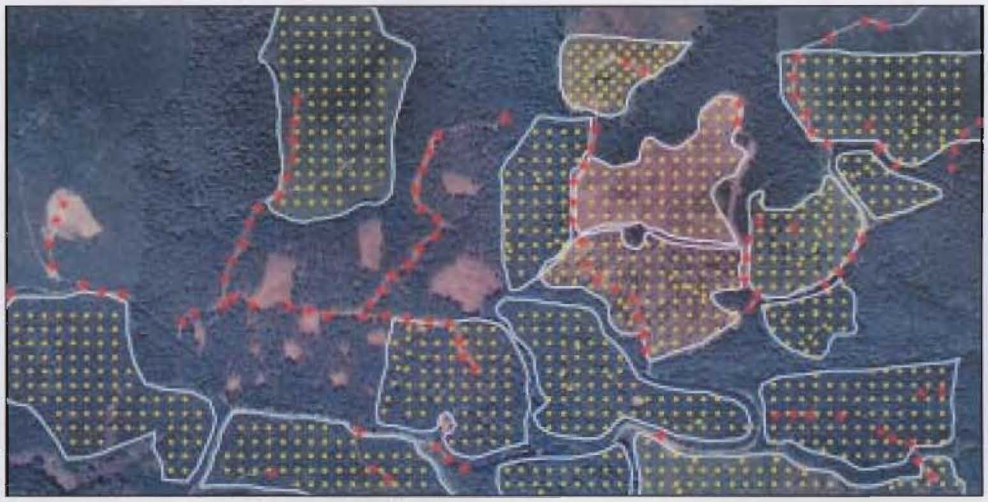

Figure 10-2—1999 orthophotograph showing location of 16 timber units in which photogrammetric spot heights were collected. Yellow dots represent spot heights in timber units. Red crosses represent spot heights on roads. (Washington State DNR, Resource Mapping Section.)

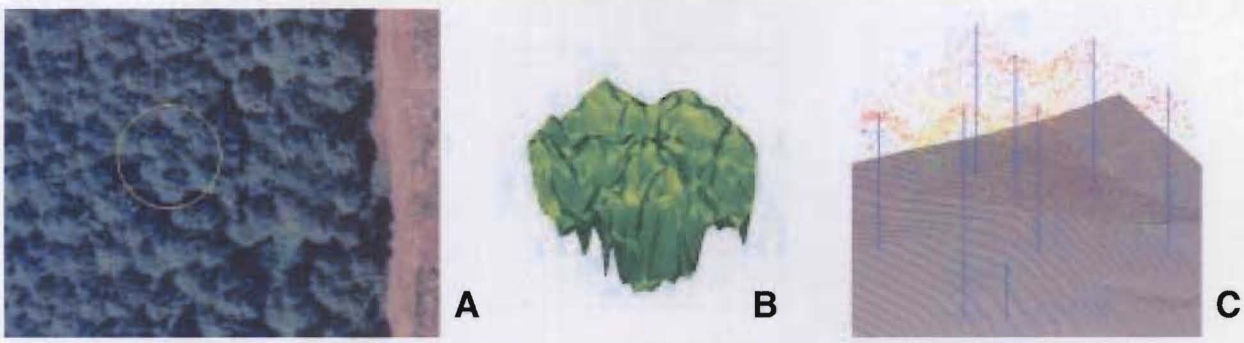

Figure 10-3—(a) Large-scale aerial photo showing growth plot, (b) detailed canopy surface model generated from LIDAR data, and (c) estimated individual tree stem locations and heights from LIDAR data.

LIDAR Measurement of Stand and Individual Tree Characteristics

In addition to assessing the accuracy of the LIDAR ground DTMs, methods are being developed to estimate both stand and individual tree metrics from the LIDAR data. Andersen et al. (2001) found that individual tree crown apexes in the overstory could be measured to within 2 m of photogrammetrically-measured tree tops. Individual trees evident on large-scale aerial photographs (fig. 10-3) were successfully detected by using LIDAR data with a "user's" accuracy of 89 percent (error of commission of 11 percent) and a "producer's" accuracy of 83 percent (error of omission of 17 percent). It appears that average stand height can be estimated well from LIDAR data; however, much work remains to determine if other metrics such as density, crown size, crown length, and diameter can be accurately estimated.

References

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