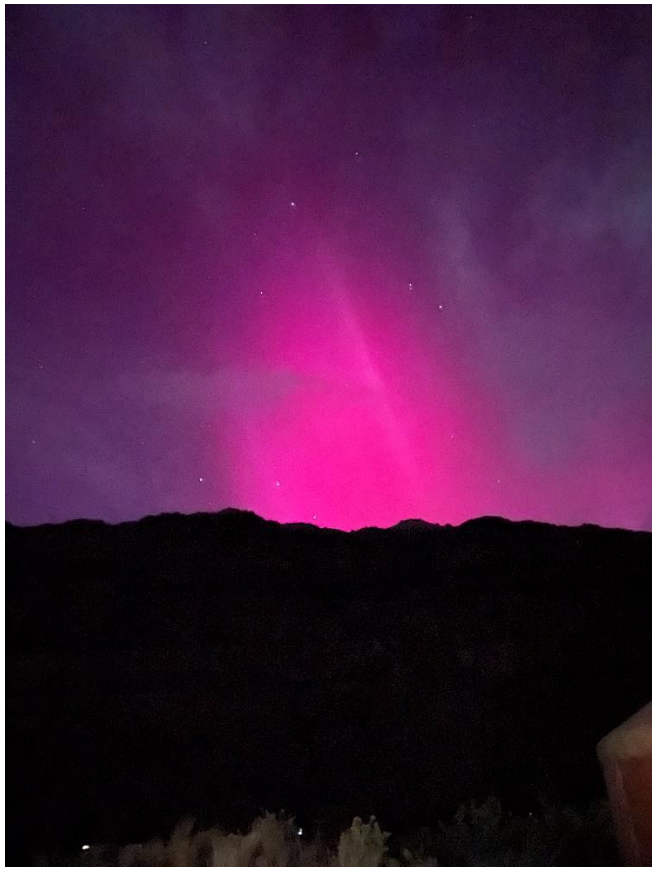
Data Collection from Bonderman Field Station

Final Report



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PART 1

Introduction

Cartography has long been considered both an art and a science, although whether these are separate concepts is debatable (Krygier 1995). It is easy to see how it is a data-driven science in 2024, when maps are used for everything from navigation to finding restaurant reviews. That said, it is the art of cartography that allows for clear communication of data, allowing it to be used effectively. At Bonderman Field Station at Rio Mesa (herein referred to as Bonderman), students were given the chance to create maps using different techniques, allowing them to find the balance between art and science.

Before a map is created, using *in situ* methodologies can be an important step if new data is being gathered (Kundu 1995). Even if data can be gathered remotely, it is important to ensure truthfulness. Additionally, field methods allow a more comprehensive understanding of the subject matter. Accordingly, students were first assigned to observe various features of their choosing at Bonderman and record them by making a hand drawn map. Then, ESRI's Field Maps was used to create a digital record. Finally, an unmanned aerial vehicle (UAV) was used to capture photography of the area and recreate it.

Study Area

About 0.8 miles past the Bonderman gate is a concrete culvert in the road where a wash crosses. This wash drains to the north into the Delores River, allowing for vegetation like rabbitbrush and yellow evening primrose to grow. Nearby were manmade features, like a weather station and a streamgage. This area was easy to traverse because of the wash, two roads, and a trail, allowing for the sensitive cryptobiotic crusts to remain undisturbed. For these reasons, this area was chosen as the study area for the first part of the Bonderman project.

Figure 1: Yellow Evening Primrose growing in the first study area.

The study area ran mostly north to south along and next to the wash. More specifically, the weather station, gaging station, and a USGS Survey marker were at the north of the study area, where an access road came to the Delores River. To the south there was a trail that led to an old icehouse. In the middle there was a fair amount of vegetation growing in the wash, as well as cottonwoods growing at the edge. The banks of the wash showed evidence of relatively serious flooding. This was also indicated by the downstream tilt much of the vegetation had. In total, there were 14 vegetation observations, 10 manmade feature observations, four geological observations, and two hydrological observations.

Methods

The first item to produce was a hand drawn map. This was done on a Rite in the Rain All-Weather Field notebook and pen. This was chosen due to the durability of the notebook and its ability to withstand various conditions. Additionally, this notebook was gridded, which aided in trying to draw to scale. The culvert itself was decided as a center point and was marked on the center of the page. The study area was then surveyed by foot along the wash, and attention-grabbing features were marked on the map. Vegetation was marked by an asterisk, while other features were marked with a one- or two-word description. The survey then continued down a nearby road, and down a part of the trail to the icehouse. A compass was used to find north, which was copied to the map. Then, a scale was made by approximating two short steps to be equal to one US foot. Strides were counted between a few features, and the grid was used as an aid.

Once the hand drawn map was made, ESRI's Field Maps app was used. A section of an existing map, Bonderman Field Station at Rio Mesa, was already downloaded for offline use. The study area was surveyed again, using the hand drawn map as an aid. Four different feature classes were used: Built Infrastructure, Hydrology, Biology, and Geology. A descriptive note was entered for each feature, and pictures were taken when possible. Upon return, this data was filtered by creator.

Finally, a DJI Mini was used to capture aerial photography. Before the flight, 10 ground control points (GCPs) were placed in the study area and their locations were measured with a high-quality receiver. The UAV was flown about 30 meters above ground in a single overlap pattern. There was a concern for battery life, resulting in the UAV being flown at a higher than ideal speed for the three second interval between image captures. The images were brought into Agisoft Metashape Professional. Using structure from motion (SfM), an orthomosaic image was stitched together. This involved creating a sparse point cloud, georeferencing the images, making a dense point cloud, building a DEM, and finally creating the orthomosaic.

The orthomosaic was missing several areas due to the combination of flight altitude, speed, and capture interval. Nevertheless, it was combined with the Field Maps data to create a map.

Results

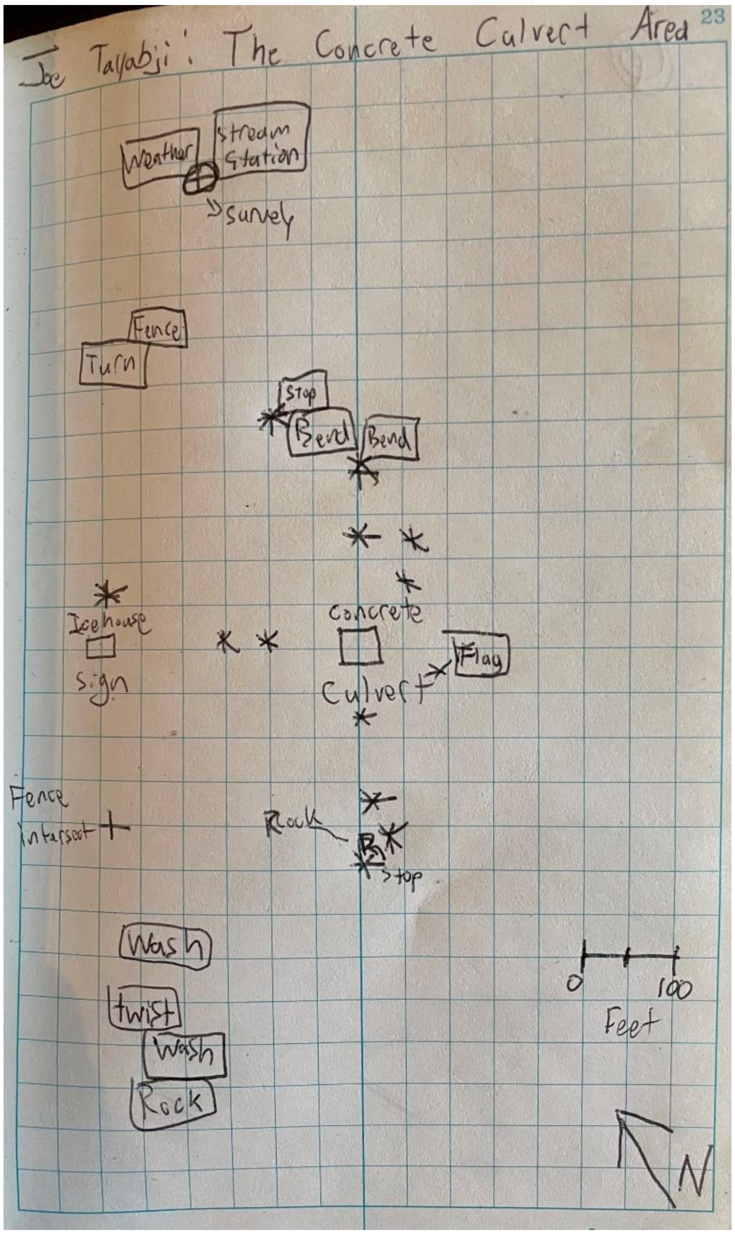

Figure 2: A hand drawn map of the culvert wash area.

The hand drawn map (Figure 2) shows that its use is admittedly limited. It was very helpful for determining relative locations of features. For example, when a vegetation sample was located in the wash it was easy to understand where the next one would be. Another advantage is that on-the-fly custom symbology and labeling could be applied. When a quick description (e.g. fence) was needed, it was easy to write. It’s also worth noting the varying accuracy of scale. On this map, it appears that the culvert is about 150 feet away from the flag. In ArcGIS Pro, this distance was measured as 155.7 feet. The distance between the culvert and the bend to its north appears to be about 475 feet but was measured at 545.6 feet.

By far the biggest issue with the digital map (Figure 3) is the missing information in the orthomosaic even if many of the features are captured in the images. However, the accuracy of the data from Field Maps is quite good considering it was created using common consumer hardware. A major advantage is the ability to make detailed, accurate measurements. Additionally, the map itself can be endlessly adjusted for cartographic purposes.

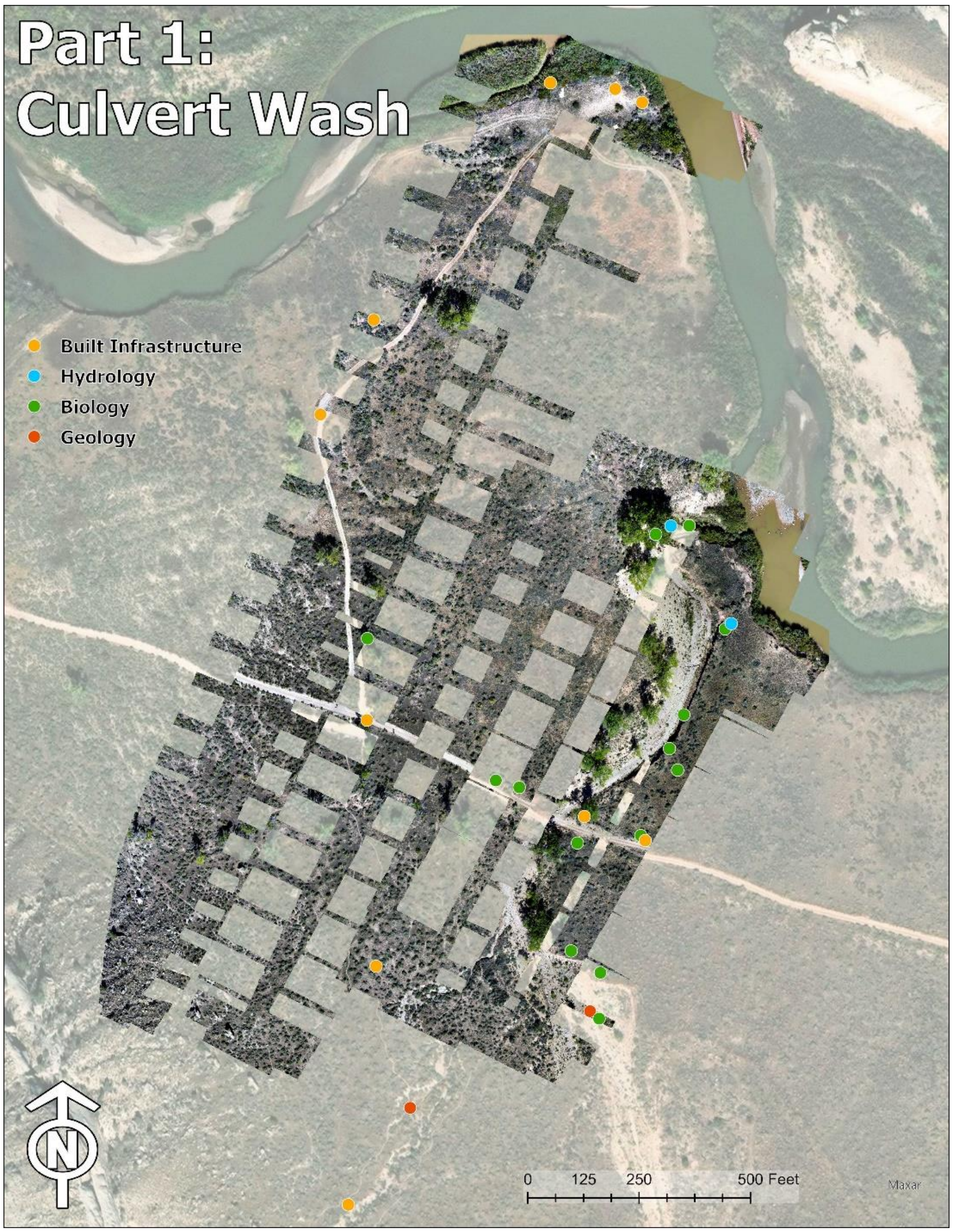

Figure 3: Field Maps data over an incomplete orthomosaic.

Conclusion

It is undeniable that there is a use for hand drawn maps. They can be made on the fly without any technology. A notebook such as Rite in the Rain can be used in nearly all weather conditions, while hardware is often sensitive to moisture. However, it is hard to be accurate with a hand drawn map without technology or, at the least, experience.

The detail and accuracy of digital mapping techniques are hard to beat. Planning and understanding how to use the technology are crucial to success. In this case, the map had to be downloaded ahead of time because of the lack of cell service. Additionally, a lack of UAV knowledge led to a low-quality product, and this was not made clear until it was too late.

PART 2

Introduction

For the second part of the project, groups were allowed to select areas just outside Bonderman to study. We were able to use both LiDAR and the DJI Mini. SfM has been useful in identifying low lying desert vegetation in studies modeling hydrothermal sites (Callahan 2023). This is made possible because of the ability to fly a UAV at relatively low altitudes. One group, Team GCP, was specifically interested in finding an area with vegetation.

The accuracy comparison was made even more exciting with the addition of LiDAR, because it meant a highly accurate method would be in place. LiDAR has been used by ecologists to not model where vegetation is, but to even gather details of their canopy (Lefsky et al. 2002). The basics of LiDAR involve emitting a light flash from a sensor and measuring the time it takes radiation to return to the sensor.

Figure 4: Markup was used on an iPhone photo to determine where the GCPs would be placed before the ground crew split up.

Team GCP used 10 GCPs and made a preflight plan that covered both flight details and ground responsibilities. The independent variable to be tested with the DJI Mini was altitude. A reference flight would be flown with the intention to terrain-follow to the best of the pilot's ability. The variable flight would be at a constant height of 70 m above takeoff.

Study Area

The study area was a 2.6 mile drive from Bonderman. There was a slickrock bowl feature with a ridge on top. Between the bowl and the road was a wash that ran from southwest to northeast. In and around the wash was vegetation that included trees and low-lying shrubs.

The slickrock bowl was striped with geological evidence of times past. The surface was steep enough that caution was mandatory, but offered enough grip that off camber traversing was possible. Towards the southwest of this bowl was an access point to the ridge, which could be easily and safely gained. While the bowl itself was barren and almost entirely slickrock, the ridge had cryptobiotic soils, dirt, rock, and plenty of vegetation. A panoramic view was available at the top, which meant the entire study area could be seen.

The wash was surrounded on either side by plenty of cryptobiotic soil. However, there was an access point by the road, and it led to an area with an entrance to the bowl. There were rock surfaces near the wash as well, which made for an appropriate location for GCPs. Team GCP was interested in the vegetation in this area. There was a variety of flora, including trees, shrubs, cacti, and other succulents.

Overall, the study area offered both drastic and subtle elevation changes, which were ideal for testing digital surface model (DSM) accuracies. Additionally, it was fairly open, which allowed for safe flying by the UAV pilots. Finally, it was traversable, and lines of sight were ample.

Methods

The preflight plan included the two pilots who decided who would fly the reference flight (terrain-follow, this was the second flight) and who would fly the variable flight (constant 70 m, this was the first flight). They additionally discussed flying a single overlap pattern, a plan for battery use, and what communication would be used. While this took place, the ground crew placed the 10 GCPs at predetermined locations, and then took their places to ensure the UAV was always insight. A rudimentary system of hand and arm signals was in place so everyone in Team GCP knew when there was danger to the UAV. Establishing clear communication procedures among the entire party is one of many important steps in a preflight checklist that must be followed (Wicks and Giverson 2023).

Figure 5: The LiDAR UAV pilot moments before takeoff.

After the two flights captured images for SfM, the LiDAR pilot flew their UAV. This involved UAV calibration and setting up a receiver for real-time kinematic (RTK) processing. This UAV had an automated flight plan, gathered data, and returned to base when the flight was complete.

Upon return, the DJI Mini images were gathered and split up by flight using file timestamps. The images were brought into Metashape as separate projects. Like Part 1, sparse point clouds were created and then the images were georeferenced. Flight 1 did not capture two of the control points, but the remaining eight were found. The average GCP error was 10.5 m for this flight. Only four GCPs were found in the images from flight 2. Among those the average error was 2.4 m. From here, dense point clouds, DEMs, and finally orthomosaics were created. Both the DEMs and orthomosaics were brought into ArcGIS Pro for further analysis.

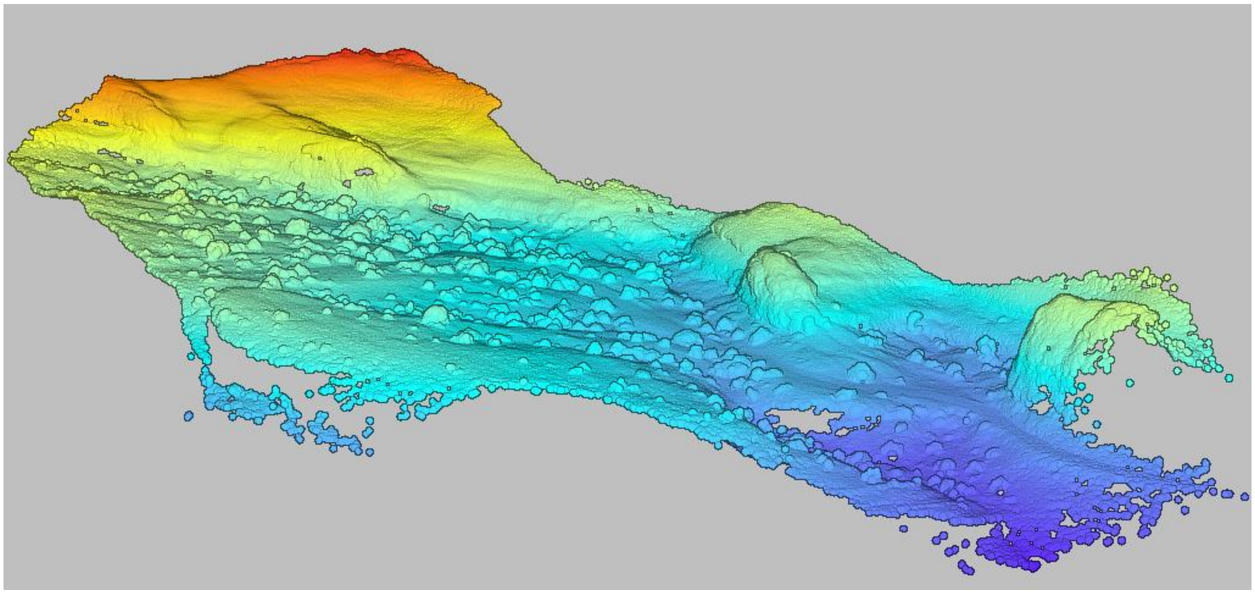

Figure 6: LiDAR point cloud visualized by elevation as shown in ArcGIS Pro.

ArcGIS Pro was also used to process the las file for the LiDAR data. A 3D scene was created to visualize the LAS points themselves (Figures 6, 7). Additionally, a DSM was created. Various visualizations were explored to create the final maps.

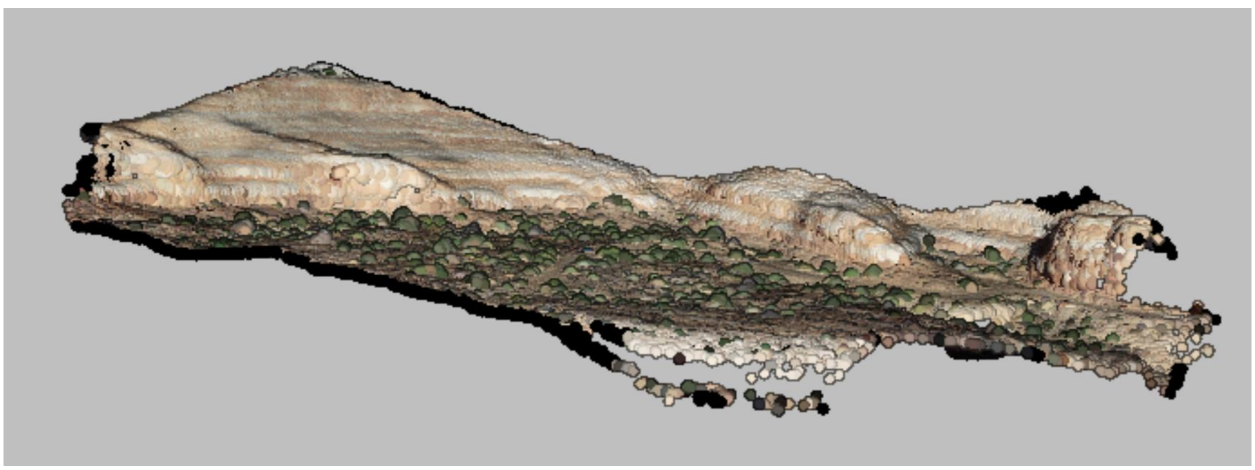

Figure 7: LiDAR point cloud visualized by RGB values as shown in ArcGIS Pro.

Results

Upon examination of the DSMs (as hillshades, Figure 8, and as aspect-slope, Figure 9), it is clear that the LiDAR data has an impressive amount of detail, particularly for the vegetation. The detail and resolution in the LiDAR are so fine that the hillshade appears rough in texture because each pixel can be easily distinguished. The canopy of vegetation is easily distinguished.

The 70 m test flight where the altitude was held constant was the next finest result. However, this may not be due to the altitude. This flight captured more GCPs than the other flight and the spatial resolution ended up being finer. Vegetation can be seen on this flight, as well as some details. The terrain-follow flight shows more coarse data, and it captured a smaller area. Trees can be made out, but not smaller vegetation.

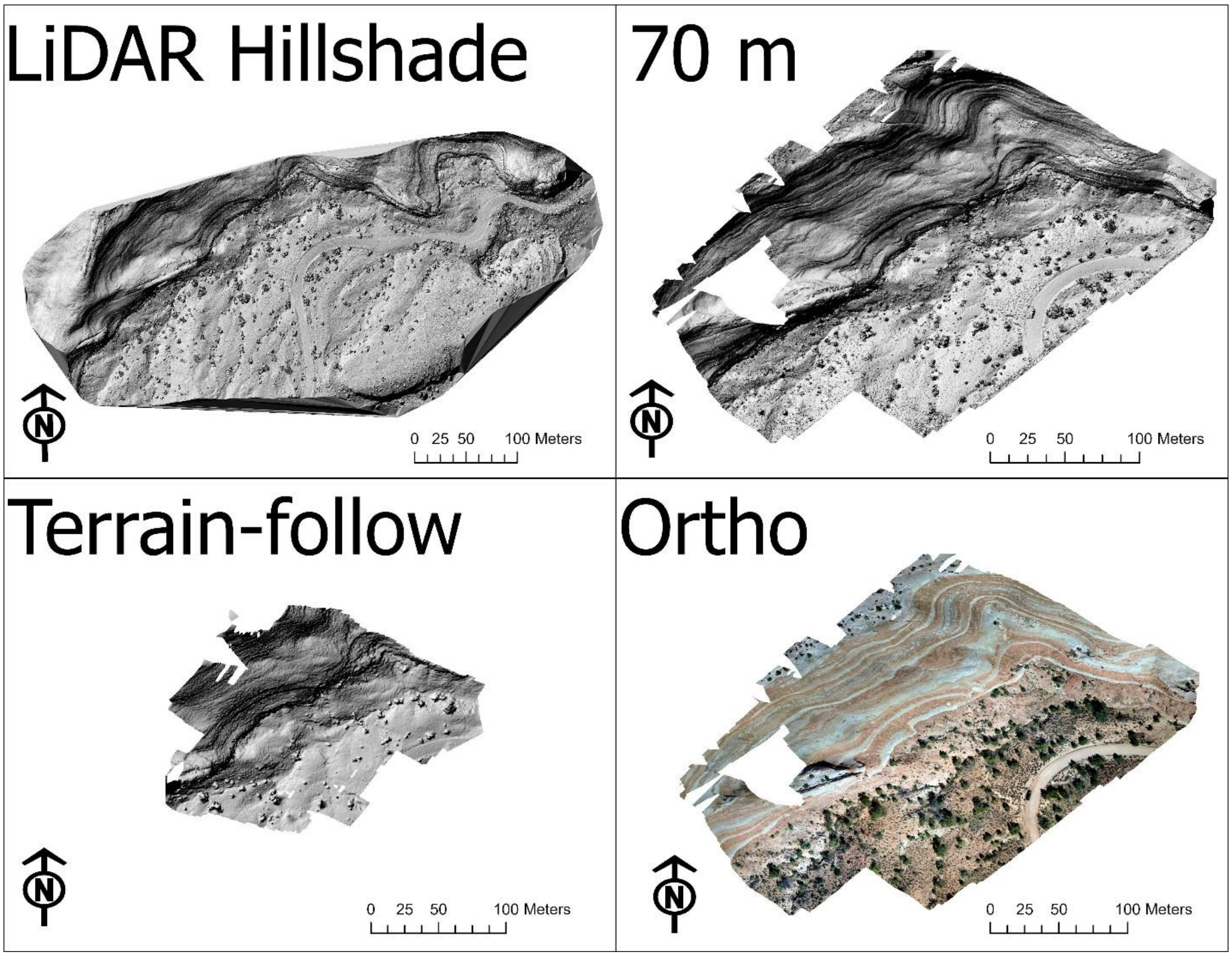

Figure 8: DSMs as hillshades.

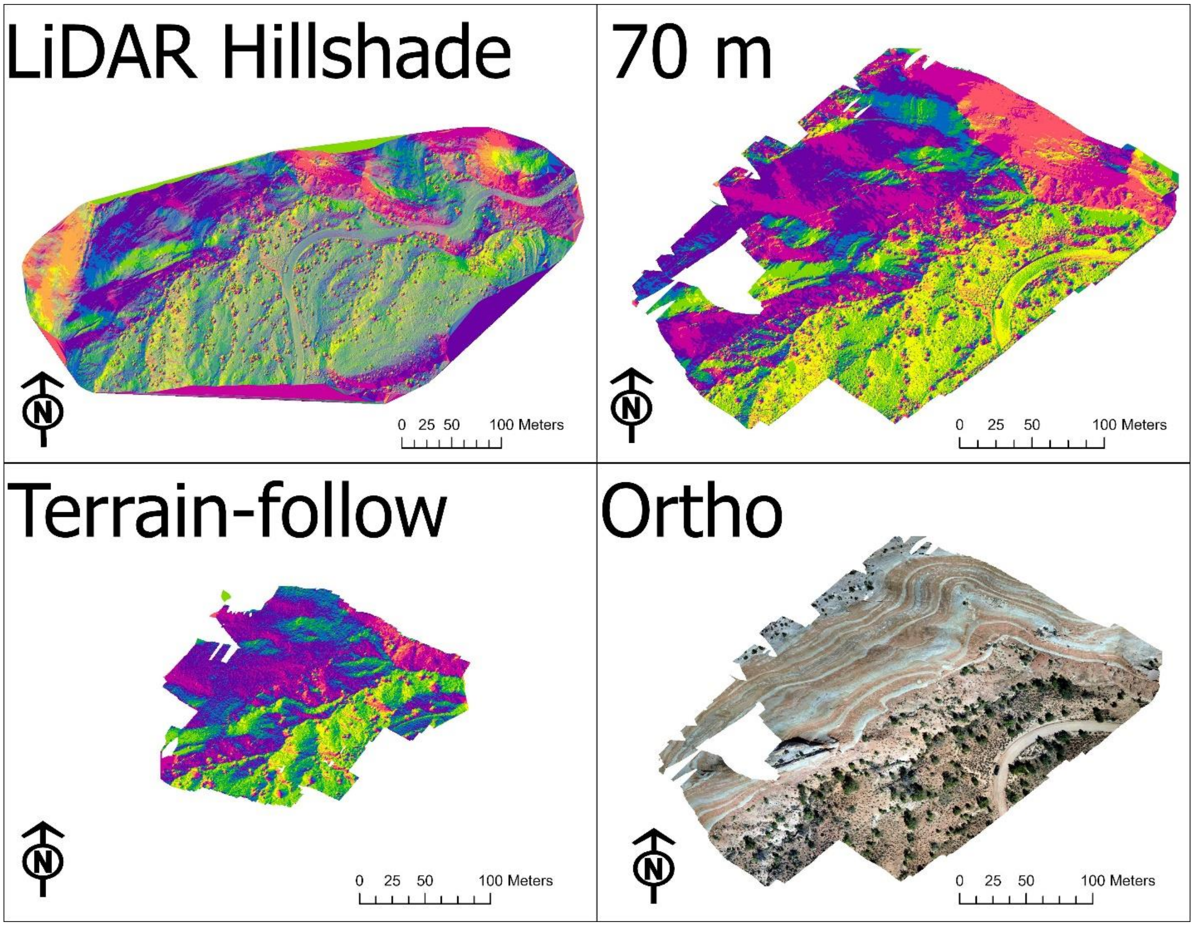

Figure 9: DSMs shown in aspect-slope.

Differences in elevation values seemed to be dependent on whether or not the area was in the bowl. When comparing LiDAR to the 70 m flight, the mean difference was -5.3 meters. The distribution was fairly even between -20 m and 7 m. When comparing LiDAR to the terrain-follow flight, the mean difference was -13.2 m, and the distribution was much more bell shaped. The areas where there are positive and negative differences are essentially opposite of one another when comparing the two differences. Using the mean values, the 70 m was more accurate.

When comparing the two DJI Mini flights, the mean difference was 9.4 m. The distribution had a tail on the low side.

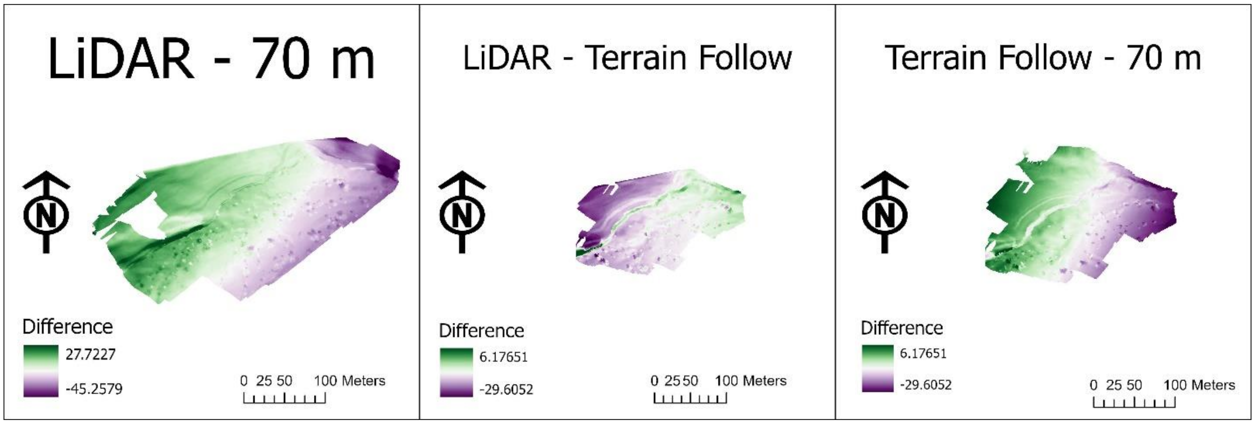

Figure 10: Elevation differences.

Conclusion

It is noteworthy that the calculated differences in elevation are related to whether the pixel is in the bowl. It is certainly possible that attempted to follow the terrain makes a big difference. The LiDAR data is certainly the most impressive data. It was offered at a spatial resolution and degree of accuracy that SfM was not able to match. More importantly, the importance of the flight itself cannot be understated. Throughout both parts of the project, understandable pilot errors played a critical role in the resulting issues. The LiDAR UAV was flown by an experienced pilot using the aid of technology, while the DJI Minis were flown by inexperienced pilots. The old saying “garbage in, garbage out” clearly applies here. In all geographic studies, the analysis is only as good as the data. Therefore, from the onset of a study the data itself must be treated with care.

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