

FOREST SERVICE REMOTE SENSING TIPS

MINERALS AND GEOLOGY MANAGEMENT

Lidar Applications for Forestry and Geosciences

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Overview

For decades, resource managers have struggled to find successful solutions for mapping forest structure and tree heights. Maturing technology called lidar (light detection and ranging) offers a means of collecting this information from aircraft. Lidar provides detailed information about not only vegetation structure but also earth-surface features beneath the vegetation canopy. For around \$1.00 per acre or less, lidar offers resource managers georeferenced information about these vegetation and earth-surface features across a large area.

Lidar Systems

Measuring tree heights or mapping small terrain features, such as debris slides, is difficult even from the ground. In the past, aerial photographs have proved useful for measuring these features, but photogrammetry can be expensive to implement and technically challenging. Lidar can collect automated measurements of vegetation, terrain, and structures from aircraft.

Lidar systems measure distances by determining the travel time of each laser pulse to an object and back. This time is divided by two and multiplied by the speed of light to calculate the distance.

An airborne lidar system scans, receives, and georeferences multiple pulse returns



Figure 1—Illustration of visualization potential of 1-meter National Agriculture Imagery Program (NAIP) aerial photography draped over a 3-D lidar digital surface model (DSM).

from the ground and tops of surfaces tens of thousands of times per second. The system records the location of each lidar return in three dimensions, resulting in a realistic surface image of the landscape (figure 2).

Commercial lidar systems often have a ground sample distance of 0.25 to 2 meters. Normal horizontal accuracy is within 0.5 to 0.75 meters, depending on the steepness of the terrain, flight height above ground, and scan angle. Vertical accuracy ranges from 0.15 to 0.5 meters. As a result, lidar can map both the vegetation and terrain to a degree not previously possible without a large number of manual measurements.

Lidar Data Products: Digital Elevation Models

Lidar systems generate millions of recorded data points. The “point cloud” of raw x , y , and z data must be processed and separated into a “bare-earth” digital elevation model (DEM) and top-of-surface model depicting features above ground level such as vegetation (figure 2). Depending on its density, many more energy pulses return from the vegetation canopy than from the ground surface. To generate a bare-earth DEM, returns representing vegetation or other nonground surfaces such as rooftops must be removed from the data cloud.

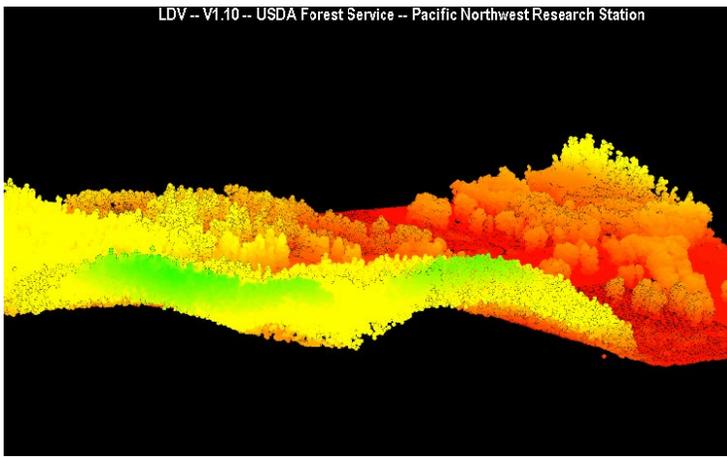


Figure 2—Visualization in 3-D of a lidar point cloud, colored by elevation (*left*); the same scene with a NAIP color photograph draped over the lidar point cloud (*right*).

The ability to generate DEMs for both of the surfaces is the reason that lidar is a useful tool for forestry applications (figure 3). The high-resolution, bare-earth DEM that results makes lidar an ideal but not yet commonly used, tool in the geosciences (figure 4). The ability to map stream channels, debris slides, and detailed surface features reduces costs for geologic and engineering applications as well.

Lidar Applications

Lidar data has proven helpful in

analyzing these natural-resource tasks (Goetz and others 2005):

- Forest inventory—provides measurements of tree height and density
- Wildlife habitat analysis—determines the forest’s structural stage
- Predictive fire-fuels modeling—determines understory vegetation density and height
- Feature extraction—depicts buildings, structures, and roads
- Three-D visualization—portrays the forest or terrain in realistic detail

- Watershed analysis—determines slope, aspect, and elevation
- Geology and Engineering—determines transportation corridors, geomorphology, and subtle terrain features
- Landslide hazard assessment—assesses presence of debris flows, slope features, and drainages.

Though lidar has disadvantages, there are several reasons to choose lidar for collecting information on vegetation structure and bare-earth features. Some advantages and disadvantages of lidar are listed on table 1.

Table 1—Advantages and disadvantages of lidar

Lidar for Natural Resource Assessments

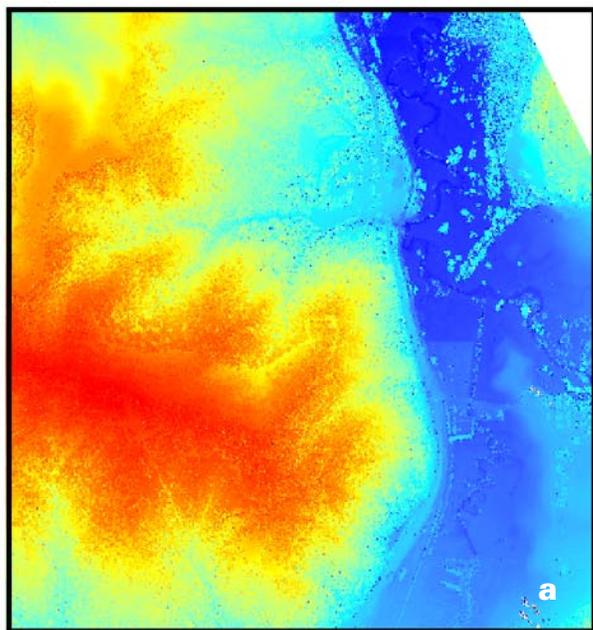
Advantages

- Lidar offers detailed elevation information acquired over large areas and at a higher resolution than conventional DEMs.
- Lidar can reduce the costs required to collect field measurements over large areas.
- Lidar data helps pinpoint locations where field data will be useful.
- The ability of lidar to penetrate dense vegetation allows collection of data over large surface areas that would be difficult to survey in any other way.
- Morphologic features that might be missed altogether by field crews can be captured at a scale that would not be possible from a 10-meter U.S. Geological Survey (USGS) DEM.
- The interpreted data layers are easy to integrate with other data sources in a GIS.
- Forest plans can efficiently incorporate results from lidar data analysis.
- Lidar data can be acquired during day or night under clear weather conditions.

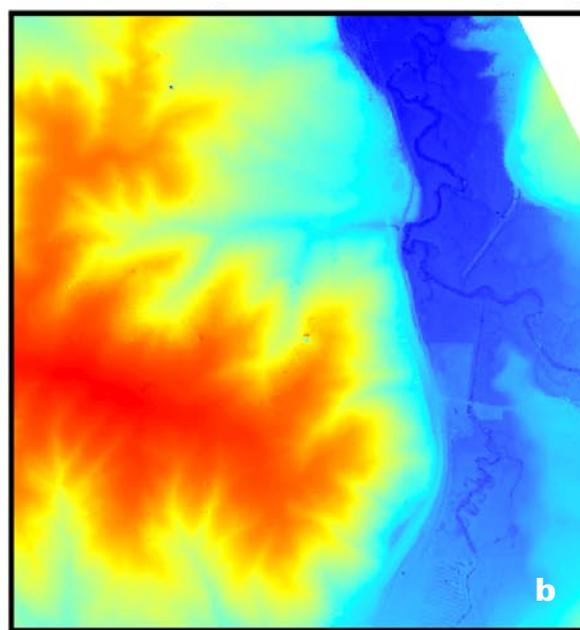
Disadvantages

- When used for forest inventory, lidar data are currently still more expensive on a per-acre basis than aerial photography.
- Processing and analyzing lidar data sets require specialized skills and software.
- Although the potential for using lidar is still growing, not all the parameters needed to address current forestry issues, especially those related to forest inventory, can be derived from lidar data and the models are not always understood well enough to generalize findings from local studies.
- Where the vegetation is so dense that light cannot penetrate the ground, such as in tropical forests, lidar probably won’t reach the ground either, and dense undergrowth may be confused with bare ground.
- Often the vegetation height calculated from lidar data is less than the height obtained through photogrammetry and field-work.

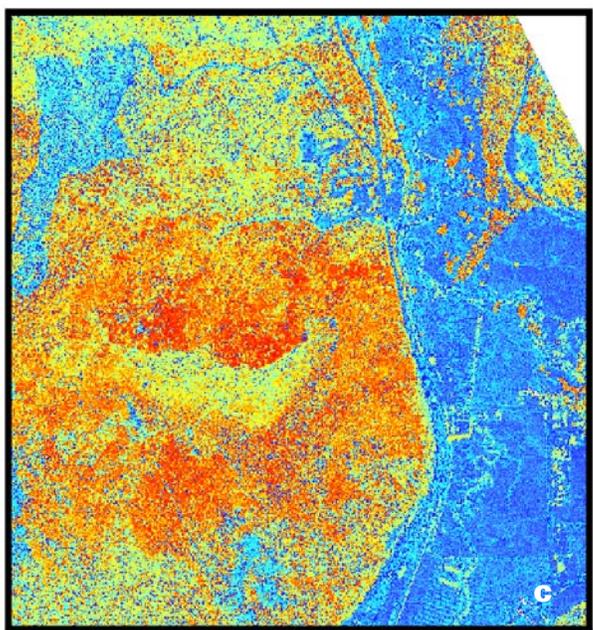
Forest Example



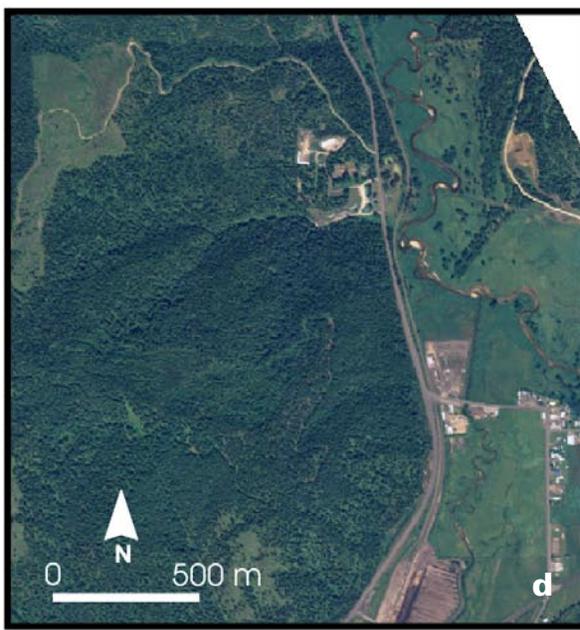
Digital Surface Model (DSM)



Bare-Earth Digital Terrain Model (DTM)



Canopy Height Model (filtered for outliers)



One-Meter NAIP Photography

Figure 3—A canopy height model (*C*)—a vegetation analysis from lidar data—is calculated by subtracting the bare-earth model generated from the last-return data (*B*) from the first-return top-of-surface model (*A*). The NAIP photograph (*D*) shows the forest clear-cuts well, but without stereo capabilities, the height differences in the dense forest are not well defined. The study area is located in the Idaho Panhandle National Forest near Emerald Creek.

Cost

It is difficult to set a precise amount for the cost of lidar acquisition, but a general rule of thumb in 2001 was between \$0.50 and \$1.00 per acre for project areas larger than 1,000 square miles (Flood 2001). Generally,

acquiring lidar over larger areas is more cost effective than surveying small areas because of mobilization costs, which vary depending on the distance from the aircraft location to the project area. Other factors influencing costs include the density of the

point spacing, the available time frame, the shape of the project area, and the spatial and vertical accuracy required for the project. The cost of the analysis increases for each value-added product requiring additional processing.

Bare Earth Example



One-Meter Bare-Earth Lidar Data

Ten-Meter DEM—Subset of Clarkia Quadrangle

Figure 4—Comparing a hill-shade relief obtained from the lidar bare-earth data (*left*) and a subset of the 10-meter U.S. Geological Survey (USGS) DEM of the Clarkia 7.5-minute quadrangle in Idaho (*right*). Notice the details visible in the floodplain and along the riverbed. Along the south end of the hill in the southwest corner of the image, the lidar data show a narrow trail that is not visible at all on the USGS data.

References and Suggested Reading

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DTM colored by tree height

