LIDAR resolution, vegetation filters and preservation of topographic discontinuities

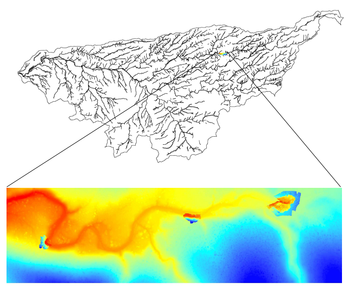
Ross Bryant, David Goodrich
USDA, Agricultural Research Service, Southwest Watershed Research Center,
2000 East Allen Road, Tucson, Arizona, 85719 USA

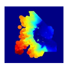
Introduction

LIDAR (Light Detection And Ranging) has been used extensively to produce high resolution digital elevation models. The effect of vegetation on topography increases with higher resolution LIDAR data. We measured the profiles of a head cut and three steep channel banks in the Walnut Gulch Experimental Watershed with three LIDAR datasets. The highest resolution dataset (0.1 meter) was acquired from a ground based LIDAR scanner. The other two data sets were obtained from an airborne platform at 0.5 meter resolution and 1 meter resolution. The airborne LIDAR characterized the channel profiles as well as the ground based laser scanner before it was filtered for vegetation. The effect of removing vegetation from the imagery on the profiles was to make them significantly less steep. A second two dimensional, multi-resolution vegetation filter was developed and applied to the data which resulted in significantly better measurement of the bank and head cut profiles.

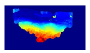
Location

The USDA Walnut Gulch Experimental Watershed (WGEW) in Southeastern Arizona is representative of approximately 60 million hectares of brush and grass covered rangeland found throughout the semi-arid southwestern United States. Cattle grazing is the predominant land use, with mining, limited urbanization, and recreation making up the remaining areas.

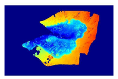




Channel Bank A



Channel Bank B



Head Cut A

Sensors

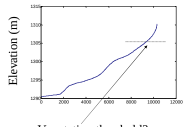
Airborne LIDAR

The Optech ALTM 1233 (Optech Incorporated, Toronto, Canada) was used to survey Walnut Gulch in the summers of 2003 and 2004. Characteristics of the ALTM 1233 include a pulse rate of 33 kHz, a scan frequency of 28 Hz, a scan angle of ± 20º, a collection mode of first and last returns, and intensity of returns from a 1064 nm laser. The spot size of the laser is approximately 15cm. The ALTM 1233 was mounted on a University of Florida plane and flown at an altitude to acquire 1 meter resolution data in 2003 and 0.5 meter resolution data in 2004.

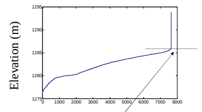
ILRIS 3d laser scanner

The ground based laser scanner used was an ILRIS-3D laser scanner manufactured by Optech with a vertical accuracy of 0.3 cm. The laser scanner actually captures a three dimensional scene of a surface by scanning a laser beam over the site of interest and capturing the return signal. The spot size is 1.5 cm in diameter at 20 meters from the scanner, which is the approximate distance used in the study. The wavelength of the scanner is 1500 nm and the field of view is 40º by 40º. The laser scanner collects x, y, and z coordinates for every 1.5 cm spot scanned for a complete 3 dimensional image of the site.

Vegetation filters

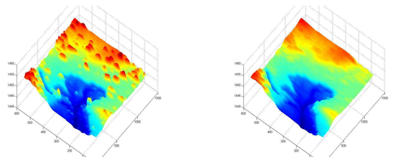


Vegetation threshold?
Sometimes the threshold is not obvious or distinct



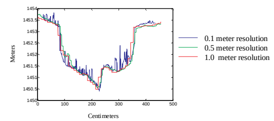
Vegetation threshold

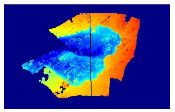
A simple approach to filtering vegetation takes ungridded LIDAR elevation data, sorts it, and then assumes data with large differences in elevation are vegetation points. These points are eliminated from the data set before the data is gridded. This is called the threshold vegetation filter.



Another approach to filtering vegetation is to do the filtering after the LIDAR data is gridded. If the vegetation is sparse like it is in Walnut gulch and much of the Southwest U.S., then it can be thought of as 'bumps' on the topographic surface. Computer code can be written to detect the bumps, or local high points. These points are removed and replaced by nearest neighbor interpolation. This kind of filter is less general because it is specific to a certain kind of vegetation but is more accurate at preserving topographic discontinuities. This is called the 'bump' vegetation filter

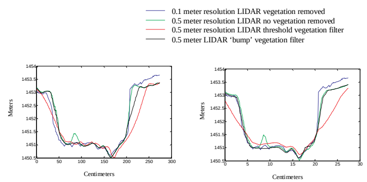
Resolution

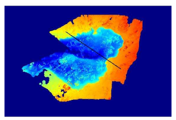




LIDAR resolution plays a key factor in characterizing a topographic surface. Our data set consisted of three resolutions. 1 meter, 0.5 meter and 0.1 meter. A higher the resolution means more data per given area and should characterize a surface more accurately. There are two problems with high resolution data: 1) more vegetation is captured in the data so eliminating it becomes more difficult. 2) It is very expensive and difficult to acquire and process. One of the goals of this research is to determine if an extremely high resolution LIDAR scan of 0.1 meter can more accurately characterize steep slopes and head cuts that are only a few meters in size both horizontally and vertically.

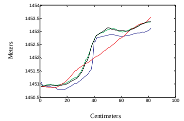
The Data

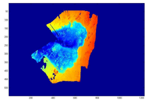




In order to compare transects of different resolutions with different vegetation filters, The 1 meter resolution image and 0.5 meter resolution images were interpolated to the resolution of the ground based LIDAR data (0.1 meters). Transects were extracted from the images processed with the two vegetation filters at both 0.5 and 1 meter resolution. These transects were compared to the ground based LIDAR data set that was filtered with the 'bump' vegetation filter.

Sample Result





	average slope	maximum slope
	(degrees)	
0.1 meter resolution LIDAR 'bump'bvegetation filter	33	82
0.5 meter resolution LIDAR no vegetation removed	32	57
0.5 meter resolution LIDAR threshold vegetation filter	22	35
0.5 meter LIDAR 'bump' vegetation filter	34	63

To analyze the slopes, the transects were thresholded at 5 degrees. In other words, only the part of the transect with a slope of greater than 5 degrees was analyzed. Consequently, the horizontal distance of each transect varied depending on the dataset. The above graph indicates that the only slope from this transect that varied significantly was from the dataset where the vegetation was filtered with the threshold filter. But maximum slope varied significantly between all three data sets. This could have important implication for terrain analysis in relation to barriers to mobility.

Results

Headcut, average altitude change = 1.9 meters average of 10 transects	average slope	maximum slope
	(degrees)	
0.1 meter resolution LIDAR 'bump' vegetation filter	**33**	**70**
0.5 meter resolution LIDAR no vegetation removed	30	56
0.5 meter LIDAR 'bump' vegetation filter	25	50
0.5 meter resolution LIDAR threshold vegetation filter	17	31
1 meter resolution LIDAR no vegetation removed	28	50
1 meter LIDAR 'bump' vegetation filter	28	47
1 meter resolution LIDAR threshold vegetation filter	16	25

Channel Bank A, average altitude change = 3.5 meters average of 5 transects	average slope	maximum slope
	(degrees)	
0.1 meter resolution LIDAR 'bump' vegetation filter	**58**	**83**
0.5 meter resolution LIDAR no vegetation removed	45	71
0.5 meter LIDAR 'bump' vegetation filter	43	71
0.5 meter resolution LIDAR threshold vegetation filter	34	47
1 meter resolution LIDAR no vegetation removed	43	65
1 meter LIDAR 'bump' vegetation filter	40	64
1 meter resolution LIDAR threshold vegetation filter	36	48

Channel Bank B, average altitude change = 2.0 meters average of 5 transects	average slope	maximum slope
	(degrees)	
0.1 meter resolution LIDAR 'bump' vegetation filter	**46**	**75**
0.5 meter resolution LIDAR no vegetation removed	34	52
0.5 meter LIDAR 'bump' vegetation filter	33	51
0.5 meter resolution LIDAR threshold vegetation filter	32	38
1 meter resolution LIDAR no vegetation removed	34	45
1 meter LIDAR 'bump' vegetation filter	32	45
1 meter resolution LIDAR threshold vegetation filter	30	40

Discussion and Conclusions

In terms of average slope, both the 1 meter and 0.5 meter LIDAR resolutions were able the characterize slopes reasonably well with the exception of Channel Bank B. Only the threshold vegetation filter had a significant impact on the results with the slopes always being lower. The 0.1 meter LIDAR always measured a significantly greater maximum slope. This may partly due to the fact that it was ground based LIDAR. The sensor was pointing directly at the slope so in effect the vertical resolution for a steep slope was higher than 0.1 meters.

Increasing LIDAR resolution from 1 meter to 0.5 meters does not greatly improve the characterization of steep channels and head cuts. The type of vegetation filter used can change the characterization significantly by smoothing out the steep slopes. The threshold filter is considered a first generation filter. Newer filters do a much better job at preserving topographic discontinuities. It would be prudent to consider reprocessing LIDAR data that was filtered with first generation filters if the original raw data is still available.

Acknowledgements

We would like to thank he University of Florida and the National Center for Airborne Laser Mapping for acquiring and processing the airborne LIDAR data and also for lending us their ground based LIDAR instrument.