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USING AN AIRBORNE LASER TO MEASURE VEGETATION PROPERTIES

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ABSTRACT

A laser altimeter mounted in a twin-engine airplane was used to measure surface patterns on the landscape of Walnut Gulch Watershed near Tombstone, Arizona. The airborne laser altimeter is a pulsed gallium-arsenide diode laser, transmitting and receiving 4,000 pulses per second at a wavelength of 0.904 μm . The laser has a 1 mrad field-of-view and is designed to have a vertical recording accuracy of 0.05 m on a single measurement. Aircraft altitude was between 100 and 300 m for the flights. Digital data from the laser are collected with a portable computer and analyzed to provide information on surface features of the landscape. Changes in landscape topography and vegetation patterns were measured with the laser data. Vegetation height, spatial patterns, and patchiness of vegetation cover were measured. Laser measured vegetation properties were significantly related with field measurement made using line-transect methods. These studies demonstrate the potential of airborne laser data to measure landscape patterns of large areas quickly and quantitatively. Rapid methods of determining canopy height and cover are valuable for understanding vegetation patterns and characteristics, improving estimates of infiltration, erosion, and evapotranspiration, and making decisions for managing our natural resources.

INTRODUCTION

An understanding of the pattern of the variation in vegetation properties across the landscape is essential for predicting evapotranspiration, infiltration, erosion, and other factors related to management of ecosystems (Forman and Godron 1986). Data on the distribution of vegetation properties and their spatial and temporal variation can be used for validation of current landscape models and for developing management plans to control infiltration, erosion, evapotranspiration, and predict vegetation growth across the landscape.

Currently vegetation properties are measured with line-intercept or line-transect methods (Canfield 1941, Eberhardt 1978) or by sampling plots (Mueller-Dombois and Ellenberg 1974, Phillips 1959). These methods involve measuring vegetation properties along randomly determined strips, lines, belts, or in plots across the landscape. These methods are expensive, labor intensive, and the area sampled is quite small. There is a need for quicker and easier methods that would allow sampling of larger areas of the landscape.

The purpose of the paper is to describe the use of an airborne laser altimeter to measure vegetation properties and compare these measurements with similar ground measurements made using classical methods to determine the feasibility of using airborne laser altimeter data to measure landscape surface patterns.

STUDY AREA

The study area was located in the Walnut Gulch Experimental Watershed near Tombstone, Arizona. This experimental watershed is an ephemeral tributary of the San Pedro River and has been intensively monitored and studied by the USDA-ARS Southwest Watershed Research Center since 1954. The area represents the mixed grass-brush rangelands in southeastern Arizona with gently rolling hills incised by a young drainage system (Renard 1970; Hershfield 1971).

This study was done as a follow up to MONSOON 90 (Kustas et al. 1991). The vegetation study sites were located near the 8 meteorological sites (Fig. 1) used during the MONSOON 90 experiment of August 1990.

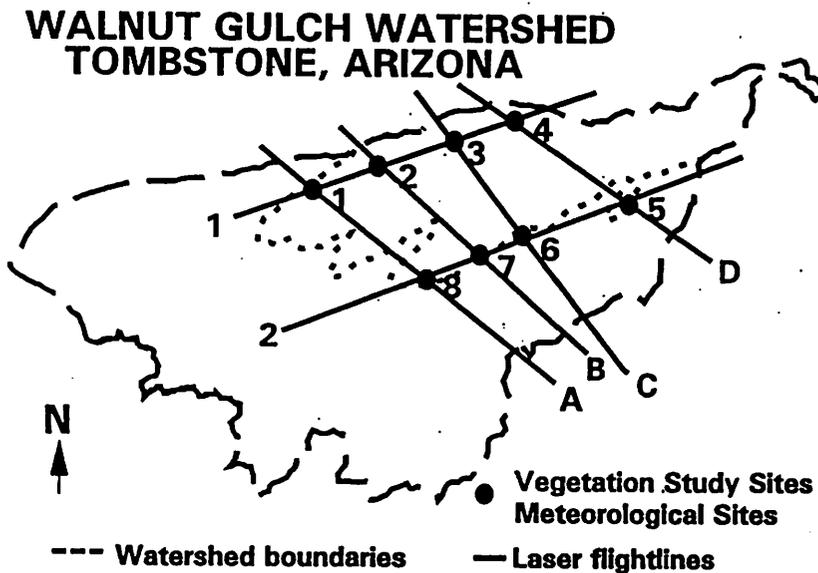


Figure 1. Map showing the boundaries of the Walnut Gulch Experimental Watershed near Tombstone, Arizona with location of meteorological and vegetation study sites and the location of the laser altimeter flightlines.

METHODS AND MATERIAL

Ground measurements of vegetation properties were made along five 30.5 m line-transects near the 8 meteorological site in August 1990 and sampled again in August 1991. Measurements of plant species, height, cover, and leaf area index of each plant that intercepted the line transect was recorded.

Vegetation properties were also measured from data collected with a laser altimeter mounted in a small twin engine aircraft in August 1991. The six laser flightlines are shown on figure 1. Each flightline was flown twice. Thus four flightlines were made across the ground vegetation study sites at the 8 meteorological sites. Two (2) flightline were parallel to the 5 line-transects used for ground measurements and 2 flightlines were perpendicular to these ground transects.

The laser measured the distance between the aircraft and the landscape surface as defined by any object (i.e., vegetation, soil, rock, man-made structure) reflecting the laser pulse (Ritchie and Jackson 1989; Ritchie et al. 1992). The aircraft flew at speeds between 60 and 75 m per second and at altitude between 100 and 300 m. The laser is a pulsed gallium-arsenide diode laser, transmitting and receiving signals at a wavelength of 0.904 μm . The laser operated at 4,000 pulses per second. Under these operating parameters, a vertical distance measurement from the aircraft to landscape surface occurred at 0.015 to 0.019 m intervals along the flightline depending on the aircraft speed. Ground resolution of the laser was between 0.13 to 0.39 m depending on aircraft altitude. The laser is designed to have a vertical recording accuracy of 0.05 m on a single measurement.

Data collected by the laser were recorded digitally on a portable personal computer and stored on a fixed disk along with data from a gyroscope and an accelerometer that were used to correct the laser data for aircraft motion. A video camera, borehole-sited with the laser, recorded a visual image of the flightline. The video records 60 frames per second. Each video frame was annotated with consecutive numbers and clock time. The video frame number was recorded simultaneously with the digital laser data to allow precise location of the laser data with the video data.

At the 8 ground measurement site, a 30.5 m transect of laser data was analyzed for each of the 4 flightlines. The location of the laser transect was made using the video data to locate flightline markers that had been placed in the middle of the 5 ground measurement transects. The location of the laser segment analyzed was as close as possible to the area where the ground measurements were made. Four laser transects for each ground sampling site were analyzed.

Actual landscape elevation for the laser profiles was calculated for each laser measurement based on the elevation at the 8 meteorological sites. Ground surface elevation was defined as the minimum elevations along a laser transect. These minimum values were determined by calculating a moving minimum elevation for 21 laser measurements; some manual editing of these minimum elevations was required in areas of dense vegetation cover to determine the ground surface. It was assumed that these minimum elevations represented ground surface while anything above the minimum was due to vegetation. Canopy height was determined by subtracting the ground surface elevation (minimum laser measurements) from the landscape elevations (actual laser measurements) at each laser measurement point.

Canopy cover was determined by canopy height by counting the number of laser measurements in a height category and dividing by the total number of laser measurements for a 30.5 m laser transect. Canopy heights were determined by 0.1-m height increments. Distribution of vegetation along the laser transect was determined graphically.

RESULTS AND DISCUSSION

Figure 2 shows the two laser profiles measured along laser flightline 1. Elevations along this west to east (parallel to the ground measurement sites) flightline ranged from approximately 1340 to 1460 m. The two laser profiles show the similarity in the landscape elevations but they also show the individuality of each flightline. While efforts were made to fly the exact flightline each time, variations in the location of the airplane gave each flightline its own unique pattern of elevations. At the East end of the flightline, the two elevation profile match, showing that the plane was close to the same line on both passes along the flightline. At other points along the line the plane was over different parts of the rolling landscape. On the video tape made during the flights, flightline markers at each meteorological site were visible. One laser profile was consistently north of the flightline markers while the other line was consistently south of the markers. We estimate based on the location of the flightline markers on the video that the two lines were within 5 to 40 meters of each other depending on the location along the line. Since the laser had a footprint of approximately 0.26 m on these lines, it would be impossible to measure the same line twice.

At the 8 meteorological sites, a 30.5 m transect of the laser data was extracted from each laser flightline for the area where ground measurements had been made. The variation in the average vegetation height measured with the laser at most meteorological sites was small (Fig. 3) showing the similarity in vegetation at a site. A major exception was meteorological site 7 where large variations occurred. Site 7 was along a stream channel that allow the development of some tall mesquite trees. Six laser

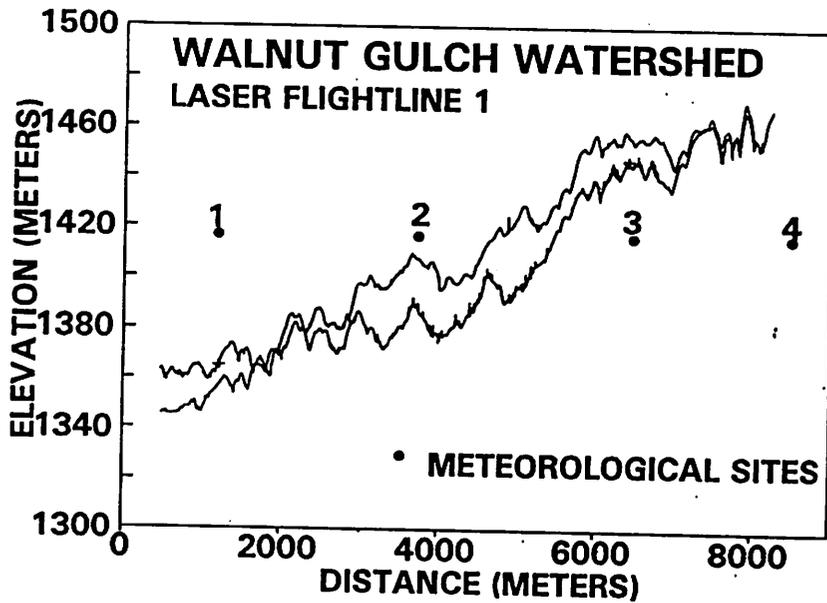


Figure 2. Landscape surface topography measured during two flights along laser flightline 1. Location of meteorological sites 1 to 4 are shown.

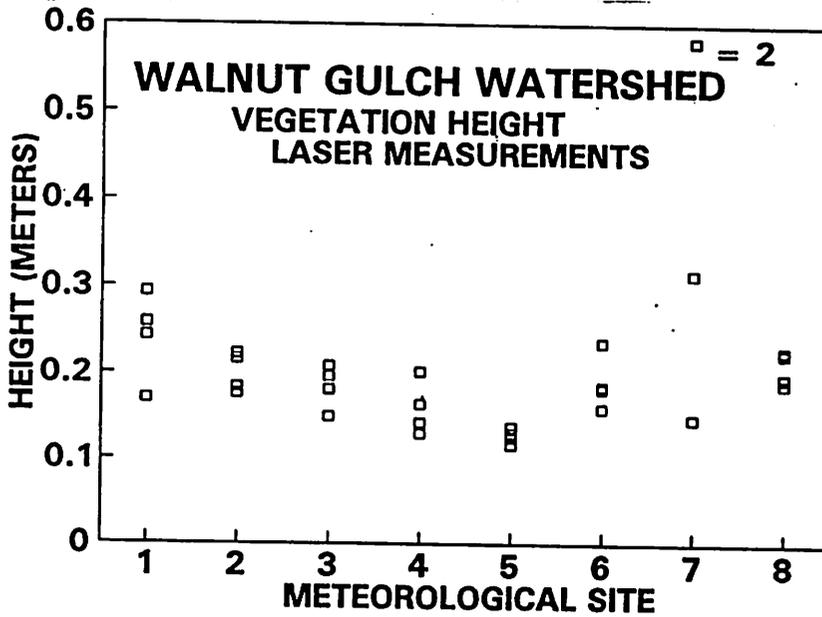


Figure 3. Laser measurements of vegetation height at the 8 meteorological sites.

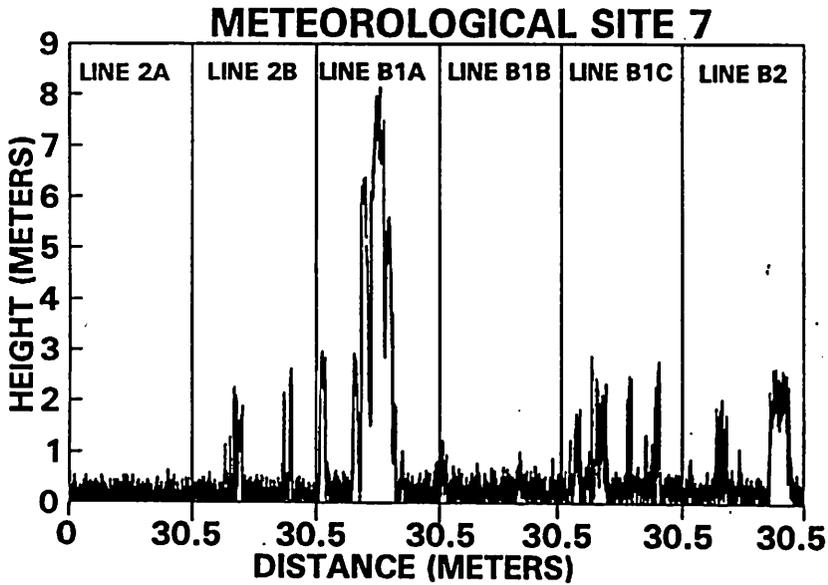


Figure 4. Laser transects used to show vegetation patterns at meteorological site 7.

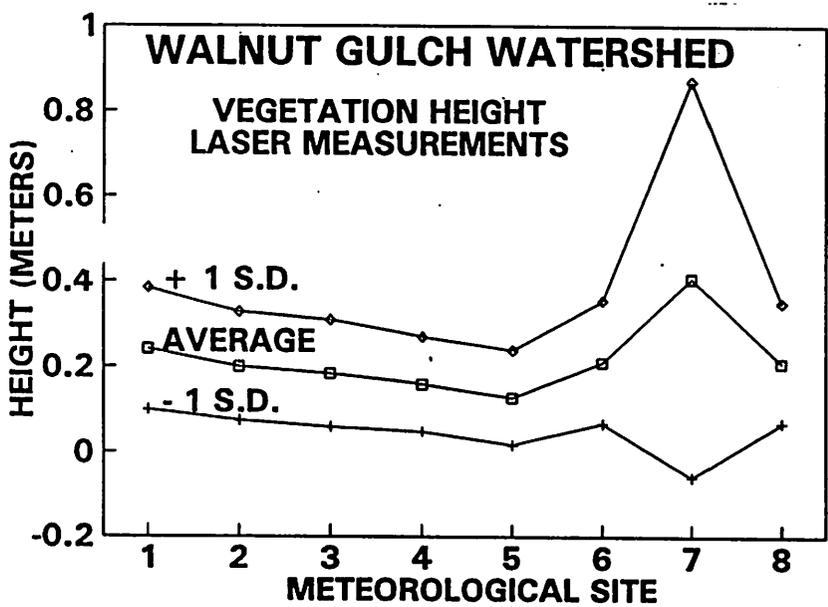


Figure 5. Average and standard deviation for the laser measurements of vegetation height.

transects were analyzed for this site (Fig. 4) to show the variation in the vegetation heights measured. Three transects were extracted from flightline B1 to show the variation that was measured. The six transects (Fig. 4) show the difficulty of choosing "representative" area for analyses. Two of the transects for site 7 show almost no vegetation greater than 0.5 m tall while the other 4 transect shows trees up to 8 m tall. These transects also show how the spatial distribution of vegetation can be measured. Extracting longer laser transects would allow the mapping of the spatial patterns of vegetation along parts or even the entire flightline.

In general vegetation heights (Fig. 5) decreased from west to east (site 1 to 4 and site 8 to 5). This follows the general pattern of vegetation on the watershed that gradually changes from brush dominated vegetation in the west to grass dominated vegetation in the east (Renard 1971). The standard deviations for the sites also tended to decrease from west to east again related to the change in vegetation. The standard deviation at site 7 represents the unique riparian vegetation community along the ephemeral stream at the site. Moisture is probably available longer at this site than at the other sites. For the 32 laser transects, only 5.8% of the vegetation was greater than 0.5 m tall. This shows the low shrubby nature of the rangeland vegetation on the watershed.

A comparison of vegetation height measured from the laser transect with those measured on the ground using line-transect techniques shows a close comparison for 6 of the 8 sites (Fig. 6). Sites 1 through 6 were located in areas of relatively uniform vegetation in terms height, density, and distribution. Thus the selection of typical transect was not critical. However sites 7 and to some extent site 8 were in areas of non uniform vegetation that made selecting typical transect more difficult. Thus unless the laser and ground transects were for the same transect, large differences could occur. At site 7, the laser transect is more representative of the tree dominated vegetation at the site while the ground transects are more representative of grass vegetation. At site 8 the reverse is true so that real height is probably somewhere between the two measurements.

Vegetation cover was estimated at each site for each laser transect. Figure 7 shows average cover for each site based on the 4 laser transect measurements and plotted for heights above the ground level. As with height, cover decreased from west to east along the flightlines with the least cover being at site 5. Visual observations in the field showed that site 5 had the least vegetation. There is less than 10 % cover due to vegetation greater than 0.5 m. except at site 7.

Some caution needs to be used in interpreting the cover data estimated from the laser transect for vegetation less than 0.2 to 0.3 m. First, the standard deviation of our laser measurements under control

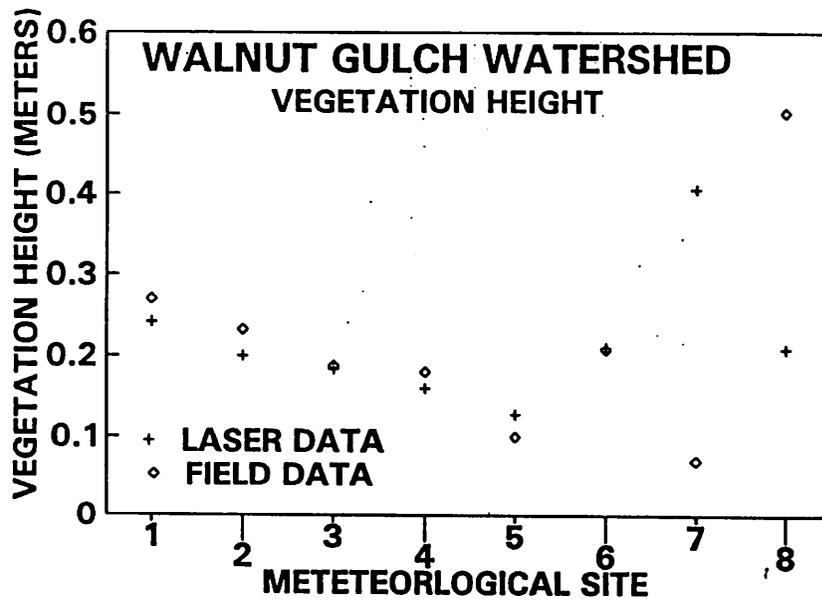


Figure 6. Comparison of vegetation heights measured with the laser altimeter and on the ground using the line-transect method.

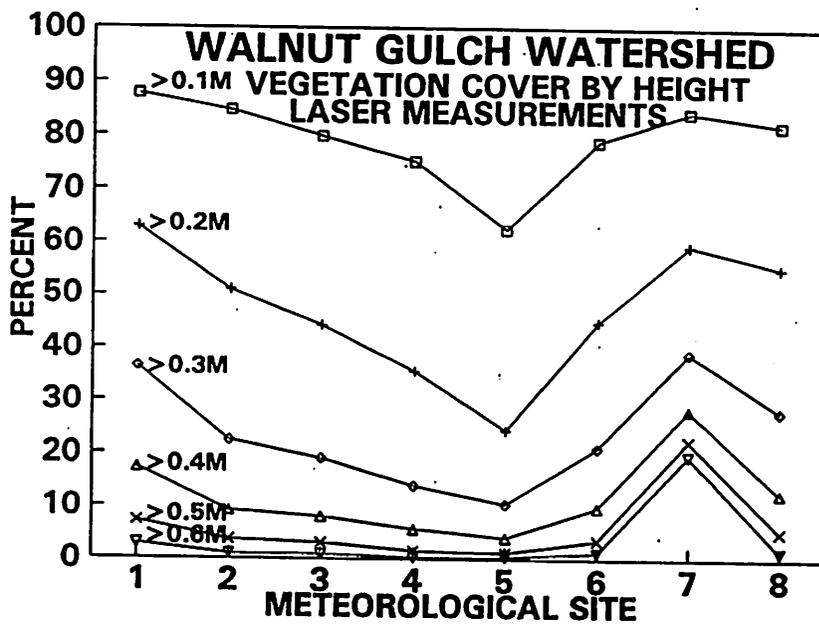


Figure 7. Laser measurements of vegetation cover in percent by height at the 8 meteorological sites.

conditions in the laboratory is 0.10 m. Thus any measurement less than 0.10 m may be due to this variation. Also, it is likely that some laser measurements of height above the ground level between 0.1 to 0.3 m may be due to large rocks or other debris on the ground surface. Currently we have no method to determine whether we are measuring a vegetation clump or a debris clump. Above 0.3 m, most objects would be vegetation and our estimates of cover would be representative (Ritchie et al. 1992)

CONCLUSIONS

Landscape surface features were measured using a laser altimeter mounted in a small aircraft. Analyses of these laser profiles were used to measure differences in vegetation height, cover, and spatial distribution. Measurements of vegetation height agreed closely with measurements made on the ground using classical line-transect techniques. Patterns of vegetation height and cover measured with the laser followed patterns of vegetation mapped on the ground. In general vegetation height and cover decreased as the ground vegetation changed from a brush-grass dominated rangeland to a grass-brush dominated rangeland. This study demonstrates that laser altimeter data can be used to measure landscape surface feature quickly for large areas of rangelands.

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May 11, 1992

Mr. Alan Voss
ASPRS/ACSM Technical Session Chairman
Tennessee Valley Authority
Haney Building 2-A
1101 Market Street
Chattanooga, TN 37402-2801

Dear Mr. Voss:

Enclosed is an original and two copies the paper (#97) entitled "USING AN AIRBORNE LASER TO MEASURE VEGETATION PROPERTIES" for the proceedings of the ASPRS/ACSM/RT 92 Convention being held in Washington, DC in August 1992.

Also enclosed are:

1. Statement of Clearance
2. Special Note to U.S. Government Employees
3. 1992 ASPRS Audio-visual Requirements
4. Biosketch Form for speaker

Thank you for your work.

Sincerely,

Jerry C. Ritchie
Jerry C. Ritchie
Ecologist/Soil Scientist

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