Available online at www.sciencedirect.com
SCIENCE DIRECT®
Remote Sensing of Environment 102 (2006) 135 – 145
Remote Sensing of Environment
www.elsevier.com/locate/rse

LiDAR measurement of sagebrush steppe vegetation heights

David R. Streutker *, Nancy F. Glenn

Department of Geosciences, Idaho State University, Boise, ID, USA

Received 19 October 2005; received in revised form 7 February 2006; accepted 9 February 2006

Abstract

Small footprint LiDAR data were used to detect and characterize vegetation in a semi-arid sagebrush steppe environment in southeastern Idaho. Processing the raw data in individual flightlines maintained the high relative accuracy of the data set and allowed for the detection of sub-meter vegetation. First return LiDAR pulse data were used to both determine the ground surface as well as calculate vegetation heights. Surface roughness maps based on vegetation heights were found to best capture the variability of the canopy and accurately distinguish burned and unburned areas. Field validation of a sagebrush presence and absence classification based on a single roughness threshold value indicates an overall accuracy of 86%. The LiDAR-determined vegetation heights are moderately well correlated to those measured in the field, although the LiDAR heights uniformly underestimate the field heights. This underestimation is believed to be due to signal threshold limits within the LiDAR sensor, producing heights corresponding to the interior of the shrub canopy rather than the top.

Keywords: LiDAR; Laser altimetry; Rangeland; Sagebrush

1. Introduction

Although a relatively young remote sensing technology, light detection and ranging (LiDAR, also referred to as laser altimetry or airborne laser swath mapping) has quickly demonstrated great potential to precisely characterize vegetative systems. Within forest canopies, both small (1 m or less) and large (10–25 m) diameter footprint LiDAR systems have found widespread success in the measurement of various ecological parameters. Waveform returns from large footprint LiDAR sensors such as the Scanning LiDAR Imager of Canopies by Echo Recovery (SLICER) and Laser Vegetation Imaging Sensor (LVIS) have successfully been used to measure variables such as tree height, canopy structure, leaf area index (LAI) and biomass (Drake et al., 2002; Harding et al., 2001; Hofton et al., 2002). Similarly, small footprint LiDAR data have been used to determine tree height and LAI in various forest types (Popescu et al., 2002; Riaño et al., 2004). Beneath the canopy, Seielstad & Queen (2003) have also used small footprint LiDAR data to measure fuel loads of coarse woody debris on the forest floor.

Despite the fact that rangelands make up an estimated 70% of the planet's land area (West, 1999), little work has addressed LiDAR applications in rangeland ecosystems relative to the large number of forestry studies. Height profiles created by profiling LiDAR sensors have been used to measure plant height and canopy cover in a rangeland environment (Weltz et al., 1994) as well as to model rangeland surface roughness (Ritchie et al., 1995). Other studies have demonstrated the applicability of scanning LiDAR combined with multispectral video imagery to map shrub coppice dunes in desert grasslands (Rango et al., 2000).

The purpose of this study is to investigate the utility of small footprint LiDAR for detecting and characterizing vegetation in a semi-arid sagebrush steppe. Sub-meter accuracies are currently achievable with LiDAR technology, allowing for the discrimination of short vegetation types. This study seeks primarily to determine the capability of LiDAR to detect the presence of sagebrush and other types of low shrub. Upon positive detection, the ability to quantify various ecological variables such as shrub height and ground cover is explored. The methods described here are similar to those used in Glenn et al. (2006) and Mundt et al. (2006), but are presented in more detail and with attention to validation, both qualitative and quantitative.

* Corresponding author.
E-mail address: stredavi@isu.edu (D.R. Streutker).

0034-4257/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.rse.2006.02.011

Sagebrush (*Artemisia tridentata*) is one of the most dominant species of vegetation in the intermountain West, with sagebrush communities present in all 11 western states (Bunting et al., 1987). Many vertebrate species utilize habitats within sagebrush steppe ecosystems to maintain viable populations, such as pygmy rabbit (*Brachylagus idahoensis*), sage grouse (*Centrocercus urophasianus*), and sharp-tailed grouse (*Tympanuchus phasianellus*). However, due to pressures from invasive species, grazing practices, agriculture, and altered fire regimes, sagebrush populations have been in decline throughout the last century. An estimated 3 million acres of public lands in the intermountain West have become dominated by invasive grasses such as cheatgrass (*Bromus tectorum*) or medusahead (*Taeniatherum caput-medusae*) (West, 1999), while big sagebrush in the Upper Snake subbasin alone has decreased an estimated 42% from historic levels (NPCC, 2004). In many areas, there has been a complete loss of the sagebrush ecosystem (Knick, 1999).

As sagebrush communities in the intermountain West become increasingly fragmented or disturbed due to agricultural and urban growth, range fires, and invasive weeds, critical habitats and historic grazing/browsing regimes become threatened (NPCC, 2004). For instance, sagebrush communities can require 15 years or more to return to preburn conditions following a fire (Bunting et al., 1987; Humphrey, 1984). Many sagebrush communities have a long history of disturbance (Knick & Rotenberry, 1997) and require active restoration techniques (Hemstrom et al., 2002; McIver & Starr, 2001). As a result, land managers and conservation agencies are in need of accurate tools to inventory and assess sagebrush ecosystems.

As in the case of forest canopies, LiDAR has the capability to provide information about rangeland vegetation structure such as heights, densities, and biomass, properties which may not readily be determined through the use of passive remote sensing. A study by Mundt et al. (2006) has shown that LiDAR can be used successfully to improve upon a hyperspectral classification of sagebrush presence/absence in southern Idaho. This study aims to demonstrate the potential of LiDAR to be a powerful and complementary tool in monitoring rangelands, both in pristine condition or after a disturbance.

2. Study area

The study area for this investigation is located within the United States Sheep Experiment Station (USSES), a facility of the United States Department of Agriculture (USDA) Agricultural Research Service (ARS). This facility is located near Dubois, Idaho, in the northeastern Snake River Plain. The study area itself is located in the northeast corner of the USSES and is approximately 5 km long and 1 km wide, with a total area of 6.9 km^2 (Fig. 1). The terrain of the study area is gently rolling rangeland, with elevations between 1777 and 1866 m.

The dominant vegetation within the study area is mountain sagebrush (*Artemisia tridentata* subsp. *vaseyana*), while

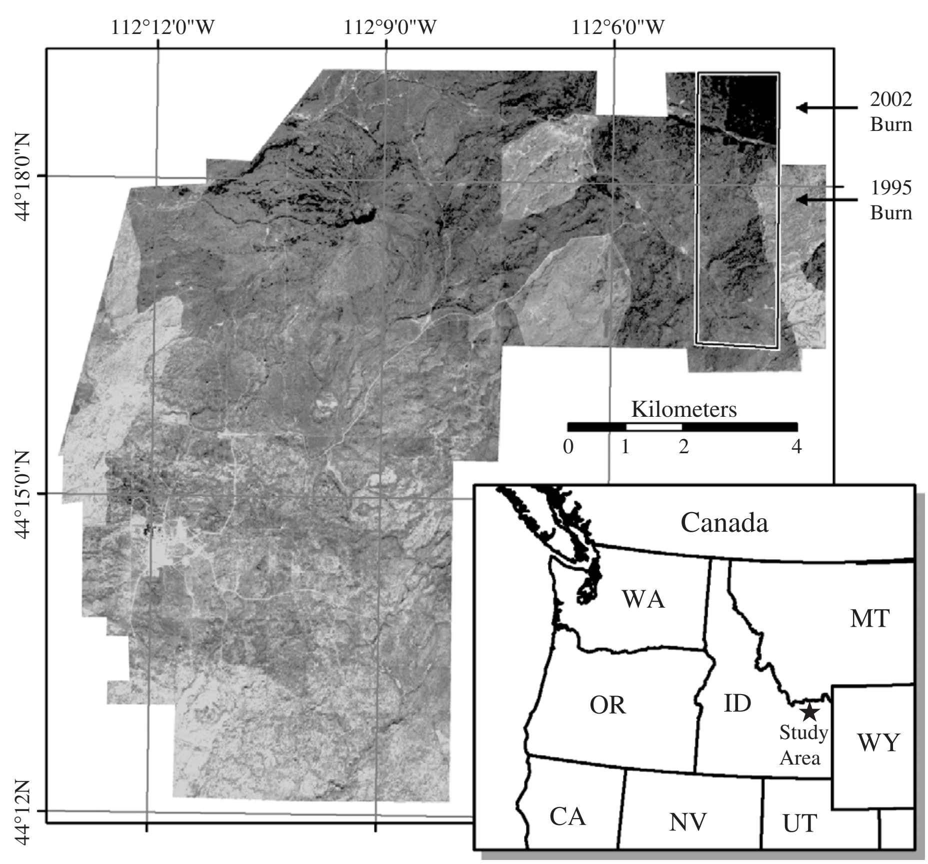

Fig. 1. Study area, outlined within the United States Sheep Experiment Station. The base map is a QuickBird image, acquired in October of 2002. The two burns within the study area are identified. The inset shows the location of the study area (★) within the state of Idaho.