

Detection and Characterization of Rangeland Vegetation Using Airborne Laser Swath Mapping

David R Streutker (stredavi@isu.edu) and Nancy F Glenn (glennanc@isu.edu), Department of Geosciences, Idaho State University
 ISU Boise Center, 12301 W. Explorer Dr. Boise, ID 83713

Abstract

Airborne Laser Swath Mapping (ALSM, also referred to as LIDAR) is used to determine the presence and height of various vegetation types in rangeland areas of southeastern Idaho. Vegetation heights are difficult to determine using established multispectral and hyperspectral remote sensing methods and are of interest in differentiating between spectrally similar subspecies (i.e. big sagebrush and threetip sagebrush) and in determining vegetation maturity (and thus history, such as evidence of past burns or other catastrophic events). While LIDAR has been shown to be of great use in studying the high-relief canopies of forests, the low canopy heights of grasses and brush encountered in rangeland areas make such vegetation difficult to discern from the bare ground surface. An added obstacle is that the elevation uncertainties of LIDAR data are often comparable to the rangeland vegetation heights. This study attempts to extract vegetation heights from first-pulse LIDAR data by assuming a partially open canopy with a relatively smooth underlying ground surface. Surface roughness and fractal analysis are then used in an attempt to classify vegetation types.



Photos courtesy Jacob Mundt, ISU

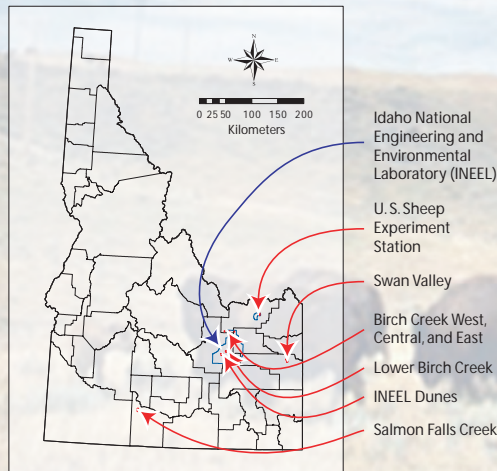
Data

LIDAR data was collected for eight locations throughout southern Idaho during the fall of 2002. Individual datasets were acquired for the U.S. Sheep Experiment Station (operated by the USDA Agricultural Research Service), a portion of Salmon Falls Creek, Swan Valley, as well as five datasets in and around the Idaho National Engineering and Environmental Laboratory (INEEL, operated by DOE). The majority of the terrain in these areas consists of gently rolling rangeland, with the exception Salmon Falls Creek, a canyon bordered by agricultural areas.

The datasets range in size between two and 15 km² and have point densities of approximately 1.2 m⁻². Each LIDAR point includes time, easting, northing, elevation, and intensity values for the both the first and last return.

Each dataset is GPS corrected to remove any overall bias. Absolute accuracies are found to be 20 cm vertical and 1 m horizontal. Relative vertical and horizontal accuracies are found to be approximately 5 cm and 0.5 m, respectively.

Relative accuracy is defined as the accuracy of the location of a data point with respect to its neighboring points. It is determined by statistically analyzing a set of points assumed to represent a flat surface. In the case of vertical accuracy, such a surface might be standing water or a rooftop, while horizontal accuracy could be determined using the outer wall of a building.



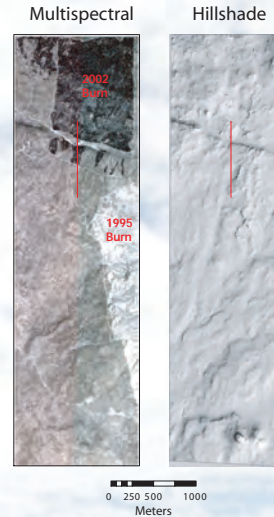
Trial Case

The U. S. Sheep Experiment station (USSES), located near Dubois, ID, was chosen as a test case for vegetation height extraction from the LIDAR data. This selection was made for the following reasons:

- 1) The LIDAR dataset, consisting of eight million postings over an area of 6.8 km², is of a relatively manageable size.
- 2) The topography of the USSES dataset is fairly uniform and smooth, with elevations ranging from 1778 to 1866 m. The average slope between adjacent data points is 11%.
- 3) The USSES is dominated by typical rangeland vegetation, consisting of grasses and low shrubs, such as sagebrush and bitterbrush.
- 4) The USSES has been the site of periodic controlled burns throughout its history. Areas within the dataset have burned as recently as 1995 and 2002. These burned areas provide ideal cases for comparing contrasting rangeland vegetation heights.

The multispectral image to the right was taken by QuickBird at approximately the same time that the LIDAR data was acquired. The 2002 burn scar, only a few months old at the time, is quite apparent. The 1995 burn scar, though in a state of recovery, is also readily visible.

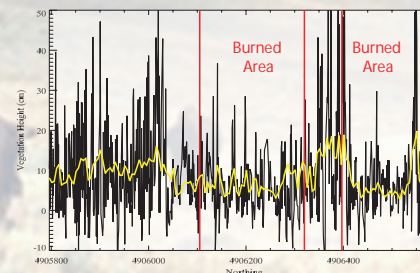
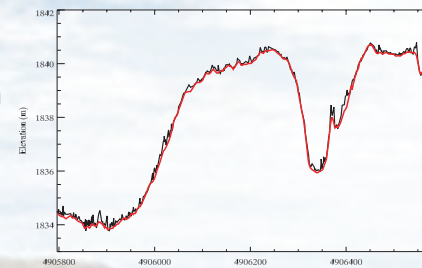
The greyscale image to the right is a hillshade created from the first pulse LIDAR data.



Method

The LIDAR data is binned into 5 m cells. The point of lowest elevation within each 5 m cell is assumed to represent the bare ground. These ground points are then located and used to interpolate a ground surface across the entire dataset.

The figure to the right shows a cross-section of the USSES elevation data. The black line represents the original LIDAR data, while the red line shows the interpolated ground surface. The location of the cross-section within the dataset is indicated by the red line in the images above.



Subtracting the ground surface from the elevation heights results in a set of feature heights which are assumed to be vegetation. These vegetation heights are then used to determine surface roughness (which is equivalent to the standard deviation) at a 5 m resolution.

The figure to the left shows the vegetation heights corresponding to the elevation data shown in the figure above. The black line represents the individual vegetation heights, while the yellow line shows the surface roughness, as calculated over 5 m intervals.

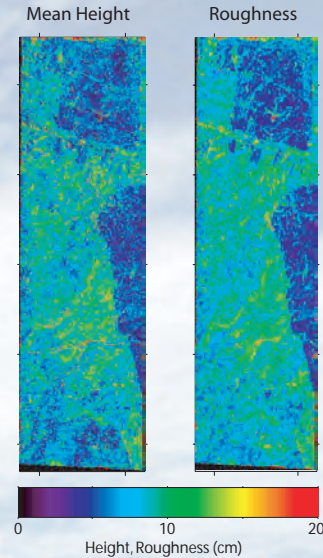
Results

The images to the right show the mean height and roughness of the vegetation. Both are calculated within 5 m grid cells. The mean height and roughness vary mostly between 0 and 20 cm.

While the height and roughness are closely related, the roughness seems to more clearly delineate regions of different types of vegetation, such as the burned areas in this case. In both images the burned areas clearly have lower vegetation heights and surface roughness, on the order of 5 cm. The unburned area, on the other hand, displays vegetation heights and roughness between 10 and 15 cm.

It is interesting to note that the 1995 burn, though it has had over seven years to recover, still shows very low vegetation heights. It is likely yet dominated by bare earth and grasses.

This demonstrates the usefulness of LIDAR to monitor rangeland growth and maturity. It also indicates the possibility of using LIDAR to measure biodiversity within a habitat and to locate areas of monoculture.

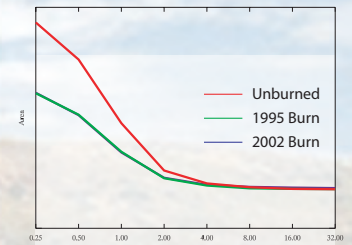


Fractal Analysis

An attempt was made to use fractal methods to analyze the vegetation types. The triangular prism method was used to determine the surface area at varying resolutions. The fractal dimension of a surface can be derived from the slope of the log-log graph of surface area versus resolution.

The graph to the right shows the result of such an analysis. The red line is the surface area versus resolution in the unburned region of the dataset. The green and blue lines represent the 1995 and 2002 burned areas, respectively.

As can be seen from the graph, the fractal dimensions of the surfaces are not well defined, as would be indicated by straight lines. At the smaller resolutions, however, each area does seem to display fractal behavior, with the unburned region having a higher fractal dimension than both of the burned areas.



Conclusions

The preliminary results of this study indicate that vegetation heights can be determined with a precision on the order of 5 cm. This should allow for the characterization of rangeland vegetation, including differentiating between grasses and low scrub bushes. Application of this method to the other Idaho sites and a thorough comparison to *in situ* measurements are the next steps in this research.

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