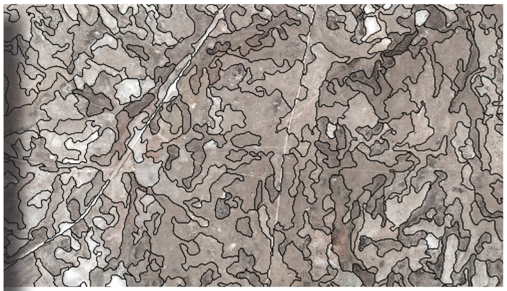
United States Department of Agriculture
Forest Service

Mapping Gunnison Sage-Grouse Habitat with Stereo Aerial Imagery

July 2014

RSAC-10035-RPT1



Abstract

The Forest Service, U.S. Department of Agriculture, Remote Sensing Applications Center, in collaboration with the Grand Mesa, Uncompahgre and Gunnison (GMUG) National Forests, evaluated the use of stereo aerial imagery to produce high resolution digital surface models (DSMs). The DSMs were then used to characterize Gunnison sage-grouse *(Centrocercus minimus)* habitat, specifically shrub height and percent cover. Object-based image analysis techniques using eCognition were also evaluated for mapping shrub cover from high resolution aerial imagery. The evaluation of the DSM creation and object-based analysis techniques was conducted on the Gunnison Basin study site, located in southwestern Colorado. The modeling products were evaluated by comparing the results with both lidar and image-interpreted datasets. Comparisons between the products and reference datasets were performed by way of a paired *t*-test, which revealed that there was no significant statistical difference between the imagery-derived shrub cover estimate and the photo-interpreted estimate at the landscape level. However, there was significant variation at the plot level. Additionally, the height comparison revealed a strong correlation between the lidar reference data and the heights derived from the 10-cm spatial resolution imagery. This comparison was only performed on maximum heights within regions of similar shrub cover, and not at the individual shrub level. Attempts to derive shrub height information from the 30-cm spatial resolution imagery were unsuccessful. The findings of this study, in addition to providing vital information about shrub cover, can be used to aid in the mapping and protection of Gunnison sage-grouse habitat.

Keywords

sage-grouse, *Centrocercus minimus*, GMUG National Forest, Gunnison Basin, eATE, PhotoScan, eCognition

Authors

Jeremy Webb is a remote sensing specialist employed by RedCastle Resources at the Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah.

Randy Hamilton is the sponsored projects group leader and a remote sensing specialist employed by RedCastle Resources at RSAC.

Matt Vasquez is a wildlife biologist working at the Gunnison Ranger District in Gunnison, Colorado.

Jess Clark is the assistant program leader for the Remote Sensing Evaluation, Applications, and Training (RSEAT) program at RSAC.

Haans Fisk is the program leader for the RSEAT program at RSAC.

Acknowledgments

We would like to especially thank Matt Bobo and Tom Noble from the Bureau of Land Management (BLM) for the help and support that they provided. Also, a special thanks to all the partners involved in this project, including cooperators from GMUG National Forests, Natural Resources Conservation Service (NRCS), BLM, National Park Service (NPS), Colorado Parks and Wildlife (CPW), and Gunnison County.

Webb, J.; Hamilton, R.; Vasquez, M.; Clark, J.; Fisk, H. 2014. Mapping Gunnison sage-grouse habitat with stereo aerial imagery. RSAC-10035-RPT1. Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Remote Sensing Applications Center. 10 p.

Table of Contents

Introduction and Background

In 2000, Gunnison sage-grouse *(Centrocercus minimus)* (GUSG) was officially designated as a separate species from the greater sage-grouse *(Centrocercus urophasianus)*. On January 11, 2013, the U.S. Fish and Wildlife Service (USFWS) proposed to list GUSG as endangered under the Endangered Species Act. Based on the best available scientific and commercial data, the USFWS determined that the principal threat to Gunnison sage-grouse is habitat loss, degradation, and fragmentation due to residential, exurban, and commercial development and associated infrastructure such as roads and power lines. Added stress is being placed on the species as a result of improper grazing management, predation (often facilitated by human development or disturbance), genetic risks in the small declining populations, and climate change. Conservation strategies have been identified to address these threats and aid in the preservation of GUSG. As a result, it is becoming increasingly important to have accurate and up-to-date information about land cover and vegetation conditions (Aldridge et al. 2012).

GUSG are found south of the Colorado River in southwestern Colorado and southeastern Utah. Seven populations have been identified, with a combined total population of approximately 4,620 birds. The largest population is located in Gunnison Basin and makes up 87 percent of the total number of GUSG. Within Gunnison Basin, there are an estimated 600,000 acres of potential GUSG habitat. However, information regarding specific seasonal habitat is lacking and is difficult to collect by field crews alone for such an extensive area (USDI FWS 2013).

Objectives

The purpose of this project was to develop and test remote sensing techniques to aid in the modeling and mapping of GUSG habitat. The main objective was to investigate the feasibility of using newly-developed software (e.g., ERDAS eATE and Agisoft PhotoScan) to derive shrub height and canopy cover information from high resolution stereo aerial imagery. The derived digital surface models (DSMs) could fill an important information gap in characterizing GUSG habitat. A secondary objective was to create an efficient and effective workflow to map the percent cover of rangeland shrubs by using the spectral qualities and spatial patterns of the imagery. This includes the use of object-based image analysis with eCognition.

Literature Review and Technology Background

High resolution aerial images have been used for over 70 years for mapping and monitoring resources. The Forest Service began acquiring high resolution resource photography over most National Forests as early as the 1930s. Since then, photography has been used on innumerable projects involving various disciplines. Although the technology has changed over the years, aerial imagery continues to be an invaluable source of data for mapping and monitoring natural resources.

Although aerial photography has been at the forefront of remote sensing from the beginning, other sensors have been developed over the years to improve our ability to map and monitor the Earth's surface. Among these newer sensors is airborne lidar. Lidar data is collected with an active sensor that emits thousands of light pulses per second from a laser. The instrument records how long it takes for each pulse to reflect off of the surface and return to the sensor. The resulting dataset contains thousands, if not millions, of individual 3-D point locations known as a point cloud. Lidar datasets can be ingested by software applications to create high resolution surface models of the terrain and features found thereon. Lidar is not the only means for obtaining 3-D data. Aerial imagery, if collected with sufficient overlap, can also be used to measure feature heights and to create surface models. Such imagery is often referred to as stereo imagery, since it can be viewed in stereo or 3-D by means of stereoscopy. Stereo imagery has been used for decades in the production of topographic maps and elevation models using photogrammetric techniques. Due to the complexity of extracting elevation data, the outputs were largely limited to spatially coarse elevation products. However, as a result of recent advancements in computer processing capabilities, optical sensors, and image matching algorithms, detailed elevation information can now be automatically extracted from stereo aerial imagery with appropriate computer hardware and software. The outputs from the stereo reconstruction software are commonly in the same file format (LAS) as the lidar data, and thus appear very similar to lidar point clouds. The point clouds are often converted to a surface model for further processing and extraction of vegetation height and cover data. In some cases, aerial imagery processed in this fashion is beginning to be seen as an alternative to lidar for deriving high resolution DSMs. The technique for creating DSMs from overlapping imagery is known as dense stereo reconstruction (DSR).

There are advantages and disadvantages associated with both lidar and DSR datasets. Since lidar is an active sensor, meaning that the instrument emits its own energy to illuminate the features, it can more effectively model the ground plane when vegetation is present. This characteristic is very important since without an accurate terrain model, estimation of canopy metrics such as height can be very difficult, if not impossible, to obtain. Aerial imagery, on the other hand, has radiometric and spectral qualities that allow it to be used effectively for classification of land cover types and spectral segmentation. Aerial imagery is also more readily available, both for historical and contemporary datasets, and generally less expensive to acquire than lidar. One of the disadvantages of DSR is its inability to penetrate the vegetation layer to model the ground surface under dense canopy cover. Since ground height is needed to calculate vegetation height, the modeling of densely vegetated landscapes may depend on the availability of a non-DSR-derived digital elevation model (DEM), such as is produced with lidar. For areas that already have existing lidar data, DSR may be a cost effective means for continued monitoring and mapping efforts. Numerous studies have suggested this approach for monitoring land cover change (Jarnstedt et al. 2012; Straub et al. 2013). Nevertheless, in some cases, it may be possible to derive height and cover information for vegetation with only DSR data if the landscape is sparsely vegetated.

Because of the benefits associated with aerial imagery, an ever-increasing interest has been shown in the use of DSR for deriving high resolution surface models. Since these capabilities are just being realized, few studies have been published to address the use of this technology for rangeland monitoring and mapping purposes. Therefore, this project investigates such technologies for use in the extraction of height and cover information for rangeland mapping and monitoring. In addition, this project includes a workflow for using the spectral information inherent in aerial imagery to automate the separation of rangeland shrubs from other land cover types.

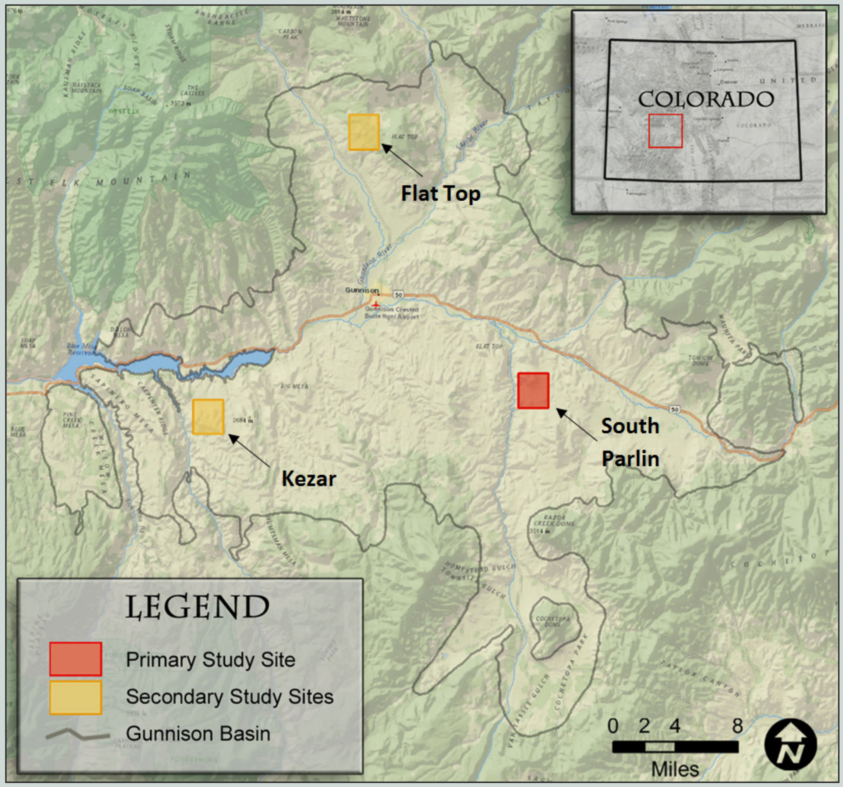


Figure 1—The study area located in Gunnison Basin, with the primary *(South Parlin)* and secondary *(Flat Top and Kezar)* pilot study sites highlighted.

Study Area

The study area is located in southwestern Colorado in the Gunnison Basin (latitude 38° 32′ N, longitude 106° 55′ W) (figure 1). The basin has over 590,000 acres of GUSG habitat that is managed by multiple landowners, including the Bureau of Land Management (BLM) (51 percent), Forest Service (14 percent), National Park Service (NPS) (2 percent), private landowners (29 percent), and the state of Colorado (4 percent). Much of the basin is made up of Sagebrush-steppe with big sagebrush *(Artemisia tridentata)* being the dominant species. The majority of the valley bottoms along the major drainages are used for agricultural purposes. Elevations range from 2,480 to 3,163 m within the areas frequently used by GUSG in our study area (Williams and Hild 2012).

Multiple pilot study sites were selected within the Gunnison Basin in order to capture a variety of rangeland vegetation types. The study sites were selected based largely on the availability of ancillary datasets, including field data, lidar, and aerial imagery. South Parlin, located in the eastern portion of the basin, was selected as the primary study site since three recent datasets were available from the BLM, including lidar, ultra-high resolution aerial imagery, and field data. Two secondary study sites, Flat Top and Kezar, were selected for the study, but were only used for a portion of the project due to a lack of reference height information.

Data

Aerial imagery was the main source of data for this project. Lidar data was also used, but only for comparing and assessing the products of the aerial images.

Aerial Imagery

This project included two stereo aerial image datasets of differing spatial resolutions, both of which cover the South Parlin study site. The two sets of imagery were delivered in four-band (blue, green, red, and near-infrared), 8-bit GeoTIFF format.

The lower resolution dataset was funded by multiple agencies and collected during the summer of 2012. The acquisition covered the entire Gunnison Basin, as well as much of the surrounding area. The imagery has a ground sample distance (GSD) of 30 cm.

The higher resolution dataset consists of imagery with a GSD of 10 cm and was funded by the BLM and collected during the summer of 2011. The acquisition covers approximately 22,000 acres near the center of Gunnison Basin and includes several ground control points for georeferencing the imagery and calibrating the camera.

Lidar Data

Lidar data, collected in June of 2011, was provided by the BLM and used as vertical reference data. The dataset served as a comparison for the DSMs created from the stereo aerial imagery. This dataset shared the same acquisition boundary as the 10-cm imagery, thus only covering the central portion of Gunnison Basin. The lidar data has a nominal pulse density of 9.7 pulses/m^2. The vertical root mean squared error (RMSE) of the data is 6 cm. A digital terrain model with a spatial resolution of 1 m was also delivered by the vendor and used for creating a canopy height model (CHM) from the lidar data.

Methods

Two approaches were evaluated for obtaining information about rangeland vegetation: (1) the use of DSR to derive shrub height, and (2) the use of image segmentation to map shrub canopy cover. Lidar data served as a reference for assessing the shrub height information produced from the aerial imagery. Additionally, image-interpreted plot data was collected and used for assessing the image segmentation workflow.

Shrub Height

There are a growing number of software packages that contain DSR tools. One of these software packages is ERDAS Imagine, which is currently the Forest Service's enterprise remote sensing software package. Since ERDAS can be installed and used by anyone in the Forest Service, it was of primary interest for extracting the vegetation height information from the aerial imagery. In 2011, a version of ERDAS Imagine was released that contained the enhanced Automatic Terrain Extraction (eATE) module. The eATE module allows the user to generate a 3-D surface from aerial imagery. It requires the user to first create or have available an Imagine photogrammetric project file, also known as a block file, which contains the orientation and correction information for the imagery. Once the block file is loaded, the user can select the area to be processed and the parameters for running eATE. The eATE module was used to process the 30-cm imagery. The outputs of eATE were in a point cloud (LAS file) format.

The results from eATE were unsatisfactory and did not yield useful products, so other software packages were considered. Based on user reviews and software capabilities, Agisoft PhotoScan was chosen for further evaluation. The package has several useful features for aligning the images, calibrating the camera sensor, and generating 3-D surfaces from aerial imagery. Training on the use of PhotoScan was provided by personnel at the BLM who were familiar with the software. PhotoScan was originally used to process the 30-cm imagery. Since PhotoScan was unable to ingest the block file created with ERDAS Imagine, the images had to be realigned in PhotoScan using ground control points (GCPs) before the surface could be created. The GCPs used for alignment were collected with a survey grade GPS unit. Once the images were aligned and the sensor parameters calibrated, a point cloud (LAS file) was generated from the imagery.

The surface created from processing the 30-cm imagery with PhotoScan also produced unsatisfactory results for accurately modeling rangeland shrubs. To further test the software and determine if more accurate shrub heights could be obtained with higher resolution imagery, we also processed the 10-cm imagery with PhotoScan. The methods and setup for processing the 10-cm imagery closely followed those of the 30-cm imagery. We used Esri ArcMap tools to create a CHM from the resulting point cloud.

More information about the settings and parameters used in processing the aerial imagery with eATE and PhotoScan can be found in the appendix.

Shrub Canopy Cover

Another objective of the study was to design a repeatable and efficient workflow for using aerial imagery to derive polygon-based shrub cover estimates of the study area. Since the 30-cm imagery was the only dataset to cover the entire basin, it was used as the input dataset for the segmentation process. In addition to the four bands of imagery, a Normalized Difference Vegetation Index (NDVI) [(near infrared - red) / (near infrared + red)] was created and used in the workflow. To better characterize sagebrush cover patterns, we created image objects (or segments) at two scales in eCognition and then combined them to form a canopy cover map. The two sets of segments targeted (1) the individual shrub level and (2) the shrub group level. Following is a description of each level of segments, as well as a description of how the two sets were merged and used for deriving canopy cover estimates at the group level.

Shrub Level

The first step to obtain shrub cover estimates was to segment and classify the individual shrubs. This was accomplished by using multithreshold segmentation in eCognition. The software automatically determined a threshold (based on the red band) to divide the imagery into two classes—shrub/tree and ground. The multithreshold segmentation process used this threshold to create a set of classified segments distinguishing the shrubs/trees from everything else. The results were then exported as a raster dataset. This approach works well for spectrally simple landscapes where the two classes of interest are spectrally distinct (e.g., dark shrubs and light-colored ground) (figure 2).

Another independent multithreshold segmentation was performed on the NDVI layer to identify trees. This was accomplished with the use of manually defined thresholds based on the standard deviation of the NDVI values within the segments. These results were also exported as a raster. A final map of just the shrubs was created by subtracting the tree raster from the shrub/tree raster in ArcMap.

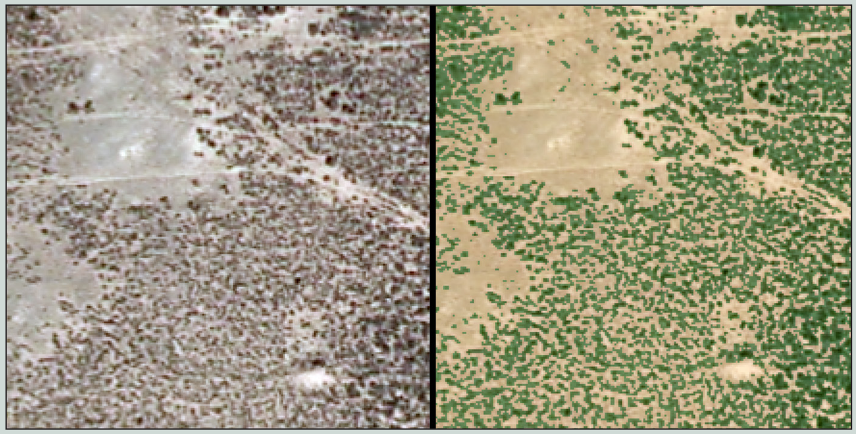


Figure 2—Rangeland area in South Parlin, shown as 30-cm imagery *(left)* and the resulting shrub-level segmentation and classification *(right)*. Green represents shrub while tan is herbaceous vegetation and bare ground.

Group Level

After the shrubs were mapped, the imagery was resegmented into the group-level segments by using multiresolution segmentation in eCognition. Following the segmentation, a pixel frequency filter (i.e., focal majority filter) was applied to a rasterized version of the segments to smooth the boundaries. The raster was then resegmented to create smoothed segments. All segments that were smaller than 0.25 acres were merged with a neighboring segment. The mean segment size for the South Parlin study site was 1.6 acres (figure 3).

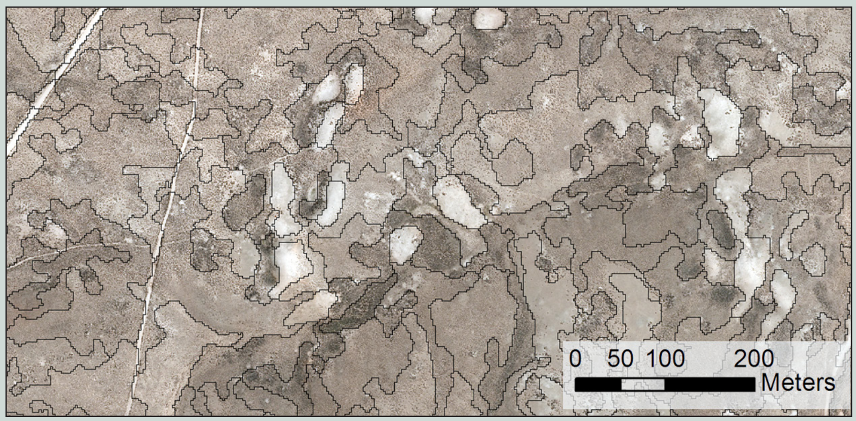


Figure 3—Group-level segments created in eCognition from 30-cm imagery over a portion of the South Parlin study site.

Merged Segments

The group-level segments were attributed with percent shrub cover values. This was done by calculating the percentage of shrub cover from the final shrub-level raster falling within each of the group-level segments. The two datasets were merged in Esri ArcMap. The shrub cover values can either be used as continuous values or categorized, per user needs, into discrete percent cover classes (figure 4).

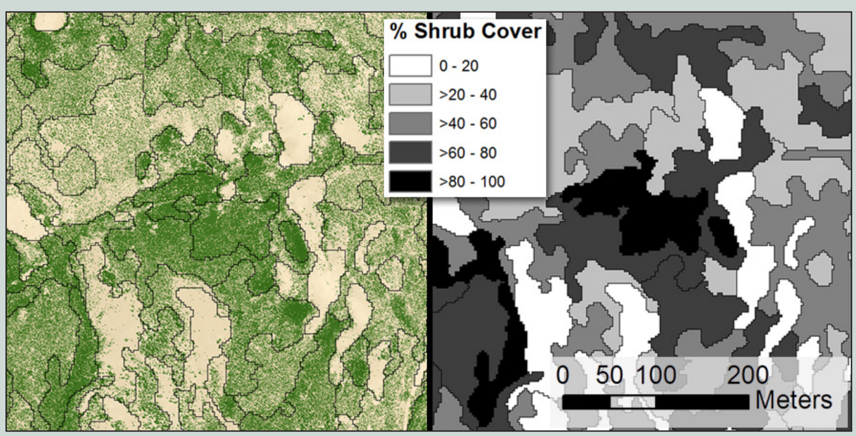


Figure 4—Group-level segments and the shrub map *(left)* were merged to create shrub cover estimates for each group-level segment *(right)*. Although the data is continuous, the bottom image has been categorized by percent shrub cover classes for display purposes.

Height Attribution of Group-Level Segments

In addition to attributing the group level segments with shrub cover estimates, we also attributed each segment with the tallest shrub height value found in the PhotoScan 10-cm CHM for the segment. So as to include only shrub heights, the lidar CHM was used to generate a mask to exclude vegetation greater than 2 meters in height. The height attribution of the group-level segments was performed in ArcMap, and was only done for a portion of the South Parlin study site since the 10-cm imagery did not exist for the other study sites (figure 5).

The group segments were also attributed based on the lidar-derived CHM. This attribution served as reference data for assessing the DSR-derived shrub heights. A paired *t*-test was used to compare the two datasets and to test the null hypothesis that there was no difference between the mean heights of the DSR and lidar CHMs.

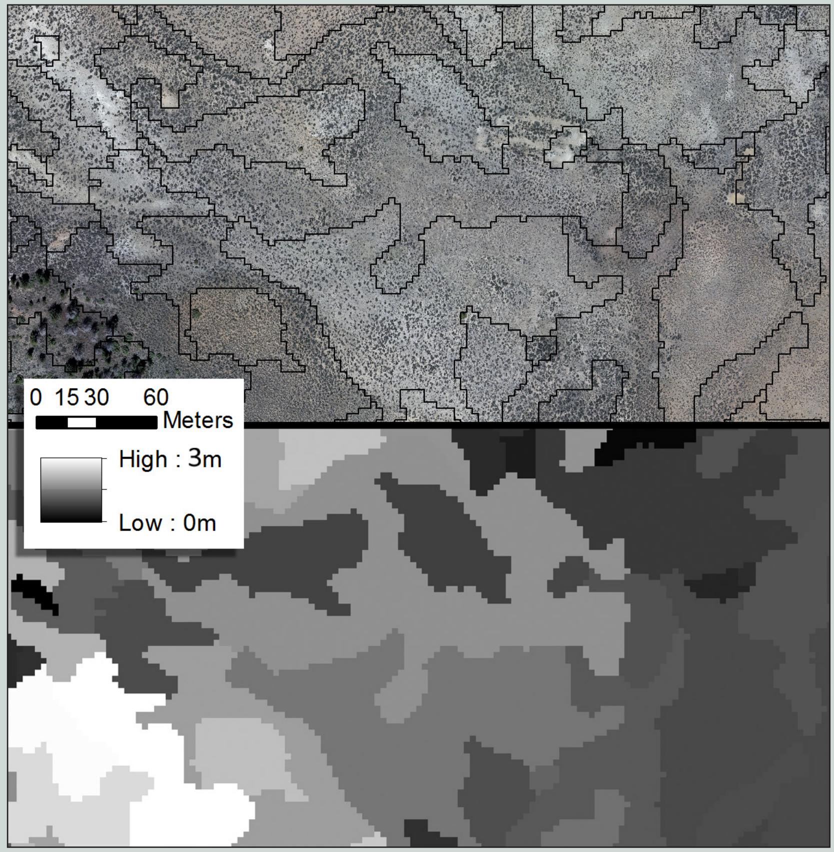


Figure 5—Subset of the 10-cm imagery and group-level segments *(top)*. The group-level segments were attributed with the maximum vegetation heights *(bottom)*, which were derived from DSR and 10-cm imagery.

Assessment of Shrub Cover

An image-interpreted estimate of the shrub cover was obtained from the 10-cm imagery. The data were then used to validate the shrub-cover estimates derived from the multi-level segments. The sampling design for the plots was based on previous work done at the Remote Sensing Applications Center (RSAC) for estimating rangeland shrub cover. This included the use of randomly selected circular plots, each of which contained a systematic grid of points (Maiersperger et al. 2006). The plots and points were created using Image Sampler, which is an ArcMap add-in created at RSAC.

So as to have a direct comparison between the segments and image-interpreted data, we needed to ensure that the randomly selected plots did not cross any group-level segment boundaries. This was done by using ArcMap to create an exclusion buffer within each of the segments. The buffer was equal to the radius of the plots that were to be created. The plots, each being a tenth of an acre, were then randomly allocated within the remaining portion of the segments.

Number of Plots

Forty randomly selected plots were initially interpreted and used to determine the necessary sample size for estimating shrub cover at a 95 percent confidence level. Using the following formula, we calculated that a total of 95 plots were required to meet the 95 percent confidence level with a ±10 percent margin of error:

$$n = ((Z_\alpha)^2(p)(q))/d^2$$

where: n is the estimated necessary sample size, Z_α is the coefficient of standard normal deviate, p is the value of the proportion of shrub cover as a decimal percent, q is one minus the value of p, and d is the desired precision level expressed as half of the maximum acceptable confidence interval width (Elzinga et al. 1987). A value of 0.44 (i.e., mean proportion of shrub cover from the initial plots) was used as p.

Dot Grid Layout and Interpretation

The systematic dot grid within each plot consisted of 97 points (figure 6). The points, which were placed 2 m apart from one another, were interpreted and given a land cover attribute of shrub, tree, or other. The number of points intersecting shrub cover was tallied and divided by the total number of points in the plot (i.e., 97) to arrive at the proportion of the cell occupied by shrubs.

The shrub cover map, derived from combining the shrub- and group-level segments, was assessed by comparison with the image-interpreted data. This was done by calculating the proportion of shrub cover within each of the shrub group-level segments, and comparing those to the values derived from the image-interpreted plots. The two datasets were compared using a paired *t*-test. The comparison tested the null hypothesis that there was no difference between the mean shrub cover values derived from image segmentation and the image-interpreted dataset.

Results and Discussion

Shrub Height Results

Superficially, the eATE- and PhotoScan-derived point clouds appeared to be very dissimilar due to the density and continuity of the points. However, after creating DSMs for both datasets, we found the results from the two applications to be fairly similar. This was the case for both the 10-cm and 30-cm imagery.

The surface model created from the 30-cm imagery contained height information for taller features, such as trees and buildings, but failed to effectively model shrubs and other small features. In areas where shrubs were visible in the imagery, the surface model remained flat with little to no vertical variation, as can be seen in figure 7.

The surface model created from the 10-cm imagery contained more detail than that seen in the DSM derived from the 30-cm imagery. Even many of the smaller shrubs (i.e., approximately 30 cm in height) appeared to be effectively modeled with the 10-cm imagery (figure 8). The maximum heights attributed to the group level segments from DSR and lidar were highly correlated (R^2 = 0.87 with an RMSE of 24 cm)(figure 9). The overall means of the maximum heights across the group-level segments were 1.04 m for the DSR-derived heights and 0.95 m for the lidar-derived heights.

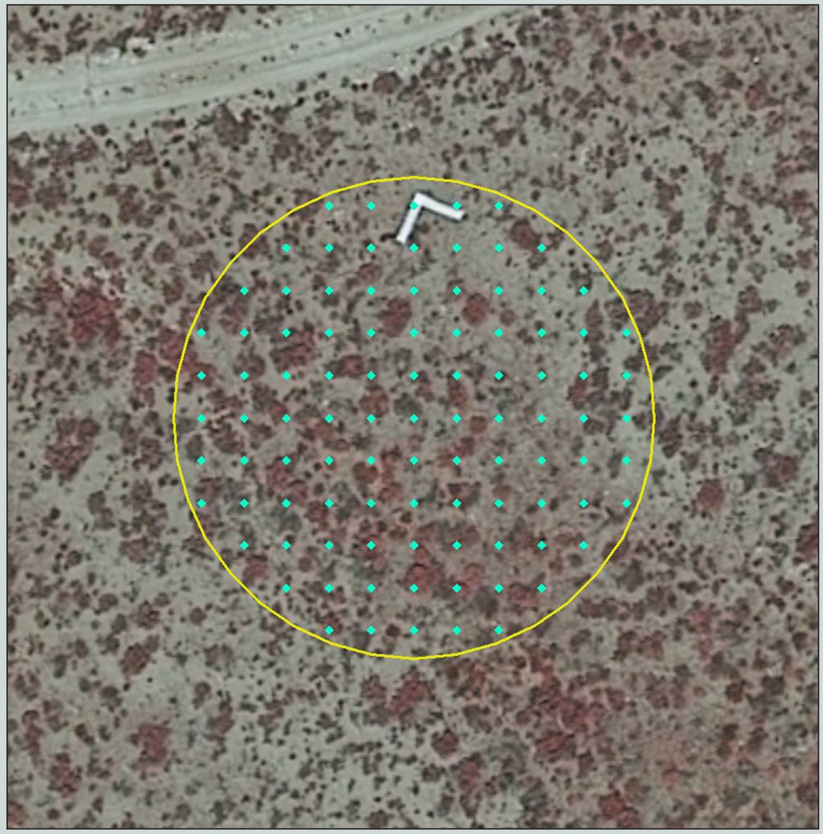


Figure 6—A sample plot and dot grid overlaying 10-cm color infrared imagery.

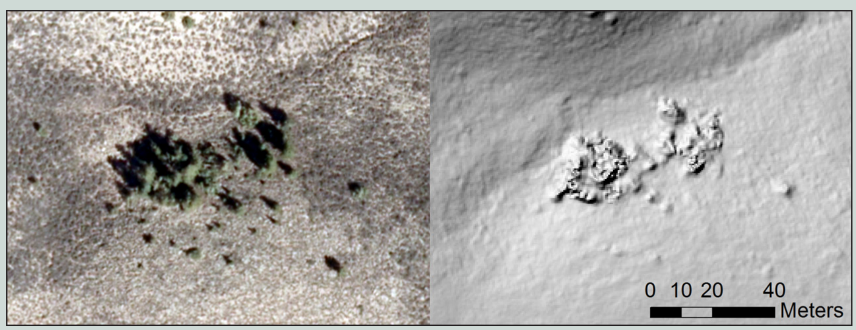


Figure 7—Subset of the 30-cm imagery *(left)* and a hillshade *(right)* created from the 30-cm imagery and PhotoScan.

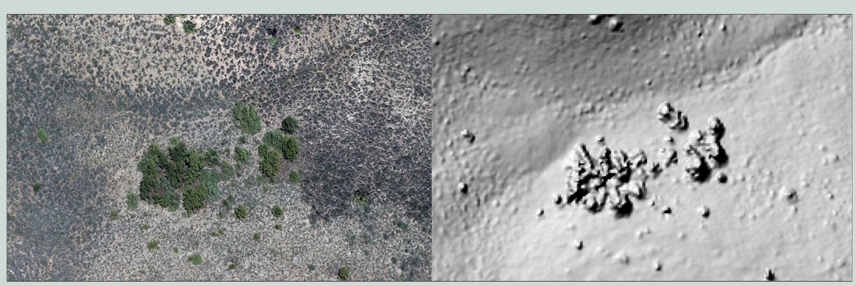


Figure 8—Subset of the 10-cm imagery *(left)* and a hillshade *(right)* created from the 10-cm imagery and ERDAS eATE.

However, a paired *t*-test comparing the maximum shrub heights within the group-level segments derived from the 10-cm imagery and the lidar data ($t(100)=1.98$, $p<0.0001$) revealed that the means were significantly different.

Although the DSM derived from the 10-cm imagery accurately modeled many of the shrubs, it did not accurately model all of them. However, when maximum DSR heights were attributed to the group level segments, the data were highly correlated with the maximum lidar heights. This comparison shows a potential use of the 10-cm imagery for identifying suitable GUSG habitat. However, accurate field validation data are needed to fully understand the accuracy and utility of the DSR- and lidar-derived shrub heights. Even if the DSR data proved to be accurate, the 10-cm imagery is not currently available for all of Gunnison Basin. The cost and volume of data associated with acquiring 10-cm imagery across the entire basin may be an obstacle for its future procurement.

Shrub Cover Results

The comparison of the image segmentation products with the image-interpreted data revealed mixed results. The paired *t*-test, which tested the null hypothesis that there was no difference between the mean shrub cover values of the image-interpreted dataset and the image-derived segments, revealed that the means were not significantly different. The mean value for the image-interpreted dataset and image-derived segments were respectively 43.1 and 42.7 percent ($t(94)=0.14$, $p=0.8862$).

Even though the paired *t*-test results show that the two datasets are not different at the landscape level, there are differences among the two datasets at the plot level. Since the segmentation algorithm was designed to spectrally separate shrubs from surrounding non-shrub classes, it was noted that errors occurred in areas where the spectral qualities of the classes were similar. For example, errors of commission for the shrub classification were noted in areas where herbaceous vegetation and/or soil were darker than normal and were, therefore, incorrectly classified as shrub. The opposite was also noted, which resulted in errors of omission for the shrub classification where the shrubs and their surroundings were particularly bright. Since the assessed area contained similar amounts of over- and under-classification of shrubs, the mean shrub cover for the study area was very similar to the image-interpreted mean. However, the large RMSE (24.2%) and low R^2 value (0.2767 for an exponential trendline), indicate that the two datasets are not as well correlated as previously thought (figure 10). The statistical results suggest that the dataset may be useful at a landscape scale, but not as reliable at the plot level.

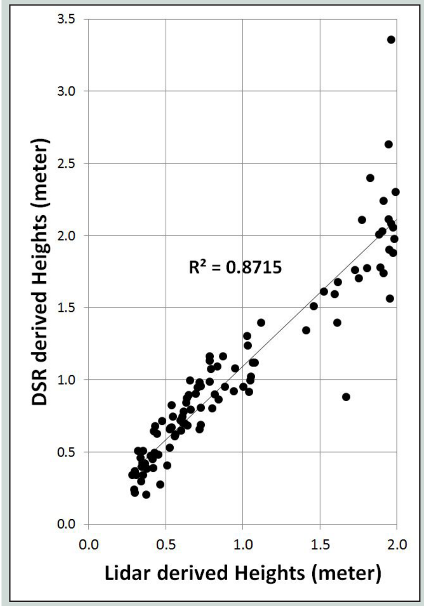


Figure 9—Scatter chart showing the tallest vegetation height attributes that were given to each of the South Parlin stand segments. Vegetation height information was derived from the 10-cm PhotoScan model and the lidar data.

Comparison of DSR Software Packages

Two software packages, ERDAS eATE and PhotoScan, were tested and evaluated for project use. Both software packages were found to be powerful tools when used with appropriate imagery for the features being modeled. One of the main advantages of eATE is the ability to adjust and fine-tune the parameters for a particular landscape. This can also be considered one of the disadvantages of eATE since it requires more knowledge to effectively set up and use. One of the main advantages of PhotoScan is its ability to quickly and easily align images and prepare them for creating a 3-D surface. PhotoScan does this by using a technique called "Structure from Motion" which aligns images, even if they have little to no locational data. The options for creating a DSR surface are also more straightforward and easier to set up in PhotoScan. Since there are several applications that have similar capabilities, future studies may include a more thorough comparison of eATE and PhotoScan, along with other software packages.

As for processing the data, both software applications can handle large amounts of data at once. However, in order for PhotoScan to process the large files associated with aerial imagery, it may be necessary to install some computer hardware upgrades (i.e., RAM and graphics card). On the other hand, ERDAS eATE, although slower in processing the imagery, was able to handle the same dataset on a standard workstation without running into memory constraints.

The inability of both software packages to accurately model rangeland shrubs using the 30-cm imagery was likely a result of the spatial resolution of the imagery. Other factors, such as the amount of image overlap, may also affect the level of detail obtained from DSR. Future studies may include a more thorough investigation of such factors on surfaces created from aerial imagery. Such information would be valuable for the planning and implementation stages of the image acquisition.

Following the completion of the evaluation of ERDAS eATE and PhotoScan, a new version of ERDAS Imagine (2014) was released which contained a DSR algorithm called Semi-global Matching (SGM). Preliminary testing of SGM revealed much faster processing and an easier-to-use interface when compared to eATE. Although these initial tests revealed great potential for modeling trees and terrain with the 30-cm imagery, SGM seems to still struggle with the modeling of rangeland shrubs. Future studies should include a more in-depth evaluation of the SGM algorithm.

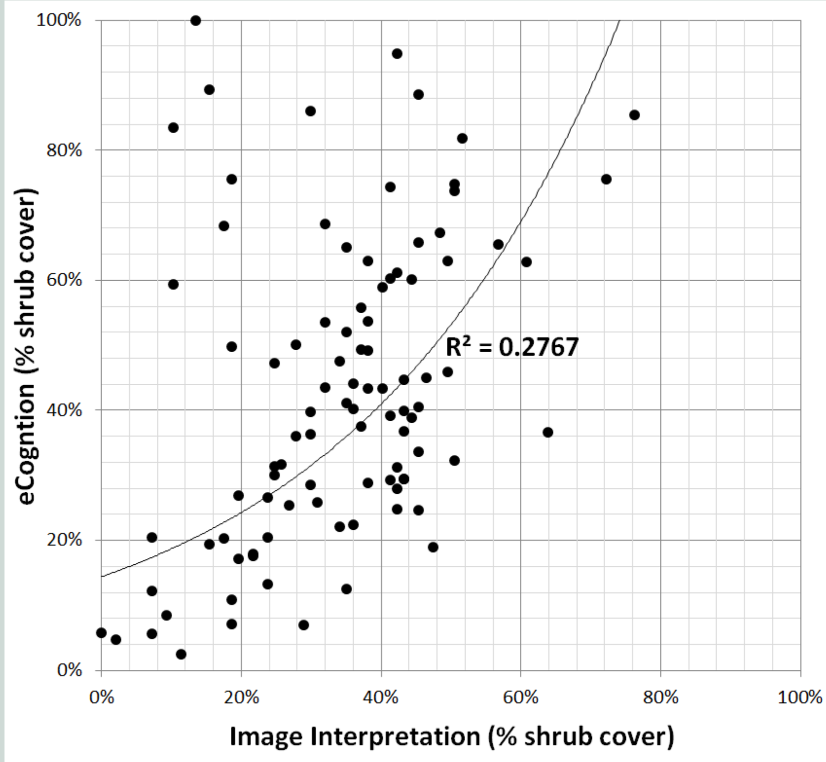


Figure 10—Comparison of shrub cover estimates derived from the image-interpreted data (10-cm imagery), and the mapped dataset (30-cm imagery and eCognition).

Conclusion

This study revealed some of the uses and limitations of 30-cm and 10-cm aerial imagery for modeling rangeland shrub height and cover. The 30-cm imagery, when processed with the DSR software, unsuccessfully modeled shrub height. This was likely a result of inadequate spatial resolution and insufficient image overlap. The 30-cm imagery could possibly be used to obtain a photo interpreted, sample-based estimate of shrub cover across the landscape. However, shrub cover estimates would likely be low due to the inability to clearly interpret smaller shrubs (i.e., less than 30 cm in width) with the 30-cm imagery. We also examined the potential to map shrub cover from this imagery. Our results showed poor correlation with photo-interpreted estimates at the plot level, but better agreement when summarized across a larger area. However, further validation needs to be done before one can assess the reliability of shrub cover maps produced from 30-cm imagery.

Although the 10-cm imagery did not cover the entire basin, it provided insights into the information that can be obtained with higher spatial-resolution imagery. It demonstrated great potential for obtaining maximum shrub heights for group level segments. However, further validation with field data should be done to better understand the accuracy of the image- and lidar-derived height models. The 10-cm imagery was also a great resource for interpreting the cover types in the sample plots. Smaller shrubs, such as black sagebrush *(Artemisia nova)* were obscure and appeared as herbaceous cover in the 30-cm imagery. However, in the 10-cm imagery, these smaller shrubs could be interpreted more easily.

Remotely sensed data, as well as the techniques to extract information from them are continually advancing. Dense stereo reconstruction seems to have the capability to produce height information for rangeland shrubs, but imagery of higher spatial resolution and having more overlap than that of traditional acquisitions may be required. Such imagery would be very costly, which may prohibit it from being a viable input for modeling rangeland shrub heights and cover over expansive landscapes. This technology may still be very applicable for small study sites or studies that involve plot-based inventorying and modeling. For such projects, close-range photography may be an effective method for collecting imagery with the required high resolution and overlap (Matthews 2008).

Future research and analysis of surface modeling with stereo imagery should include evaluating the effects of image characteristics, namely spatial resolution and image overlap, on the resulting surface models. Additionally, mapping shrub cover from resource imagery by using image segmentation shows potential; however, further validation is needed to fully understand the accuracy of the data. Field data, collected specifically to validate the height and cover estimates, should be considered for future studies.

References

Aldridge, C.; Saher, D.; Childers, T.; Stahlnecker, K.; Bowen, Z. 2012. Crucial nesting habitat for Gunnison sage-grouse: a spatially explicit hierarchical approach. The Journal of Wildlife Management. 76(2): 391–406.

Elzinga, C.; Salzer, D.; Willoughby, J. 1998. Measuring and monitoring plant populations. Technical Note 1730-1. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 477 p.

Jarnstedt, J.; Pekkarinen, A.; Tuominen, S.; Ginzler, C.; Holopainen, M.; Viitala, R. 2012. Forest variable estimation using a high-resolution digital surface model. ISPRS Journal of Photogrammetry and Remote Sensing. 74: 78–84.

Maiersperger, T.; Maus, P.; Fisk, H.; Lachowski, H.; Johnson, C.; Elsbernd, V.; Partridge, A. 2006. Estimating rangeland shrub cover from high resolution digital aerial imagery. RSAC-0070-RPT1. Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Remote Sensing Applications Center. 8 p. http://fsweb.rsac.fs.fed.us/index.php?option=com_docman&task=doc_download&gid=148&Itemid=255.[1] (May 1, 2014).

Matthews, N. 2008. Aerial and close-range photogrammetric technology: providing resource documentation, interpretation, and preservation. Technical Note 428. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, National Operations Center. 42 p.

Straub, C.; Stepper, C.; Seitz, R., Waser, L. 2013. Potential of UltraCamX stereo images for estimating timber volume and basal area at the plot level in mixed European forests. Canadian Journal of Forest Research. 43(8): 731–741.

U.S. Department of the Interior, Fish & Wildlife Service. 2013. Gunnison sage-grouse: proposed listing and responsibilities under the Endangered Species Act. Denver, CO: U.S. Department of the Interior, Fish & Wildlife Service. 4 p. http://www.fws.gov/mountain-prairie/species/birds/gunnisonsagegrouse/January2013FactSheet.pdf. (May 12, 2014).

Williams, M.; Hild, A. 2012. Characteristics of Gunnison sage-grouse habitat in dry mountain loam and mountain loam ecological sites of the Gunnison Basin. Laramie, WY: University of Wyoming. 54 p.

[1] This resource may be accessed only from within the Forest Service intranet.

For additional information, contact:

Haans Fisk, RSEAT Program Leader
Remote Sensing Evaluation, Applications & Training
Remote Sensing Applications Center
2222 West 2300 South
Salt Lake City, UT 84119

phone: (801) 975-3750
e-mail: mailroom_wo_rsac@fs.fed.us

This publication can be downloaded from the RSAC Web site: http://fsweb.rsac.fs.fed.us

Appendix: DSR Applications

This appendix includes additional information about the setup and processing of the aerial imagery with the two software applications chosen for evaluation, which were ERDAS eATE and Agisoft PhotoScan.

ERDAS eATE

Since ERDAS Imagine is currently the Forest Service's enterprise remote sensing software package, it was the first application evaluated in this study. ERDAS Imagine, at the time of evaluation, contained two tools for creating digital surface medels (DSMs)—Automatic Terrain Extraction (ATE) and enhanced Automatic Terrain Extraction (eATE). We focused on eATE since it allowed for the creation of a dense lidar-like point cloud from the aerial imagery.

Both the 10- and 30-cm imagery were processed using eATE. Many of the parameters of eATE were adjusted to improve the surface modeling of rangeland. Some of the most important parameters were set as follows:

- Normalized cross-correlation was selected as the algorithm for correlation, with a window size of 9 by 9 pixels.
- "Spike" was used as the interpolation method, which removes outlying points identified as spikes from the dataset.
- Reverse matching was activated, which rechecks the match by reversing the master and search images.
- Smoothing was set to low; this was to minimize the omission of actual low-growing vegetation from the image-derived surface.

The eATE algorithm creates multiple configuration files for each of the stereo image pairs and triplets. After all configuration files have been processed and point clouds for individual image pairs have been created, eATE merges the files into a single point cloud file (LAS). The LAS file is then used to create a DSM.

Agisoft PhotoScan

After obtaining unsatisfactory results from ERDAS eATE, we considered other applications. Only Agisoft PhotoScan was chosen for full evaluation. It was selected largely due to positive reviews from users, as well as to the fact that there were personnel at the Bureau of Land Management who were familiar with the software and willing to share their knowledge.

PhotoScan follows a workflow similar to that of ERDAS Imagine in preparing imagery for the creation of a DSM. This includes providing the software with information about the camera sensor and defining the coordinate system and image scale with the locational (GPS and Inertial Measurement Unit) image information. PhotoScan contains several useful features that reduce the time required to prepare the imagery, including a semi-automated approach for placing ground control points. Another useful feature of PhotoScan is its ability to automatically align images that have no locational information. Since both project datasets contained locational information, this feature was not used. However, for other image datasets, this feature may greatly facilitate the process. Following are some of the other project specific settings used while processing the imagery with PhotoScan.

- Image alignment was set to high. Although the higher setting increases the amount of processing time, it also allows the user to align the images more accurately.
- "Ground Control" was specified as the method for image alignment since both datasets contained IMU/GPS data.
- All quality levels were tested while creating the dense point cloud. Although the ultra-high setting attempts to match every pixel, for this project, we had the most success with this setting set to medium.
- Depth filtering was set to mild, which retains the most detail in the surface.
- For this project, no further processing was required within PhotoScan. However, the software does contain a number of other useful tools to further process a dataset. For example, the dense point cloud can be used to generate a 3-D mesh of the model, which can then be textured using the original images. This results in a 3-D model that contains the high spectral and spatial detail of the imagery. From these products, one can then create orthocorrected images, as well as export the 3-D model into various file formats.