PRECISION OF LVIS AND MISR CANOPY HEIGHT ESTIMATES FOR DESERT GRASSLAND SHRUB CANOPIES ASSESSED WITH FIELD AND UAV ESTIMATES IN A MULTISCALE APPROACH

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Many science questions in large-scale terrestrial ecology are concerned with changes in the Earth's carbon cycle and ecosystems and the consequences for the Earth's carbon budget, ecosystem sustainability, and biodiversity [1]. To address these questions, we must know the distribution of aboveground woody carbon stocks; how much, where, and why woody carbon stocks are changing; and what proportion of the annual net flux to/from land is the result of disturbance and recovery [2]. These questions can be addressed using measures of forest canopy physical structure (horizontal and vertical distributions) through the synergistic use of data from lidar and radar remote sensing instruments [3]. Although satellite systems with global observing capability are at least eight years away [4] many studies are being conducted to assess the capabilities and limitations of these technologies. It is known that full waveform lidar can provide good estimates of various canopy parameters, including height, in medium-density temperate forests, while performance in dense tropical and boreal forest and in shrub canopies is less well-defined. While savannas and grasslands with shrubs are low biomass environments, they are extensive, occupying around 40% of the terrestrial land area. The goal of the research described here was thus to determine the performance of the NASA Laser Vegetation Imaging Sensor (LVIS) in estimating canopy height and aboveground standing live woody biomass in desert grasslands in southern New Mexico, USA, a region in which shrubs have mostly displaced native grasslands over the last 120 years.

To assess the precision and accuracy of LVIS height estimates we conducted a field campaign in desert grasslands in the United States Department of Agriculture (USDA), Agricultural Research Service (ARS) Jornada Experimental Range in September 16-17, 2008, with an LVIS survey completed from the air on September 19. The objectives of the campaign were to assess the precision of LVIS aboveground woody biomass and canopy height estimates in extensive low biomass environments (~40% of global terrestrial surface); to assess crown shape effects on LVIS the estimates; to seek synergies between lidar and multiangle remote sensing technologies (multiangle data can be trained using more sparse lidar estimates (an empirical approach), or the data can be used together in a model inversion framework); and to provide data that are adequate for the validation and improvement of MISR geometric-optical model inversion results over desert grassland with invasive shrubs. Airborne lidar data are the only source of suitable data for this purposes: ground data such as those in the Forest Inventory Analysis database suffer from the large disparity in scale relative to moderate resolution sensor footprints; and ICESat Geoscience Laser Altimeter System height estimates are too imprecise. It is also possible to make use of data from the NASA Multiangle Imaging SpectroRadiometer (MISR) [5] to obtain first-order estimates of primary canopy parameters (fractional crown cover, mean canopy height), at moderate resolution, and from 2000 onwards, and to estimate aboveground standing live woody biomass from these parameters. This capability has been demonstrated for arid and semi-arid regions in published studies ([6]-[8]). However validation is only possible using lidar and we do not know how well lidar can map canopy heights in shrub canopies; hence the need for field validation. The campaign was thus based on a multi-scale approach:

1. field measurements of shrub heights (100 x 40 m belt transects)
2. UAV-based estimates of shrub and mean heights within the belt transects based on shadowing (using the field measurements to estimate error)
3. use of (1) and (2) to estimate the error on LVIS height estimates for ~ 20 m LVIS footprints
4. use of LVIS mean canopy height estimates to estimate the error on mapped MISR height retrievals mapped on a 250 m grid.

The ground data were acquired over grassland, grass-shrub transition, mesquite, and mesquite dune sites by a team of Montclair State University graduate students and USDA researchers. A creosote bush site was infested with rattlesnakes and could not be surveyed. The height of every woody plant (shrub or *Acacia spp*.) was measured by hand using a surveying rod. The location, maximum height of any element (shrubs sometimes have leafless branches that extend beyond the crown), generalized crown maximum height, and species recorded in Trimble GPS receivers. Differential corrections were provided by remote stations in Hatch and Las Cruces. At the mesquite dune site a GPS-equipped camera was used to record heights, instead of manual readings (Figure 1). Very high resolution imagery was acquired with a BAT unmanned aerial vehicle (UAV) late in October 2008, with flights taking place around 9 am to ensure that the shadows of shrubs would be visible. The numerous images were mosaiced together using orthophoto techniques into accurate, seamless images covering each of the sites. Shrub heights can be estimated from shadow lengths and averaged over the plot, with accuracy assessed against the ground data. The LVIS waveform data were transformed to vector data and RH100 (elevation of 100% energy return) ASCII XYZ point data were extracted and interpolated to a 20 m UTM grid. MISR red (672 nm) band terrain radiance data in nine viewing angles were obtained for the end of the dry season in 2000, 2002, and 2009.

Fig. 1. Use of a GPS camera to record mesquite heights at the dune site.

These data were used to obtain maps of woody plant fractional crown cover, mean canopy height, and aboveground standing live biomass via inversion of the Simple Geometric-optical Model (SGM) that is based on the principles of Boolean geometry first exploited in Li-Strahler models [9]. The contribution of the background in the MISR geometry is provided by the empirical four-parameter Walthall BRDF model [10]; for each MISR observation the background contribution was predicted *a priori* by developing relationships between the isotropic, geometric, and volume scattering kernel weights of the semi-empirical LiSparse-RossThin kernel-driven bidirectional reflectance distribution function (BRDF) model (adjusted against the same MISR red band data) and the four Walthall model parameters. We used a background BRDF regression that was based on coefficients developed using 19 grass- and shrub-dominated sites in the USDA, ARS Jornada Experimental Range and MISR nadir (An) camera BRFs as well as the red band kernel weights [6].

A large pool of terrestrial carbon is stored in aboveground woody biomass and associated understory and in belowground biomass pools in savannas and desert grasslands. Quantifying changes in the size of these pools, their horizontal distributions, and vertical structures resulting from natural and human-induced disturbances and recovery processes is critical for quantifying ecosystem change. In the southwestern US this is important in both extensive desert grasslands and upland forest. The results from this research will provide insights into the accuracy and precision of LVIS and MISR-derived heights for these environments. This is important because it will establish precision limits for both lidar and multiangle imaging in mapping shrub and savanna canopy heights over large areas.

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