LA-UR-16-23317

Title: High-Resolution Data for a Low-Resolution World

Author(s): Brady, Brendan Williams

Intended for: Final paper for a graduate engineering class

Issued: 2016-05-10


High-Resolution Data for a Low-Resolution World

Brendan Williams Brady

University of New Mexico / Los Alamos National Laboratory

CE 547 – May 2016

Motivation / Background

In the past 15 years, the upper section of Cañon de Valle has been severely altered by wildfires and subsequent runoff events. Loss of root structures on high-angle slopes results in debris flow and sediment accumulation in the narrow canyon bottom. The original intent of the study described here was to better understand the changes occurring in watershed soil elevations over the course of several post-fire years. An elevation dataset from 5 years post-Cerro Grande fire was compared to high-resolution LiDAR data from 14 years post-Cerro Grande fire (also 3 years post-Las Conchas fire). The following analysis was motivated by a problematic comparison of these datasets of unlike resolution, and therefore focuses on what the data reveals of itself.

Objective

The objective of this study is to highlight the effects vegetation can have on remote sensing data that intends to read ground surface elevation. A raster layer representing the difference between elevation datasets (Figure 1) is investigated both in small areas unaffected by wildfire as well as areas where significant change may have taken place.

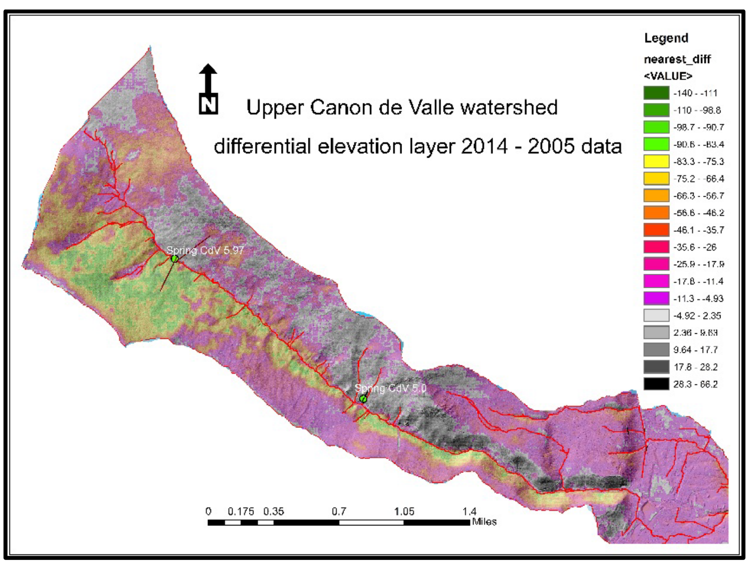

Figure 1: Differential raster used in analysis.

Methods

Enhanced 10 meter digital elevation models (DEMs) from 2005, downloaded from the New Mexico Resource Geographic Information System (NM RGIS) program, were brought together and filled to cover the area of Cañon de Valle. A 2014, 1-foot resolution dataset, made with an aerial LiDAR setup, was provided by the Environmental Remediation group at Los Alamos National Laboratory. The 2014 data came as a clipped file projected in Universal Transverse Mercator coordinates, using the NAD 1983 datum for the New Mexico State Plane Central Region. Everything else used the same system or projected on the fly. There would be very little distortion in the relatively geographic small area. A wildfire intensity layer for 2000 was also sourced from RGIS and placed into the data frame in ArcMap. A shapefile of the canyon boundary was included with the LiDAR data, which made clipping and alignment of other data layers simple. The fire intensity layer is shown looking uphill in ArcScene in Figure 2.

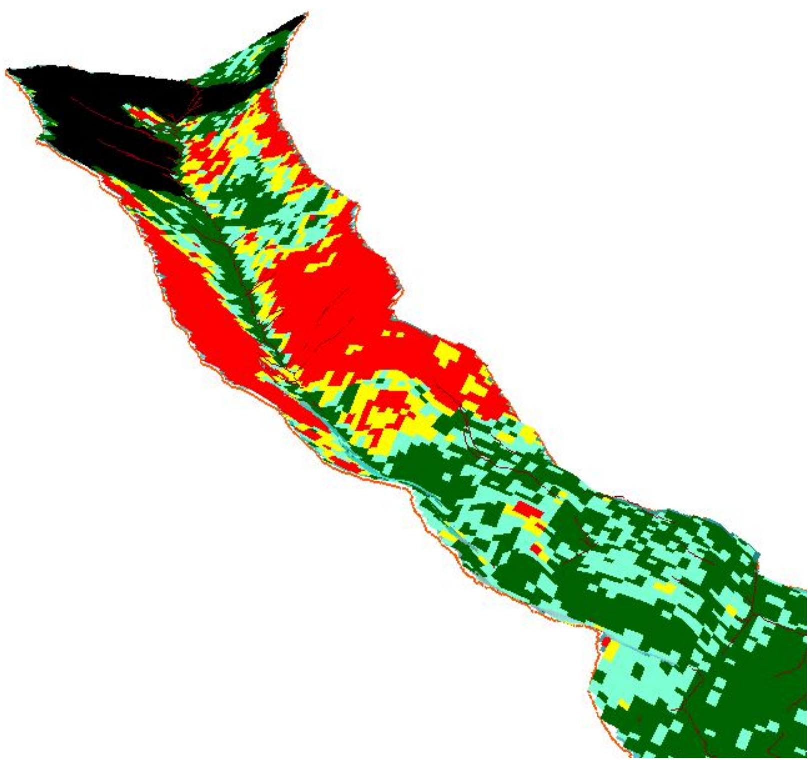

Figure 2: Burn intensity of the 2000 Cerro Grande fire in Cañon de Valle.

The 1-ft. resolution layer could be compared to the 10-meter layer only after resampling. As there are about 1,076 square feet inside of ten square meters, a single elevation value is chosen from among them to represent the ten meter pixel. Of three resampling methods used by ArcGIS, the nearest neighbor algorithm was chosen to minimize error, though the bilinear and cubic methods gave nearly identical results. A differential layer was created with the raster calculator by subtracting the 2005 DEM layer from the resampled 2014 LiDAR layer. This layer, together with a detailed hillshade layer made with the 1-ft. data and observations from recorded points on the ground, was used for spatial analysis in ArcGIS.

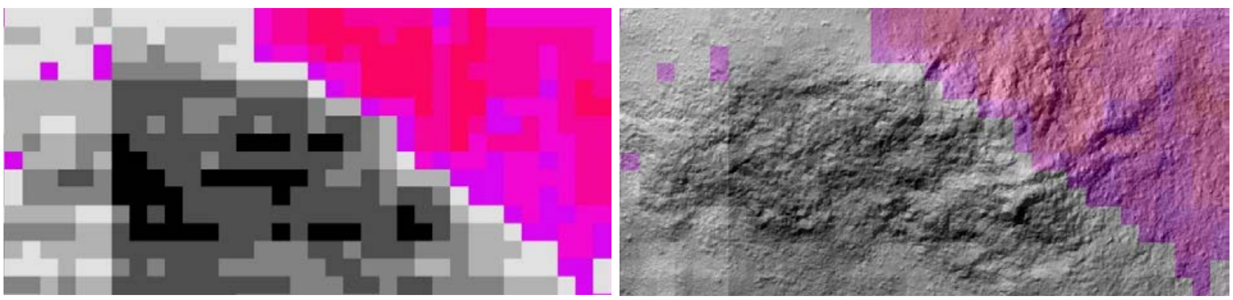

Figure 3: Comparison of raw differential pixels (left) and same with transparent high-resolution hillshade.

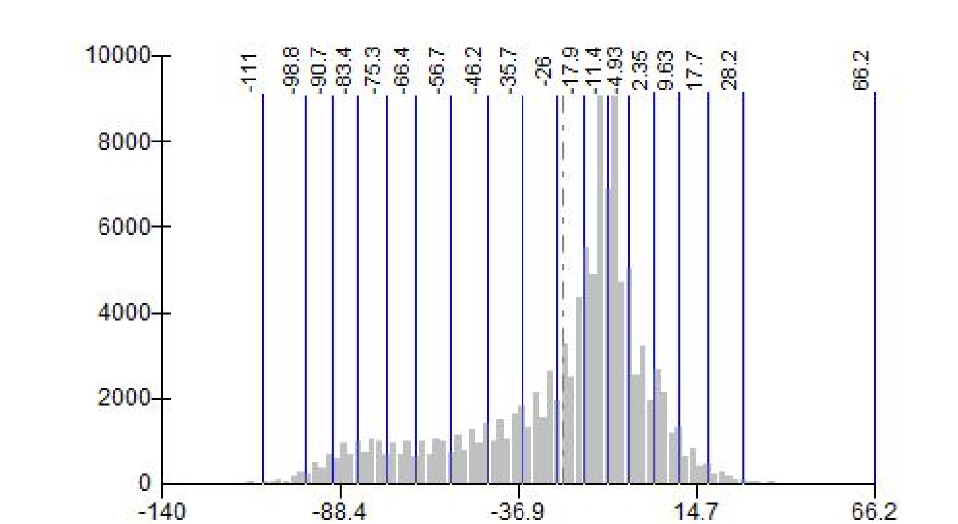

Figure 4: Histogram shows the distribution of values in the differential layer. Offset of the peak from zero suggests a minimum baseline error between datasets.

The error inherent to this exercise was determined by use of 3D analyst tools **Interpolate Line** and **Profile Graph** together with the differential layer in localized areas that would have seen little to no change between 2005 and 2014. Two lines placed along the road surface, one within a value class (where n=18 classes) and one across 3 classes, gave baseline errors of between -6.5 and -19 feet elevation over about 100 feet of length. The source of an error in this range is understood to be related to pixels that include variable terrain adjacent to the road, as well as the error associated with comparing resampled raster data. In either case, the road investigation indicates that observations resulting from the overall analysis can be considered valid only in a qualitative sense. Negative values indicate that 2005 data output was set generally higher in elevation. A third test considers the profile across an intermittent stream, where elevation change is possible and variability is certain; here the error varies between 0 and -30 feet.

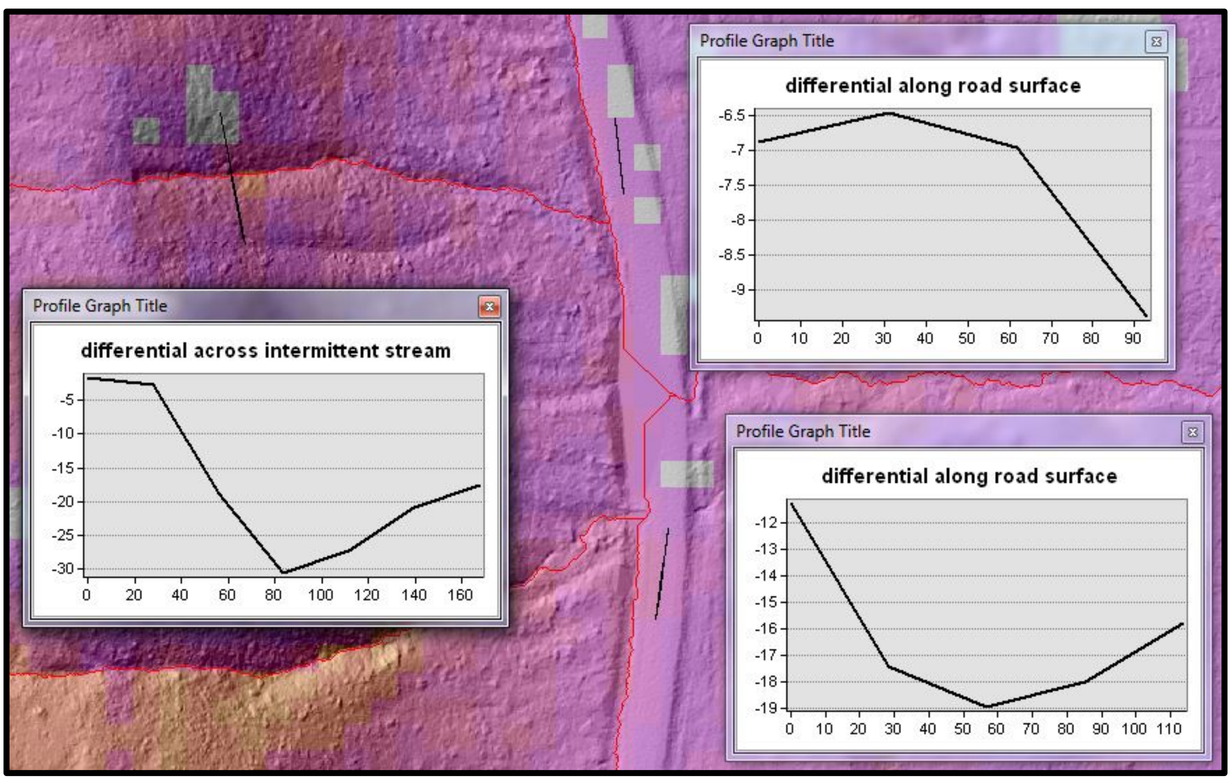

Figure 5: Analysis in areas known to have little to no elevation change between 2005 and 2014.

The same 3D analyst tools were used for further inquiry in areas where the differential layer showed greater negative values and significant positive values. Negative values in the many tens of feet correspond to areas on the 2000 fire intensity layer that did not burn; these are concentrated on the northeast-facing slope at higher elevations. The greatest positive values are concentrated in small areas on the opposite slope, though smaller positive values are more widespread. Locations for the interpolated lines are placed on the map using coordinates recorded for two spring locations, and the photographs are shot uphill in the same approximate directions.

Results

The line profile uphill to the SW from Spring CdV 5.97 shows strong negative values until it reaches the canyon bottom; this is in the unburned zone, and the photograph confirms that trees are still standing. It indicates that the 2014 LiDAR data shot the ground elevation, or enough of it that during resampling the raster showed a preference for ground-level data. The 2005 DEM apparently read the canopy here, as differential values are in the range of -80 to -100.

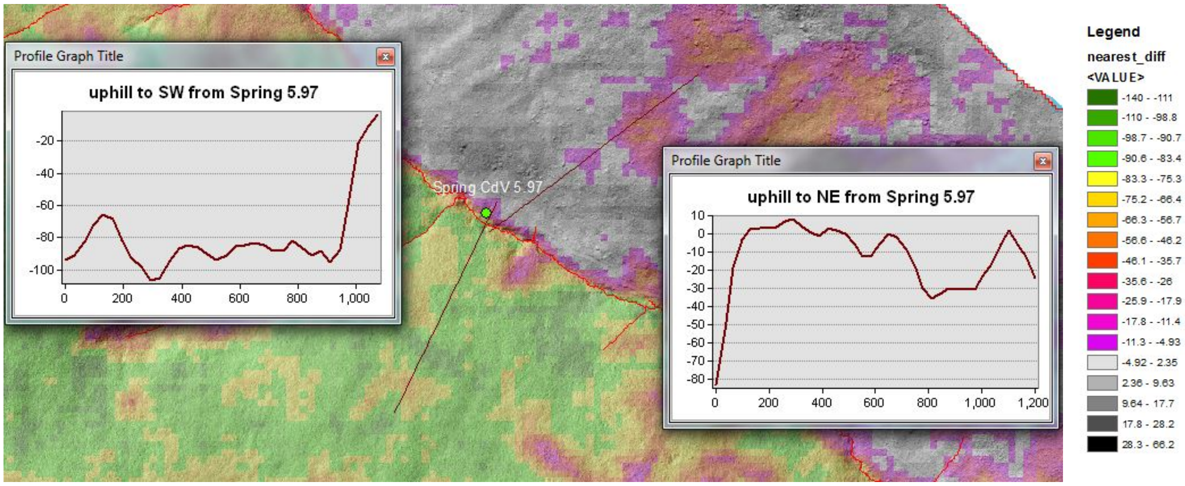

Figure 6a: Interpolated Line and Profile Graphs with approximate uphill views (shown below).

Figure 6b: Views from Spring CdV 5.97, uphill to SW (left) and uphill to NE (right).

The line profile uphill to the NE from Spring CdV 5.97 shows differential values near zero and areas with lesser negative values. The photograph indicates that patches of smaller trees remain in some areas, which may correspond to the negative values of -40 to -60 feet.

The same linear profile idea is illustrated by a different in Figure 7, where line interpolation of the elevation rasters is done separately and differences are approximated graphically.

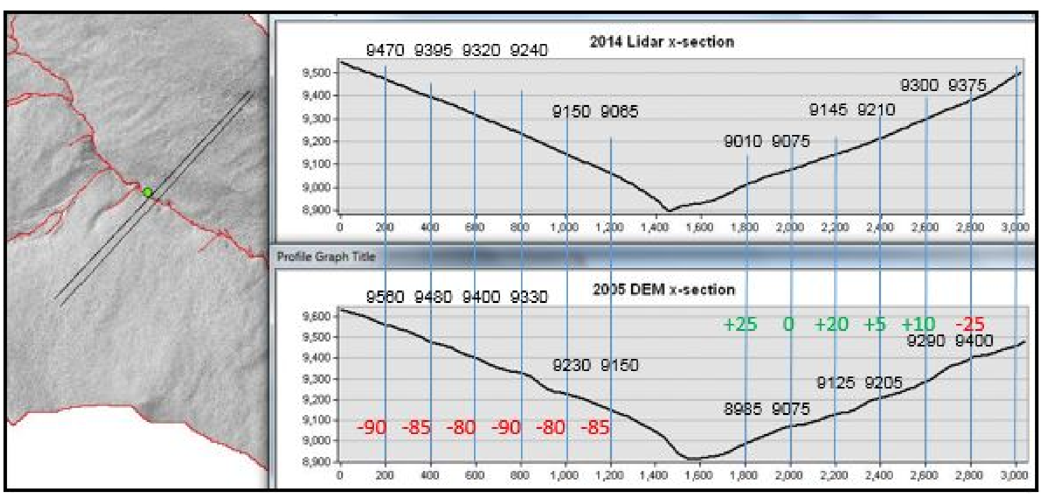

Figure 7: Linear profiling using elevation layers separately, with differences approximated.

In order to better read the hillshade and differential layers, the positive value classes were changed to gray-scale, with the most positive class in black. The most negative values are in shades of green. Small black groups or isolated black pixels appear mostly where large rock outcrops are present, with the darker gray areas surrounding them (shown in Figure 3). Lighter gray pixels appear to the NE of Spring 5.0, in an area where saplings crowd a prolific water source.

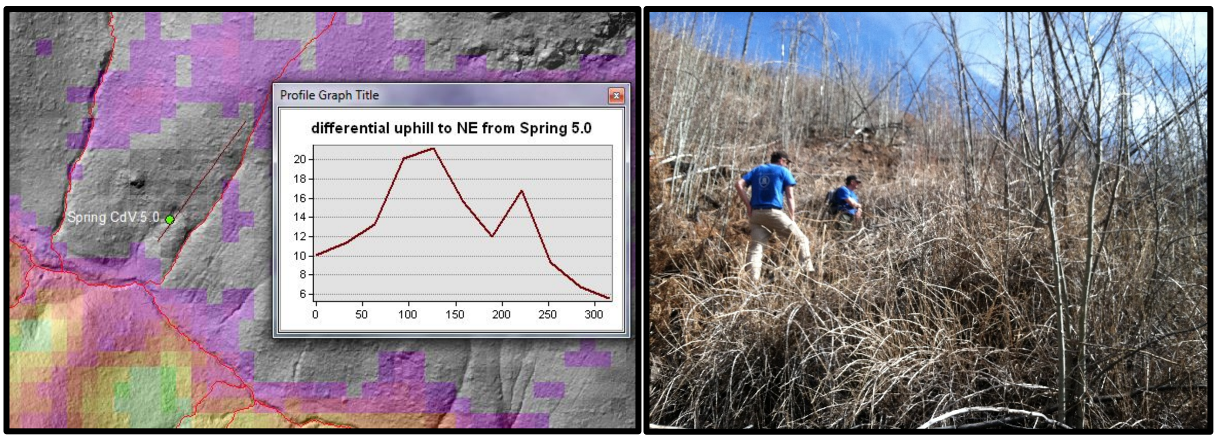

Figure 8: Profile of positive differential and approximate uphill view to NE.

These smaller positive values seem to indicate new growth happening between 2005 and 2014, though more likely it represents post-Las Conchas fire (2011) growth specifically. If lower elevation was read here by the 2005 DEM (5 years post-Cerro Grande), the reason may be that extreme fire intensity had destroyed the soil structure in 2000, inhibiting regrowth more so than in 2011.

Watershed runoff analyses were performed separately using both datasets, without resampling of the 1-ft. data. The 10-meter stream polyline is added to the 1-ft. map and hillshade layer, showing divergence, in Figure 9. Though some movement of the channel is possible, the figure seems to indicate error in the 10-meter runoff analysis, some of which may be related to the influence of tree canopy raster values. Sub-watersheds are shown in ArcScene in Figure 10.

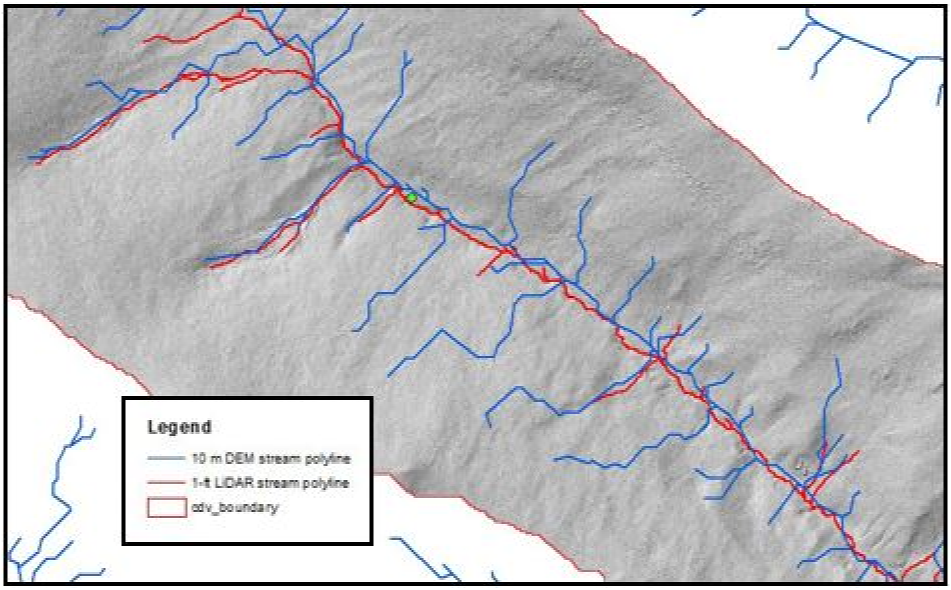

Figure 9: Difference in stream polylines resulting from runoff analysis. Un-resampled 1-ft. data was used.

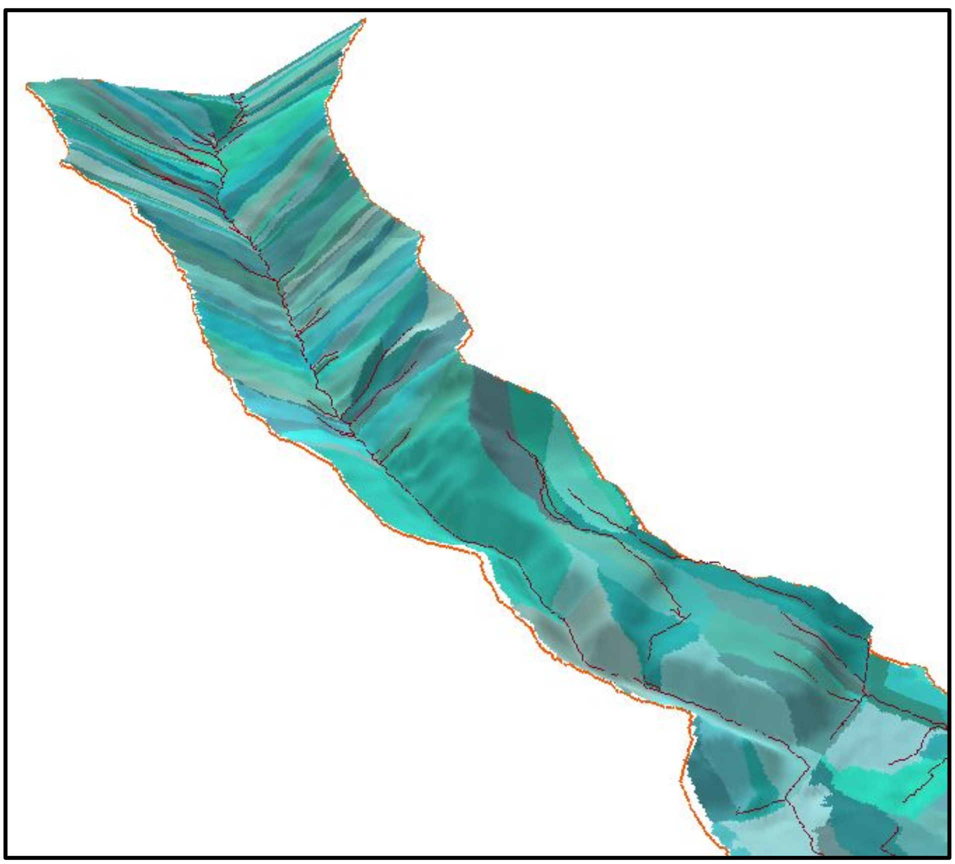

Figure 10: Sub-watersheds as derived with un-resampled high-resolution data.

Conclusion

Overall, the concentration of points shot by the LiDAR instrument seems better suited to describing such variable terrain. There is uncertainty associated with application of remote sensing data, though for this study the hillshade function serves as an excellent guide, as the high-resolution data can be used without resampling, and overlaid transparently on the differential layer. However, interpretation of results is a process requiring attention to specific map features and reflection between layers, informed by fire event and regrowth history.

Future work

The interpretation in this analysis would be improved by addition of 2010 pre-Las Conchas fire data, and certainly the study could be broadened to include pre-Cerro Grande fire data. This would be the best way to see the actual transport of sediment into the canyon bottom; presumably, the problem identified here in sensing the bare ground surface would be present in pre-fire data, though changes to surface elevation in and around the channel might be apparent.

Appendix

Background

Surface hydrology and groundwater – surface water interaction in upper Cañon de Valle are of particular interest now because of contaminated zones of perched intermediate groundwater further downgradient in the same system. Potential future transport and introduction of contaminants into the regional aquifer depends on flow pathways of groundwater recharge. As a result of sediment deposition and scour in the channel following the cycle of fire and flood, conditions for recharge in this system have been altered significantly. A surface flow gauge just west of the road used to sample occasional runoff, and no longer does. Channel flows in the upper section now access pathways to the subsurface that were apparently not there before, and groundwater, in general, seems to recharge higher up in the system. It is a curious condition, since abundant sediment that fills the lower channel now, though it would seem to provide a conduit for interflow (shallow near-surface flow), is dry. Scoured bedrock exists in a channel section below where the water disappears underground. Rather than the water finding its way over or through the sediment, it finds a way under. My research involves understanding subsurface connectivity and mountain-block recharge, and so I was interested in the deposition of sediment plug in the lowest reach of the upper channel.

Procedure followed so that work can be replicated and verified

High–resolution data used in this study was given as a clipped file to minimize the file size. The shapefile for the watershed boundary was used throughout to clip other files to the right extent. The enhanced 10 meter DEMs were downloaded, filled and saved as a single file. In both cases, runoff analysis was performed by creating flow direction and flow accumulation grids. For the high-resolution data, the threshold for definition of a cell as belonging to a stream was determined by scaling from the relationship between total cells and stream cells in the 10 meter grid. Sub-watersheds were defined and brought into ArcScene. The layers seem to need separation in space for elements to not completely mask one another, even when transparency is used for the uppermost layer. This was achieved only by trial and error.

The resample tool in Data Management was used to convert the LiDAR data to 10 meter pixels. Use of the raster calculator to create the differential layer, as well as the 3D analyst tools to create line profiles, was performed as described in the analysis and results.