ESTIMATING VEGETATION COVER USING VARIOUS GIS TECHNIQUES[1]

Mark Heil[2], Anne Wagner and Bruce A. Buchanan

Abstract: Vegetation cover data were collected between 2004 and 2009 from a total of 260 transects randomly located at a molybdenum tailing facility operated by Chevron Mining Inc., near Questa, New Mexico. Various GIS procedures employed the use of aerial imagery (NAIP, 2009) and interpolation methods to predict the percent of vegetation cover at unsampled locations based on vegetation cover transect data for a given area. The predicted vegetation cover values are dependent on the actual vegetation transect values and relative locations of the transect data. Aerial imagery reflectivity values, which represented vegetation cover, were used in conjunction with transect data to generate a surface of predicted vegetation cover values. This process, known as universal kriging, incorporates more information about the vegetation cover data by overlaying a dataset that acts as a trend model (in this case aerial photograph reflectivity values) with the values generated by the kriging of the transect data points. Mean vegetation cover was generated and compared from the GIS techniques employed. A mean value of 21.8% vegetation cover was derived from the transect data. Of all the GIS techniques employed, there was a maximum of 2.3% difference from the mean of the transect points. All of the datasets generated had very similar means. The application of the aerial photography into the kriging process resulted in a non-significant difference between data sets when examined as a whole. These data suggest that aerial photography is a potentially useful tool for determining vegetation cover within the study area. However, when examining the geospatial properties of the datasets, they were found to be only moderately accurate at best. Ground truth points, where vegetation cover percentages were recorded in 2010, were used to examine the geospatial accuracy of the generated vegetation cover datasets. A linear regression of the ground truth points and the generated vegetation cover prediction datasets produced r-squared values that ranged from .01 to .61.

Additional Key Words: GIS, vegetation cover, aerial photography, universal kriging, interpolation, simple filter, SAGA

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Introduction

Since 2004, annual plant community monitoring surveys have been conducted at the Questa tailing facility, Chevron Mining Inc., located near the town of Questa, New Mexico. Each year since 2004, total vegetation cover percentages have been calculated from transect data. The tailing sites are composed of areas from 4 different periods of interim reclamation. Each tailing area is composed of molybdenum tailing topped with approximately 10 inches of cover soil. The most recent tailing interim reclamation area (reclaimed from 1998 to 2004) was used for the study.

The study area exists at approximately 7,500 ft in elevation, occurring at the base of the western slopes of the Sangre de Cristo mountain range. The surrounding native vegetation in is composed of *piñon* and juniper woodlands with intermittent sagebrush flats. Vegetation within the tailing area is composed of a variety of seeded grass, forb, and shrub species, with a mean vegetation cover of approximately 22% over a six-year period.

A survey of literature indicated that aerial imagery techniques offer an alternative way of determining vegetation cover (Link et al., 2005). Aerial imagery offers the possibility to obtain vegetation cover data of an entire study area by the use of reflectance values. It also assesses vegetation cover data more rapidly than traditional field methods.

ESRI ArcGIS 9.3 was used to create the maps and generate mean vegetation cover values for the study. SAGA (System for Automated Geoscientific Analysis) 2.0.6 was used to conduct geospatial analyses for the study. Microsoft Excel 2007 was used to generate linear regression statistics displayed in the results section of the report.

A process of filtering the aerial imagery known as the simple filter method (SAGA, 2007) was explored within the study. Aerial images often have a high variation of reflectance values that occur within small areas. The simple filter is intended to decrease the variation in order to derive more of a contiguous pattern. The effectiveness of applying the simple filter method to aerial imagery for the purpose of estimating vegetation cover was explored.

Another technique that has been used to estimate vegetation cover is kriging. Kriging is an interpolation process that generates data from point values for predicting values within the same area (Karl, 2010). Kriging assumes that the data being estimated is stationary and that the average value (as well as variation in the values) of the data is relatively constant. When spatial trends occur in the data, such as a high variation in rocks within an area, the assumption is violated. When this occurs, the spatial trend can be incorporated into the data by the using a drift function. A drift function is a simple polynomial function, which is used to model the trend. A residual is created, which is the difference between the actual data and the trend. The drift function is then used to perform the kriging process on the residual values, which are treated as stationary data (EMS, 2010).

The universal kriging process creates the possibility of incorporating information about trends such as geospatial raster datasets in conjunction with point datasets to predict unknown data values in areas that occur in the same location. This process makes it possible to include additional information about a trend within a study site to increase the accuracy of the kriging process. This study explores the possibility of using universal kriging to predict vegetation cover values in locations within the study area where transects were not conducted. Aerial imagery (NAIP, 2009) and the simple filter method will be incorporated into the universal kriging process along with 260 vegetation cover values derived from transects from 2004 to 2009. Reflectance grid values from the aerial imagery represent a trend of data and will be analyzed in conjunction with vegetation cover transect data.

The purpose of the study is to determine whether the methods explored will be useful in determining a mean for the vegetation cover value. In addition to the mean vegetation cover value, it is the purpose of this study to determine the geospatial accuracy of the methods used. A total of four vegetation cover estimation processes will be conducted. The mean vegetation cover derived from the four datasets will be compared to determine whether they can provide a sufficient overall representation of vegetation cover within the study area boundary. A ground-truth method will be applied to the dataset with 50 vegetation cover transect points from 2010 to determine the geospatial accuracy of the data[1].

Methods

Vegetation cover data were collected between 2004 and 2009 from a total of 260 transects randomly located at a molybdenum tailing facility operated by Chevron Mining Inc., near

1 The 2010 ground truth dataset did not cover the entire study area because of issues of inaccessibility. There was a presence of large machinery in the southern portion of the study area due to the construction of a solar facility in the proximity.

Questa, New Mexico. In 2010, 50 transects were conducted in the study area for the use of ground truthing. The random points were visited, where 50 m transects were conducted. One hundred readings were taken at each transect. At every 0.5m for the length of the 50 m transect, a reading was obtained directly underneath the transect tape. The number of times that vegetation occurred out of the 100 readings determined the vegetation cover percentage for that transect. For example, if Grass Species A occurred 5 times in the transect, then Grass Species A could be said to have 5 percent cover.

Aerial imagery (NAIP, 2009) was used to derive reflectance values for the study area. The aerial image's reflectance values were inverted. This process was conducted assuming that within the original aerial imagery, pixels with low values (darker pixels) are representative of areas of high vegetation cover and pixels with high values (lighter pixels) are representative of areas of low vegetation cover. A predicted vegetation cover mean from the aerial imagery was normalized for the purpose of comparing it to the actual vegetation cover values derived from the 2010 ground truth points. Figure 1 and 2 show the study area and the associated aerial imagery with overlaid transect data points.

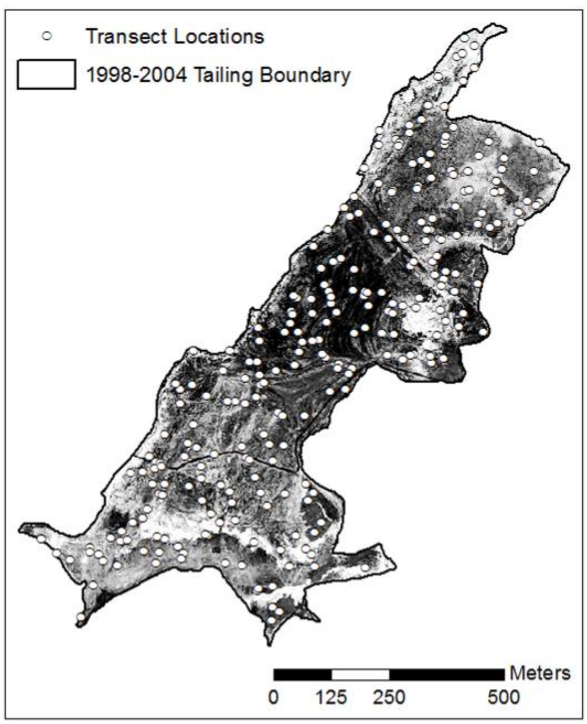

Figure 1. The image above illustrates 260 points that represent transect locations where vegetation cover values were collected from 2004 to 2009.

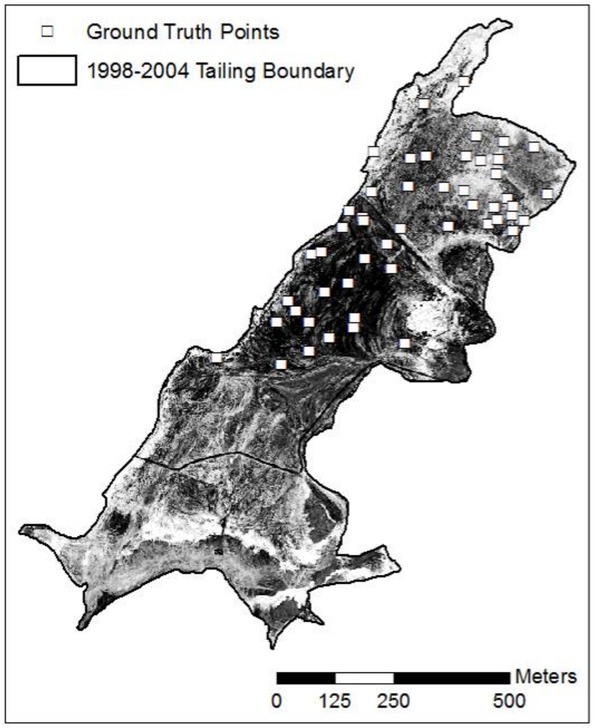

Figure 2. The image above illustrates the 50 points from 2010 that represent transect locations where vegetation cover values were collected and used for ground truth purposes.

The simple filter method of smoothing was applied to the aerial imagery. This method uses a matrix that involves calculating values of neighboring grid cells within any given radius to calculate a value for the center grid cell. For this project, a radius of 50m was chosen to account for the length of the transect from the starting point. Since the transect data occurs as points and are not representative of the actual 50 meter transect line, it is necessary to account for the discrepancy by smoothing the data.

The variation occurring within the reflectance values of the aerial imagery reflects not only variation occurring within the tailing vegetation cover, but is also a result of shrub shadows, and other factors. Large variation may occur within a small area in the aerial photograph and as a result may not display a legitimate representation of the vegetation cover. For example, a 50 m radius circle on an aerial photograph contains a wide variety of reflectance values ranging from 1 to 90 on the reflectance spectrum. The mean reflectance of all the grid cells within the 50m radius circle is 25. However, the fundamental nature of a transect point is discrete. This means that the point occurs within only one grid cell and is not representative of the 50 m radius circle. If the transect point is attributed with a vegetation cover of 25, and the grid cell that it occurs within has a reflectance value of 75, the transect point's vegetation cover value is not a good representation of the single grid cell. However, the point more closely represents the mean of the 50 m radius circle. This scenario is representative of the nature of this project's data and can be accounted for by using the simple filter method.

To further simplify predicted vegetation cover values, the quantile method of classification (ESRI, 2007) was used. The reflectance values within the aerial photo and the simple filter data were divided into 2 classes (binary data). Every value that is less than the mean is put into one category. Every value that is more than the mean is put into the other category. The creation of binary data from the complete range of predicted vegetation cover values decreases the magnitude of variation within the aerial imagery and simple filter datasets. In the case of the scenario described in the paragraph above, all of the grid cell values neighboring the point become a part of the same class. The values within the neighborhood of grid cells no longer show the same magnitude of variation because they all become a part of the same class.

The quantile method of classification was applied to each vegetation cover prediction dataset. A comparison was made between the quantile classification results and results derived from continuous datasets. Data values that occurred below the mean were assigned a value of 1. Values that occurred above the mean were assigned a value of two. A geospatial representation was created for each method and can be seen in Figures 3 through 8.

The predicted vegetation cover values are dependent on the actual vegetation transect values and relative locations of the transect data. Aerial imagery reflectance values, which represented vegetation cover, were used in conjunction with the kriging process to generate a surface of predicted vegetation cover values. Universal kriging was performed in two applications of this study. The 260 vegetation cover values derived from the transect data were incorporated into the universal kriging process in both instances. In one instance, the raw aerial imagery reflectance values were used as trend data. In the other instance, the dataset that consisted of reflectance values resulting from the simple filter of the aerial imagery was used as trend data.

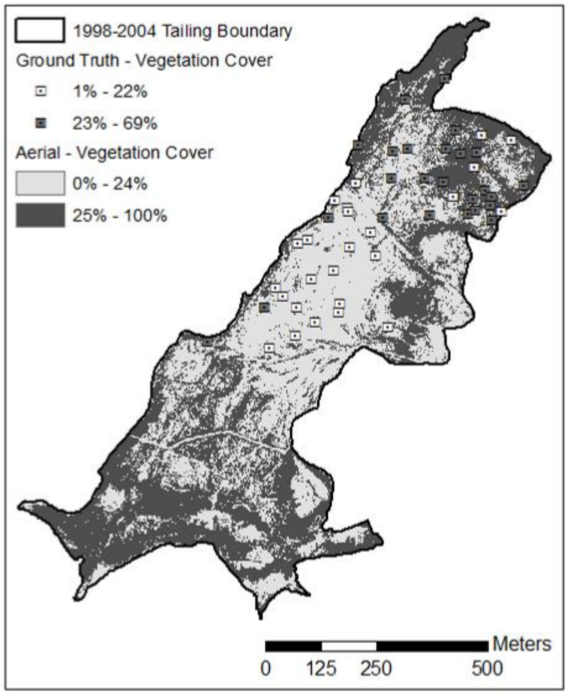

Figure 3. The image above shows the inverted aerial imagery classified into 2 classes using the quantile method is shown as a base layer. The ground truth points are shown within the study area.

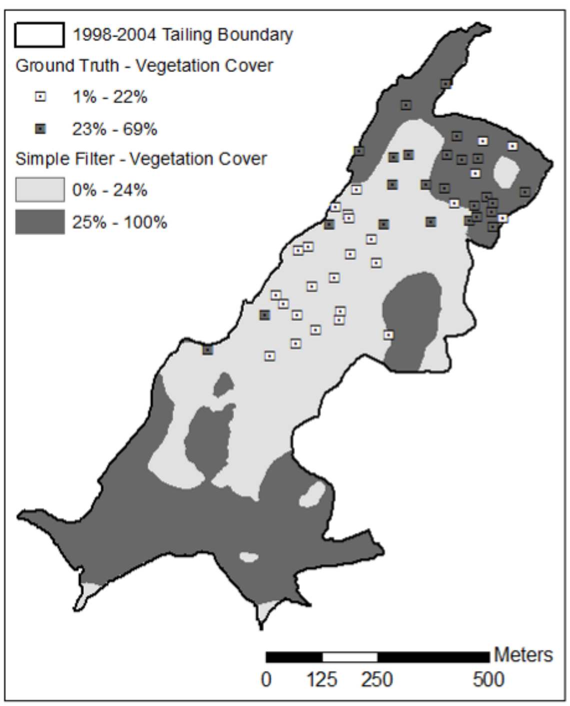

Figure 4. The image above shows the ground truth points overlaid with the inverted simple filter method applied to aerial imagery. The imagery and points are classified into 2 classes using the quantile method and is shown as a base layer.

The universal kriging process, in both instances, was conducted assuming that all of the data values were distributed normally. A simple polynomial drift function was used to model the trend values (aerial imagery, and simple filtered imagery). Residuals were then created from the difference between the trend data drift function and the vegetation cover transect data. It was assumed that the residuals were stationary. The drift function was then used to model the residuals. The resulting datasets are shown in Figure 5 though Figure 8, with the overlaying vegetation cover transect points.

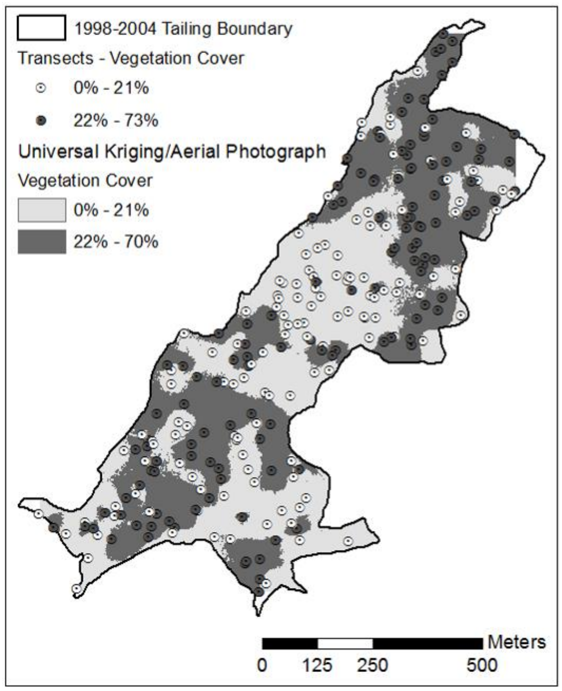

Figure 5. The image above displays the points that represent the vegetation cover transect data collected from 2004 to 2009. The universal kriging method that incorporated the use of the transect data from 2004 to 2009 and aerial imagery from 2009 is displayed. Data within the figure was divided into 2 classes using the quantile method of classification.

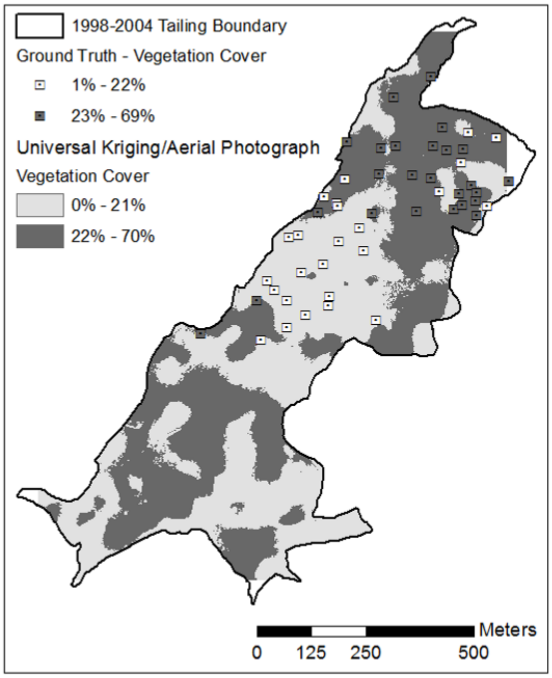

Figure 6. The image above displays the points that represent the vegetation cover ground truth points collected in 2010. The universal kriging method that incorporated the use of the transect data from 2004 to 2009 and aerial imagery from 2009 is displayed. Data within the figure was divided into 2 classes using the quantile method of classification.

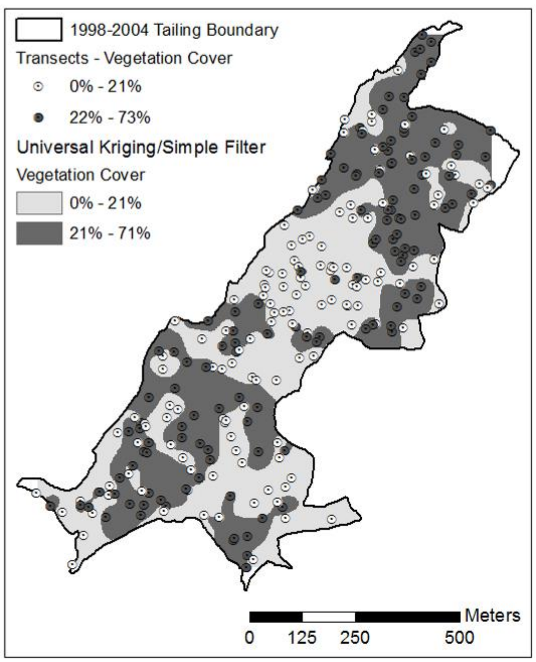

Figure 7. The image above displays the points that represent the vegetation cover transect collected from 2004 to 2009. Also displayed herein is the universal kriging method that incorporated the use of the transect data from 2004 to 2009 and the simple filter method. Data within the figure was divided into 2 classes using the quantile method of classification.

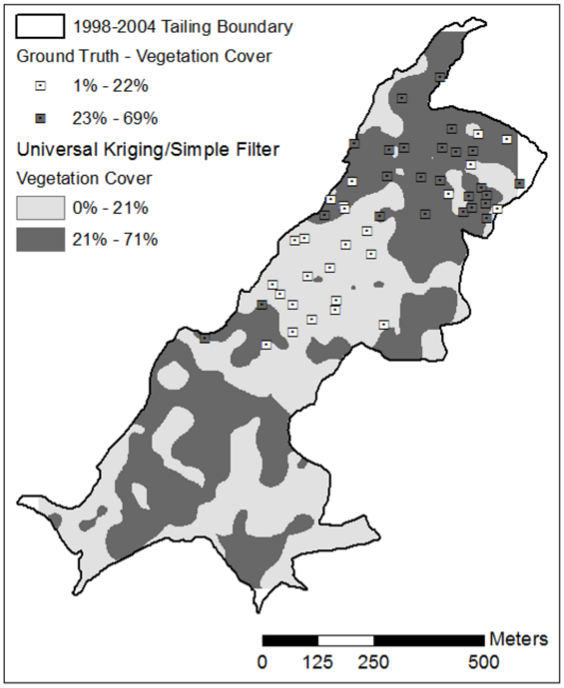

Figure 8. The image above displays the cover transect sample locations that served as ground truth data collected in 2010. Displayed herein is the universal kriging method that incorporated the use of the transect data from 2004 to 2009 and the simple filter method. Data within the figure was divided into 2 classes using the quantile method of classification.

Results

Mean vegetation cover values were generated from the transect data, the kriging process, and the universal kriging process and compared. A mean value of 21.8% vegetation cover was derived from the original 260 transect points collected from 2004 to 2009. The aerial imagery generated a mean of 24.1% after the data were normalized. The simple filter method of estimating vegetation cover derived a predicted vegetation cover mean of 23.9%. The universal kriging of the original transect points in conjunction with the aerial imagery resulted in a vegetation cover mean of 22.1%. The universal kriging of the original transect points in conjunction with the simple filter dataset resulted in a predicted vegetation cover mean of 21.7%. These results suggest that each method provided a reasonable way to estimate vegetation cover within the study area as a whole.

To assess geospatial accuracy of the estimated vegetation cover, a linear regression process was performed for all vegetation cover estimation operations. A ground truth method involved using the 2010 transect field data vegetation cover values. The transect field data served as the independent variable. The vegetation cover estimation datasets served as the dependent variables. The R-Squared values for each operation is shown in Figure 9.

R-Squared Values for Ground-Truth Data		
Method	Binary Data	Continuous Data
Aerial	0.28	0.37
Simple Filter	0.20	0.30
Universal Kriging - Aerial	0.54	0.01
Universal Kriging - Simple Filter	0.61	0.40
Mean of R-Squared Values	0.41	0.27

Figure 9. The table displays the R-Squared values for the four methods used to predict vegetation cover.

As shown in Figure 9, more variation is accounted for when using a binary method to classify vegetation overall. However, more variation in the data was accounted for by the use of the continuous method in the base layers (aerial and simple filter methods). The universal kriging method in conjunction with the simple filter method, categorized as binary data, accounts for the highest amount of variation within the 2010 ground truth vegetation cover data points.

Discussion

Each method used for vegetation cover estimation resulted in a non-significant difference between data sets. These data suggest that each evaluated method accurately depicts the vegetation cover mean for the study area. The use of aerial imagery reflectance to estimate a mean vegetation cover has useful applications. In addition to cutting down on field work, the technique can be used as a way to check the accuracy of field work.

The aerial imagery reflectance method was shown to provide a way to determine a mean vegetation cover with fewer steps than the other methods. Although vegetation cover means were generated for the universal kriging methods and the simple filter method, it may be unnecessary to generate means from these methods solely for the purpose of checking the accuracy of field work. The universal kriging method and the simple filter method are inherently geospatial in nature and may indicate that they are more appropriate for determining how vegetation cover is related to locations within the study area as opposed to simply generating a mean.

Universal kriging with the simple filter method was the most accurate method evaluated in relation to the ground truth data points. The use of a simple filter to the aerial imagery was a useful tool, reducing large variation in reflectance values. By reducing the large variation in reflectance values, the variability that occurs due to misrepresentative shrub shadows is reduced.

With the highest R-Squared value of 0.61, it evident that geospatial estimates of vegetation cover have low accuracy. Converting the data into binary values resulted in a simplification of the data and showed higher accuracy for universal kriging. Since there is a high level of geospatial inaccuracy, none of these methods are recommended for geospatial vegetation cover prediction.

The fact that the correlation coefficients for the reflectance predictions based on the 2009 image versus 2010 field measurements were very low may be a cause of annual variability in vegetation cover. The methods used in the study assume that cover data from years prior to 2009 had strong similarity to the reflectance values derived from the 2009 image. There is a cause for considerable caution in use methods conducted within the project as a replacement for actual field observation.

Literature Cited

EMS. 2010. Environmental Modeling Systems, Inc. http://www.ems-i.com/gmshelp/Interpolation/Interpolation_Schemes/Kriging/Universal_Kriging.htm. Accessed on January 12, 2011.

ESRI. 2007. ArcGIS 9.3 Software Suite (2007). Redlands, CA: Environmental Systems Research Institute.

Karl, J.W. 2010. Spatial Predictions of Cover Attributes of Rangeland Ecosystems Using Regression Kriging and Remote Sensing. Rangeland Ecology and Management. 63(3) (May, 2010) http://dx.doi.org/10.2111/REM-D-09-00074.1

Link, S.O., Keeler, C.W., Hill, R.W., and Hagen, E. 2005. Bromus tectorum cover mapping and fire risk. Washington State University.

NAIP. 2009. USDA-FSA-APFO Digital Ortho Mosaic. National Agriculture Imagery Program. Toas County, NM. (Salt Lake City, Utah, 2009)

SAGA. 2007. System for Automated Geographical Analysis (SAGA) Software, Department for Physical Geography, University of Gottingen, Germany, http://www.saga-gis.org , [accessed December 12, 2010].