ESTIMATING CANOPY COVER USING AERIAL PHOTOGRAPHY FOR A MIXED CONIFER ZONE, NORTHERN, NEW MEXICO[1]

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Abstract: In 2010 an evaluation was conducted to determine if aerial photography could be used to accurately estimate canopy cover. Canopy cover data were estimated from 12 randomly selected sites. The sites were located in the Goat Hill subsidence area, at the Chevron Mining Inc. molybdenum mine in northern New Mexico. With aerial photography (NAIP, 2009), the 12 selected sites were separated into three canopy groups (A, B, C) based on the homogeneity of the associated canopy cover density. Each group had at least three study sites with three 20m parallel transects located 5m up slope from center, on center, and 5m down slope from center. A densiometer was used to read canopy cover every two meters along each transect (10 readings per transect, 30 per study site). A total of 360 canopy cover readings were created for the 12 sites. Data for each group were collected in 2007 and 2010. A mean canopy cover was calculated for each canopy group by combining the study site data for the two years. Polygons were digitized for each group using the aerial photo as the land area base. The data within the polygons were combined into two separate classes using the Natural Breaks (Jenks) method of classification. Both values were tallied and the sums were compared. The percentage canopy cover data were derived by dividing the sum of each value by the total value for each class. This resulted in an estimated canopy cover percentage for each class. The field data canopy cover percentage and the aerial photography estimated percentage were compared. The percentages derived from group A, B and C were 50%, 13%, 60% respectively. Estimated aerial photography canopy cover percentages for class A, B, and C were 51%, 13% and 56% respectively. A regression analysis was conducted between both data sets, yielding a correlation (R^2) of .99. The correlation suggests that aerial photography can be used to estimate canopy cover within the subsidence area and potentially elsewhere on the mine. This technique has potential application for areas that may be difficult to access on foot, but are accessible with aerial photography.

Additional Key Words: aerial photography, mixed conifer, canopy cover, mine subsidenence

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Introduction

Mining operations at the Chevron Mining Inc. Questa Molybdenum Mine began in 1919. The mine is located three miles east of the Village of Questa, New Mexico in Taos County, and west of the Red River. Topography in the area consists of steep mountainous slopes and narrow canyons in a mixed conifer ecosystem. The mixed conifer ecosystem is composed of white fur (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*) and White pine (*Pinus strobes*).

In 1983, underground mining began in the area of Goat Hill using block cave methods. These methods ultimately resulted in surface subsidence and the formation of the Goathill glory hole (Gilbride et al., 2005). Some areas of the Goat Hill continue to be difficult to safely access as a result of the continued settlement of the zone following mining. The surface subsidence resulted in a disturbed vegetative community. The resulting surface topography in Goat Hill is steep, with 30-40 degree slopes and a vegetative cover of mixed conifers, shrubs and grasses. Also in the Goat Hill drainage is a naturally occurring hydrothermal scar with erodible soils and little vegetation.

In 2007, Buchanan Consultants conducted a canopy cover survey at 32 randomly selected sites within the Goat Hill subsidence area to evaluate the natural revegetation in the area. Canopy cover is defined as a fixed area covered by the crown of an individual plant species, delimited by the vertical projection of its outermost perimeter (Nix, 1997). In 2010, Buchanan Consultants had planned to visit the Goat Hill subsidence area to read the canopy cover at the 32 sites. However, because of current conditions within the subsidence area, only 12 sites were visited. The remaining 20 sites were in areas of the subsidence that were unsafe to enter.

In 2010, aerial photography obtained from National Agricultural Imagery Program (NAIP, 2009) was used to estimate canopy cover for the 12 sites surveyed in 2007 and 2010. The purpose of using an aerial photo and GIS software was to determine how estimated canopy cover relates to field data and if a correlation was present. If successful and a high correlation exist then it may be possible to apply the method of using aerial photography to the 20 remaining sites as well as areas of the mine that are not accessible.

Methods and Materials

Twelve sites were randomly located in the study area. At each site, three parallel 20m transects were established. These transects were located at 5m upslope, 5m down slope, and at the site center. A densiometer was used to read canopy cover every two meters along each transect. A total of 10 readings per transect (30 per site) were recorded for a total of 360 canopy cover, understory vegetation cover, shrub density and tree density readings from the 12 selected sites. The 2007 field data and the 2010 field data were compared and found to be similar. A mean canopy cover was calculated from the two datasets for each of the 12 sites to establish a more accurate representation of the canopy cover.

Using 1m spatial resolution aerial photography (NAIP, 2009) the 12 sites were separated into three groups based on site location and the homogeneity of the associated canopy cover density (Fig. 1). After the groups were established, the photo was converted from a multispectral image to a single spectral band black and white image. The aerial photo was clipped to the extent of the group boundary. The groups were labeled A, B, and C. Group A consisted of five sites, group B four sites and group C three sites. Subsequently the values within each group were separated into two classes, canopy and understory. The Natural Breaks (Jenks) method was used to identify class breaks to group similar values and maximize the differences between the classes (ESRI, 2007). The black values represent the canopy cover while the white values represent the understory (Fig. 2).

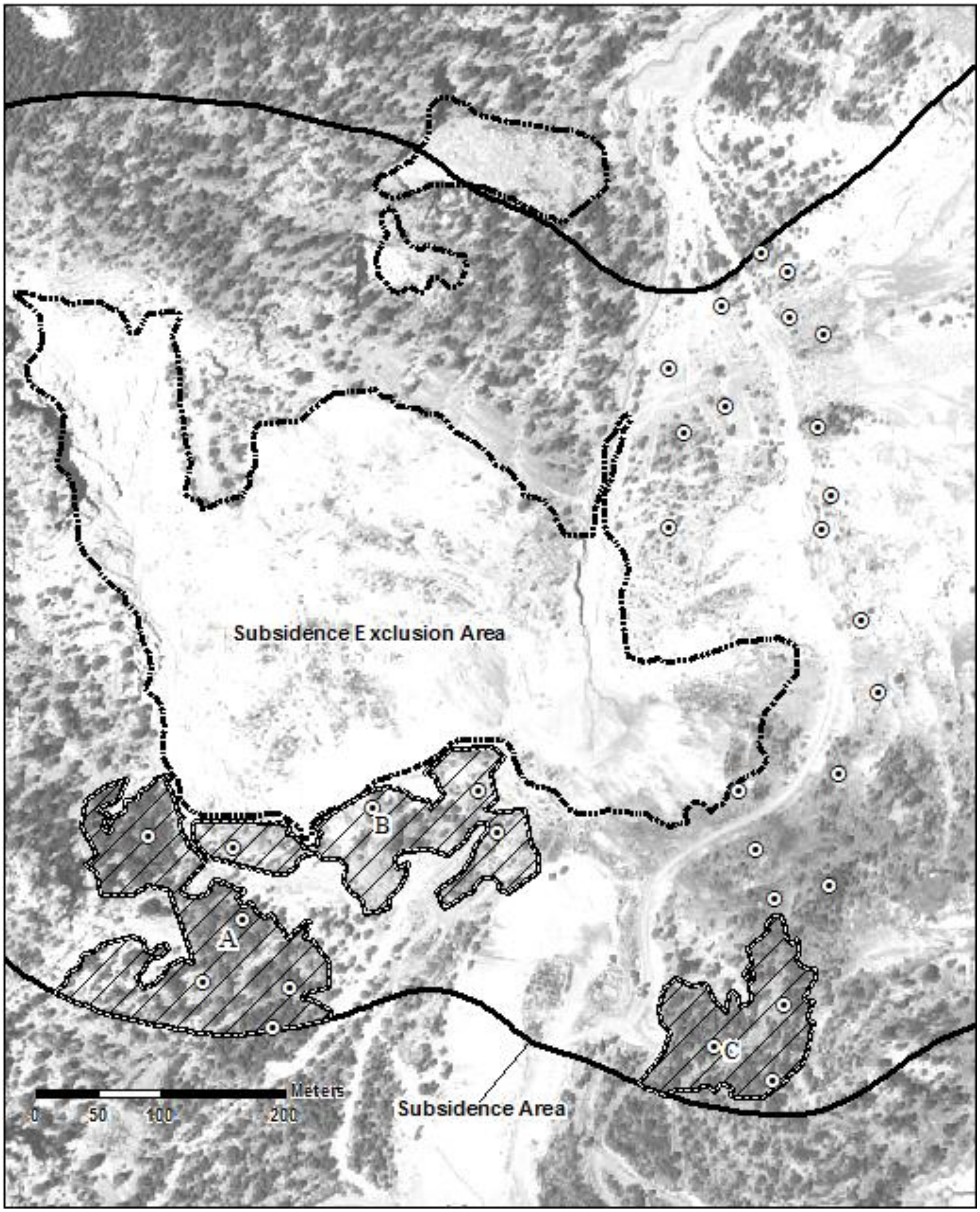

Figure 1. The locations of Groups A, B and C within the subsidence area.

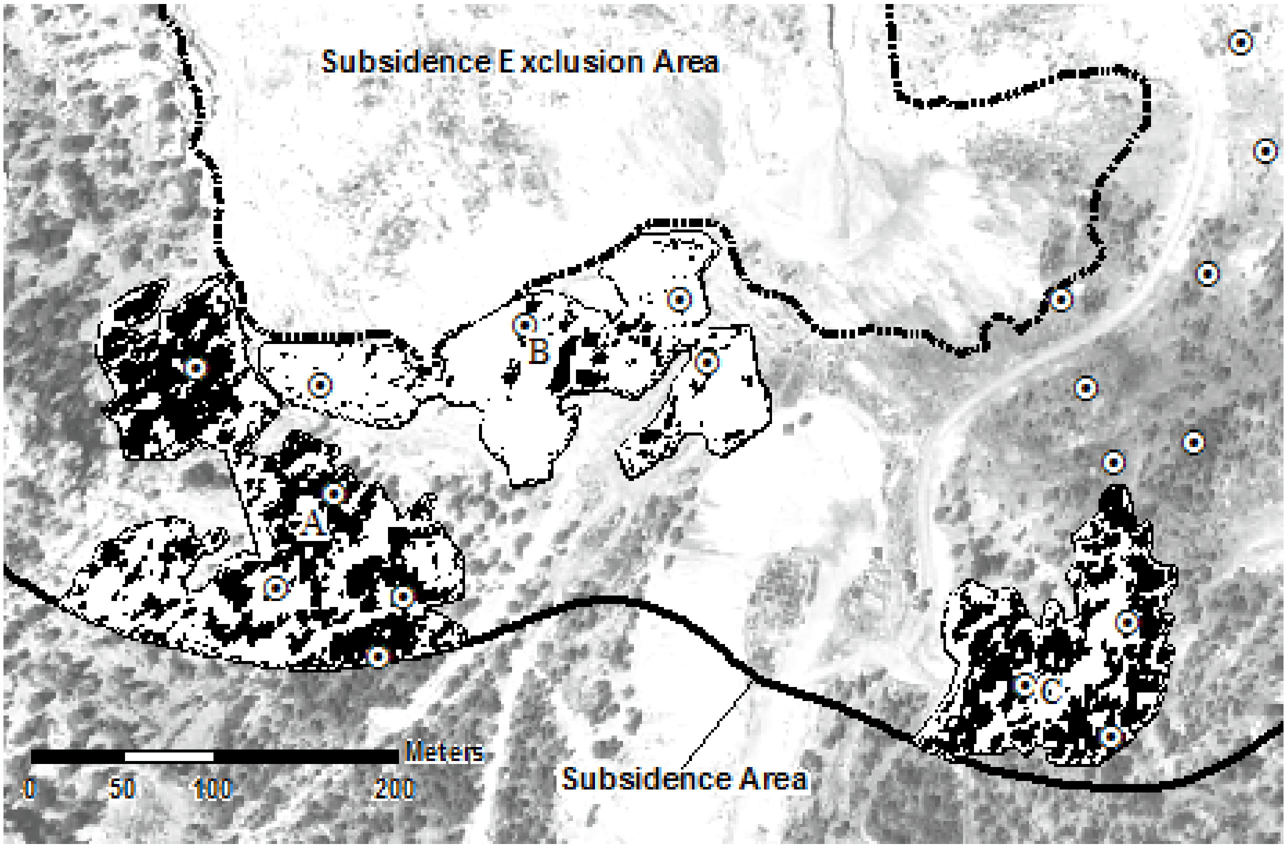

Figure 2. Groups A, B and C with the black (canopy cover) and white (understory) values after the Natural Breaks (Jenks) method of classification was applied.

The values within the groups ranged from 6 to 249 with value 110 being the class break. Any pixel with a value of 6 through 110 represented canopy cover and appeared in the group as black. A pixel with a value above 110 and up to 249 represented understory and appeared in the group as white. The total number of canopy cover pixels within each group was then divided by the total number of pixels. A canopy cover percentage was derived for each group (Table 1).

Table 1. Estimated Canopy Cover Results with the canopy pixel count divided by total number of pixels.

Group	Canopy Pixel Count	Total Number of Pixels	Estimated Canopy Cover Percentage
A	11113	21651	0.51
B	1892	15103	0.13
C	6309	11348	0.56

A histogram was generated from each group that displays the range of values and the class break associated with that group. The class break for each histogram depicts the black pixels (canopy cover) to the left of the class break (value 110) and the white pixels (understory) to the right of the class break. Figures 3, 4 and 5 display the histograms for Groups A, B and C respectively.

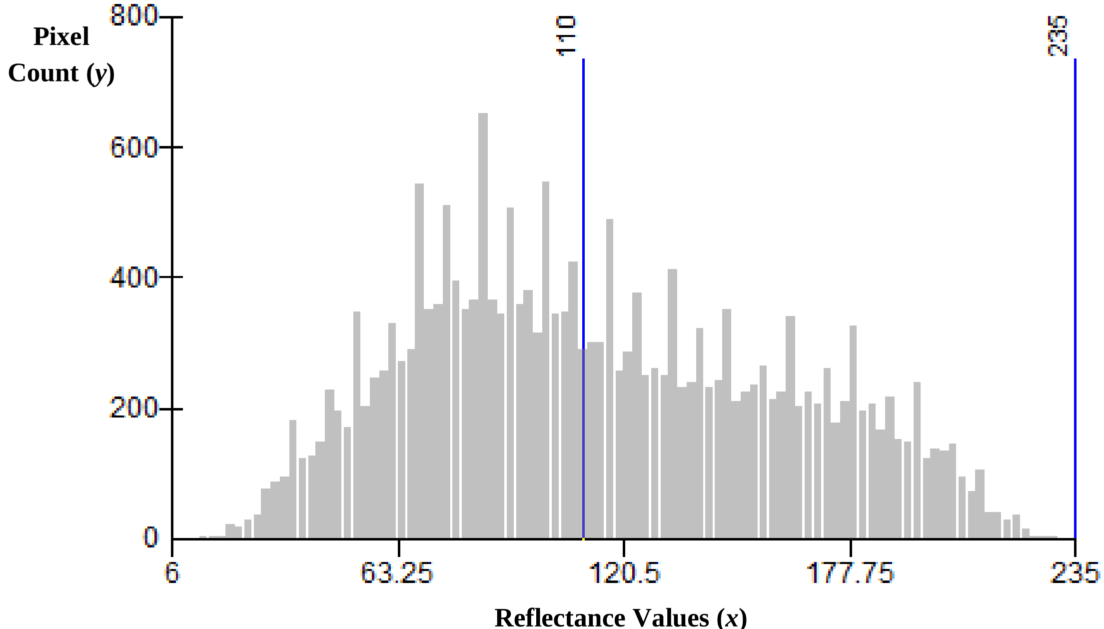

Figure 3. Group A values ranged from 6 to 235 with the values to the left of the class break representing the canopy cover.

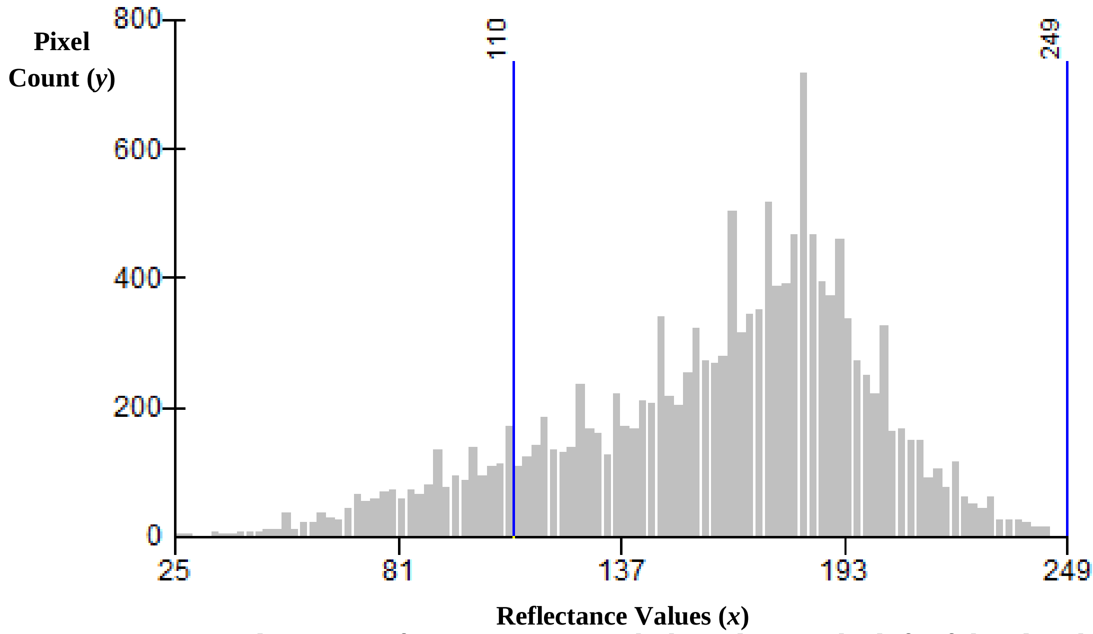

Figure 4. Group B values range from 25 to 249 with the values to the left of the class break representing the canopy cover.

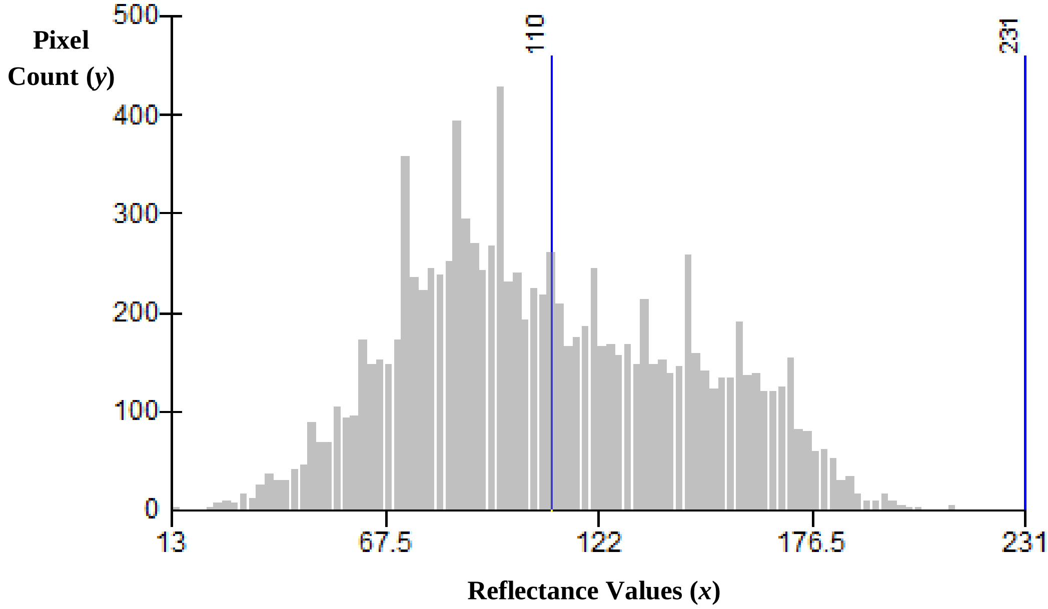

Figure 5. Group C values range from 13 to 231 with the values to the left of the class break representing the canopy cover.

Results

The field data for classes A, B and C resulted in a mean canopy cover percentage of 50%, 13% and 60% respectively (Table 2). The mean presented in Table 2 for each site shows the canopy cover for each site is essentially the same for the two years. Estimated aerial photography canopy cover percentages for class A, B and C were 51%, 13% and 56%. A regression analysis was conducted between both data sets yielding a correlation of (R^2) of .99 (Table 3).

Group A was the largest group in both the number of sites and area. Field data produced a canopy cover of 50% for the group with aerial photography resulting in 51% canopy cover. Group B was the second largest group with four sites but was also the least densely populated with the mixed conifers. Both the field data collected and the aerial photography resulted in a canopy cover of 13%. This group was the only group of the three that did not yield a difference between the two methods. Group C was the smallest group with three sites but had the highest number in canopy cover percentage. Field data canopy cover was 60% compared to the 56% obtained from the aerial photo. Group C had a difference of 4% between the two methods and this was the highest of the three groups.

Table 2. Canopy Cover Field Data Recorded In 2007 & 2010

Class A					
Site ID	Year	Transect 1	Transect 2	Transect 3	Mean
RN8E4	2010	0.5	0.6	0.8	0.63
	2007	0.5	0.4	0.8	0.57
RN5E7	2010	0.7	0.4	0.6	0.57
	2007	0.7	0.3	0.8	0.60
RN4E6	2010	0.3	0.3	0.2	0.27
	2007	0.2	0.2	0.2	0.20
RN4E8	2010	0.7	0.4	0.4	0.50
	2007	0.6	0.4	0.5	0.50
RN3E8	2010	0.7	0.4	0.3	0.47
	2007	0.7	0.8	0.5	0.67
Total Mean		**0.56**	**0.42**	**0.51**	**0.50**

Class B					
Site ID	Year	Transect 1	Transect 2	Transect 3	Mean
PN7E6	2010	0	0.1	0	0.03
	2007	0.1	0.1	0	0.07
PN8E10	2010	0.1	0	0	0.03
	2007	0.3	0.1	0.2	0.20
PN9E13	2010	0	0	0	0.00
	2007	0	0.2	0	0.07
PN7E13	2010	0.3	0.4	0.4	0.37
	2007	0.3	0.2	0.4	0.30
Total Mean		**0.14**	**0.14**	**0.13**	**0.13**

Class C					
Site ID	Year	Transect 1	Transect 2	Transect 3	Mean
RN1E19	2010	0.5	0.8	0.4	0.57
	2007	0.6	0.8	0.4	0.60
RN2E18	2010	0.6	0.6	0.2	0.47
	2007	0.8	0.4	0.3	0.50
PN3E19	2010	0.9	0.4	0.8	0.70
	2007	0.9	0.5	0.9	0.77
Total Mean		**0.72**	**0.58**	**0.50**	**0.60**

Table 3. Results of regression analysis (R^2) between both data sets.

	Class A	Class B	Class C
Field	0.50	0.13	0.60
Aerial	0.51	0.13	0.56
Correlation	0.995		

Discussion

Aerial photography was used to estimate canopy cover in three study areas (A, B, C) of the Goat Hill subsidence area. The purpose of this study was to determine if aerial photography could be used in areas of the mine, particularly the subsidence areas that may be inaccessible by vehicle or foot. Field data collected from sites A, B and C were compared with the estimated canopy cover obtained from an aerial photo with the use of GIS software and the Jenks Natural Breaks method. The result of a regression analysis between the field data and aerial photo yielded a correlation of .99.

Such a high correlation suggests that an aerial photo can be used to estimate canopy cover at other areas of the Goat Hill subsidence area. Further evaluations of an aerial photo along with the 2007 data can be used to predict the remaining canopy cover for the 20 sites that were not visited in 2010. This technique has the potential application to other areas of the mine where access may be limited.

In 2010 a similar study was done in southwestern Idaho. The purpose of the study was to use aerial imagery (NAIP, 2009) to estimate the canopy cover of the Western juniper (*Juniperus occidentalis*) to help with juniper control programs (Davies et al., 2010). This study area consisted of 12 340ha area located on Juniper Mountain in Owyhee County, Idaho. The results of the study in Idaho showed an overall accuracy of .92% between ground survey methods and the use of aerial photography (Davies et al., 2010) The high accuracy between field data and aerial imagery further suggests that using aerial imagery with GIS applications could replace the need to gather field data if the purpose alone is predicting canopy cover. This method may become highly reliable to mining operations in assisting with the reclamation process.

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