

Modeling Semiarid Low-Height Vegetation with Airborne LiDAR

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Abstract - Low-height vegetation, common in semiarid regions, is difficult to characterize with airborne LiDAR (light detection and ranging) due to the similarities, in time and space, of the point returns of vegetation and ground. Other complications may occur due to the low-height vegetation structural characteristics and the effects of terrain slope. This research is focused on modeling methods and error assessment of low-height vegetation in varying terrain. Several methods to best determine vegetation height and 2-d crown area are developed using both the LiDAR point cloud and rasters derived from the point cloud. These methods are tested on varying sloped terrain. Error assessments of bare earth terrain models in low-height vegetation cover types and slopes are also performed. Recommendations for modeling low-height vegetation and/or filtering low-height vegetation from terrain models will be presented, along with open-source algorithms.

Keywords: LiDAR, laser altimetry, shrub steppe, semiarid, slope, crown area

1. INTRODUCTION

Vegetation communities in semiarid environments are typically low in stature and spectrally indeterminate (Mitchell and Glenn, 2009) and, therefore, challenging to quantify with remotely sensed data. Spectral measurements can provide spatially contiguous information on 2-dimension canopy projection (crown area) and cover (e.g. Chopping et al., 2008; Glenn et al., 2005) but require additional ground measurements to establish relationships between these parameters and height.

Light detection and ranging (LiDAR) remote sensing, also known as laser altimetry, provides direct estimates of vegetation height that complement spectral data used for canopy cover estimation (Mundt et al., 2006; Sankey et al., 2010). However, the low-height (typically < 2 m tall) and sparse cover of semiarid shrub-steppe communities present challenges for LiDAR data retrieval (Streutker and Glenn, 2006; Glenn et al., in press; Mitchell et al., in press). These challenges include confusion of vegetation and ground returns (Riano et al., 2007), high canopy penetration due to sparse cover (Streutker and Glenn, 2006), and vegetation and ground classification errors on steep slopes (Chow and Hodgson, 2009; Su and Bork, 2006; Spaete et al., 2011).

In this study, we report results from LiDAR canopy measurements at the individual shrub scale in sloped and flat terrain in the semiarid shrub-steppe. Sagebrush canopy measurements included height and crown area, which is equivalent to the 2-dimensional canopy projection. Shrub crown area measurements across large areas using LiDAR

data could provide useful information on disturbance history and shrub age, which are important input variables in wildlife habitat models and community-level assessments (Chopping et al., 2008).

2. MATERIALS AND METHODS

The study areas are located within the Reynolds Creek Experimental Watershed (RCEW) in southwestern Idaho, USA and the Department of Energy Idaho National Laboratory (INL) in southeastern Idaho. Sagebrush and grassland communities are the dominant vegetation cover in the two study areas.

2.1 Field Sampling

Field sampling included collecting the location and physical characteristics of approximately 100 sagebrush at each location. At RCEW, we stratified our selection based on three hillslope classes, with sagebrush occupying slopes <10°, slopes between 10° and 15°, and slopes > 15°. All sampled sagebrush plants were spatially isolated with at least a 1-m space around the plant. Height and canopy diameter measurements were collected for each sagebrush. The crown was divided into six equal zones from a planimetric view and the maximum height was recorded for each zone.

2.2 LiDAR Data

LiDAR data for RCEW and INL had a mean point density of approximately 4.5 and 9.5 points/m², respectively. The vertical accuracy of the LiDAR data was within approximately 0.10 m and 0.02 m for RCEW and INL, respectively. Horizontal error was approximately 0.28 m and 0.50 m for RCEW and INL, respectively.

2.3 LiDAR Processing

The LiDAR data for the two study areas were processed using Idaho State University's publically available LiDAR processing tools (<http://bcal.geology.isu.edu/Envitools.shtml>) as described in Streutker and Glenn (2006), Glenn et al., in press, and Mitchell et al., in press. The LiDAR point clouds were height filtered to separate ground returns from vegetation returns using a 7 m natural neighbor interpolation method.

3. RESULTS

3.1 Sagebrush Height Estimates

LiDAR-derived sagebrush heights were estimated accurately to within +/- 0.26 – 0.32 m (two standard deviations) at the RCEW study area, with no significant difference between slope classes (Glenn et al., in press). At the INL study site (flat terrain), LiDAR-derived sagebrush heights were estimated to within +/- 0.28 m (two standard deviations) (Mitchell et al., in press). We found the use of both the point cloud and raster data to be equally successful. Overall, the

results indicate that sagebrush height is underestimated by LiDAR in most cases.

3.2 Sagebrush Crown Area

The comparison between the LiDAR-derived 2-D sagebrush crown area and the field-based sagebrush crown area indicate an average underestimation using LiDAR by 49% at RCEW and 33% at INL (Glenn et al., in press; Mitchell et al., in press). The underestimation at RCEW was equivalent in all slope classes.

4. DISCUSSION AND CONCLUSIONS

Overall, sagebrush height was estimated accurately to within 0.30 m. We conclude that sloped terrain has little influence on height and crown area estimations. The average shrub height in the two focus areas was less than 1 m and thus our height error is equivalent to roughly one third of the total sagebrush height. A related study (unpublished data) indicates a similar underestimate in LiDAR-derived shrub heights even after sampling 500 shrub-dominated plots of 3 m x 3 m. Taken together, our results indicate that LiDAR data can be successfully used in medium height vegetation of big sagebrush and bitterbrush-dominated communities when corrected for underestimated heights. However, LiDAR applications might be limited in low sagebrush-dominated communities, especially in younger plants of low stature.

The sagebrush height errors may be attributed to errors in the bare ground raster used for height estimates (including vertical accuracy of the LiDAR sensor), horizontal accuracy of the LiDAR sensor, and the LiDAR canopy penetration (including the LiDAR missing the top of the sagebrush crown). The error associated with the bare ground raster used for height estimates was calculated using a comparison to field-measured bare ground GPS points with a resulting RMSE of approximately equal to or less than the vertical accuracy of the LiDAR sensors. Thus, bare ground estimation likely has a minor effect on the height estimation error in sagebrush canopy where penetration is relatively high and point density is at least 4.5 points/m².

Based on Glenn et al. (in press) and Mitchell et al. (in press), our crown area estimates provide the first available descriptors for LiDAR-based low-height-vegetation crown area. Underestimation of canopy-projected area by a mean of 33-49% is substantial; however, these, and height-estimation errors, may be corrected by supplementary ground measurements. Development of a methodology to characterize smaller-stature vegetation is an important first step toward future estimates of biomass and mixed canopy characterization with LiDAR.

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