

# Very Large Scale Aerial (VLSA) Imagery for Assessing Postfire Bitterbrush Recovery

Corey A. Moffet, J. Bret Taylor, and D. Terrance Booth

**Abstract**—Very large scale aerial (VLSA) imagery is an efficient tool for monitoring bare ground and cover on extensive rangelands. This study was conducted to determine whether VLSA images could be used to detect differences in antelope bitterbrush (*Purshia tridentata* Pursh DC) cover and density among similar ecological sites with varying postfire recovery periods. In 2005, VLSA images were acquired at 253 points from high bitterbrush potential ecological sites at the USDA-ARS, U.S. Sheep Experiment Station, Dubois, Idaho. For each image, fire history was classified and bitterbrush density and cover were measured. Bitterbrush cover in images with no recorded history of fire during the previous 68 yr (22 percent of all images) was 1.71 percent and density was 875 plant ha<sup>-1</sup>. Areas with postfire recovery interval between 10 and 68 yr (60 percentage of all images) had bitterbrush density (587 plant ha<sup>-1</sup>) and cover (1.23 percent) that were not different ( $\alpha = 0.05$ ) from areas with no fire history. Images with postfire recovery interval less than 7 yr (18 percent of all images) exhibited less bitterbrush cover (0.49 percent) and density (263 plant ha<sup>-1</sup>). These results are consistent with other studies of postfire bitterbrush recovery in eastern Idaho and indicate that analysis of VLSA imagery is an effective method for evaluating the impact of fire history on bitterbrush recovery.

## Introduction

Natural resource assessments have been limited to detailed measurements on small areas (usually by people working on the ground) or to inexact measurements from space or high-altitude aerial photography. Ground-based measurements are expensive and usually impractical for landscape-scale assessments. Conventional aerial and space imagery are suitable for obtaining a large-area perspective, but inadequate for accurate measures of plant and soil parameters supporting land-management decisions. However, innovative technology is opening new avenues of resource

assessment. The recently developed very large scale aerial (VLSA) imagery has high resolution, a narrow field of view, and is generally acquired as intermittent samples across the landscape, permitting detailed measurements on a landscape scale (Booth and Cox 2006; Booth and others 2006). VLSA images are acquired using a high-resolution (>10 MP) digital camera mounted on a light, piloted aircraft. Typically, VLSA images are acquired from altitudes between 100 and 300 m above ground level (AGL) and the camera lens focal length ranges between 100 and 840 mm. The pixel ground sample distance (GSD), a measure of resolution, and the image on-ground footprint depend on the combination of AGL altitude, lens focal length, and camera imaging chip characteristics (Booth and Cox 2006; Booth and others 2006).

Antelope bitterbrush (*Purshia tridentata* Pursh DC) is easily distinguished from other plant species of the sagebrush steppe in 1 mm GSD VLSA imagery. Bitterbrush is a widely distributed, long-lived (90 to 162 yr) western shrub that is important for wildlife and domestic livestock particularly on winter ranges (Ganskopp and others 1999, 2004; Kituku and others 1992; Lesperance and others 1970; Nord 1965). Annual production increases with plant age until a maximum is reached between 60 and 70 years (McConnell and Smith 1977). In native stands, bitterbrush plants may require 10 or more years to produce seed (Nord 1965).

The response of bitterbrush to fire varies among populations. Bitterbrush populations in portions of California, Oregon, Montana, and much of the Great Basin, rarely re-sprout and are nearly eradicated by fire (Ayers and others 1999; Clark and others 1982; Clements and Young 2002; Nord 1965). In eastern Idaho, parts of Oregon, and some areas in California; however, populations of bitterbrush re-sprouted frequently after fire (Blaisdell and Mueggler 1956; Busse and others 2000; Nord 1965). For those populations that have high bitterbrush re-sprouting potential, postfire response will depend on a number of other factors. Re-sprouting may occur as soon as 3 weeks after fire or may be delayed as much as 13 months (Blaisdell and Mueggler 1956). Furthermore, re-sprout mortality may be delayed after fire. In central Oregon, 39 percent of bitterbrush plants re-sprouted after fire, but by the fifth growing season only 25 percent of burned re-sprouts remained alive (Busse and others 2000). Similar mortality of re-sprouts was measured in eastern Idaho (Blaisdell and Mueggler 1956). Greater re-sprouting was observed following a 1953 fire in plots that also burned in 1939 compared to plots with no evidence of prior burning (Blaisdell and Mueggler 1956). Greatest re-sprouting success in central Oregon was found for 20-yr old and younger plants (Busse and others 2000).

In: Kitchen, Stanley G.; Pendleton, Rosemary L.; Monaco, Thomas A.; Vernon, Jason, comps. 2008. Proceedings—Shrublands under fire: disturbance and recovery in a changing world; 2006 June 6–8; Cedar City, UT. Proc. RMRS-P-52. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Sites in the northern portion of the USDA-ARS, U.S. Sheep Experiment Station (USSES), Dubois, Idaho, headquarters property have potential for a significant amount of bitterbrush in the plant composition. A long history of fire research at the USSES coupled with good geographic records of fire history provided good opportunities to study bitterbrush recovery after fire at the landscape scale. The objective of this study was to determine whether VLSA imagery could be used successfully to assess differences in bitterbrush cover and density due to past fire history at the landscape scale and whether these results were consistent with published postfire bitterbrush response at the USSES.

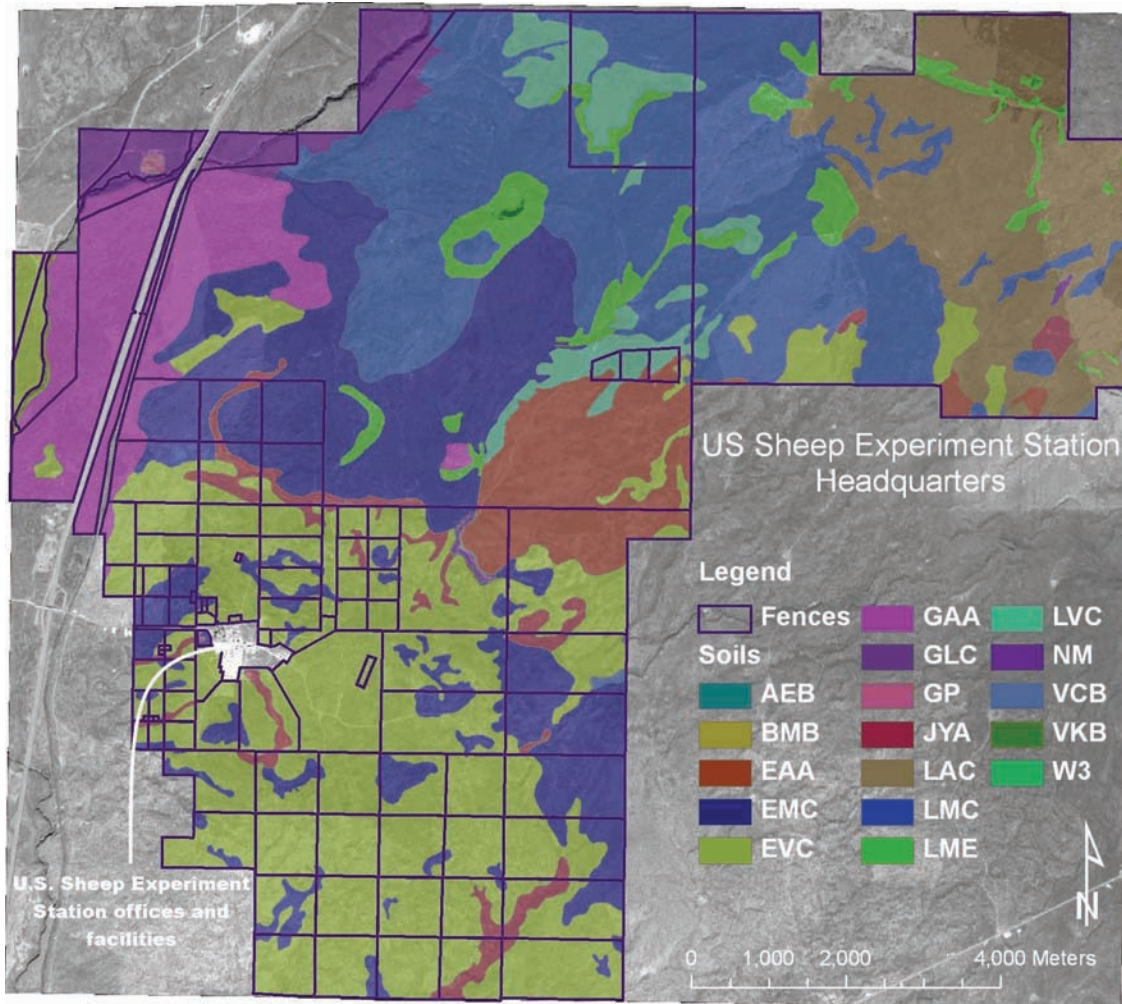
## Materials and Methods

### Site Description

This study was conducted on a 4,400 ha site at the USSES headquarters property near Dubois, Idaho (44° 17' N, 112° 7' W, 1800 elevation m). From 1971 to 2000, median annual precipitation at the nearest climate station (44° 14' 37"

N, 112° 12' 2" W, 1661 m elevation) was 326 mm (NOAA 2003). Interannual variation in precipitation is large, one tenth of years had less than 234 mm and one tenth had greater than 437 mm (NOAA 2003). Mean January temperature was -7 °C, and mean July temperature was 20 °C during this same 30-yr interval (NOAA 2003). The study site, northeast of the climate station, typically receives greater annual precipitation. Estimated median annual precipitation at the study area for 1971 to 2000 is 400 mm (PRISM Group 2006).

The study site was chosen to correspond with 4 soil mapping units (the map unit symbols LAC, LMC, LME, and LVC) at the USSES (fig. 1). These soil mapping units were selected because their component soils were associated with high bitterbrush potential ecological sites (USDA-NRCS 1995, unpublished report). For this study, high bitterbrush potential sites are those sites allowing greater than 5 percent annual bitterbrush production in the historical climax plant community. The four soil mapping units were each complexes of two or more of the following tentative soil series: Akbash (fine-loamy, mixed, superactive, frigid Calcic Pachic Argixerolls), Maremma (fine-loamy, mixed, superactive,



**Figure 1**—Soils map of the U.S. Sheep Experiment Station headquarters property near Dubois, Idaho. Map background is Quickbird imagery of October, 2002. High bitterbrush potential soils are LAC, LMC, LME, and LVC.



frigid Calcic Pachic Haploxerolls), and Pyrenees (loamy-skeletal, mixed, superactive, frigid Typic Calcixerolls). These soil map units only occur in the northern portion of the property (fig. 1).

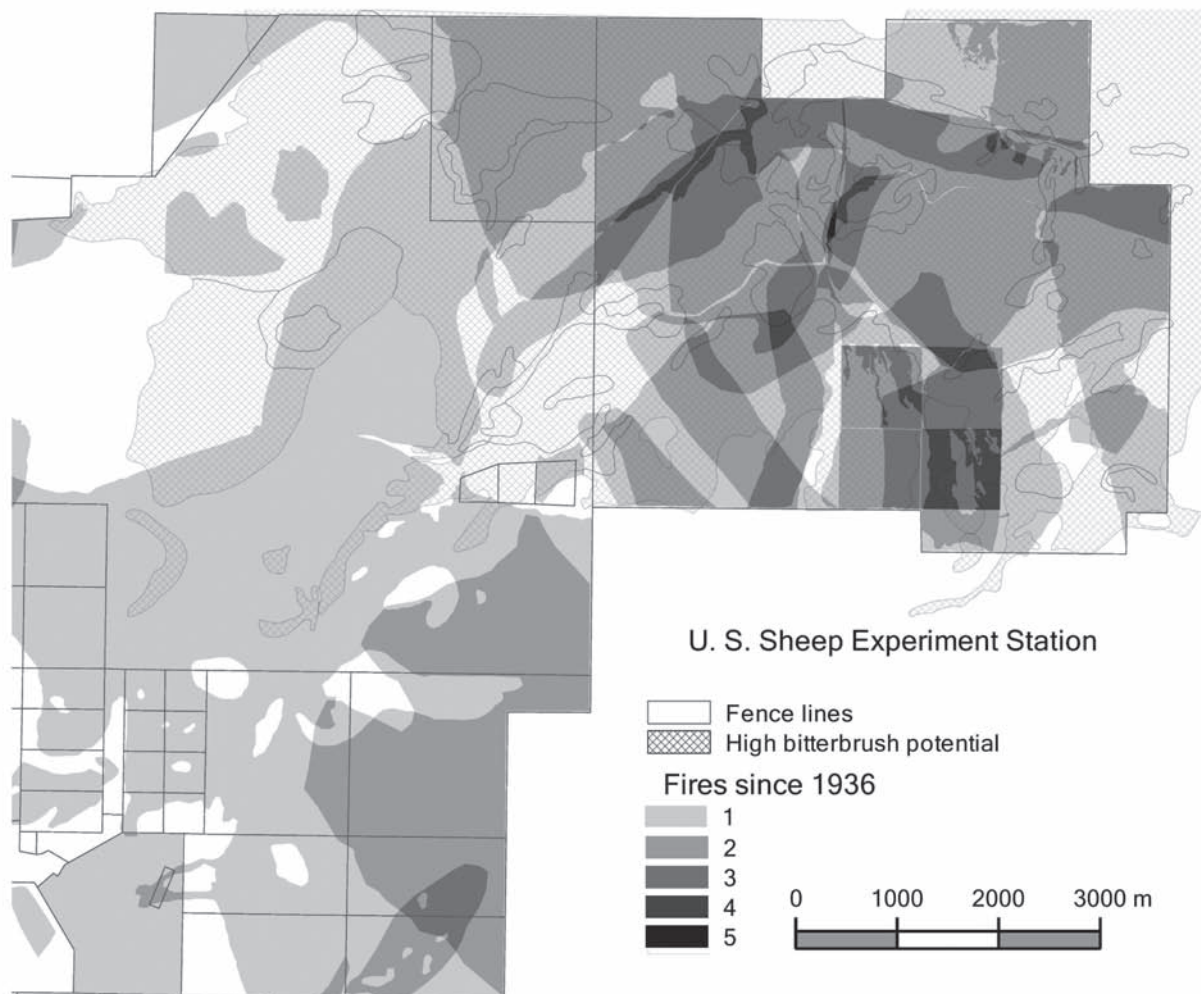
### Fire History

Researchers have been conducting rangeland fire research at the USSES since 1936 and fire history on the headquarters property is known. Fire polygons digitized in a geographic information system (GIS) prior to 1995 were derived from hand-drawn maps. From 1995 to the present, fire polygons were digitized using GPS or satellite imagery. The 1995 and newer fire polygons exclude unburned islands within fire boundaries. In 2005, when images were acquired, about 22 percent of the study site had no history of fire since 1936. The remainder of the study site had burned at least once and few small areas had burned as much as five times since 1936 (fig. 2). Recovery interval since last fire was well distributed (table 1 and fig. 3). There was, however, one large gap in recovery interval—between 32 and 57 years. Most areas burned between 1948 and 1973 have burned subsequently.

Additionally, a disproportionate number of samples were from the 24-yr recovery interval, which corresponds to a 1981 wildfire (table 1 and fig. 3). About 30 percent of the study site was last burned in a 1981 wildfire (fig. 3). In 2005, the shortest recovery interval on the study site was 2 yr.

### Imagery

VLSA images were acquired July 12, 2005 with a Canon EOS 1Ds (Canon USA, Inc., Lake Success, NY) 11MP digital SLR camera mounted in a light, piloted, fixed-wing airplane flown at 27 m s<sup>-1</sup> average ground speed 100 m AGL. The camera was equipped with a Canon 600 mm, F/2.8 EF lens plus a 1.4x teleconverter to yield the equivalent of an 840 mm, F/4.0 lens. Images acquired with this configuration were 4064 x 2704 pixels and covered approximately 14 m<sup>2</sup> on the ground (4.54 x 3.02m) with a mean resolution of 1.118 mm GSD. The images were acquired as part of a USSES rangeland survey. A total of 703 VLSA images were collected in accordance with the flight plan (400 x 400 m point grid overlay of the property) and of those, 253 were within the study site. An aerial survey system (Track' Air, Hengelo, The

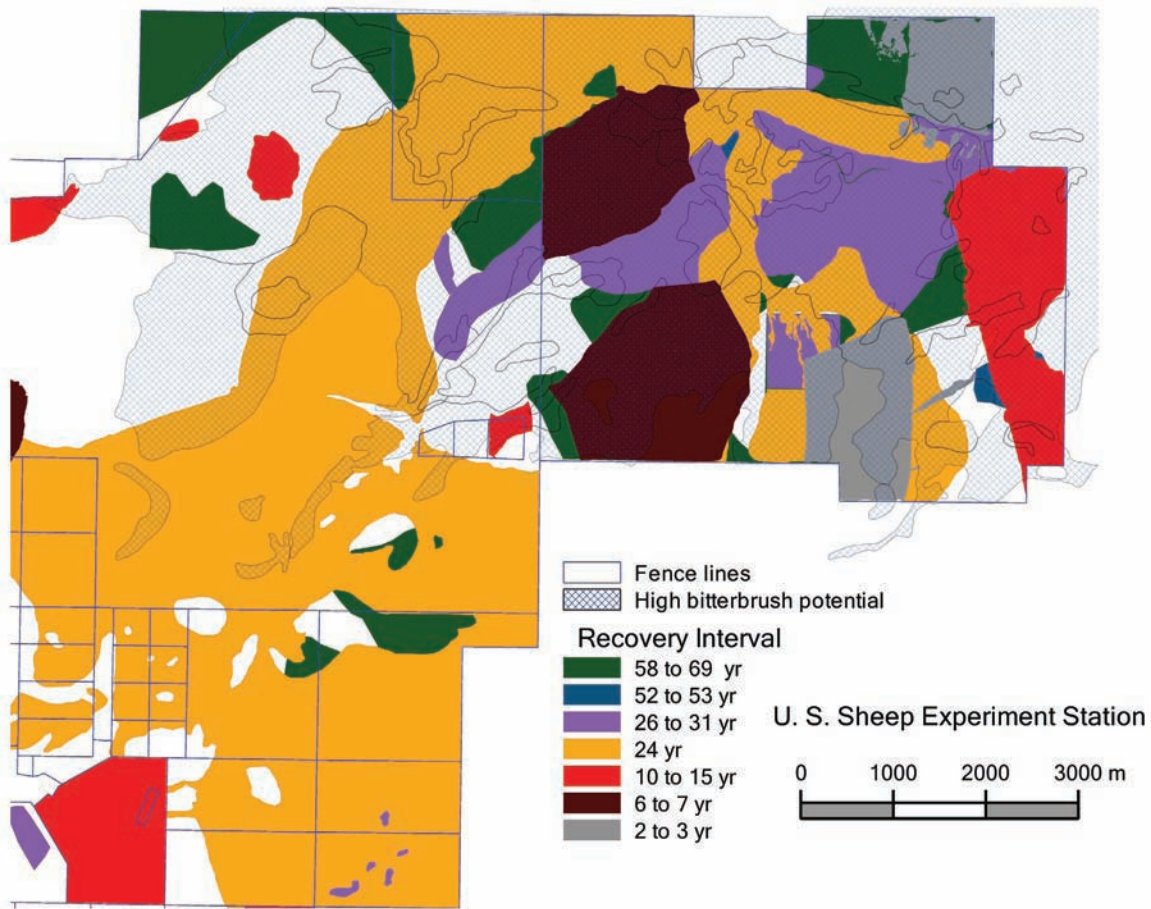


**Figure 2**—Map of the number of fires that have occurred since 1936 in the northern portion of the U.S. Sheep Experiment Station headquarters property.

**Table 1**—Image counts for each fire recovery interval and the groupings of images into recovery interval classes.

Recovery interval class	Images in class	Year of last fire	Recovery interval (yr)	Images in interval
2-3	17	2003	2	9
		2002	3	8
6-7	28	1999	6	14
		1998	7	14
10-15	18	1995	10	15
		1993	12	1
		1990	15	2
24	77	1981	24	77
26-31	32	1979	26	4
		1977	28	14
		1974	31	14
		1947	58	7
58-68	25	1942	63	1
		1939	66	4
		1938	67	5
		1937	68	8
69+	56	— <sup>a</sup>	69+	56

<sup>a</sup>Year of last fire is uncertain because fire history records prior to 1936 are not available.



**Figure 3**—Map of fire recovery interval classes as defined in table 1 for the high bitterbrush potential sites at the U.S. Sheep Experiment Station.



Netherlands) was used to automatically trigger the camera as the pilot maneuvered the airplane over each point in the flight plan grid. A laser range finder used as an altimeter recorded the airplane's altitude AGL at high frequency. A geographic positioning system (GPS) receiver recorded the coordinates of the airplane. Time stamps logged from the altimeter and GPS were matched with the trigger time logged by the camera to determine the altitude and location of the airplane at the time the image was captured (Booth and Cox 2006; Booth and others 2006).

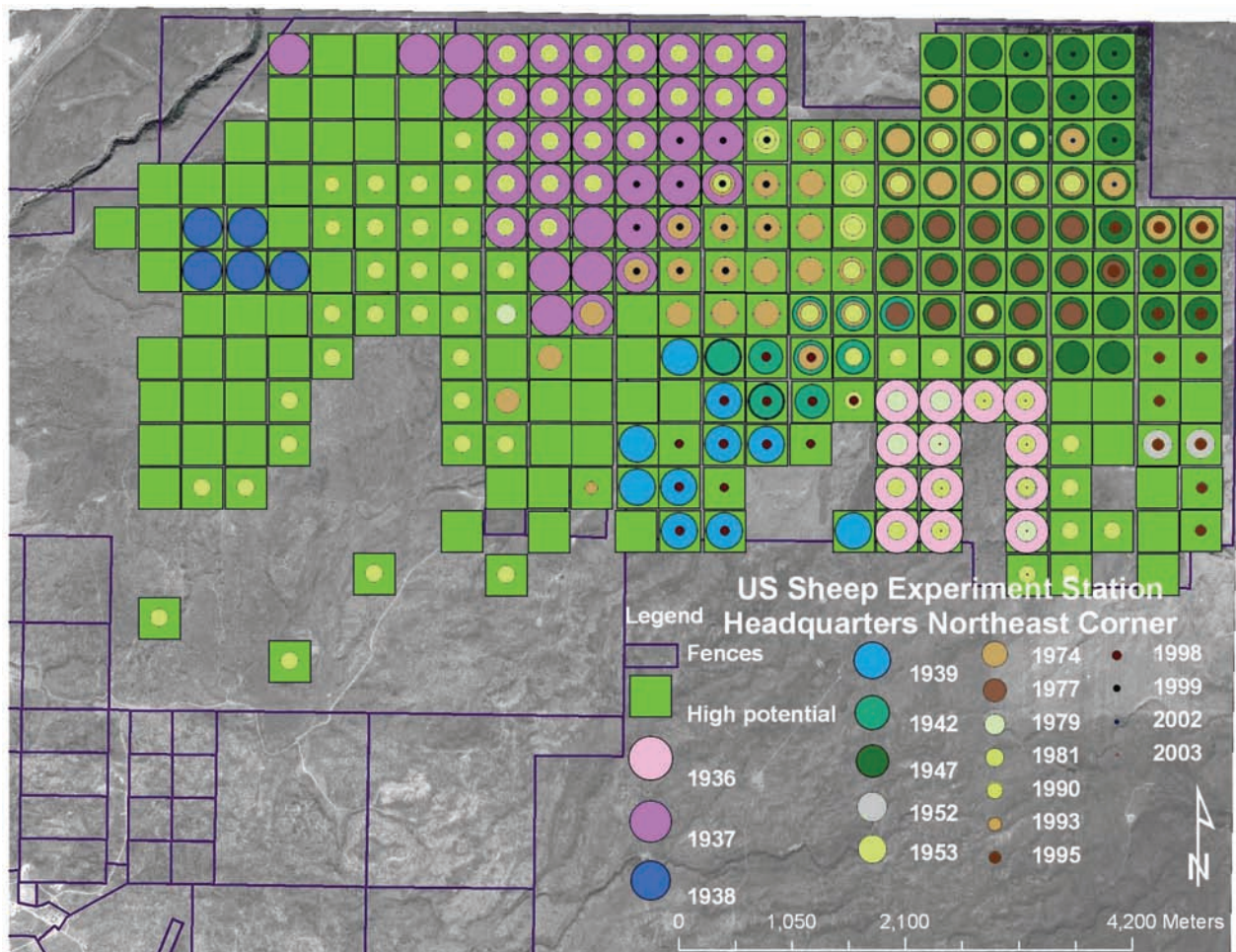
The soil map unit and fire history data were associated with each image by intersecting the image coordinates with soil and fire history layers in a GIS (fig. 4). Images with coordinates intersecting the four soil map units that define the study site were analyzed for bitterbrush cover and density.

Images were converted from a RAW file format to a TIF file format so that it could be loaded into image analysis software. In this study, we used the ImageJ software for image analysis (Rasband 2006). Images were analyzed by one technician experienced in bitterbrush identification. Aside from hints due to obvious difference in total shrub cover between images of

recent and older burns, the technician did not know the fire history of an image at the time the images were analyzed. The polygon selection tool was used to delineate the drip lines of each bitterbrush shrub in each image (fig. 5). The polygons selected with this tool are known in ImageJ as regions of interest (ROI). The ROI manager tool was used to save each bitterbrush plant ROI and measure the size (pixels in the ROI) of each bitterbrush ROI. The pixel GSD, calculated from the laser altimeter measurement for the image, was used to convert ROI and total image pixel area to on the ground area (m<sup>2</sup>). Unique ROIs were counted as single bitterbrush plants for density calculations.

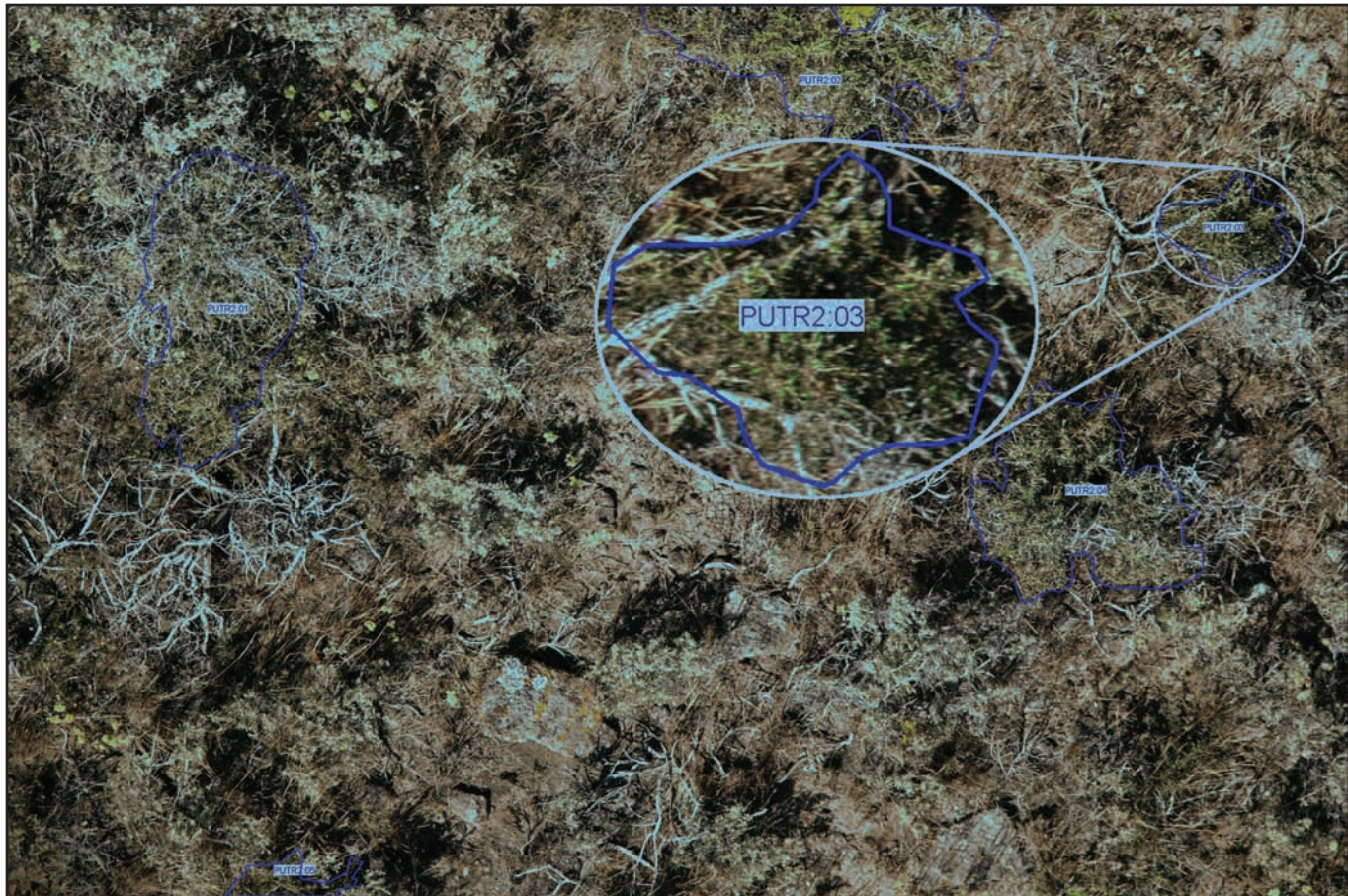
### Analysis

The images were stratified into 7 recovery interval classes according to when the image point was most recently burned. Since there are no fire records at the USSES for the period prior to 1936, any image point not intersecting a fire polygon was grouped into the 69+ yr recovery interval class. Other interval classes were designed to include between 15 and 30 images, where possible (table 1).



**Figure 4**—Map of the location and fire history classification for all VLSA images acquired on high bitterbrush potential sites at the U.S Sheep Experiment Station.





**Figure 5**—Example of a VLSA image with bitterbrush canopies delineated. Inset is a 3x zoom in to one of the bitterbrush plants. The labels are the plant symbol (USDA, NRCS 2006) and unique plant identification number for each plant delineated in the image.

One-way analysis of variance (ANOVA) was used to test whether cover and density were different among fire recovery interval classes. Homogeneity of error variance was tested using Levene's test (Levene 1960). Normality of the errors was tested with the Shapiro-Wilk test (Shapiro and Wilk 1965). When the Shapiro-Wilk test was significant, the data were log transformed and reanalyzed. All results reported are back transformed to the original units. When Levene's test was significant for an ANOVA, Welch's modified F-test was used to test recovery interval effects (Welch 1951). Further, when Levene's test was significant and Welch's F-test was significant, a modified t-test using Satterthwaite's denominator degrees of freedom was used to separate means (Satterthwaite 1946). If the homogeneous error variance assumption was satisfied and the conventional F-test was significant, then we proceeded to separate means by least significant difference (LSD). Due to unequal replication among recovery interval classes, LSDs were computed using the pooled mean square error as the estimate of variance and standard errors were computed specific to each contrast (Damon and Harvey 1987).

## Results and Discussion

Back-transformed mean bitterbrush density was not different among 10-yr and longer recovery interval classes (table 2). Density in 7-yr and shorter recovery interval class images was less than in 58-yr and longer recovery interval class images (table 2). Blaisdell and Mueggler (1956) reported a 50 percent mean bitterbrush sprouting rate after fire with a 33 percent subsequent mortality rate. Using 965 plants  $\text{ha}^{-1}$  (mean 58- to 68-yr recovery interval class density) as a base density we expect 280 plants  $\text{ha}^{-1}$  density in the 2- to 3-yr class from re-sprouting alone. This is near the measured densities in the 7-yr and shorter recovery interval classes. It is likely that seedlings established in these intervals. Bitterbrush seedling recruitment is greatest in years soon after fire. Up to 80 percent of bitterbrush seedlings established in the first 5 years after fire (Nord 1965). Some seedlings may have escaped detection in the short recovery interval class images. The minimum size bitterbrush plant measured from the VLSA images was 0.06  $\text{m}^2$  and 75 percent of plants were greater than 0.22  $\text{m}^2$ . Density may be over estimated

**Table 2**—Mean bitterbrush canopy cover and density for seven classes of postfire recovery interval at the U.S. Sheep Experiment Station, Dubois, Idaho, measured from VLSA imagery.

Recovery interval class (yr)	N	Bitterbrush canopy cover (percent)	Bitterbrush density (#/ha)	Mean canopy size (m <sup>2</sup> )
2–3	17	0.30 c	262 bc	0.142 b
6–7	28	0.61 bc	264 b	0.355 ab
10–15	18	1.33 ab	460 ab	0.549 a
24	77	0.94 ab	534 ac	0.185 b
26–31	32	1.19 ab	493 ab	0.192 b
58–68	25	2.06 a	965 a	0.337 a
69+	56	1.71 a	875 a	0.313 a

in all VLSA images (perhaps more so for the longer recovery interval classes) due to uncertainty about where a plant was rooted when the whole canopy was not contained in the image. For density calculations, all bitterbrush canopies were counted as a plant inside the image area. The branching pattern found in older bitterbrush plants often makes it difficult to determine whether adjacent canopies are part of the same plant or separate. The mean size of a canopy increased with increasing recovery interval for the first 15 years of recovery, but then decreased in the 24 to 31 yr recovery interval. Ganskopp and others (1999) reported increased bitterbrush canopy diameter with increasing recovery time throughout 6 years of recovery. Nord (1965) reported that stem layering is common in bitterbrush, but that it should not be expected on plants less than 12 yrs old. The young bitterbrush branches are erect and have little opportunity to layer, but as the plants get older and larger, the likelihood of a branch reaching the ground and rooting is increased. It may be that what we detected with the dip in canopy size of bitterbrush plants in the 24-yr to 31-yr recovery interval was due to a change in their branching habit, from more erect to more decumbent layered branches. In this analysis, each discontinuous region of bitterbrush canopy was counted as a unique plant.

Canopy cover is not subject to the edge effect errors that the measure of density has with this method. Back transformed mean bitterbrush canopy cover was low regardless of recovery interval class (table 2). Bitterbrush cover was less in 7-yr and shorter recovery interval class images than 58-yr and longer recovery interval class images (table 2). Sampling cover suffers from problems of appropriate scale due to the aggregation of cover within the canopy and within shrub clusters. The distribution of the data is effected by the selection of plot size. If plot size is too small, then plots may have no bitterbrush to measure in the plot when there is bitterbrush in the community. Regardless of recovery interval class, greater than 48 percent of images had no bitterbrush plants. This could be remedied by acquiring images with a larger footprint. Increased footprint reduces GSD resolution. During image analysis the technician typically viewed the images at 33 percent magnification (9 pixels rendered as 1) with good differentiation between bitterbrush and other species. By acquiring images with a larger footprint and lower GSD resolution, we can reduce variability and mitigate some of the error distribution problems.

## Conclusions

The very large scale aerial technology has been demonstrated as an effective tool to monitor important rangeland indices such as bare ground and total cover. In this work, we demonstrate the utility of this technology for measuring the response of antelope bitterbrush to fire recovery interval at the landscape scale. The measurement of increases in cover over the first 7 yr after fire was consistent with eastern Idaho postfire bitterbrush recovery literature. Difficulty in determining whether adjacent canopies belong to the same plant makes it difficult to accurately measure plant density from VLSA images. Analysis of species with a more compact canopy may not have this issue. The small size of the image footprint used in this study resulted in large experimental errors and significantly non-normal data that required transformation. These data characteristics are likely to be improved with larger footprint images. Larger footprint images, given the same acquisition equipment, will result in greater GSD and, if the images become very large, could make identification of the species of interest difficult. Images with up to three times the GSD should achieve improvement in the data characteristics without jeopardizing the ability to differentiate bitterbrush from other plant species.

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