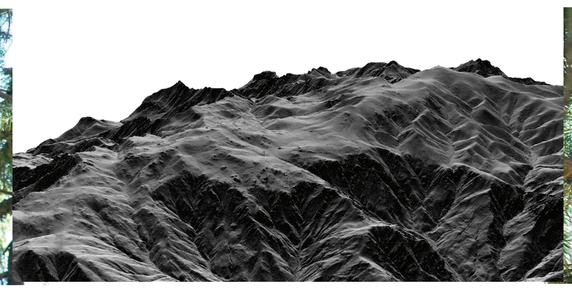
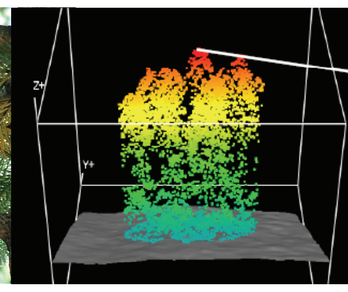
Pinaleño LiDAR

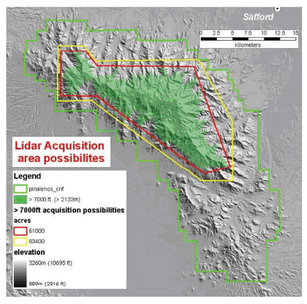
New Tools for Forest Restoration





INTRODUCTION

Changes in forest composition and structure have lead to large and severe wildfires and devastating insect outbreaks in the Pinaleño Mountains of Southeastern Arizona. The risk of additional wildfires have prompted a restoration effort aimed at habitat protection for the Mt. Graham red squirrels (*Tamiasciurus hudsonicus grahamensis*), a federally listed endangered species. Airborne Laser Scanning or LiDAR has been used as a more cost effective means to gather forest structure and biomass information.



What is LiDAR?

Light **D**etection **a**nd **R**anging also called Airborne Laser Scanning.

LiDAR is an active remote sensing system that uses laser light to determine elevation. The travel time of each laser pulse to objects on the ground and back is divided by two and multiplied by the speed of light to calculate the precise distance.

Passive remote sensing systems, such as aerial photographs or multispectral satellite imagery, capture reflected solar energy. These systems produce two-dimensional (x, y) images. LiDAR adds the third dimension of elevation (z). LiDAR systems for terrestrial surveys use a near-infrared laser, enabling them to record the intensity of reflected energy. When available, this intensity data, which looks like a gray-scale image, can distinguish between different types of surfaces (for example, vegetative and impervious).

An airborne LiDAR system scans, receives, and georeferences multiple pulse returns from the ground, treetops, rooftops, and other objects tens of thousands of times per second. The system uses an inertial navigation system (INS) and a global positioning system (GPS) to determine the location of each LiDAR return in three dimensions, automatically adjusting for the "look angle."

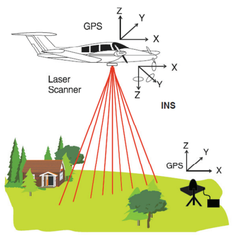
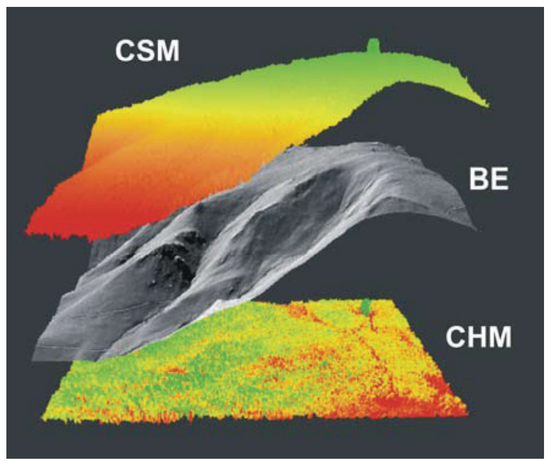


Figure 2 — Illustration of the components of an operating lidar system (Renslow 2001).



LiDAR data models (right) from the Pinaleño Project
Canopy Surface Model (CSM)
Bare Model (BE)
Canopy Height Model (CHM)

PROJECT GOALS

Enhanced mapping of the forest structure to better understand Mt. Graham Red Squirrel habitat and the implementation and monitoring of the Pinaleño Ecosystem Restoration Project (PERP).

OBJECTIVES:

- Mapping of canopy, biomass, fuel loading, canopy base heights, forest structure characteristics.
- Mapping of aspen, remaining mixed-conifer old growth patches.
- Mapping of recent disturbances from insect activity and wildland fire.
- Collection of forest stand parameters useful in updating stand inventories.
- Collection of forest stand data in locations where data does not currently exist and is difficult to obtain.

Phase 1. Project Design and Data Acquisition.

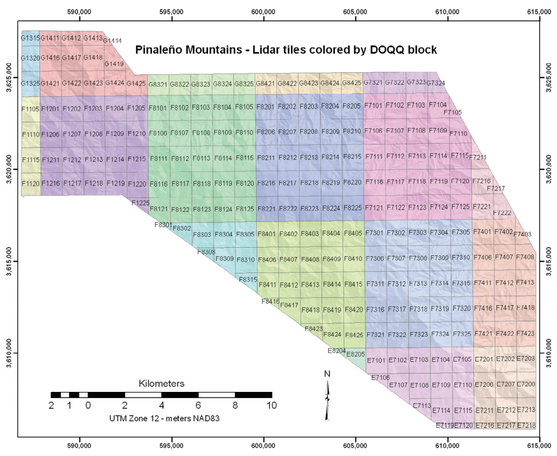
Technical contract specifications to acquire LiDAR data were developed and contract awarded. LiDAR data was acquired on 85,518 acres (35,000 ha) September 2008. Post processed data sent to RSAC January 2009.

Partial List of Lidar Project Specifications in Forested Areas*	
Pulse density per sq. meter	Minimum 1 for stand-level canopy models and medium-resolution ground models (2-m grid). 4+ for individual tree-canopy measurements and high-resolution ground models (1-m grid).
Returns per pulse	Minimum 2 for canopy and ground-surface measurements. 4+ for improved mid- and low-canopy structure measurements.
Laser beam divergence	Narrow beam settings have provided better tree-height information and a higher percentage of ground returns in limited studies. Narrow beam allows higher flight altitudes.
Scan angle	±15 degrees of nadir (13 degrees recommended) or less increases ground returns in heavy forest cover, but narrower scan angles increase the number of flight lines required and costs. Because the operational mechanics of most sensors require them to slow down before they reverse scanning direction as well as a little time to speed up again, the pulse density will increase along the outer edges of the swath width. To keep the point density more evenly spaced across a swath width (and over the project area), the vendor should acquire data over a slightly wider swath width (say, for example, a few degrees wider than required) but clip these outer additional degrees on both sides from the data set. The aggregate point density should be calculated based on the data clipped to the narrow scan angle.
Swath overlap	Usually 50 percent or more sidelap on adjoining swaths, i.e., survey is designed for 100 percent double coverage at planned aircraft height above ground to reduce any possibility of data gaps. Adjacent flight lines should come from parallel opposing directions. Ideally 50 percent sidelap provides information from different scan angles for areas on or near the surface. The opposing directions can help in the flight line to flight line calibration.
Season of survey	Leaf-off in areas of significant hardwood cover and no significant snow cover result in better ground measurements but can be difficult to achieve in higher elevations. Leaf-off flight window can be very constrained by weather in the Northwest, resulting in lower probability of on-time mission success. Leaf-off also allows separation of hardwoods from conifers, but dead trees are difficult to distinguish from leaf-off hardwoods. Leaf-on for distinguishing live from dead trees. Conifer areas can be flown leaf-on, but poor visualization of hardwoods from conifers results. Leaf-on flight window is often larger, resulting in higher probability of on-time mission success.
Absolute lidar measurement accuracy	Horizontal: typically +/-0.5 to 1 m, depending on survey objectives. Vertically: typically +/-0.15 to 0.5 m, depending on survey objectives
Swath-to-swath lidar relative accuracy	Horizontal: +/-0.25 to 0.5 m, depending on survey objectives. Vertically: +/-0.10 to 0.5 m, depending on survey objectives
Lidar instrument ownership	A vendor who owns the sensor needed to meet the required specifications will be able to do so at a lower cost than one who has to subcontract with others or lease an instrument for the job.

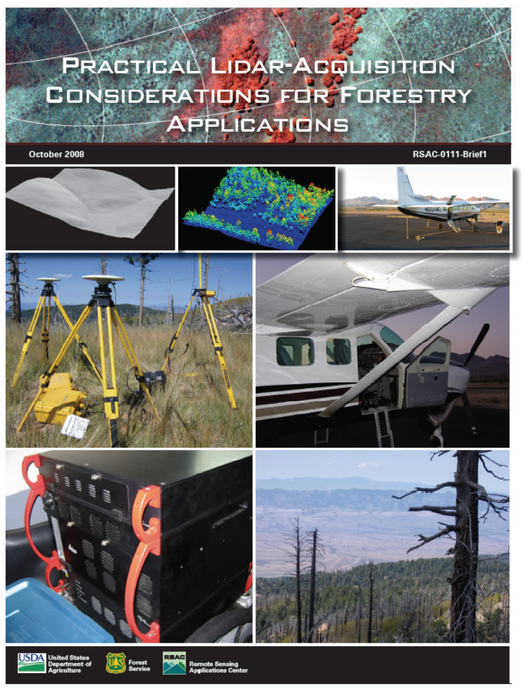
*Adopted from the Puget Sound Lidar Consortium (PSLC)

Acquisition dates	September 22–27 2008; Leaf-On
Aircraft	Cessna Caravan
Lidar scanner	Leica ALS50 Phase 2
Pulse rate	70 to 90 kHz
Scan rate	52.2 Hz
Maximum returns per pulse	4
Scan angle	+/-15 degrees
Beam divergence	19 – 29 cm
Flight above ground level	800 – 1300 m
Flight line configuration	Opposing adjacent parallel lines
Flight line overlap	50% sidelap
Average lidar pulse return spacing	7.36 points/m2
Average ground point density	0.98 points/m2
Acquistion area	85,518 acres
Total numbers of returns	2,892,925,979

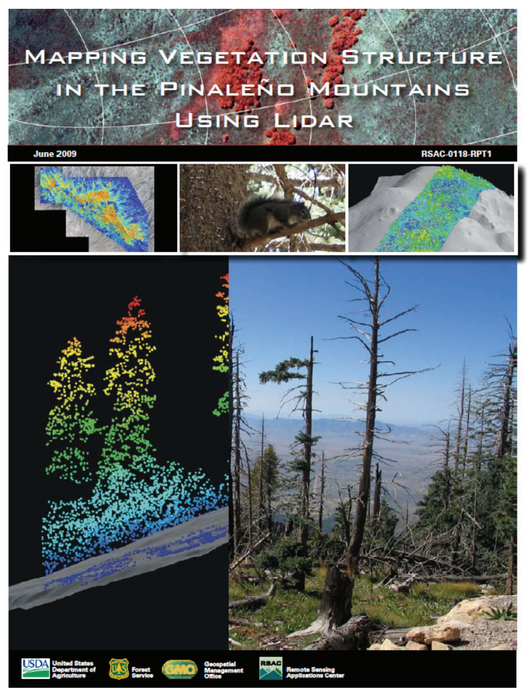
Project post-processed data summary



LiDAR data tiles for Pinaleño Project by DOQQ block



Pinaleño LiDAR Project Documentation
Phase 1 (above) Phase 2 (below).



These publication can be downloaded from the RSAC Web sites: http://fsweb.rsac.fs.fed.us

FUSION Software can be downloaded from RSAC Website: http://www.fs.fed.us/eng/rsac/fusion/

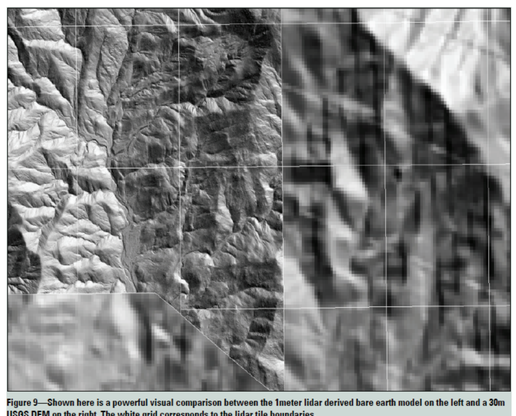
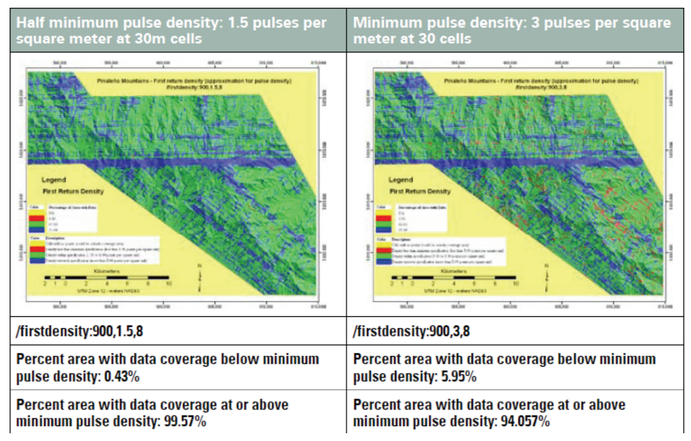


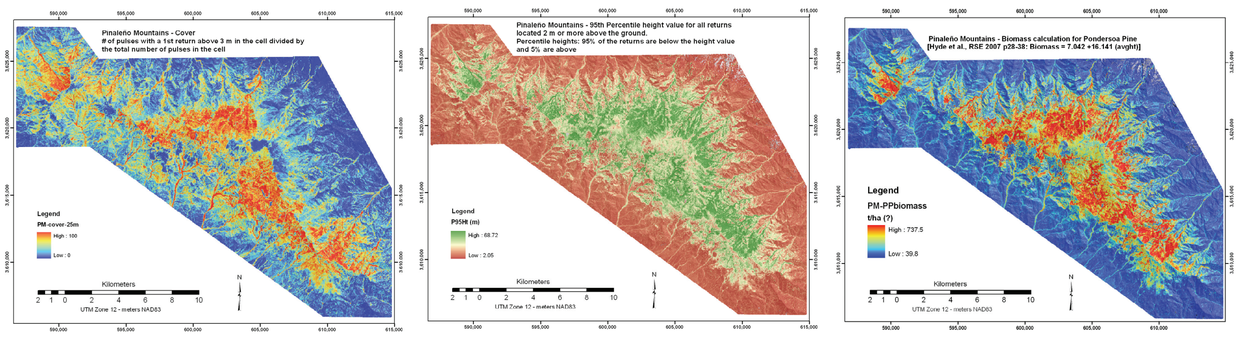
Figure 9—Shown here is a powerful visual comparison between the 1meter lidar derived bare earth model on the left and a 30m USGS DEM on the right. The white grid corresponds to the lidar tile boundaries.

Comparison of LiDAR Bare Earth models to current USGS DEM



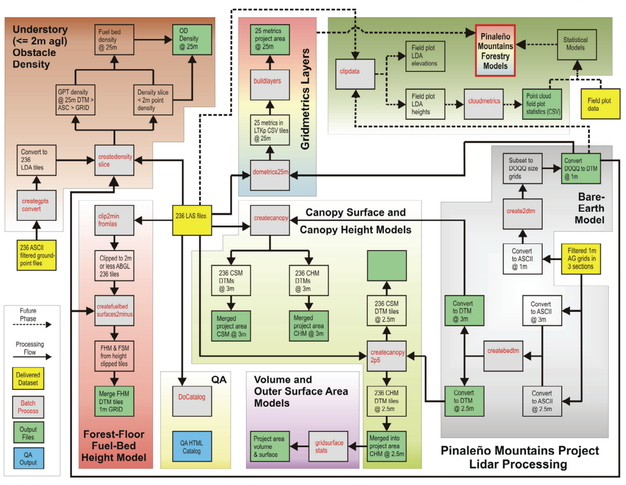
Half minimum pulse density: 1.5 pulses per square meter at 30m cells	Minimum pulse density: 3 pulses per square meter at 30 cells
/firstdensity:900,1.5,8	/firstdensity:900,3,8
Percent area with data coverage below minimum pulse density: 0.43%	Percent area with data coverage below minimum pulse density: 5.95%
Percent area with data coverage at or above minimum pulse density: 99.57%	Percent area with data coverage at or above minimum pulse density: 94.057%

Quality assurance of data is a key initial step in the process flow



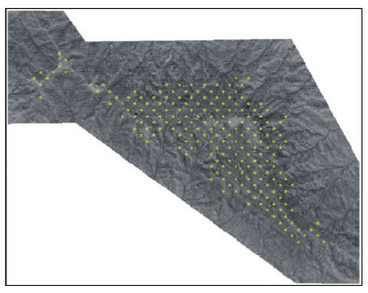
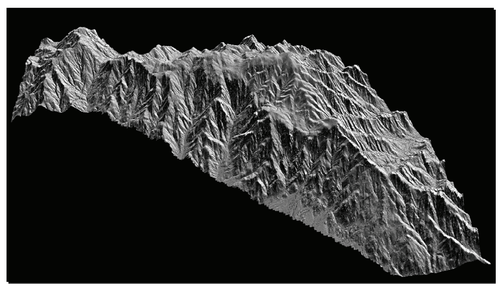
LiDAR as an active sensor directly derives forest attributes of tree heights and vegetation cover, (upper left and center) attributes such as biomass (upper right) must be indirectly derived based on relationship of heights and cover. Biomass map is an example based on a relationship developed for ponderosa pine and a similar relationship will be developed for mixed-conifer in the Pinaleño Mountains.

Phase 2. Initial data processing procedures and development of LiDAR GIS base layers.



LiDAR process flowchart for Phase 2. Much of the software processing of LiDAR data for forestry purposes is done using the FUSION software program. LiDAR is a data intensive tool.

Phase 3. Field Data Acquisition and Processing. Current phase of the project

Field plot grid (above) , of the 200 potential 0.05 ha plots only 79 plots were sampled due to terrain limitations on accessibility. Plots were mapped to submeter locations.

PROJECT PARTNERS

USDA Forest Service – Remote Sensing Applications Center (RSAC), Southwest Region Geospatial Group, Coronado National Forest, Forest Health Program – Arizona Zone Office, Rocky Mountain Research Station, Pacific Northwest Research Station
University Of Arizona – School of Natural Resources and the Environment, Laboratory for Tree Ring Research, wildlife Conservation and Management, Office of Arid Land Studies
USDI Fish and Wildlife Service – Ecological Services

USDA FOREST SERVICE
CORONADO NATIONAL FOREST

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