

COMPARING BEDLOAD CONDITIONS IN THE CASCABEL WATERSHEDS, CORONADO NATIONAL FOREST

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Oak savannas and woodlands are a significant ecosystem type of the Southwestern Borderlands spanning approximately 800,000km² (31,000 mi²). However, there is little hydrologic data available to aid in the informed management of these lands (Gottfried and others 2001). Therefore, an ecosystem-scale experimental watershed study was established to study the hydrology and ecology of southwestern oak savannas, as well as evaluate the effects of cool and warm season prescribed fires on multiple ecosystem components.

Fire was the most significant natural disturbance in southwestern oak savannas prior to European settlement. However, due to past over-grazing and fire suppression practices, fire has been far less frequent on the landscape (Neary and Gottfried 2004). These management activities have caused ecosystem changes and increased fuel accumulations which could contribute to stand replacing fires (Kruse and others 1996). Prescribed fire is a proposed management technique to restore natural processes within oak savannas by reducing woody species density, increasing herbaceous plant production, and creating vegetative mosaics on the landscape. Questions concerning the seasonality of burn treatments and the overall effects of these treatments on hydrologic and ecologic processes need to be addressed prior to broad management application. Twelve small watersheds on the eastern slope of the Peloncillo Mountains of southwestern New Mexico, termed the Cascabel Watersheds, were selected to address these questions.

A collaborative research effort between the US Forest Service's Rocky Mountain Research Station and Coronado National Forest, the Malpai Borderlands Group, the Animas Foundation, the International Arid Lands Consortium, the Natural

Resources Conservation Service, and their associates has amassed considerable hydrological and ecological information on the oak savannas of the Peloncillo Mountains since 2002. This paper compares changing bedload conditions between 2003 and 2006 on four of the Cascabel watersheds scheduled for treatment. This information is necessary to the understanding of hydrologic and geomorphologic characteristics of these watersheds prior to treatment. These observations are also important for they may influence the treatment assignment blocking design used for this study pending further analysis.

SOUTHWESTERN OAK SAVANNAS

This ecotype is dominant in the Coronado National Forest of southern Arizona and New Mexico covering approximately 342,800 ha (847,000 ac). These oak savanna/woodland ecosystems span elevations from 1,220 to 2,225 m (4,000-7,300 ft), with annual extremes in precipitation ranging from 305 to 1,016 mm (12 to 40 in) (Gottfried and others 2002).

Hydrologic information pertaining to the oak savannas is limited (Lopes and Ffolliott 1992). The bulk of hydrologic research in the region has been conducted in the Chihuahuan Desert near Tombstone, AZ (Osterkamp 1999). There is a lack of information concerning surface runoff characteristics in oak savannas (Gottfried and others 2002). Surface runoff is affected by spring and winter rainfall and snowmelt events; however, the majority of runoff is from high intensity summer rainfall (Gottfried and others 2002). These high intensity precipitation events can accelerate erosion and sedimentation (Hester and others 1997). Good watershed condition consisting of healthy well-stocked stands of trees and herbaceous vegetation is necessary to avoid accelerated sedimentation and erosion that could impact water quality (Lopes and Ffolliott 1992). However, due to increasing fuel accumulations in the oak savannas, there is increased potential for stand replacing

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wildfire which can have substantial impacts on watershed processes-increasing erosion, sedimentation and creating hydrophobic soils (Allen 1995).

THE CASCABEL WATERSHEDS

Twelve small watersheds were selected for study on the east side of the Peloncillo Mountains (Figure 1) in southwestern New Mexico to ascertain the impacts of cool season and warm season prescribed burning on oak savanna ecosystems. The watersheds are located north of Whitmire Canyon in the Coronado National Forest, approximately 50 km (31 mi) south of Animas, New Mexico. The watersheds range in size from 8-34 ha (20-83 ac) at elevations between 1,664 to 1,692 m (5,460 -5,550 ft). Annual precipitation at the Cascabel Ranch east

of the experimental area averaged 597 mm (23.5 inches) between 1981 and 1999 (Gottfried et al. 2007).

The parent material in the study area is rhyolite-a fine-grained volcanic rock. The common soils documented in the 1991 General Ecosystem Survey of this area of the Peloncillo Mountains (completed by the Southwestern Region of the Forest Service) are generally Typic Haplustalfs, mesic, deep, gravelly loam compacted or deep very cobbly sandy-loam gullied (Neary and Gottfried 2004). The soils in the area have been classified as rock land with bedrock at 0-30 cm-however, exposed bedrock is common.

The Cascabel watersheds were selected based on their potential usefulness for addressing questions related to multiple ecosystem components of the oak

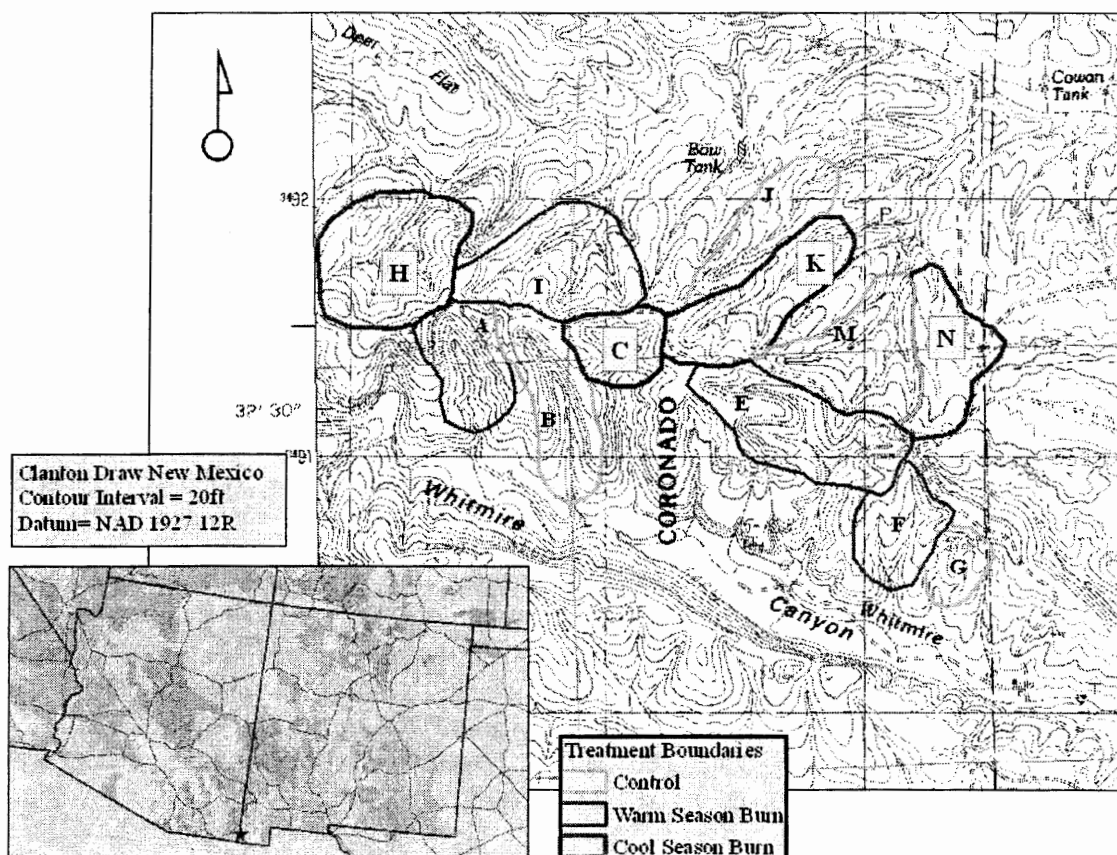


Figure 1. Watershed location and current experimental design: H, A, K, and G are controls, C, E, J, and M will be treated with a cool season burn and B, I, F, M will be treated with a warm season burn. The changing bedload conditions of watersheds H, A, N, F could result in reassignment of the treatments.

savannas such as flora and fauna, hydrological processes and soil properties. Usefulness is judged by multiple logistical and morphological factors. Watershed criteria includes the ecotype of interest (oak-savanna), accessibility, distinct channel formations (measurability), adequate gauging sites for flume installation, and being relatively similar in size, slope and elevation. The Cascabel Watersheds are representative of many oak-savannas and open woodland sites of the Southwest borderlands based on elevation, annual and seasonal precipitation, and percent of oak cover (Gottfried and others 2002). Six watersheds were selected on the north and south sides of a ridge between Whitmire and Walnut Canyons and divided into groups of three. Each group of watersheds have two burn treatments and an untreated control. Watersheds A through G are on the south-side of the ridge and watersheds H through N are on the north-side (Figure 1).

EVALUATING BEDLOADS

Changing bedload conditions for watersheds A, H, N and F are evaluated in this paper. These watersheds are on the eastern (N and F) and western (A and H) extremes of the study area. They have been selected to contrast differences in bedload conditions and total precipitation based on aspect and east/west orientation. Table 1 outlines the topographic characteristics such as elevation, area, watershed and channel slope, and aspect of selected watersheds (A, F, H and N). Bedload dynamics, which are characterized by great temporal and spatial variability, are extremely important to aid understanding of channel evolution (Renault and Regüés 2006). To gain a perspective on the changing bedload conditions, the mechanisms

affecting bedloads over time and space (e.g., the flow conditions and the supply of bed-load material) must be addressed.

Ward and Trimble (2004) define bedload as sediment transported along a channel bed by a combination of sliding, rolling, and saltation that contributes to building point bars and banks in the main channel. Bedload conditions and their contributing factors are assessed here by a combination of survey methods that assess physical and morphological characteristics. Substrate cover was determined for the reach of each watershed, while channel morphological characteristics of slope and cross-section formation were collected at the permanent cross-sections. Channel cover and morphology data provide insight into the amount of erosion and sediment movement occurring over time (Ward and Trimble 2004).

A channel condition survey was completed in 2003 to determine initial substrate cover of each channel. The physical condition of the channels, whether or not they are comprised of fine sediment, vegetative cover, or long reaches of exposed bedrock, is thought to potentially have a strong influence on hydrologic response (e.g. peak flows, sediment movement, etc).

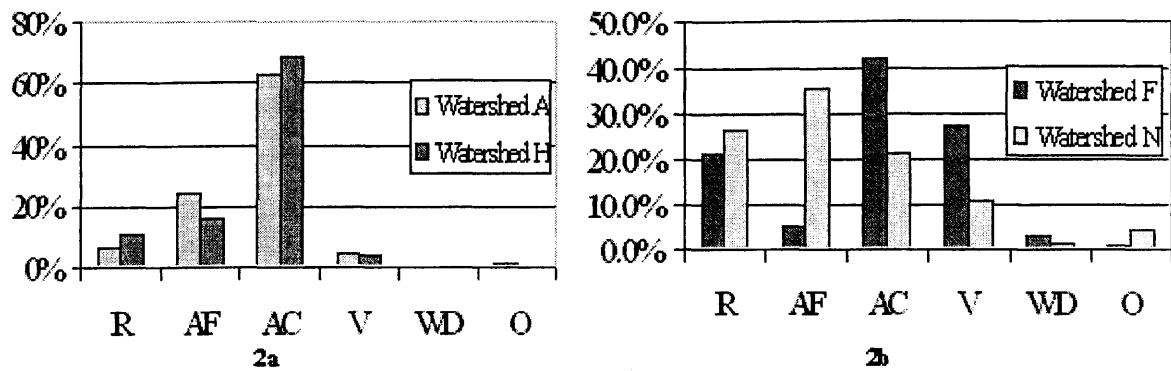
Channel condition was evaluated by completing line transect surveys in 100 m increments upstream from the sediment weir through the reach of the watershed until no distinct channel could be determined (including side channels). The substrate condition of the channel was measured and averaged by watershed (Figures 2a and 2b).

The second survey method used in the comparison of bedload conditions determines cross-sectional formation. This was measured by surveying

Table 1. Topographic characteristics of selected Cascabel watersheds, Peloncillo Mountains.

<i>WS</i>	<i>Area</i> (<i>ha</i>)	<i>Mean</i> <i>Elevation (m)</i>	<i>Mean</i> <i>Slope (%)</i>	<i>Channel</i> <i>Length (m)</i>	<i>Channel</i> <i>Slope (%)</i>	<i>Aspect</i> <i>degrees</i>	<i>T_c</i> [*] (<i>hours</i>)
A	13.8	1692	22.8	380	5.6	160	0.13
F	12.5	1665	16.2	429	6.4	190	0.228
H	22.3	1695	18.7	550	5	180	0.126
N	10.9	1672	9	421	3.6	360	0.283

* T_c (time of concentration) is the time it takes for runoff to travel from the most distant point of the watershed to the outlet. (Source: Gottfried GJ, Neary DG, Bemis RJ. 2002.)



Figures 2a and 2b. Channel characteristics for western (A and H) and eastern (F and N) oriented watersheds. Substrate abbreviations used R-rock, AF- fine alluvium sediment, AC- coarse alluvium sediment, V- vegetation, WD- woody debris, and O- other.

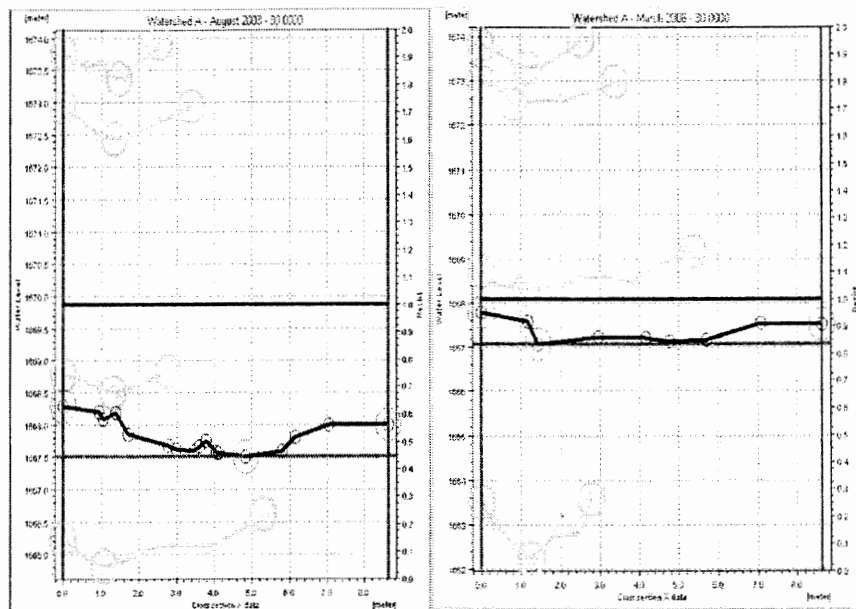
elevational changes in channel gradient across transects using a stadia rod and surveying level. The cross-section data were then entered into a stream channel modeling program called Mike 11 (Figures 3-6). Five cross-sections for each watershed of interest (A, H, F, and N) were modeled in two separate years between 2002 and 2006 to compare changes in bedload conditions. Elevation in meters is on the y-axis and channel width in meters is on the x-axis. The cross-section highlighted in black is the same in the side by side images and will be used to determine changing bedload conditions. The other information presented in these figures (i.e. red and blue lines) are not pertinent to this comparison and will not be discussed.

There is a visibly significant change in bedload conditions on watershed A between 2003 and 2006 (Figures 3a and 3b). The elevation of all cross-sections has risen-implying an increase in deposited sediment. Watershed H (Figures 4a and 4b) shows a similar trend as watershed A, though there is a less pronounced increase in elevation by individual cross-sections. Both of these watersheds are situated on the western portion of the study area and they have similar bedload trends. The changes are different in the eastern oriented watershed N (Figures 5a and 5b). Significant sediment accumulation only occurs upstream, which may be due to erosion or a rock slide event. Further investigation on the ground and modeling of cross-sections are needed to ascertain the causal factor. Watershed F (Figures 6a and 6b) presents

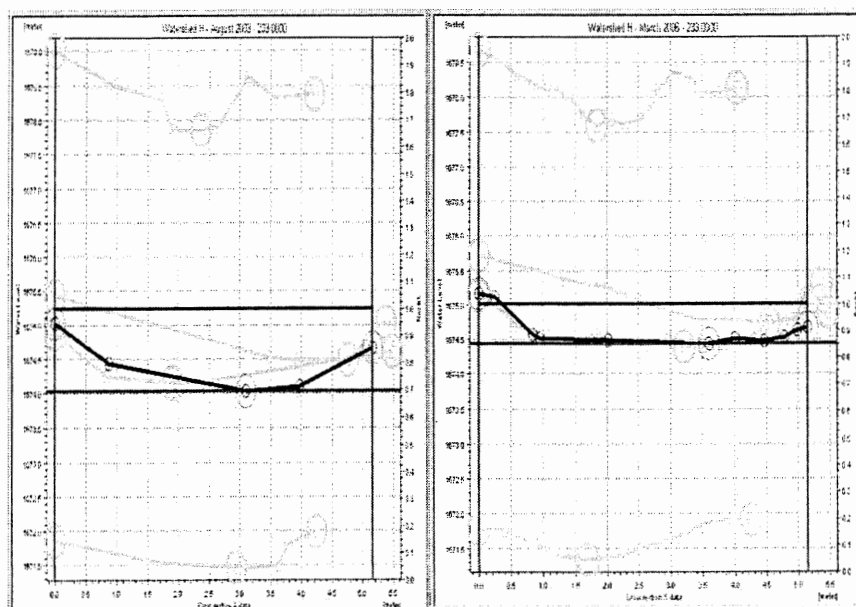
another irregularity. Instead of sediment deposition, some channel incision or degradation were observed between 2003 and 2006. The causality of this will need to be determined after further analysis.

One trend that holds true for the four watersheds examined is that the watersheds on the western portion of the study exhibit more sediment transport and accumulation. The topography and size of the individual watersheds, their physical condition (i.e., channel condition), and their orientation on the landscape (east or west and northern or southern aspect) are the major variables impacting morphological changes over time as seen in the cross-section analysis. Research on coarse sediment transport by Reid and others (2007) states that certain areas of the watershed could act as key sediment sources. The inconsistent bedload conditions between the eastern and western watersheds presented here could be impacted by a greater number of sediment sources or substrate homogeneity on the western side of the study area. However, these are simply conjectures based on preliminary observations of the calibration data.

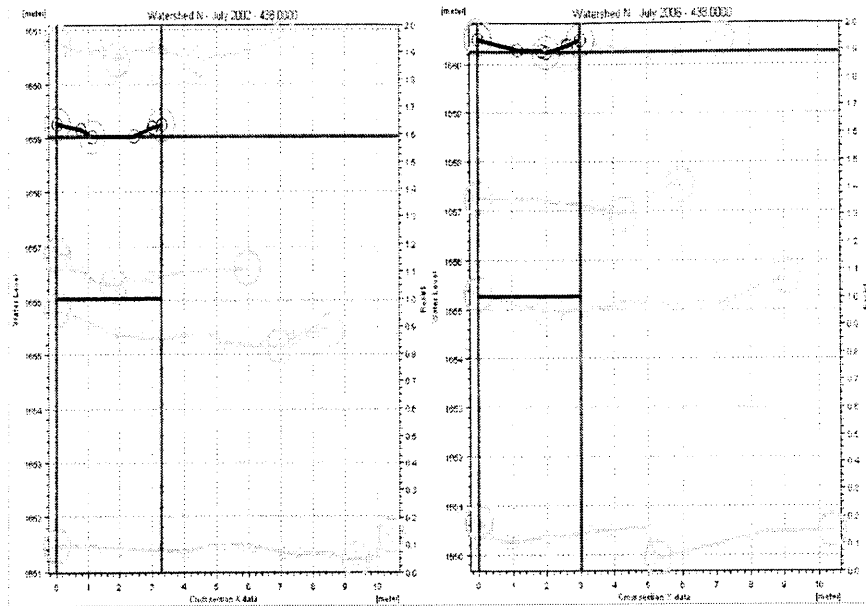
For this comparison of bedload conditions, channel condition and cross-sectional survey information were combined with the data from a high-intensity precipitation event on August 23, 2005. The objective of this bedload comparison was to determine whether or not storm/ precipitation trends correspond with the observed changes in bedload condition. Tables 2 and 3 quantify the peak flows following that precipitation event and the



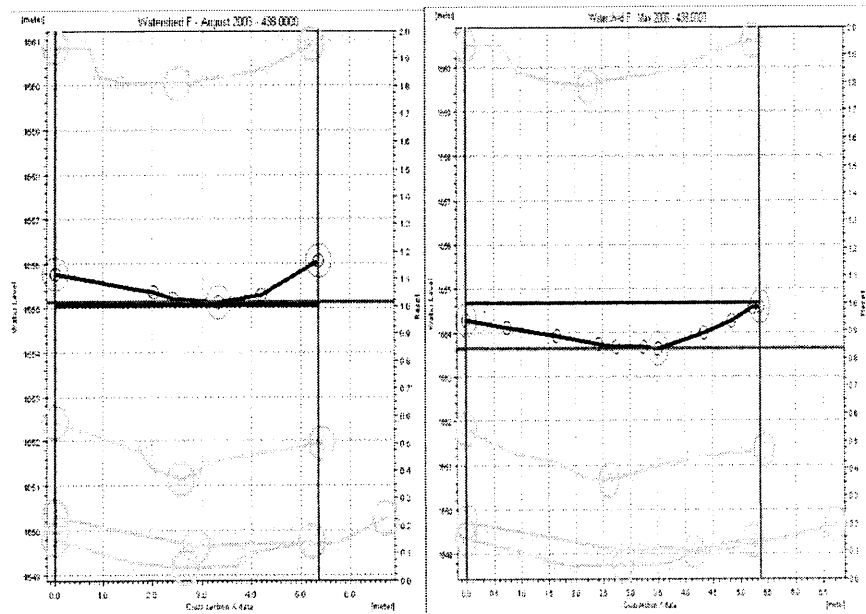
Figures 3a. and 3b. Watershed A cross-sectional model for August 2003 and March 2006, respectively.



Figures 4a and 4b. Watershed H cross-sectional model for August 2003 and March 2006, respectively.



Figures 5a and 5b. Watershed N cross-sectional model for July 2002 and July 2006.



Figures 6a and 6b. Watershed F cross-sectional model for August 2003 and May 2006.

amount and duration of precipitation on a per watershed basis. Only the watersheds of interest are presented. In the initial experimental design, watersheds were blocked into those facing north and those facing south and then replicated block treatments were assigned as shown in Figure 1. The rationale guiding this decision was that aspect (northern vs. southern exposure) will have the

information presented here is a relative comparison of cross-section changes over time and does not actually quantify the amount of sediment movement that has occurred.

CONCLUSIONS

This preliminary assessment of bedload conditions in the Cascabel watersheds highlights some

Table 2. Peak storm flows, August 23, 2005

Southern Aspect	Peak Flow (cfs)	Peak Flow (cms)	Northern Aspect	Peak Flow (cfs)	Peak Flow (cms)
A	67.2	1.903	H	76.8	2.175
F	24.6	0.697	N	31.3	0.886

Table 3. Precipitation for August 23, 2005

Weather Station	Total Precipitation (inches)	Total Precipitation (cm)	Start Time	End Time
H	2.36	5.99	12:00	16:00
A-B	2.64	6.71	12:01	15:44
F-G	1.36	3.45	12:09	15:49
N	1.43	3.63	12:21	15:52

greatest impact on total precipitation and peak flows. However, the data in Tables 2 and 3 (which reflect average storm data on the Cascabel watersheds) show east and west orientation as a more significant factor than aspect. Peak discharge and effective runoff have considerable impacts on bedload and therefore need to be viewed in tandem (Renault and Regüés 2006). Table 3 documents typical storm movement that begins in the west and moves eastward resulting in a greater amount of precipitation and corresponding peak flows in western oriented watersheds (A and H). Although aspect appears to be a factor there is less variation between watersheds on north and south slopes (A and H, N and F) as is between watersheds on east and west sides of the study area (A and F, H and N).

The changes observed in cross-section analysis match the variation in precipitation data remarkably well, although they require further analysis. The

important factors for consideration regarding this research project and watershed research as a field. Further analysis and modeling should be completed prior to the planned treatments. The data presented here support a reassignment of replicated blocks based on an east/west boundary instead of a north/south one. However, this requires complete cross-sectional modeling, some time-series analysis and an analysis of covariance to determine the most important sources of variability between watersheds during the calibration period. Utilizing calibration data pre-treatment and continued monitoring post-treatment are an attempt to increase the knowledge of the hydrologic and ecologic processes of southwestern oak savannas to improve overall land stewardship for a myriad of private and public stakeholders.

Observing bedload changes during the calibration period further supports an adaptive and flexible

approach to the experimental design used in a paired-watershed study to achieve multiple objectives and decrease variability between replicates. By examining these data prior to prescribed fire treatments, we are able to improve the design of this study, and therefore provide more conclusive data for land managers. The initial analysis also provides support for gathering and utilizing substantial calibration data prior to treatment application.

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