

**Technical Summary and Proposal of LiDAR-based Ecological Monitoring
for the Dinkey Landscape Restoration Project
December 1, 2010**

Marc Meyer, Southern Sierra Nevada Province Ecologist
USDA Forest Service Pacific Southwest Region

What is LiDAR?

LiDAR is an acronym for *light detection and ranging*. Lidar is an active remote sensing system that uses laser light to provide information related to topography of an area, including the shape, height, and structure of surface features (e.g., vegetation; Figure 1). The travel time of each laser pulse, often from airborne laser scanning, to objects on the ground and back is measured to calculate the precise distance, often with accuracies between 15 and 30 cm.

An airborne topographic lidar system scans, receives, and georeferences multiple pulse returns from the ground, treetops, rooftops, and other objects tens of thousands of times per second (Goetz et al. 2006). Analogous to the use of radio waves in radar technology, lidar uses light outside the visible spectrum to estimate the precise range to an object by measuring the time delay between transmission of a pulse and detection of the reflected signal.

How does LiDAR differ from passive remote-sensing and ground-based sampling methods?

Passive remote sensing systems, such as aerial cameras or multispectral sensors, capture reflected solar energy (Goetz et al. 2006). These systems produce two-dimensional (x, y) images, whereas lidar adds the third dimension of elevation (z). Additionally, Lidar-based terrestrial surveys use a near-infrared laser, enabling them to record the intensity of reflected energy. When available, this intensity data can distinguish between different types of surfaces (e.g., vegetative and impervious).

Like other remote sensing methods, lidar has the advantage of collecting spatial data over large areas and across various spatial scales. In comparison, ground-based sampling to quantify forest structure at large landscape scales is often hampered by methodological, logistic, and economic constraints. The use of lidar in concert with existing and future ground-based vegetation sampling data for the Dinkey Landscape Restoration Project (Dinkey LRP) is an ideal method for quantifying vegetation structure in an efficient and cost-effective manner.

What are the benefits and potential uses of this data? How will it contribute to adaptive management for the Dinkey LRP?

Lidar provides accurate models of topography (e.g., 1-meter Digital elevation models; DEMs), as well as detailed information about the vertical structure of objects on the earth surface (e.g., vegetation; Fig. 2). It can penetrate forest canopies to produce high-resolution images of ground topography. Numerous ecological and other applications for lidar have been developed (Goetz et al. 2006), including but not limited to:

- Forest inventories and monitoring

- Wildlife habitat evaluations (Figure 3)
- Wildland fuel assessments
- Meadow and stream channel mapping
- Watershed/floodplain assessments
- Snowpack monitoring
- Road or utility corridor mapping
- Landslide hazard assessments

Lidar can contribute to adaptive management of the Dinkey LRP by monitoring changes in vegetation structure and habitat for late-seral wildlife species (e.g., Pacific fisher, California spotted owl) throughout the entire project area prioritized for ecological restoration treatments. Such monitoring is a critical step for adaptive management of the project. It can also provide pre-treatment information to assist in setting priorities for ecological restoration. For example, lidar data can be used to identify: (1) forest stands most prone to crown fire, (2) montane meadows that are currently threatened conifer encroachment, or (3) high quality wildlife habitat for fisher and spotted owl at a variety of spatial scales.

What are its limitations? Are there examples?

There are several limitations of Lidar. It does not provide species composition information for forests and other vegetation types. Vegetation data under dense forest canopies can be limited due to high canopy interference. Lidar also depends on ground-based vegetation data to provide accurate estimates of forest metrics, such as basal area, forest biomass, and tree density. Additional limitations and examples of practical applications are outlined in Goetz et al. (2006).

Do we have to ground-truth the LiDAR?

Field-based vegetation data is required to estimate most metrics such as basal area and stand density, but it is not required for canopy cover or stand/tree height estimation. Using a combination of existing plot data with additional field data collection will allow us to determine the accuracy of our lidar-based estimation.

Is this technique an accepted method or are we doing research?

One of the strengths of LiDAR is that it appears to be used widely for a variety of applications by research, management, and industry. It is a cutting-edge technology that is widely accepted as high-quality data. This technology appears new to most people, but it has already been in use by at least a dozen different National Forests for the sole purpose of helping guide management decisions through inventory or monitoring.

How common is the use of LiDAR and is it accepted by reviewing peers?

The use of LiDAR for our purposes is not common, but recent technological advances and lower cost of LiDAR has led to an exponential increase in its use for a variety of applications. Among the scientific community, LiDAR is not a new technology (developed in the 1970's), but its application in quantifying forest structure and wildlife habitat is considered reliable, comprehensive, and innovative.

What are some of the potential LiDAR-derived vegetation metrics?

1. Tree Density—the number of trees per unit area.
2. Tree Height—distance along the axis of the bole of the tree from the uppermost point.
3. Stand Height—average height of all dominant and codominant trees in a stand.
4. Canopy Cover—amount of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage or plants, including small canopy openings.
5. Canopy Density— amount and compactness of the crown foliage of trees and shrubs.
6. Canopy Height—vertical distance from the ground to the crown base of a standing tree.
7. Basal Area—cross-sectional area of all stems of a species or all stems in a stand measured at breast height and expressed per unit of land area.
8. Forest Biomass—living or dead weight of organic matter in a forest expressed in units such as living or dead weight, wet or dry weight, ash free-weight, etc.
9. Forest Volume—volume of the main stems of trees, excluding the stumps and tops.
10. Leaf Area Index—sum of all the upper or all-sided leaf surface areas projected downward per unit area of ground beneath the canopy.
11. Rumple –rugosity (amplitude of the height of a surface) of canopy surface. This is a measure of canopy surface heterogeneity/complexity and is calculated as the ratio of the canopy surface area divided by the underlying ground surface ratio. Analogous to the degree to which the surface of a sheet of paper is crumpled when it is compressed.

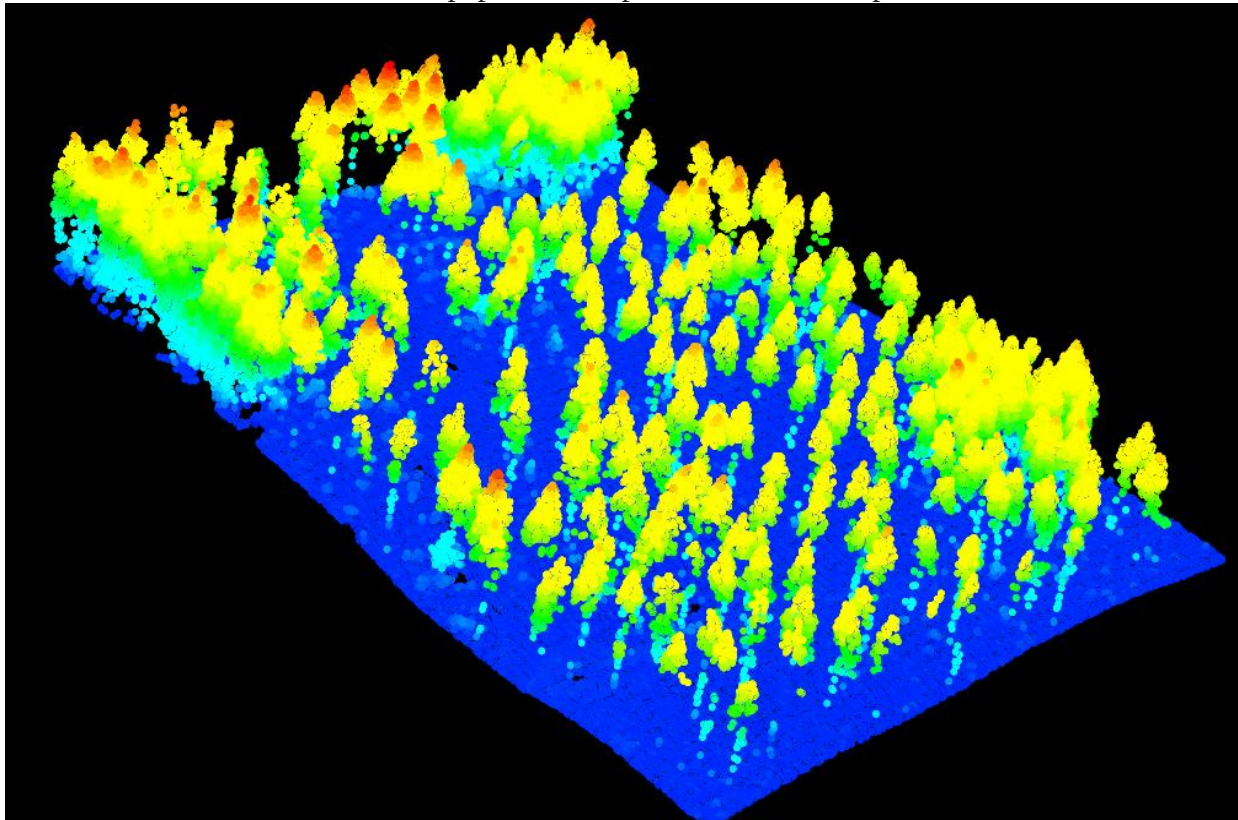


Figure 1. Example of forest stand from LiDAR data collected at the Lubrecht Experimental Forest in Montana (U.S. Forest Service Remote Sensing Applications Center 2010). Stand visualization image created with FUSION software (PNW 2010).

Additional specific monitoring objectives mentioned by the Dinkey Collaborative Planning Group (responses in *italics*):

- (1) Vegetation composition and structure (understory and overstory) in fisher home ranges – *Only forest structure information will be provided, as composition data is not available.*
- (2) Effects of prescribed fire and thinning on fisher habitat (pre-and post-treatment comparison) – *This can potentially be evaluated by comparison of pre- and post-treatment lidar data.*
- (3) Forest restoration treatments meet the objectives outlined by the Dinkey collaborative group (PSW GTR-220 implementation) – *Some potential metrics include mean and variance in canopy height, canopy cover, basal area, or canopy density, as well as rumple (canopy surface complexity). Metrics will be calculated across different portions of the forest landscape (canyons, ridges, N-facing vs. S-facing slopes).*
- (4) Large snag BA estimation – *Published research (Martinuzzi et al. 2009; Remote Sensing of Environment 113:2533-2546) indicate that this is possible but will rely on adequate ground-based data; larger diameter (>20" dbh) snags may be more informative for fisher habitat.*
- (5) Meadow (and watershed) restoration efforts (presumably identification of priority meadow for restoration efforts and monitoring treatments) – *Possible but requires further evaluation.*
- (6) Canopy cover – *This metric will be analyzed for the entire Dinkey LRP AOI.*

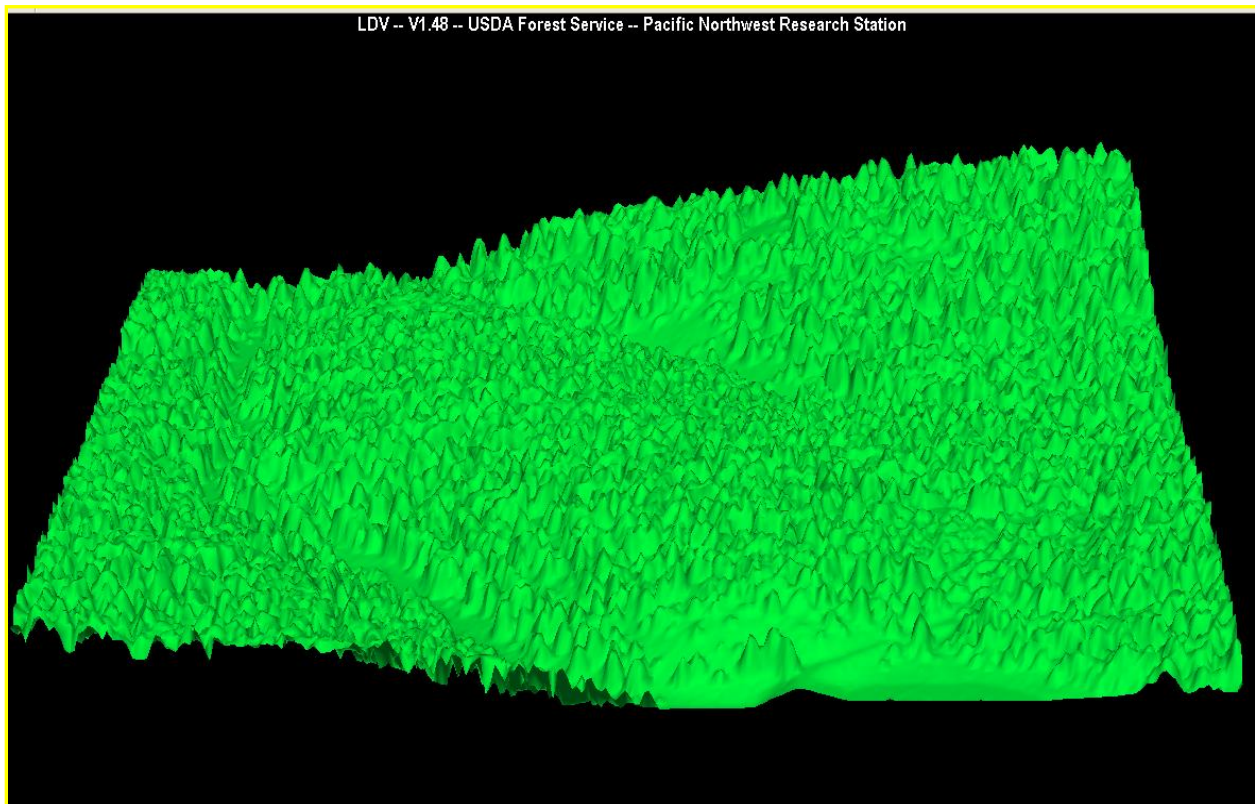


Figure 2. LiDAR-derived canopy surface model used to estimate canopy height (prior to subtracting the bare earth surface) over an entire sub-watershed (USFS RSAC 2010). Model produced using FUSION software (PNW 2010).

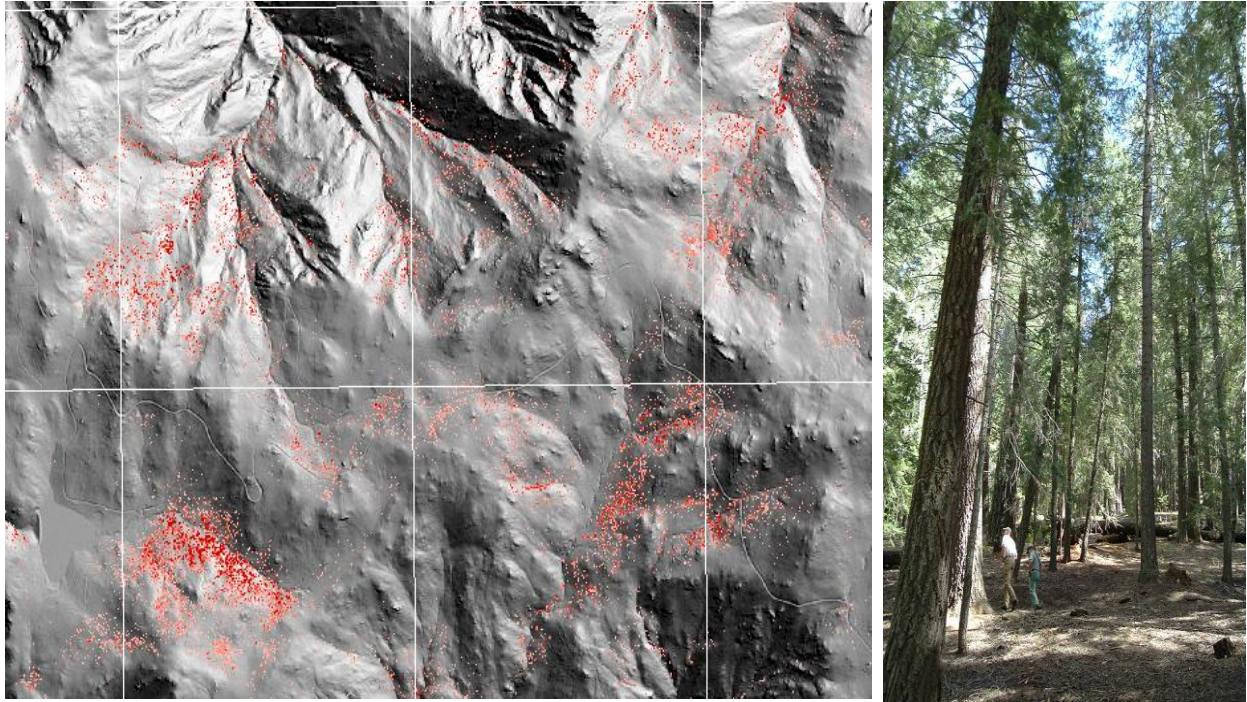


Figure 3. LiDAR-derived canopy height and canopy cover habitat model for Mount Graham red squirrel (federally-listed endangered species) habitat in the Pinaleno Mountains of the Coronado National Forest, Arizona. Red pixels on the map to the left represent areas that exceed 70 ft canopy height and 50% canopy cover. Typical Mount Graham red squirrel habitat is shown on the left, consisting of mid-elevation old-growth forest with tall trees and relatively high canopy cover (USFS RSAC 2009).