ESTANCIA BASIN WATERSHED HEALTH AND MONITORING PROJECT: 2011 ANNUAL REPORT

Prepared for

ESTANCIA BASIN WATERSHED HEALTH, RESTORATION AND MONITORING STEERING COMMITTEE

Composed of: Claunch-Pinto Soil and Water Conservation District, Edgewood Soil and Water Conservation District, East Torrance Soil and Water Conservation District, Estancia Basin Water Planning Committee, Chilili Land Grant, Manzano Land Grant, New Mexico State Forestry, New Mexico Environment Department, New Mexico Forest and Watershed Restoration Institute, New Mexico Department of Agriculture
(with funding through the New Mexico Water Trust Board)

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EXECUTIVE SUMMARY

The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee) oversees forest thinning projects and monitoring of forest and watershed health in the Estancia Basin in coordination with the New Mexico Forest and Watershed Restoration Institute. The primary goals of the Steering Committee are to improve forest health and create defensible space from wildfire. Funding for forest and watershed monitoring has been provided by the New Mexico Water Trust Board.

In 2007, SWCA Environmental Consultants (SWCA) was awarded a contract to conduct monitoring for forest thinning effectiveness on the eastern slopes of the Manzano Mountains. SWCA finalized a comprehensive monitoring plan in March 2008—which is available online at the New Mexico Forest and Watershed Restoration Institute's website (http://www.nmfwri.org/images/stories/pdfs/Estancia_Basin_Monitoring/EstanciaBasinMonitoring.pdf)—that provides background information, research questions, and a discussion of methods relative to forest thinning and monitoring. The monitoring plan calls for two years of pre-thinning data to provide background information on all study sites prior to implementing thinning treatments and monitoring treatment effectiveness. Results from the 2008, 2009, and 2010 monitoring seasons are presented in the 2008, 2009, and 2010 annual reports, which can also be found on the New Mexico Forest and Watershed Restoration Institute's website. The principal goals of forest and watershed monitoring are to determine the effectiveness of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife. SWCA is responsible for planning and implementing forest thinning monitoring in order to evaluate these resources. SWCA has also assumed responsibility for the South Mountain Weather Station that was previously installed by another contractor in 2006. After monitoring began, three major wildfires (Ojo Peak, Trigo, and Big Spring) occurred in the monitoring area in late 2007 and early 2008. The Trigo fire destroyed one of the forest thinning monitoring sites, which was replaced during summer 2008. SWCA has additionally initiated a monitoring study of post-Trigo fire recovery on private forest lands.

This 2011 Annual Report provides information on the results of forest thinning and post-wildfire monitoring during the calendar year 2011. We also provide summaries of weather data from the South Mountain Weather Station, which serves as a baseline for monitoring area climate data. Initial 2008, 2009, and 2010 baseline pre-treatment monitoring data from permanent monitoring study sites provide information on rainfall, ambient and soil temperatures, soil moisture, soil surface profiles to assess erosion over time, soil surface stability, soil chemistry, bird and small mammal composition and relative abundance, and vegetation composition, structure, and cover. 2011 monitoring data represent information on the above parameters for the first year following thinning treatments. The monitoring sampling design employs paired monitoring plots at two piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodland sites and two ponderosa pine (*Pinus ponderosa*) sites. One plot of each pair was randomly selected and treated by thinning tree stands in late 2010/early 2011. Those thinning treatments were completed in early 2011, and SWCA will continue to monitor the above mentioned parameters through at least June 2013 to examine the impacts and effectiveness of forest thinning treatments. Not only are paired study plots being compared to each other in a treatment/control design, but also each treated plot will be monitored over time in order to assess change resulting from thinning treatments.

Results from the first year of post-treatment monitoring data revealed some differences in parameter values between treatment and control plots that were not present prior to thinning treatments.

- Tree and woody vegetation structure was greatly changed from the thinning treatments, resulting in more open forest stands.
- Tree basal areas were reduced on the treatment plots according to New Mexico State Forestry guidelines; Chilili pre-treatment basal area was 210 ft^2/acre and was reduced to 80 ft^2/acre, Wester basal area was 220 ft^2/acre pre-treatment and 99 ft^2/acre post-treatment, Kelly was 155 ft^2/acre pre-treatment and 47 ft^2/acre post-treatment, and Vigil was 124 ft^2/acre pre-treatment and 39 ft^2/acre post-treatment.
- During the 2011 monitoring period, relatively few rainfall events and surface runoff events occurred. However, when flows did occur, the treated watersheds had higher peak flows and runoff ratios when compared to the controls. Future monitoring of flow events will reveal if this increased runoff on thinned sites persists and for how long.
- Soil moisture was found to be higher on treated plots than control plots, especially during dry periods following rainfall events.
- Herbaceous vegetation canopy cover was higher on half of the treated plots compared to the control plots.
- Rodent densities declined on treated plots.
- Other parameters such as soil chemistry, soil surface erosion and surface stability, and bird communities have not yet shown differences between treatment and control plots.

Given that 2011 was an extreme drought year in the region, some parameter responses may have been dampened by a lack of rainfall.

Fourth-year results from the post-wildfire monitoring suggest the Trigo fire area is slowly regenerating. The high burn severity plots supported a dramatic increase in herbaceous ground cover while at the same time saw a reduction in bare ground. The low-severity plots also exhibited elevated herbaceous cover when compared to 2008 and 2009, but not 2010, which can be attributed to the current drought. Measurements taken on the low-severity plots were beginning to take on similar patterns of cover to the unburned reference plots. Much of the high-severity plots had experienced 100% mortality of the trees, and many of these trees had begun to fall, particularly as a result of wind throw. The low-severity plots had exhibited patchy mortality in 2008 and 2009; some of the worst-hit trees, those that were more than 50% scorched, had begun to die as a result of the physiological stress. Soil erosion on the fire plots that appeared to be elevated in 2008 had decreased by 2009, 2010, and 2011, but soil movement was highly variable across plots. Soil movement bridge measurements revealed both erosion and deposition at small scales. Regrowth of the herbaceous layer, dominance of seeded grasses, dead and fallen trees, and increased litter layers all contributed to the maintenance of the soil layer. The automatic wildlife cameras that were originally installed in late 2008 continue to capture wildlife use in the Trigo burn area. Mule deer (*Odocoileus hemionus*) was the dominant species captured in photographs. Due to falling trees and overall site safety, the 2011 monitoring period will be the last collected, as the post-wildfire monitoring project is being suspended until deemed safe to work in and around the area.

TABLE OF CONTENTS

List of Figures

List of Tables

1.0 INTRODUCTION

This 2011 Annual Report provides summaries of monitoring data collected during the 2011 calendar year for the Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee (Steering Committee). Details about research questions and the background and administration of this monitoring project may be found in the "Estancia Basin Watershed Health and Monitoring Project: Monitoring Plan Evaluation" (2008 Monitoring Plan) (SWCA Environmental Consultants [SWCA] 2008), which is available at the New Mexico Forest and Watershed Restoration Institute (Restoration Institute) website (http://www.nmfwri.org). The 2008 Monitoring Plan provides detailed information on the background knowledge of forest thinning in the Southwest and presents the goals and methodologies for the Estancia Basin forest thinning monitoring project. The 2008 Annual Report (SWCA 2009) also provides important background information for the Trigo wildfire monitoring project that was initiated in 2008. Previous years' annual reports for 2008, 2009, and 2010 summarize overall monitoring findings from those three years, and they also may be found at the Restoration Institute website.

The Steering Committee oversees forest thinning and effectiveness monitoring of forest thinning on ponderosa pine (*Pinus ponderosa*) forests and piñon/juniper (*Pinus edulis/Juniperus monosperma*) woodlands on private and state lands on the eastern slopes of the Manzano Mountains, New Mexico. Principal members of the Steering Committee include the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts; New Mexico State Forestry; and the Restoration Institute. The Restoration Institute is additionally providing oversight and public relations for forest thinning and monitoring activities.

The principal goals of the Steering Committee are to create defensible space around homes and other structures from wildfire and to improve overall forest health, following forest thinning prescriptions determined by New Mexico State Forestry. The primary goals of forest thinning monitoring are to determine the impacts of standard prescribed forest thinning on soils, hydrology, water yield and quality, vegetation, and wildlife.

The scope of work for this monitoring project was described in the Steering Committee's 2007 request for proposals as follows:

1. Plan and implement methods to determine how vegetation thinning and removal affect water yield.
2. Plan and implement methods of establishing reliable and repeatable vegetation monitoring methods to allow for both qualitative interpretation and quantitative documentation of change in vegetative structure and composition over time.
3. Plan and implement methods of monitoring small mammal and avian populations, which are indicators of ecosystem health.

SWCA is currently under contract for five years of monitoring, beginning in 2008, and is responsible for study site maintenance, data collection, data management, data analysis and interpretation, and information dissemination (including monthly meetings, monthly reports, and annual reports). The current Steering Committee plan calls for three years of baseline pre-thinning treatment monitoring (2008–2010), thinning treatments implemented during the winter of 2010 and 2011, and two years of post-treatment monitoring (2011–2012).

Several new subprojects were added to the overall monitoring project in 2008, including post-fire monitoring of soils, hydrology, vegetation, and wildlife on private forest lands following the Trigo wildfire. These tasks involve developing and implementing ephemeral stream and groundwater monitoring to assess the effects of both forest thinning and the Trigo fire on water resources, as well as assuming the operation and reporting for the South Mountain Weather Station (SMWS), initiated by EnviroLogic in 2006. A map of all study sites for these projects is presented in Figure 1.1 (note that the SMWS is located north of Edgewood, New Mexico, and is not on the map presented in Figure 1.1, but is on the map presented as Figure 5.1 in Chapter 5.

This 2011 Annual Report is similar in format to the previous 2008, 2009, and 2010 annual reports, and it provides complete data files (appended on DVD) and summaries of findings from field monitoring measurements conducted during the calendar year 2011 for the four primary subprojects: 1) forest thinning monitoring of weather, soils, hydrology, vegetation, and wildlife; 2) post-Trigo wildfire monitoring of soils, vegetation, and wildlife; 3) overall Manzano watershed ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; and 4) SMWS weather and soil moisture data, including addenda representing the four quarterly 2011 reports. Data collected in 2008, 2009, and 2010 represent baseline conditions prior to forest thinning treatments, which were begun in late 2010 and were completed by May 2011. Data collected after thinning in 2011 will then provide measures of thinning treatment effectiveness and a comparison of post-treatment environmental conditions. Monitoring data from subsequent years will provide data on thinning treatment effects over time.

This report provides analyses of parameter changes over the four years of monitoring and comparisons of paired treatment and control plots to evaluate treatment effects. Some statistical tests of parameter values between paired study plots are also provided to compare pre-thinning treatment baseline conditions to post-treatment conditions in order to determine if the paired plots differ in parameter values resulting from imposed thinning treatments. Additionally, post-Trigo fire monitoring data collected in 2008, 2009, 2010, and 2011 provide information on the recovery of soils and vegetation following the fire. In late 2011, Trigo fire monitoring was suspended due to safety issues regarding falling dead trees. Post-Trigo fire monitoring may resume at some future date.

Numerous discrete datasets have been collected, and SWCA has been active in creating data collection, storage, and management plans for each of the subprojects. SWCA has created metadata for each of these datasets that outline the date range of each dataset, the collection methods, the unit measurements, and the abbreviations and codes used within each data file. The metadata files will also state any caveats or general comments to which the viewer should be aware before analyzing the data.

SWCA is making these data available in a form that can be easily disseminated, using readily available software packages such as Microsoft Word and Excel. Some information, such as those data collected from the WatchDog Mini Weather Stations, is collected using proprietary software. These data are converted into Microsoft Excel files so they can be viewed by the general public. SWCA also intends to make the data available in forms that are easy to analyze.

Some data, such as those related to the flumes, which are recorded in five-minute intervals, must be partitioned into several files, as the data exceeds Microsoft Excel's capacity of data rows. All of these data are being made available to the Restoration Institute for dissemination on its website. Note that measurements from various aspects of monitoring are reported in English units (e.g., feet, acres), while others are reported in metric units (meters, hectares). The protocols for monitoring measurements were obtained from different sources that use different units of measure. The U.S. Department of Agriculture (USDA) Agricultural Research Service Rangeland Monitoring Manual (Herrick et al. 2005) uses metric units, while the U.S. Forest Service (USFS) Forest Inventory and Analysis Guide (USFS 2005) uses English units. In general, scientific research worldwide has adopted the metric system as the standard for measurements, while some federal and state agencies use English units of measure. For ease of comparison, values are presented in this report with both English and metric units, except where not feasible.

This 2011 Annual Report provides summaries of findings from field monitoring measurements conducted during the calendar year 2011 for the above mentioned projects and subprojects. This report is partitioned into different sections for each subproject: 1) forest thinning monitoring; 2) post-wildfire monitoring; 3) ephemeral stream and groundwater monitoring, associated with both forest thinning and post-wildfire monitoring; 4) SMWS data; and 5) planned monitoring for 2012 (year five).

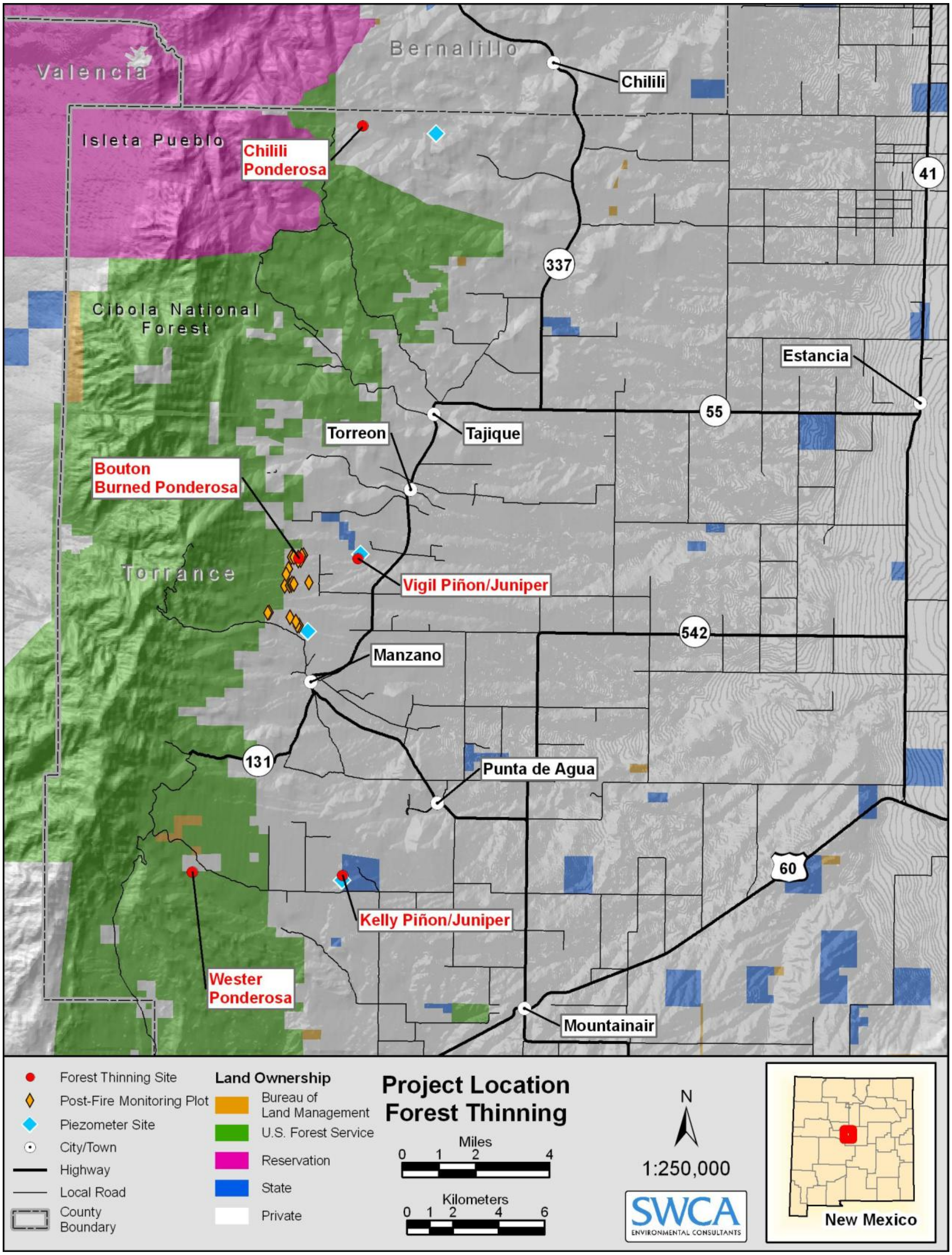


Figure 1.1. Map of all Estancia Basin forest and watershed monitoring locations addressed in this report.

2.0 FOREST THINNING MONITORING

Details of forest thinning monitoring protocols are provided in the 2008 Monitoring Plan (SWCA 2008). Background information on the known environmental effects of forest thinning on southwestern forest ecosystems is presented in the 2008 Monitoring Plan, along with detailed discussions of the experimental study design and methods used in this research to measure various environmental responses to forest thinning treatments.

Forest thinning projects on private lands on the eastern slopes of the Manzano Mountains are overseen by the Steering Committee and include projects in both ponderosa pine forests and piñon/juniper woodlands. Forest thinning monitoring has been designed to address forest thinning in both of these forest types, so four monitoring study sites have been established: two in ponderosa pine forests and two in piñon/juniper woodlands. Each ponderosa pine site has been paired with a piñon/juniper site in the same watershed, so that each of two watersheds has a ponderosa pine and a piñon/juniper monitoring site. One pair of sites is situated at the northern end of the study area (eastern slopes of the Manzano Mountains), and the other at the southern end (see Figure 1.1). Two paired study plots have been installed at each of the four study sites. Descriptions of physical site characteristics such as slope, aspect, parent materials, plant associations, and habitat types are provided in the 2008 Monitoring Plan (SWCA 2008). Surface elevations of the flumes on the thinning plots can be seen in the Table 2.1 below. All study sites chosen are representative of the surrounding area; for example, all sites, excluding the Wester property, undergo a livestock grazing regime, which is typical of the private land use in the Manzano Mountains. One plot of each pair was randomly selected for forest thinning treatments, and the other plot of the pair will serve as an untreated control. Parameters being measured for monitoring at each of the eight study plots include rainfall, ambient temperature, soil moisture and temperature, soil chemistry, soil movement, soil surface stability, soil surface hydrology runoff, vegetation canopy cover and species composition, vegetation vertical structure, tree stand structure, density, composition and health, and bird and small mammal species composition and abundance.

Table 2.1. Surface elevations of the flumes on the forest thinning plots.

Site	Elevation (m)	Elevation (ft)
Chilili (T)	2288	7507
Chilili (C)	2292	7520
Wester (T)	2267	7436
Wester (C)	2275	7466
Kelly (T)	2114	6937
Kelly (C)	2111	6925
Vigil (T)	2068	6783
Vigil (C)	2073	6802

Actual forest thinning treatments were implemented in November 2010 and were completed by May 2011. This 2011 report presents the fourth year of pre-thinning treatment baseline data and comparisons of paired study plots. From 2011 on, the various environmental parameters being measured will be compared between the treatment and control study plots, and each study plot will be compared to itself over time.

2.1 FOREST THINNING TREATMENTS

One study plot of each forest thinning monitoring paired (plots 1 and 2) was randomly selected to be treated with the standard New Mexico State Forestry prescribed thinning treatment (piñon/juniper or ponderosa pine prescriptions) in late 2010 and early 2011 with the other plot being left as a control (plots T and C respectively). The minimum area and boundaries for thinning treatments were determined for each of those four plots and mapped with a sub-meter accuracy global positioning system (GPS) unit in October and November 2009. Those GPS coordinates were used to produce geographic information system (GIS) maps of the treatment areas and boundaries for each of the four treatment study plots (maps of the thinning areas were presented in the 2009 Annual Report [SWCA 2010]). The thinning treatment areas for each of those plots included the entire subwatershed that was previously defined and mapped in 2007, the vegetation/soils measurement plot, and the mammal and bird sampling plot, all within the area of each treatment plot to be thinned. A minimum treatment buffer area of 10 m (33 feet) was extended from the boundaries of each subwatershed and study plot to ensure that all areas from which soil, hydrology, vegetation, and animal measurements are being collected were thinned on those treatment plots. Monitoring measurements in 2011 were conducted on plots after the thinning treatments were completed. Table 2.2 shows which plots were treated by tree thinning and which ones remained undisturbed as controls.

Table 2.2. Treated and Control Plots across the Four Monitoring Study Sites

Site	Treated Plot	Control Plot
Chilili	Plot 1	Plot 2
Kelly	Plot 2	Plot 1
Vigil	Plot 1	Plot 2
Wester	Plot 1	Plot 2

Note that results presented above refer to plot number, and all treated plots were plot number 1 except at the Kelly site where the treated plot was number 2.

Tree thinning treatments were conducted as planned and were inspected by New Mexico State Forestry to ensure that all protocols were followed and that the thinning was conducted to the agency's standards developed for the region for both ponderosa pine and piñon/juniper woodland. In addition to reducing the density of trees on treatment monitoring plots, the thinning process also required that small branches from cut trees be chipped on-site and spread on the ground surface. Large-diameter wood was removed from the sites for firewood. Figure 2.1 through Figure 2.4 show views of both the non-treated control plots and adjacent treatment plots that where trees were thinned from each of the four monitoring sites, photographed in late fall 2010 and early spring 2011, following tree thinning treatments. Note the open structure of the trees stands and wood chips spread over the ground surfaces of the thinned plots.

a. Non-thinned control plot (plot 1).

b. Thinned treatment plot (plot 2).

Figure 2.1. Kelly piñon/juniper site thinning treatment plot after excess trees have been removed in late 2010.

a. Non-thinned control plot (plot 2).

b. Thinned treatment plot (plot 1).

Figure 2.2. The Vigil piñon/juniper site following tree thinning treatments in late 2010. Note the open stand and wood chips. Stacked wood was removed shortly after the photograph was taken.

a. Non-thinned control plot (plot 2).

b. Thinned treatment plot (plot 1).

Figure 2.3. The Chilili ponderosa pine site following tree thinning.

a. Non-thinned control plot (plot 2).

b. Thinned treatment plot (plot 1).

Figure 2.4. The Wester ponderosa pine site in early spring 2011 following tree thinning. The stacked wood was removed in early summer.

2.2 RAINFALL AND TEMPERATURES

Spectrum WatchDog automated data-logging rain gauges installed at each of the paired vegetation and soils monitoring plots at all of the study sites (see Figure 1.1) have run continuously since they were installed in November 2007 (Figure 2.5). The WatchDog stations are located in openings in the tree canopy in order to reduce effects of interception. Additional details regarding the setup of the weather stations are provided in the 2008 Monitoring Plan (SWCA 2008). The tipping bucket rain gauges on the WatchDog stations are set to record rainfall and snowmelt sums at one-hour intervals continuously. In fall 2008, a graduated cylinder rain gauge was added to each of the automated rain gauge locations to serve as backups in case of power failure or other malfunction of the data logger (Figure 2.6). These graduated rain gauges and their recorded values are checked monthly when Time Domain Reflectometer (TDR) soil moisture and temperature readings are taken; mineral oil is also added to these gauges at this time to prevent evaporation of water collected. The WatchDog stations are set to record ambient temperature, soil moisture 10 cm (4 inches) below the soil surface (-10 cm), and soil temperature -10 cm, all at one-hour increments. Soil moisture and temperature data from each WatchDog station provide baseline comparisons for the Field Scout TDR 200 soil water content and soil temperature data that are sampled monthly at each study plot. All data from the stations are off-loaded approximately every three months and entered into a database. Summaries for precipitation, ambient temperature, soil moisture, and soil temperature from 2011 on all thinning plots are presented as examples below.

During the 2011 monitoring period a persistent drought was occurring throughout the state of New Mexico, particularly over the project area (Figure 2.7). The project area falls within the category of exceptional drought, which means there are exceptional and widespread crop/pasture losses, and shortages of water in reservoirs, streams, and wells, creating water emergencies. This drought has impacted the region as can be seen by the decreasing groundwater levels at both Chilili and Punta de Agua and also the decrease in overall herbaceous production in 2011.

Figure 2.5. WatchDog mini weather station at the Wester ponderosa pine site.

Figure 2.6. Graduated rain gauges are used for backup in the case of failure from one of the WatchDog weather stations.

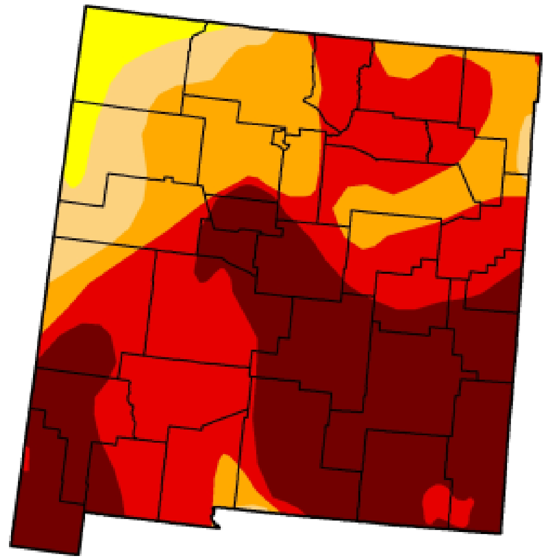
U.S. Drought Monitor

New Mexico

October 4, 2011
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	96.40	88.99	69.61	36.04
Last Week (09/27/2011 map)	0.00	100.00	96.40	88.99	69.61	35.13
3 Months Ago (07/05/2011 map)	0.00	100.00	100.00	93.96	79.34	49.09
Start of Calendar Year (12/28/2010 map)	6.16	93.84	40.40	0.00	0.00	0.00
Start of Water Year (09/27/2011 map)	0.00	100.00	96.40	88.99	69.61	35.13
One Year Ago (09/28/2010 map)	76.66	23.34	0.00	0.00	0.00	0.00



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu

Released Thursday, October 6, 2011

Figure 2.7. Drought monitor map of New Mexico from the week of October 4, 2011, showing the project area located within Torrance County experiencing an exceptional drought (U.S. Drought Monitor 2011).

2.2.1 PRECIPITATION

Hourly precipitation totals have been summed to monthly totals and show similar monthly precipitation totals between the paired study plots at the Kelly piñon/juniper study sites (Figure 2.8), the Vigil piñon/juniper study sites (Figure 2.9), the Wester ponderosa pine study sites (Figure 2.10), and the Chilili ponderosa pine study sites (Figure 2.11).

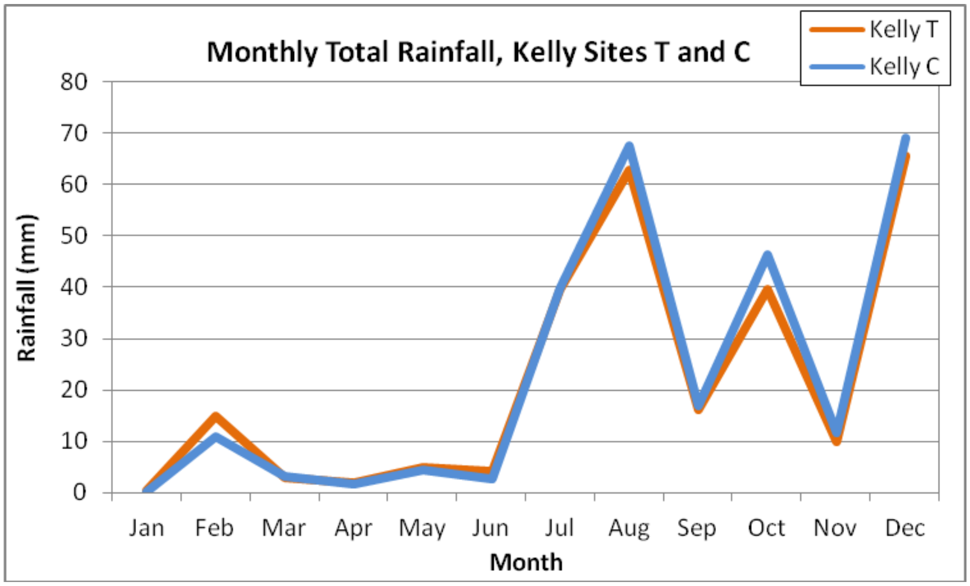


Figure 2.8. **Monthly cumulative precipitation (rainfall and snow) from the two paired Kelly piñon/juniper study plots.**

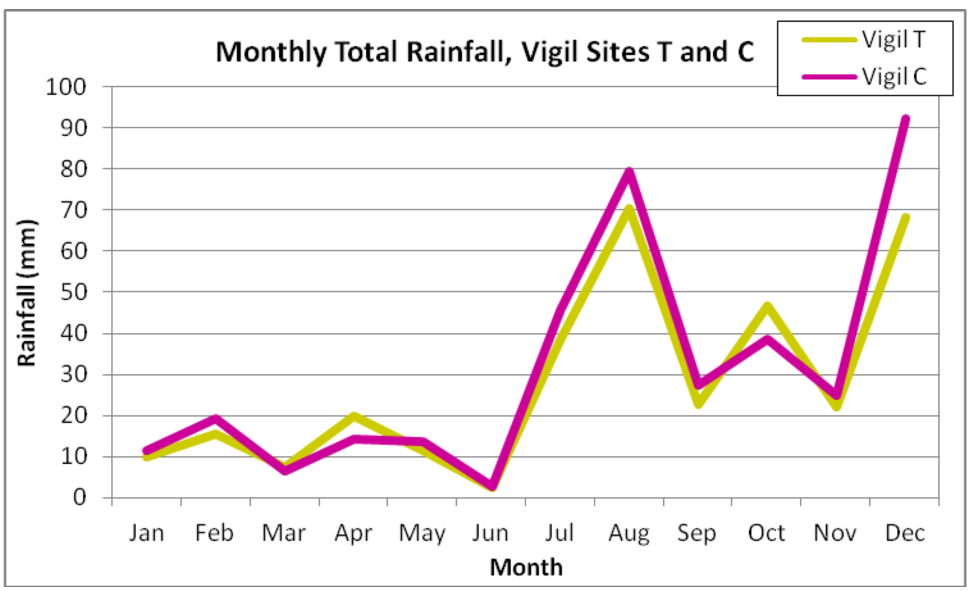


Figure 2.9. **Monthly cumulative precipitation (rainfall and snow) from the two paired Vigil piñon/juniper study plots.**

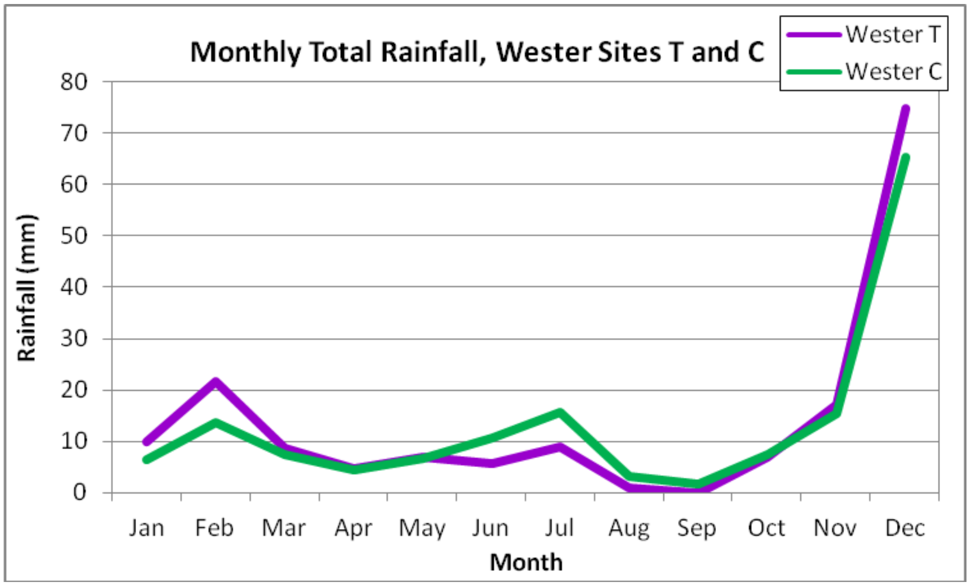


Figure 2.10. Monthly cumulative precipitation (rainfall and snow) from the two paired Wester ponderosa pine study plots.

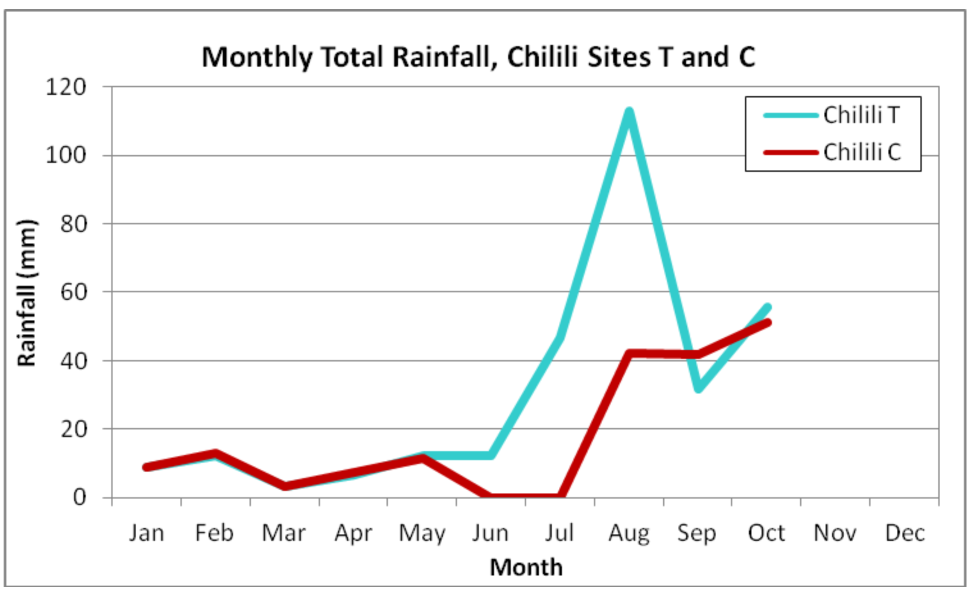


Figure 2.11. Monthly cumulative precipitation (rainfall and snow) from the two paired Chilili ponderosa pine study plots.

As seen in Figure 2.11, precipitation was not recorded consistently, the Chilili ponderosa site from the WatchDog weather station on the control plot from late June through mid August because of damage to the weather station caused by a black bear (*Ursus americanus*) (Figure 2.12). However, the WatchDog weather station on the treated plot was not damaged and recorded all the precipitation events. The graduated cylinders that serve as backups to the WatchDog stations also recorded the precipitation events during this period, but only on a monthly basis (not daily).

Figure 2.12. Damage to the tipping bucket rain gauge caused by a black bear on Chilili Control Plot.

2.2.2 AMBIENT TEMPERATURE

An example of monthly averages of hourly ambient temperatures is presented for the Kelly piñon/juniper study sites (Figure 2.13). These graphs show similar monthly average ambient temperatures between the paired study plots, as was typical at all of the study sites.

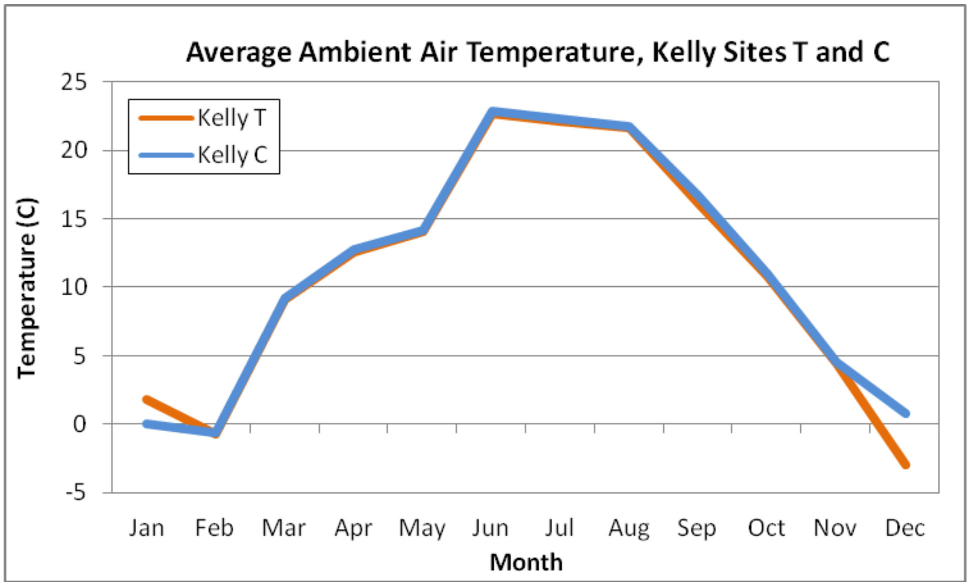


Figure 2.13. Monthly average ambient temperatures from the two paired Kelly piñon/juniper study plots.

An example of monthly averages of hourly -10 cm soil moisture readings are presented for the paired study plots at the Kelly piñon/juniper site (Figure 2.14). Soil moisture was measured with Watermark soil moisture probes that measure soil water tension in kilopascal (kPa) values that are directly equivalent to California Bearing Ratio (cbr) values for soil water saturation. Results for paired plots were generally similar.

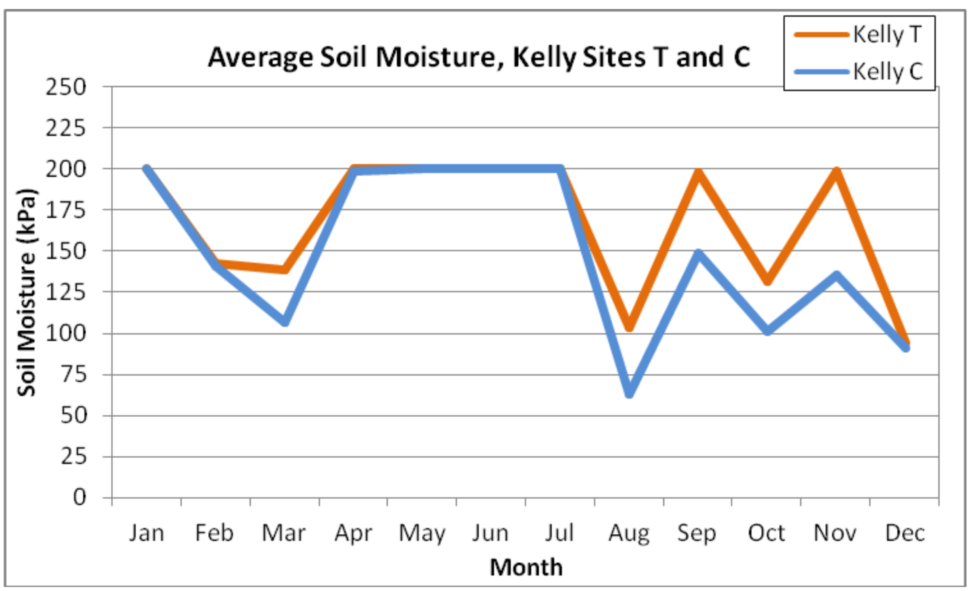


Figure 2.14. Monthly average soil moisture tensions (-10 cm) from the two paired Kelly piñon/juniper study plots.

2.2.3 Soil Temperature

An example of monthly averages of hourly -10 cm soil temperature readings are presented for the paired study plots at the Kelly piñon/juniper sites (Figure 2.15). The graphs show similar monthly average soil temperatures between the paired study plots (T and C) at both study sites, which was generally the pattern across all sites.

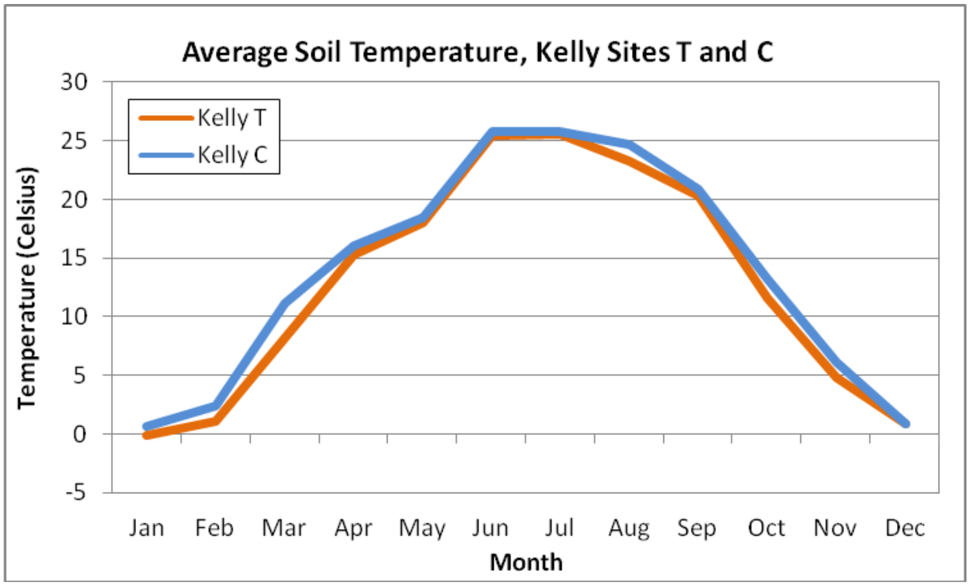


Figure 2.15. Monthly average soil temperature (-10 cm) from the two paired Kelly piñon/juniper study plots.

2.3 Soils

2.3.1 Entire Study Plot Soil Water Content and Temperature (TDR)

Continuous hourly soil moisture and temperature measurements recorded by the WatchDog station at each plot only provide a single reference point measurement for each plot, measured and recorded hourly. In order to sample soil moisture and temperature from locations throughout each vegetation and soil monitoring plots, a portable Field Scout TDR 200 soil moisture meter was used. Further information on the detailed methods can be found in the 2008 Annual Report (SWCA 2009).

Average percent soil volumetric water content on paired plots from 2008 through 2011 is displayed below in Figure 2.16. These results show that the two plots on all thinning sites are acting in similar fashion prior to the thinning treatments completed in 2011. Average soil moisture between the paired plots on a monthly basis is presented below for 2011 from all forest thinning plots (Figure 2.17–Figure 2.20). These figures indicate that the treated sites retain on average more soil moisture throughout the year, especially after storm events and during times of drought. These figures also show the difference in soil moisture between the treatment and control is more pronounced on the piñon/juniper plots than the ponderosa pine plots. This finding can likely be contributed to the decrease in canopy cover and the increase in ground cover in the form of wood chips. Whether these findings continue to persist into the future remains to be seen.

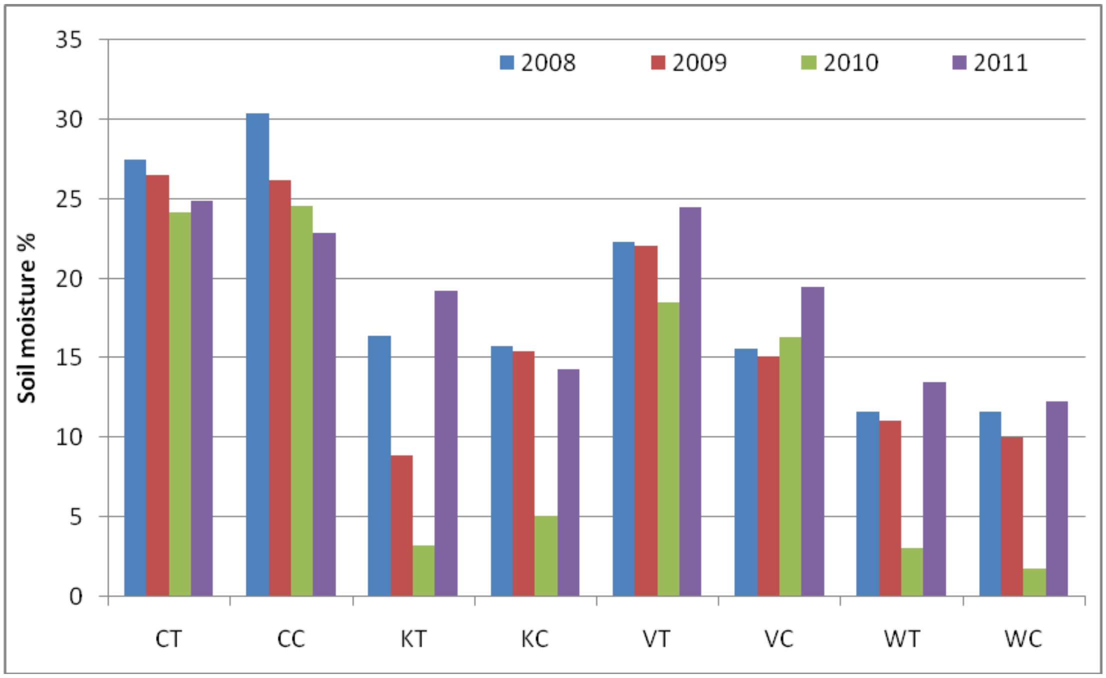


Figure 2.16. Annual average soil moisture percentage at each of the forest thinning sites; moisture readings were taken monthly with the Field Scout TDR 200.

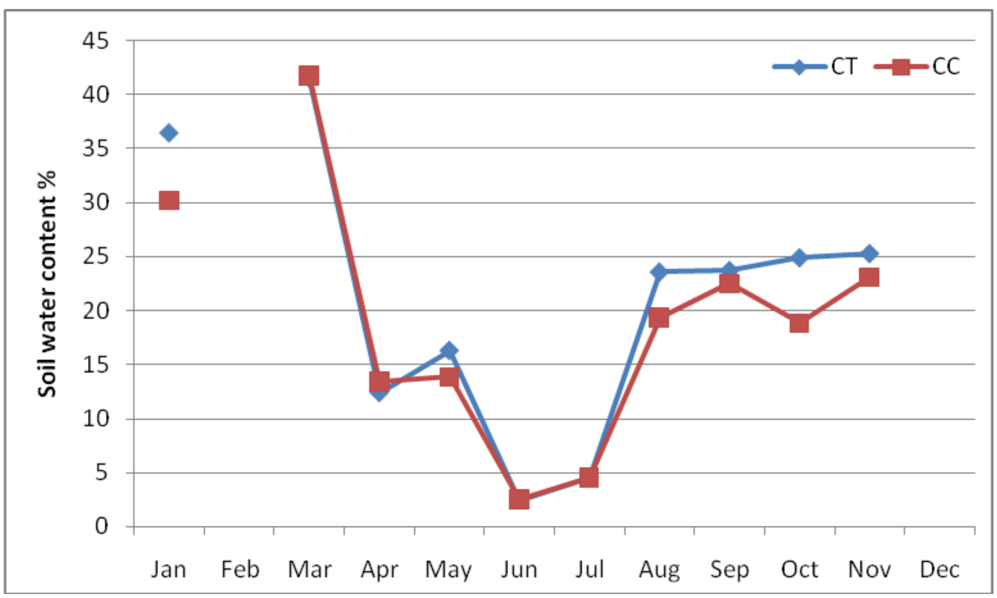


Figure 2.17. Average monthly soil moisture readings taken in 2011 at the Chilili site; measurements were not taken in February due to the site being inaccessible.

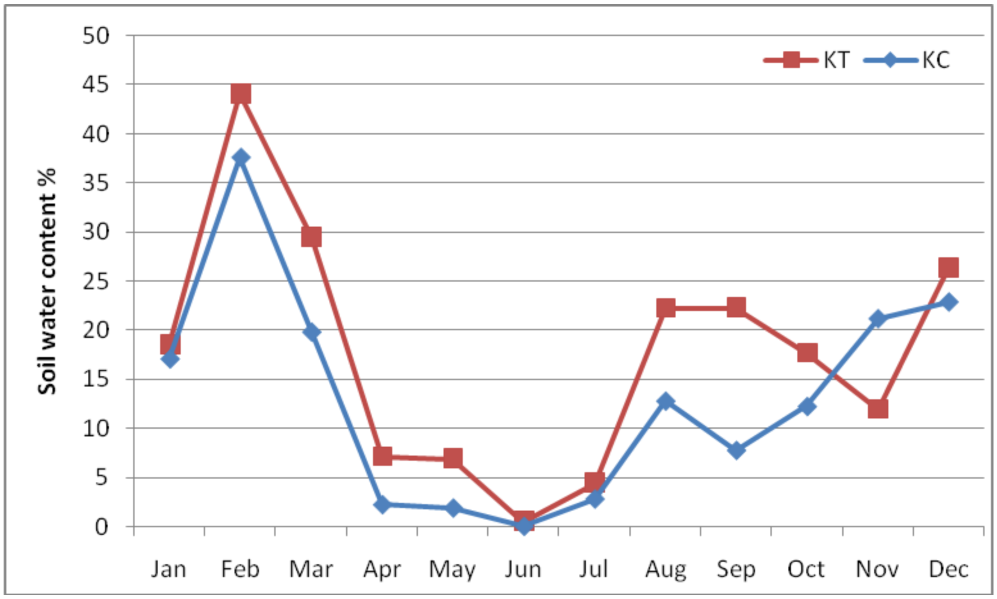


Figure 2.18. Average monthly soil moisture readings taken in 2011 at the Kelly site.

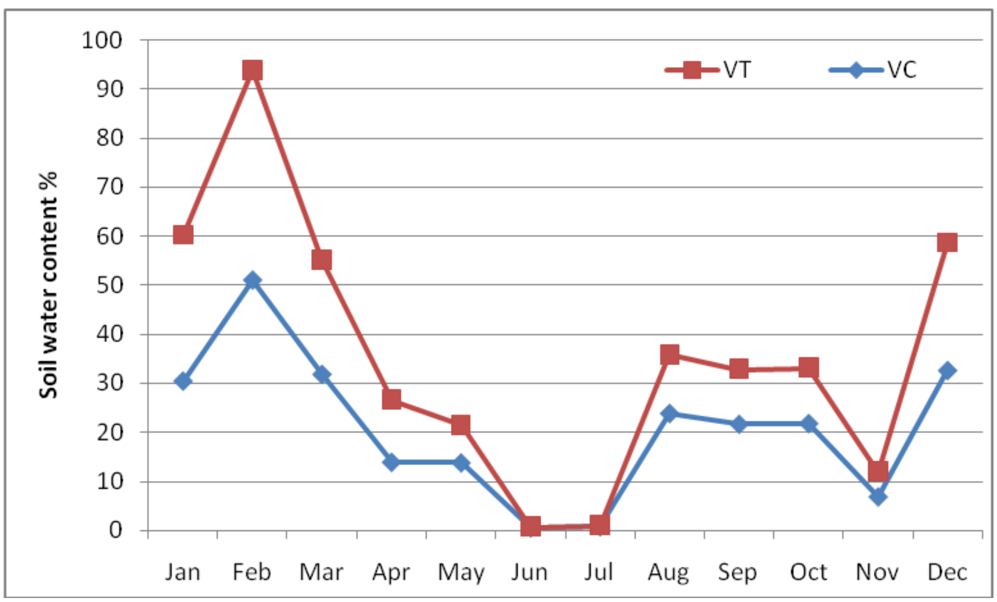


Figure 2.19. Average monthly soil moisture readings taken in 2011 at the Vigil site.

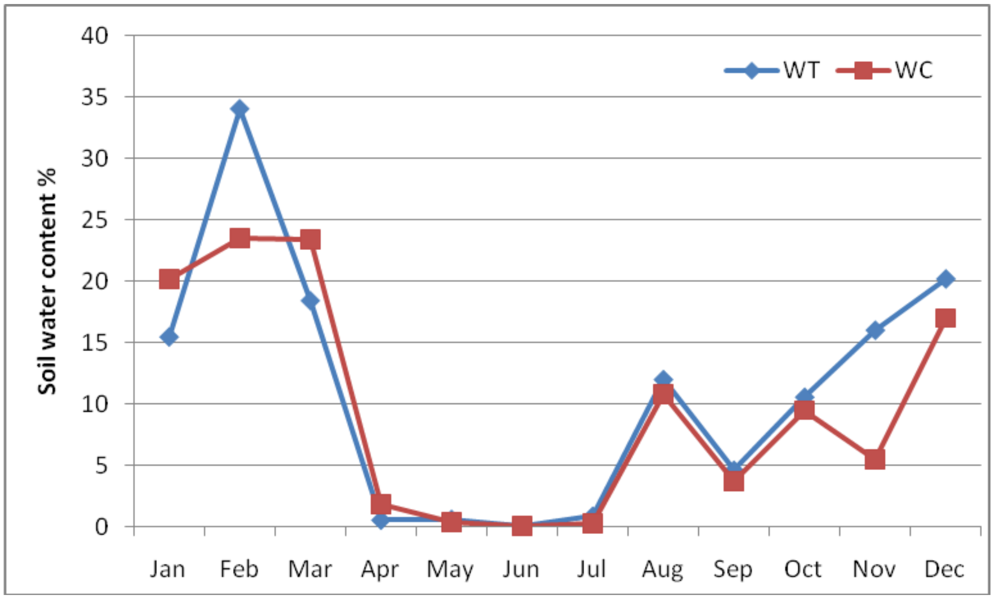


Figure 2.20. Average monthly soil moisture readings taken in 2011 at the Wester site.

2.3.2 Soil Surface Stability

Soil surface stability was measured and scored in June 2011 using the Soil Stability Test Kits developed by the USDA Agricultural Resource Service (Herrick et al. 2005) (Figure 2.21). Further details of the measurement methods and a review of the literature can be found in the 2008 Monitoring Plan (SWCA 2008). Figure 2.22 provides average soil surface stability scores for each of the eight subplots for both 2010 and 2011 from the four sites (Chilili, Kelly, Vigil, and Wester). Figure 2.23 provides average subsurface (1 cm below the soil surface, or -1 cm) soil stability scores for each of the eight subplots for both 2010 and 2011 from the four sites (Chilili, Kelly, Vigil, and Wester).

In general, the data show there was not much of a change in soil surface or subsurface stability from 2010 to 2011, meaning the thinning practices did not initially affect stability. The data do show, however, that the stability scores are higher on the ponderosa pine sites (Chilili and Wester) than on the piñon/juniper sites (Kelly and Vigil). This difference can largely be attributed to the large accumulation of organic matter that occurs underneath tree canopies in the ponderosa pine vegetation type, which can add as much as 2,000 pounds/acre/year of fine fuels (Ffolliott et al. 1968). Most of those soils at the sites measured were underneath litter layers and contained organic material and fungi.

Figure 2.21. Soil stability test in use on the study sites.

Figure 2.22. Soil surface stability average scores for 2010 and 2011 by site, plot, and subplot (18 subsamples/subplot).

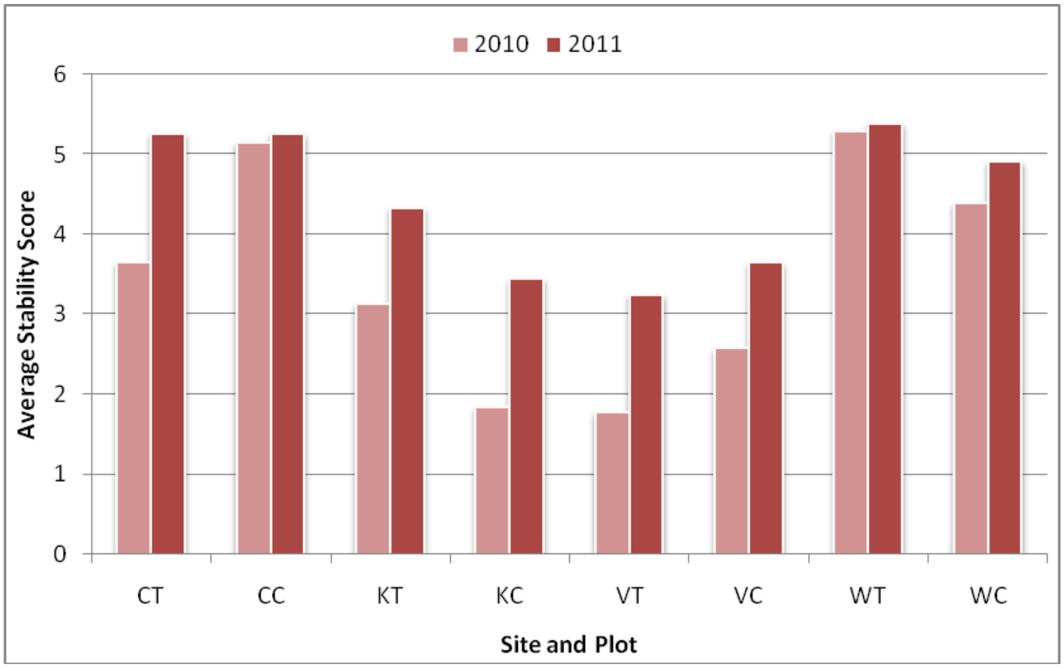


Figure 2.23. Soil subsurface (-1 cm) stability average scores for 2010 and 2011 by site, plot, and subplot (18 subsamples/subplot Soil Movement Bridges

2.3.3 Soil Movement

Soil movement was monitored using soil movement bridges (called soil erosion bridges in the 2008 report) (Figure 2.24) modeled after White and Loftin (2000). Permanent bridge support posts were installed at consistent, systematically determined, and unbiased locations at one of each of the vegetation and soil subplots for a total of three bridges at each paired plot at all four sites. Please refer to the 2008 Annual Report for detailed monitoring protocols and literature associated with soil movement (SWCA 2009). Figure 2.25 shows the micro-soil topography profile from one of the three sampling points at the Kelly piñon/juniper site for 2008, 2009, 2010, and 2011. The graph clearly shows the yearly variability associated with soil movement on a plot and a slight trend for overall soil loss over the four-year period. Figure 2.26 shows average soil profile values averaged over all points per bridge, and over three bridges per paired plot, for 2008, 2009, 2010, and 2011. This figure shows there has been little overall change in average soil surface levels over that four-year period. The processes of soil erosion and soil deposition can clearly be seen when plotting data from all four years. Over a series of years, this study will document losses and/or gains to the soil surface profiles at each bridge site and will provide average values for each of the eight plots in this study.

Figure 2.24. Measurement of soil surface topography using a soil movement bridge helps understand the yearly variability associated with soil topography.

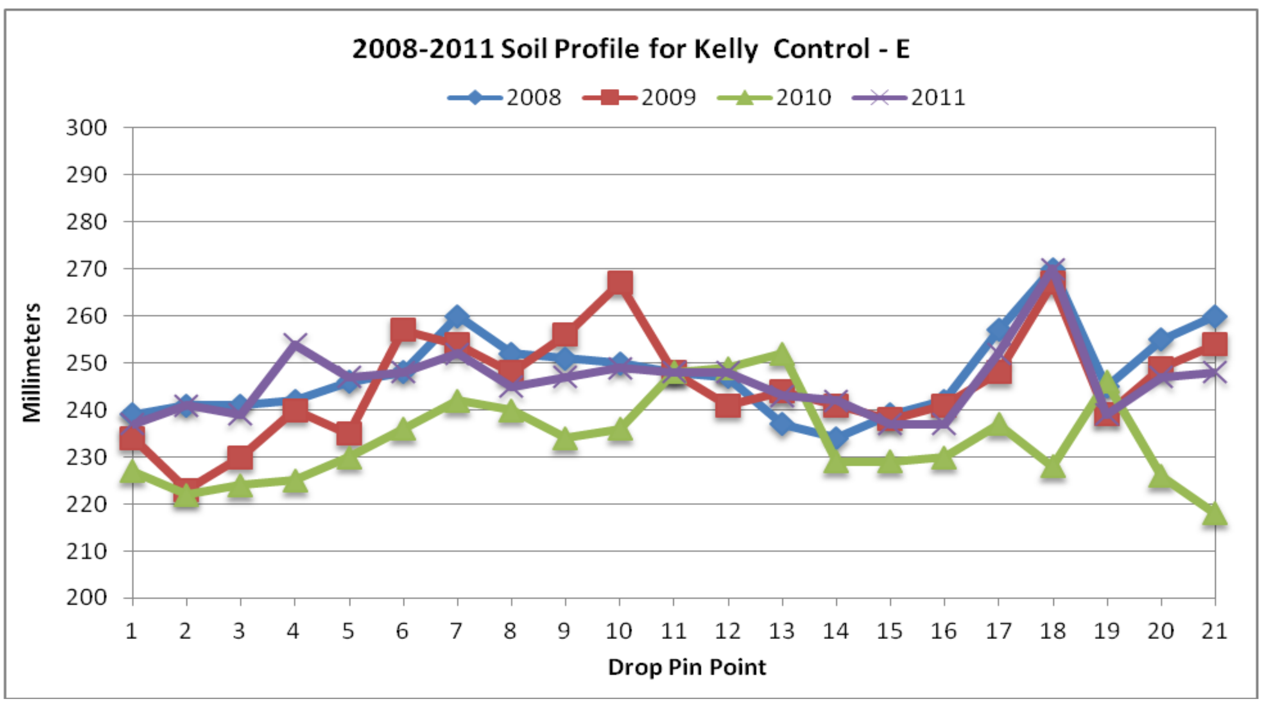


Figure 2.25. Soil surface profile from the soil movement bridge located at the Kelly piñon/juniper control site over 2008–2011, showing variation in the soil surface profile over a four-year period. Each point 1–21 on the X axis represents one measurement point from the soil surface to the level bridge above the surface. Point 11 is the set point (head of a spike) for calibration.

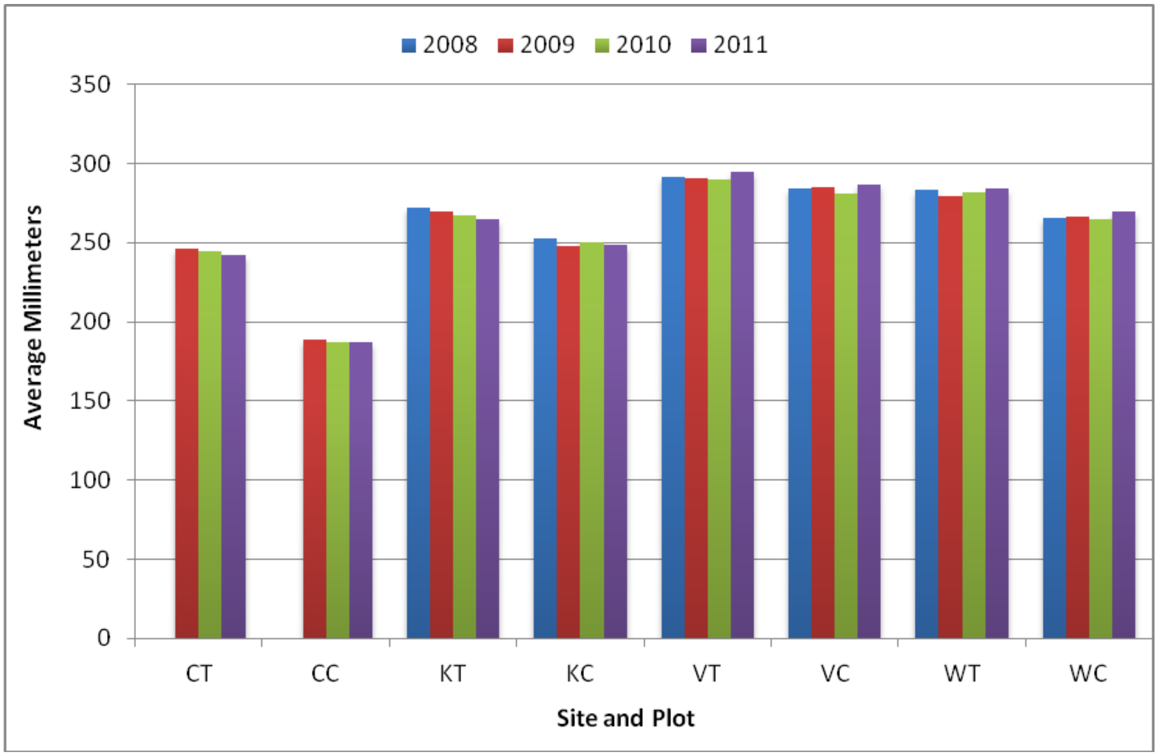


Figure 2.26. Average soil surface profiles, averaged from three soil movement bridges located on each of the paired study plots over the four-year period, 2008–2011.

2.3.4 Soil Chemistry

The chemistry comprising the soil is an important parameter in the overall health and functioning of a watershed. In particular, the top layer of soil, the A-horizon, is important because it is the zone where most biological activity occurs and therefore the most fertile layer. The A-horizon is also the layer of soil most susceptible to disturbance because it is exposed at the surface to the elements of nature and man. Soil chemistry plays a key role in sustaining the productivity of plants and soil biota, which directly affect the ability of soil to infiltrate water. Understanding the chemical makeup of a soil before treatment or disturbance can shed light on how restoration techniques affect the chemical composition of the soil.

Baseline measurements of soil chemistry were obtained in 2008, 2009, 2010, and 2011 before thinning treatments at the Kelly, Vigil, and Wester sites; Chilili was not included until the 2009 sampling because this plot had yet to be established. The purpose of taking these measurements is to quantify changes to soil chemistry potentially caused by thinning activities. The methods used in 2008, however, were slightly different than those used in 2009 and 2010 and can be a reason for any large differences seen between years. The soil samples were obtained using a 4-cm-diameter (1.6-inch-diameter), 20-cm-deep (8-inch-deep) impact soil corer at the four corners of the three established vegetation plots (Figure 2.27). In 2008 the 12 subsamples were placed in labeled separate bags in order to attempt in house analysis with Cardy soil kits. The variability associated with these kits, however, proved to be too great for reliable results, so the subsamples were combined into one bag for each site and sent to the New Mexico State University Soils and

Water Testing (SWAT) laboratory for further analysis. In 2009, 2010, and 2011 the collection of the 12 subsamples was combined into the same bag at the time of sampling. These pooled samples were considered to be representative of the study areas. The 2009, 2010, and 2011 samples were sent to the SWAT laboratory for analysis. These methods followed the USFS Forest Inventory and Analysis Guide procedures (USFS 2005).

Figure 2.27. Soil cores were taken using an impact corer, shown above, for chemical analysis.

The variables measured by the SWAT laboratory included saturated paste pH, electronic conductivity, total soluble salts (sodium, calcium, and magnesium), sodium adsorption ratio, organic matter, nitrogen (nitrate) (NO_3), bicarbonate phosphorous, potassium, and a texture estimate. The initial results of soil organic matter and the macro nutrients nitrogen, phosphorus, and potassium from samples taken in 2008, 2009, 2010, and 2011 are presented in Figure 2.28 through Figure 2.31.

The various soil chemistry compounds varied quite a bit at a given plot, between paired plots, between sites, and between years. This amount of background variation will be important to consider in determining if thinning treatments affect soil chemistry. Such treatment differences will need to be above this background variation.

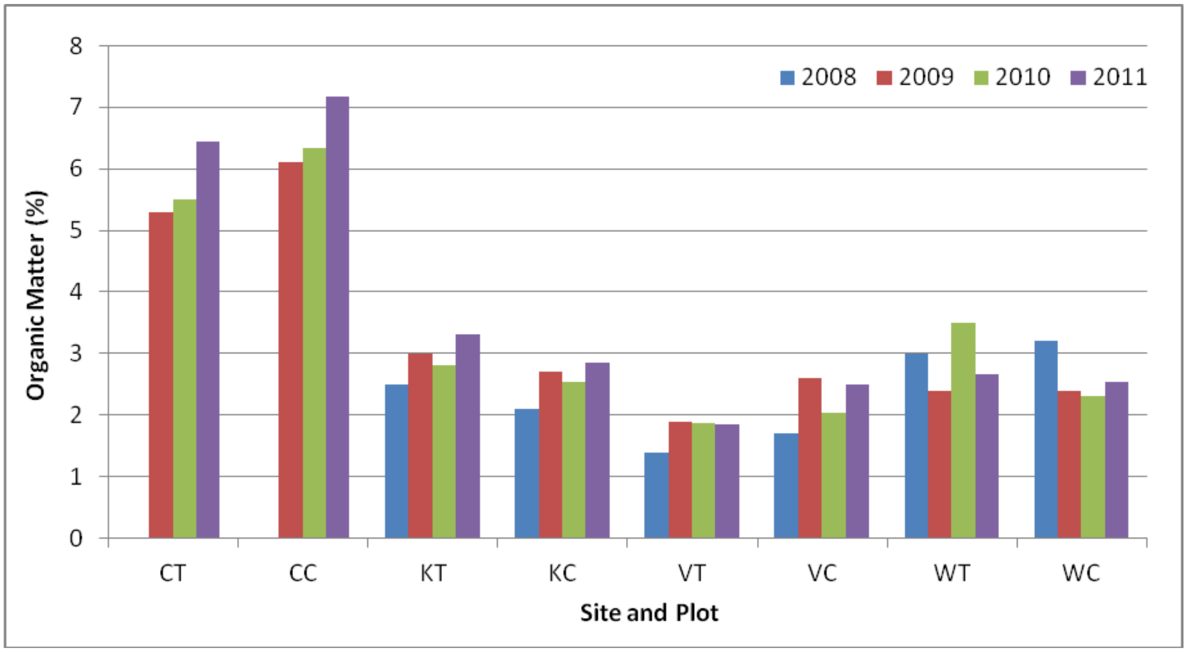


Figure 2.28. Organic matter concentrations measured during 2008, 2009, 2010, and 2011.

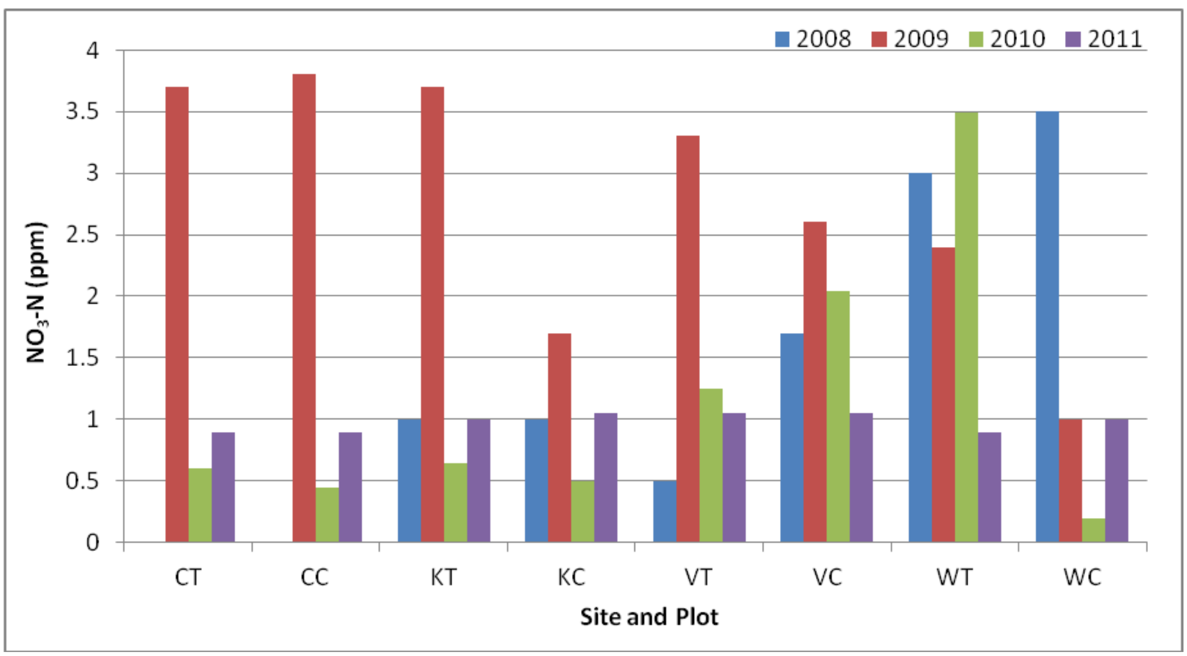


Figure 2.29. NO_3-N concentrations measured during 2008, 2009, 2010, and 2011.

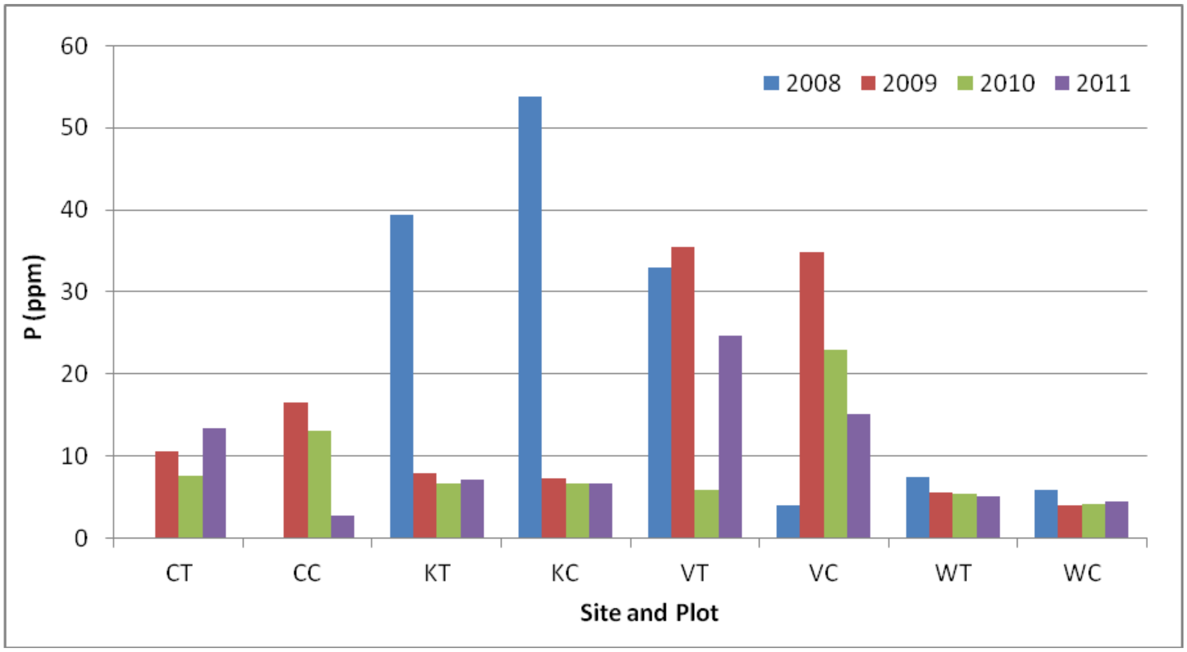


Figure 2.30. Baseline concentrations of phosphorus measured during 2008, 2009, 2010, and 2011.

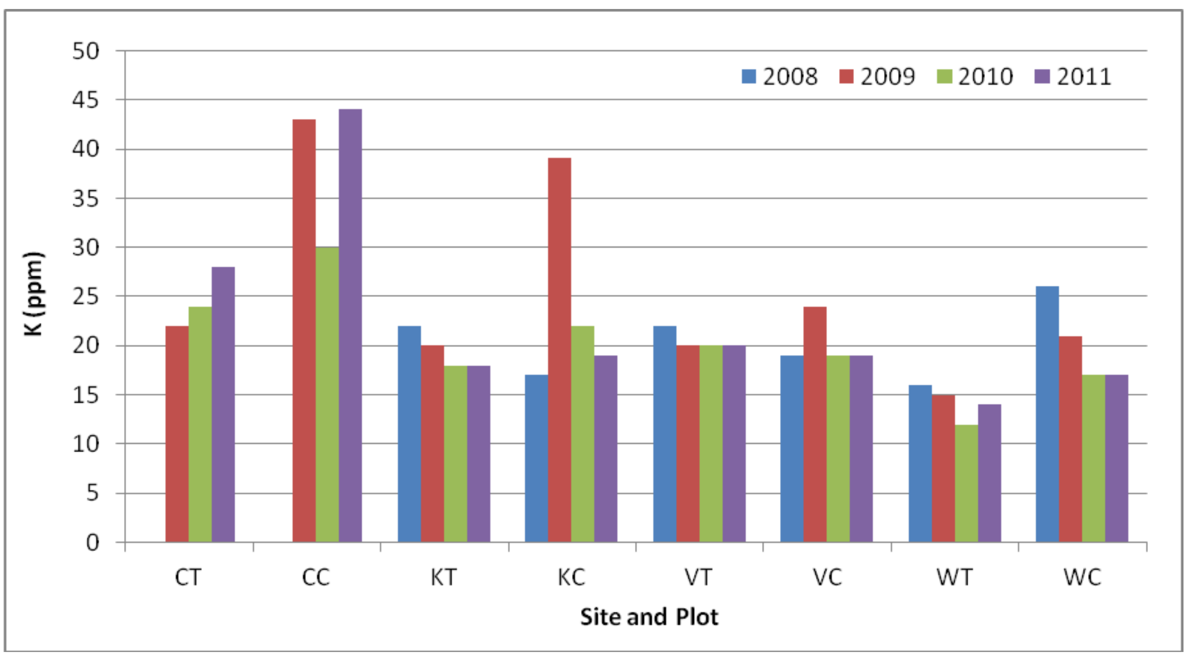


Figure 2.31. Baseline potassium concentrations measured during 2008, 2009, 2010, and 2011.

2.4 FOREST THINNING HYDROLOGIC MONITORING

Monitoring flumes (Parshall flumes) complete with pressure transducers were installed at study sites in order to study impacts of tree thinning to surface flow (Figure 2.32). To study this, flumes were installed at all four monitoring sites. For more detailed information on the methodology, site location, and relevant background information, please refer to the 2008 Monitoring Plan (SWCA 2008).

Figure 2.32. Parshall flume located at the thinned Chilili site.

During the 2010–2011 monitoring period, rainfall occurred in the project area on 26% of the days monitored. However, about 70% of these rainfall events were relatively small and totaled less than 2.5 mm (0.1 inch). During the same monitoring period, only five flows were recorded across all watersheds, which was considerably lower than the previous years where 45 flow events were recorded during the 2009–2010 monitoring period. While a handful of flow events occurred where minimal (or even no) rain was recorded in the nearest rain gauge, flows generally did not generate without at least 7.6 mm (0.3 inch) of rainfall, which again was the case in 2011. The sites located in the ponderosa pine study plots generated runoff with slightly less rain (7.6 mm [0.3 inch]), whereas the piñon/juniper sites required about 12.7 mm (0.5 inch) of rain to generate runoff events.

During the 2010–2011 monitoring period there were no basin-wide storm events that generated flow across all study sites. Many of the flumes did not even record flow during the 2011 monitoring season, which is a product of the persistent drought over the region. The flumes that did not record surface flow during the 2010–2011 season included both Kelly sites, both Wester sites , and the Chilili control. Even though there were very few recordable storm events, there are still trends that are beginning to show. The flumes that did record events were Vigil treatment and control, which recorded flows on two separate days in August, and Chilili treatment, which recorded the highest peak flow to date (0.11 m [0.37 feet]) (Figure 2.33). The results of these flows can be found in Table 2.3 through Table 2.5. The storm event that occurred over the Chilili watersheds on August 21, 2011, produced over 48 mm (1.89 inches) of precipitation and caused the highest recorded peak flow yet (Table 2.3); however, the control watershed produced no flow. This flow event displayed characteristics of a large surface runoff event creating channels and rills through the litter duff, while also clogging the flume throat with pine needles and wood chips (Figure 2.34–Figure 2.36). Whether the differences in peak flows on the treated watershed versus the control watershed persist remains to be seen, and with more future flows this picture will become more clear.

The first flow event at Vigil site occurred on August 5, 2011. The flow events that occurred on the control and treatment sites were similar in nature and did not show any difference in terms of peak discharge (Table 2.4). During the second measureable storm event on August 20, 2011, however, the treated watershed had a 39% higher peak storm flow than the control (0.09 m vs. 0.14 m [0.28 feet vs. 0.46 feet]), which is the largest difference seen between the two sites (Figure 2.37 and Figure 2.38). All Parshall flumes were functioning properly during the 2011 season.

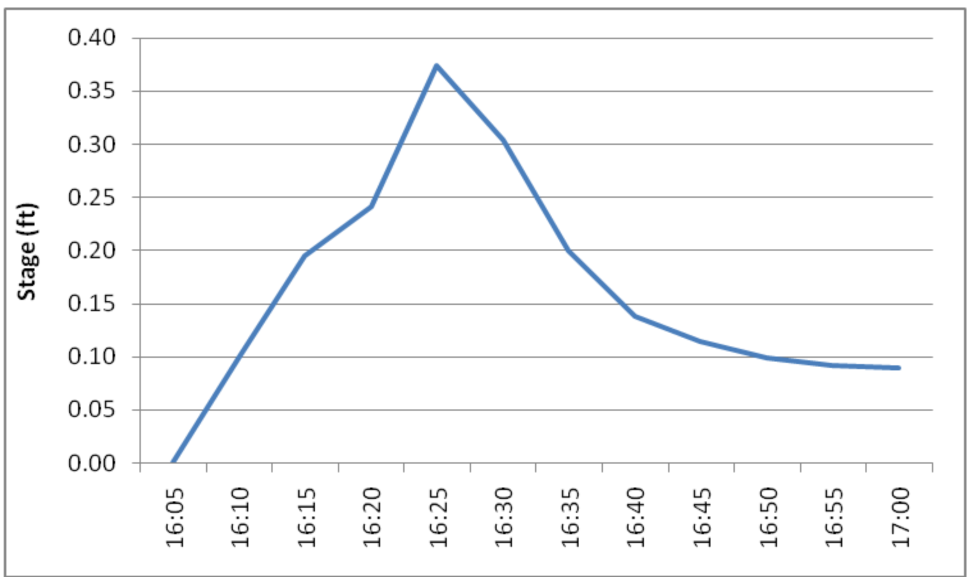


Figure 2.33. Hydrograph showing the peak flow at the treated Chilili site during the flow event on August 20, 2011.

Table 2.3. Summary of Runoff Events for Chilili August 21, 2011

Runoff Parameters	Study Site
	Chilili Treated
Flow start	16:05
Flow stop	17:00
Peak stage (feet)	0.37
Peak flow (cubic feet/second)	0.212
Flow duration (minutes)	55
Total volume of flow (cubic feet)	244.5
Watershed area (acres)	3.5
Volume of flow per acre (cubic feet/acre)	70
Total rainfall (inches)	1.89
Total volumetric rainfall (cubic feet)	24012
Rainfall/Runoff ratio	0.01

Table 2.4. Summary of Runoff Events for Vigil August 5, 2011

Runoff Parameters	Study Sites	
	Vigil Treated	Vigil Control
Flow start	17:50	17:52
Flow stop	18:15	18:12
Peak stage (feet)	0.21	0.22
Peak flow (cubic feet/second)	0.088	0.095
Flow duration (minutes)	25	20
Total volume of flow (cubic feet)	115.2	107.1
Watershed area (acres)	0.68	0.1
Volume of flow per acre (cubic feet/acre)	169	1071
Total rainfall (inches)	0.58	0.67
Total volumetric rainfall (cubic feet)	1432	243
Rainfall/Runoff ratio	0.08	0.44

Table 2.5. Summary of Runoff Events for Vigil August 20, 2011

Runoff Parameters	Study Sites	
	Vigil Treated	Vigil Control
Flow start	14:00	14:02
Flow stop	14:35	14:22
Peak stage (feet)	0.46	0.28
Peak flow (cubic feet/second)	0.298	0.138
Flow duration (minutes)	35	20
Total volume of flow (cubic feet)	279	101
Watershed area (acres)	0.68	0.1
Volume of flow per acre (cubic feet/acre)	411	1008
Total rainfall (inches)	0.58	0.74
Total volumetric rainfall (cubic feet)	1876	269
Rainfall/Runoff ratio	0.15	0.36

Figure 2.34. The flume on the treated Chilili site clogged with pine needles and wood chips following a flow event that occurred on August 20, 2011.

Figure 2.35. The flume on the treated Chilili site after the pine needles and wood chips were removed from the throat, following a flow event on August 20, 2011.

Figure 2.36. The flow event on August 21, 2011, created flow paths through the pine needles and woodchip along the road designed to access the site.

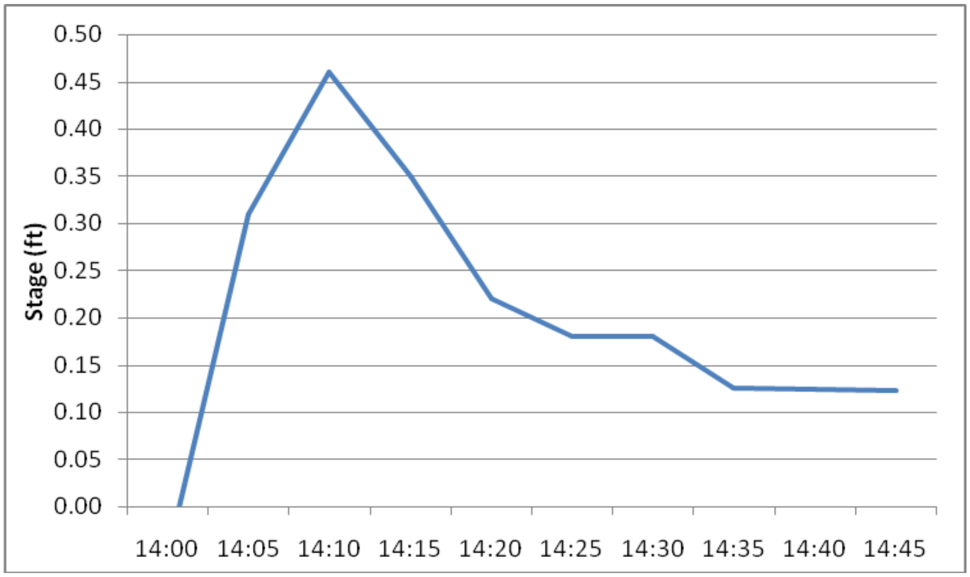


Figure 2.37. Hydrograph showing the peak flow at the treated Vigil site during the flow event on August 20, 2011.

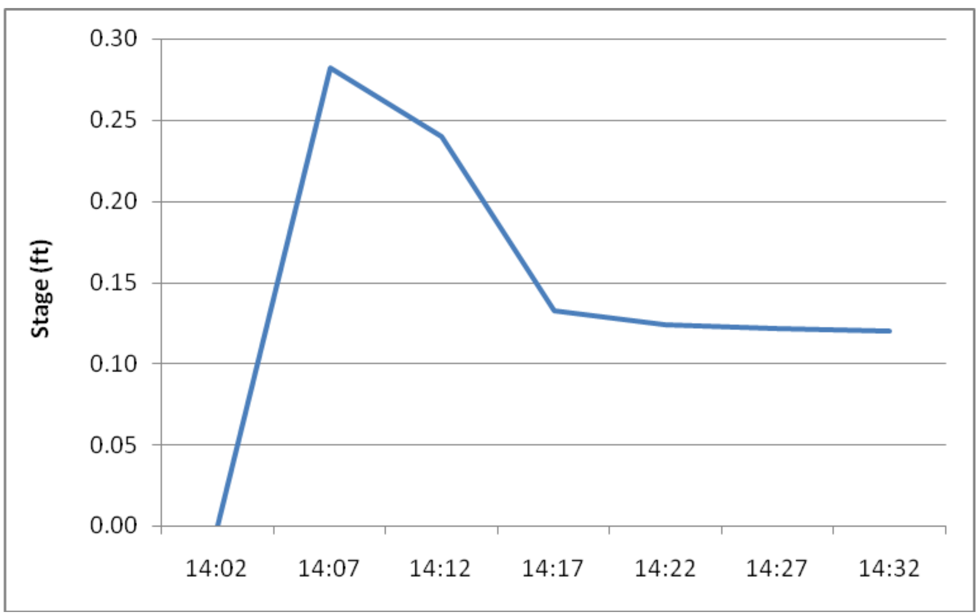


Figure 2.38. Hydrograph showing the peak flow at the control Vigil site during the flow event on August 20, 2011.

With respect to site hydrology, there are four conditions that could change because of forest thinning or from the effects of wildfire: 1) increased frequency of flow, 2) greater duration and volume of flow, 3) increased peak flow, and 4) a greater ratio of runoff to rainfall.

2.4.1 Flow Frequency, Duration, and Volume

Frequency of flow will be able to be analyzed over time as data are collected; however, based on the period of record so far a baseline has been established for the remaining parameters. The parameters of flow duration and volume will likely be the least useful in assessing effects from forest thinning, as these parameters are highly dependent on rainfall duration and intensity. In general, the ponderosa sites generated flows of longer duration and greater volume than those in the piñon/juniper sites, which can likely be attributed the elevation differences (Table 2.1). A summary of all the number of flow events (frequency), flow duration, and flow volume for the observed runoff events is shown in Table 2.6.

Table 2.6. Summary of Flow Frequency, Duration, and Volume

Location	Number of Flow Events	Range of Duration (minutes)	Median Duration (minutes)	Range of Volume (cubic feet)	Median Volume (cubic feet)
Chilili T	3	55–840	512.5	245–17,751	9,197
Chilili C	8	25–715	167.5	36–2,564	920.5
Kelly C	4	25–35	30	38–392	54.5
Kelly T	1	15	15	69	69
Vigil T	9	15–115	40	46–197	117
Vigil C	4	20–80	50	123–290	218
Wester T	4	10–235	102.5	39–4,765	210
Wester C	7	10–760	90	42–9,458	444
All ponderosa	**22**	**10–840**	**95**	**35–9,458**	**468.5**
All piñon/juniper	**18**	**15–115**	**32.5**	**38–392**	**93**

2.4.2 Peak Flow/Stage

Peak flow can be affected by the intensity of rainfall, but it is also a measure of the flashiness of flow; particularly in post-fire monitoring, runoff can occur rapidly with large peaks appearing very quickly. The highest peak stage was recorded at the Chilili 1 site during 2011 (0.11 m [0.37 feet]), while the greatest recorded peak flow of 1.29 feet was recorded at the Wester 2 site on July 2, 2010 (coinciding with the greatest observed daily rainfall). A summary of peak stage runoff events for all years is shown in Table 2.7.

Table 2.7. Peak Stage of Runoff Events

Location	Number of Flow Events	Range of Peak Stage (feet)	Median Peak Stage (feet)
Chilili T	3	0.19–0.76	0.475
Chilili C	8	0.11–0.57	0.375
Kelly C	4	0.14–0.39	0.175
Kelly T	1	0.23–0.23	0.23
Vigil T	9	0.12–0.46	0.19
Vigil C	4	0.22–0.28	0.27
Wester T	4	0.15–0.85	0.19
Wester C	7	0.12–1.29	0.38
All ponderosa	**22**	**0.11–1.29**	**0.35**
All piñon/juniper	**18**	**0.12–0.46**	**0.175**

2.4.3 RAINFALL/RUNOFF RATIO

The rainfall/runoff ratio is perhaps the most useful parameter to observe. All other parameters can vary due solely to the magnitude or intensity of rainfall; the rainfall/runoff ratio normalizes the flow events, although intensity and antecedent soil moisture conditions will still affect the amount of runoff. The rainfall/runoff ratio looks at the percentage of rainfall falling on the watershed leaving as surface runoff. A value of zero indicates no water left the watershed, and a value of 1 would indicate all water falling on the watershed was observed leaving as surface runoff (this is highly unlikely). In natural settings, the rainfall/runoff ratio typically falls in the 0.1 to 0.3 range. The rainfall/runoff ratios observed during flow events from the watersheds are summarized in Table 2.8. Note some rainfall/runoff values were not calculated due to missing rainfall data. In general, rainfall/runoff ratios were highly variable, including some extremely high values; however, almost 70% of the flow events had rainfall/runoff ratios of less than 0.10. Ponderosa sites exhibited a slightly lower rainfall/runoff ratio than piñon/juniper sites, which can likely be attributed to the large amounts of litter and duff that serve as a sponge and retain the water.

Table 2.8. Rainfall/Runoff Ratio for Observed Flow Events

Location	Number of Flow Events	Range of Rainfall/Runoff Ratio	Median Rainfall/Runoff Ratio
Chilili T	3	0.01–0.561	0.561
Chilili C	8	0.003–0.550	0.022
Kelly C	4	0.045–0.460	0.088
Kelly T	1	–	–
Vigil T	9	0.034–0.160	0.056
Vigil C	4	0.399–0.654	0.439
Wester T	4	0.029–0.058	0.044
Wester C	7	0.015–0.848	0.407
All ponderosa	**22**	**0.003–0.848**	**0.058**
All piñon/juniper	**18**	**0.034–0.479**	**0.075**

2.5 VEGETATION

For details regarding the research questions, monitoring protocols, and plot design for vegetation monitoring, as well as a full literature review, please refer to the 2008 Monitoring Plan (SWCA 2008).

2.5.1 REPEAT PHOTO POINTS

Repeat photo points provide a visual means for qualitatively assessing change in woody and herbaceous vegetation over time, and repeat photographs are useful to help interpret quantitative vegetation measurement data from the same locations. Permanent photo points were established on each of the three 10 × 30–m (33 × 98–foot) vegetation and soils measurement subplots for a total of three repeat photographs taken at each of the eight study plots (24 photographs in all). The first baseline photographs were taken in fall 2008. Repeat annual photographs were again taken in fall 2009, 2010, and 2011. An example of those repeat photographs comparing the west vegetation subplot of treated plot at the Vigil site in 2008, 2009, 2010 and 2011 is shown in Figure 2.39.

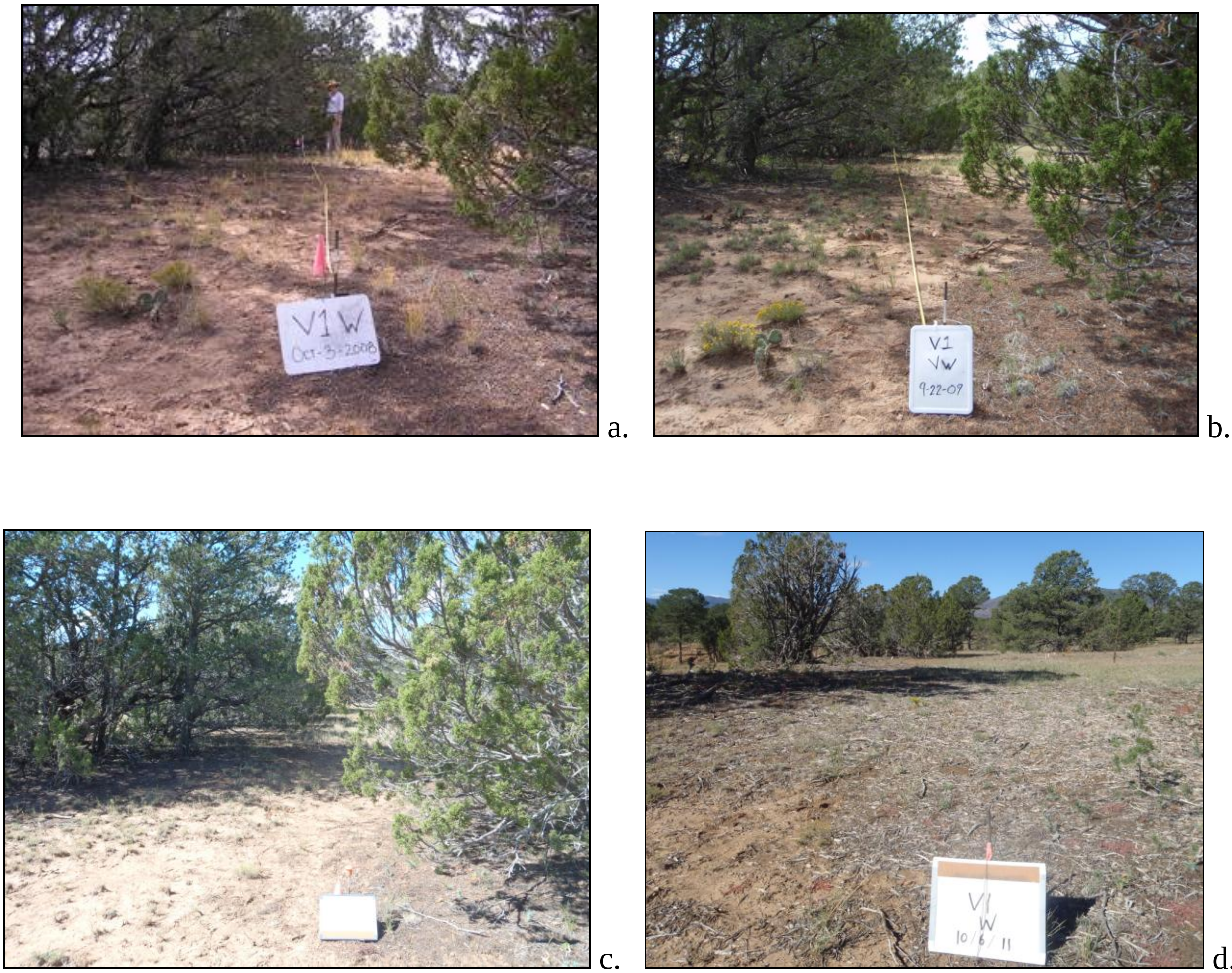


Figure 2.39. Repeat photographs of the Vigil piñon/juniper site, west vegetation subplot photographed in a. 2008, b. 2009, c. 2010, and d. 2011. Note the absence of trees and the presence of wood chips on the ground in 2011 following tree thinning treatments.

2.6 Trees

Tree monitoring measurements in the spring of 2011 included observations of canopy dieback, disease or damage, live and dead status, and canopy and bole measurements.

2.6.1 Basal Area Measurements

Basal area measurements were taken in the fall of 2009 and the spring of 2011, after treatments were completed (Table 2.9). Figure 2.40 shows the change in basal areas from the treated plots.

Table 2.9. Treatment Designation for All Plots (with basal area totals)

Site	Treatment or Control	Average Basal Area (square feet/acre) 2008	Average Basal Area (square feet/acre) 2011
Chilili 1	Treatment	210	79
Chilili 2	Control	194	194
Kelly 1	Control	106	106
Kelly 2	Treatment	155	47
Vigil 1	Treatment	124	39
Vigil 2	Control	129	129
Wester 1	Treatment	220	99
Wester 2	Control	213	213

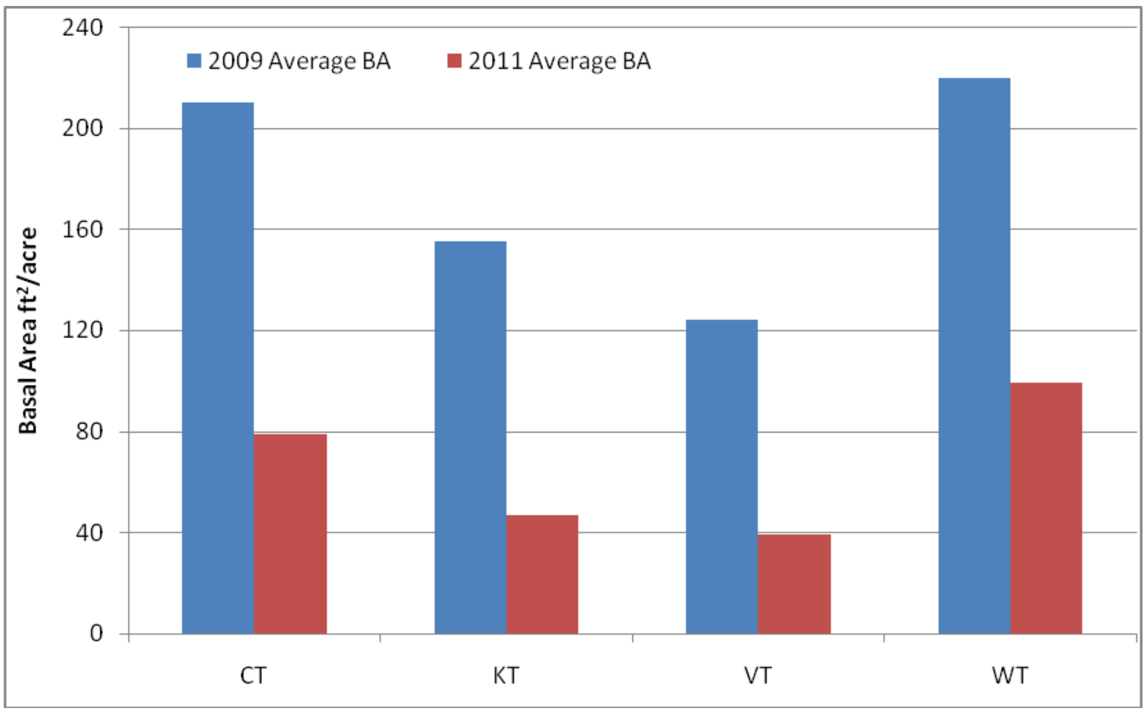


Figure 2.40. Basal area (BA) on the treatment plots showing the results of thinning treatments.

2.6.2 CROWN DIEBACK

Percent crown dieback is the percentage of the leafy canopy of each tree that showed signs of physiological stress (i.e., brown needles and leaves). Crown dieback could result from a number of environmental factors, for example, drought, insect attack, competition, and disease. Measurement of crown dieback is highly dependent on the time of year; as a result, efforts are made to take measurements consistently during late September to early October each year. Figure 2.41 illustrates crown dieback across all sites.

Crown dieback levels from 2008 to 2011 are presented below by site and year (see Figure 2.41). This graph clearly shows the inherit variability associated with measuring crown dieback. Crown dieback of individual trees can be highly variable across a plot based on tree size and position and the environmental factors it is exposed to; however, we believe that these dieback levels are within the normal range of variability for all four years.

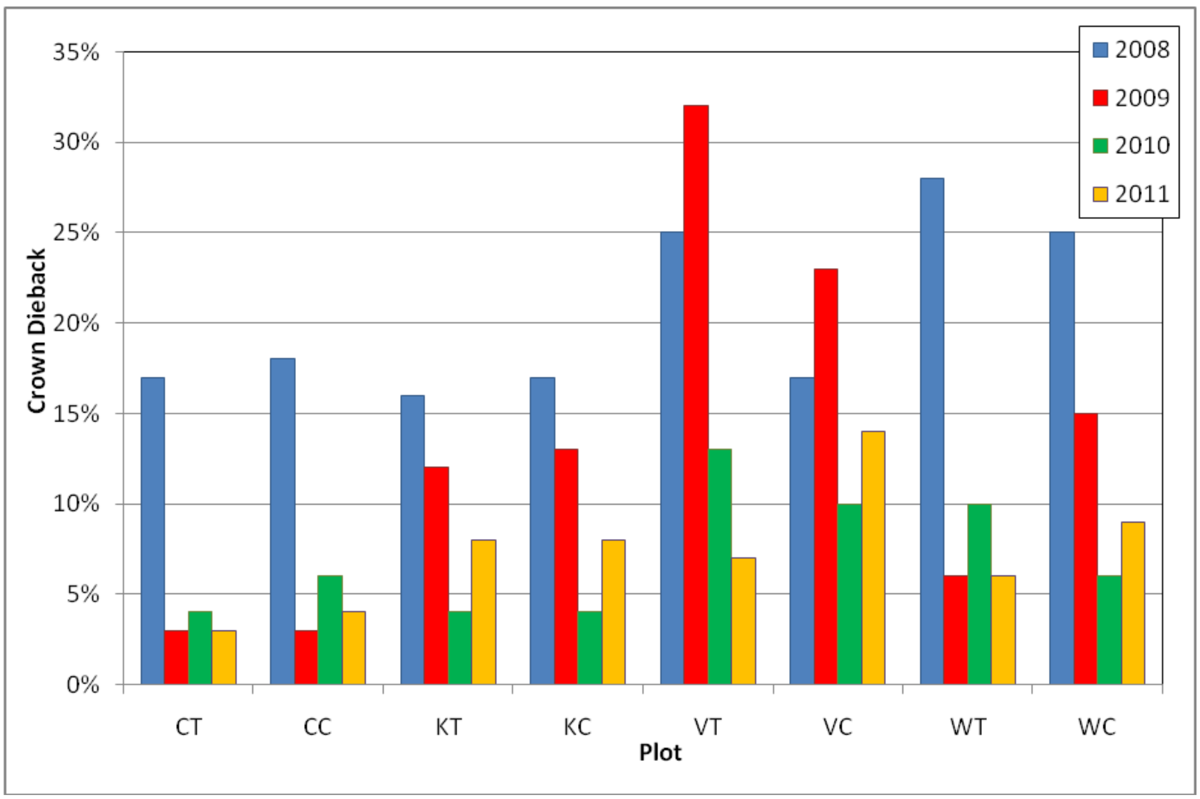


Figure 2.41. Average percent crown dieback of tree canopies for each thinning plot, 2008–2011.

2.6.3 TREE MORTALITY

In total, 613 trees were tagged across all watersheds in this study with species composition from ponderosa pine, piñon pine, one-seed juniper, and alligator juniper (*Juniperus deppeana*). In 2008 there were no dead trees tagged on any plots. From 2008 through 2010, percent tree mortality has been limited to just three plots: Kelly 1 (9.4%), Wester 1 (1.5%), and Wester 2 (4.0%); however, in 2011 it was only limited to one plot Kelly 1 (6.7%) (Figure 2.42). All mortality occurred in 2009 and 2010. The Vigil plots that had exhibited greater crown dieback than other plots, particularly in 2009, did not experience any mortality over the three years. Conversely, the three plots that did have mortality did not seem to exhibit higher crown dieback than other plots over the study period. The data so far reveal no obvious relationship between crown dieback rates and actual tree mortality. The high mortality at the Kelly site could be attributed to a number of environmental factors, including drought, beetle infestation, and competitive stress. Post-treatment monitoring may help isolate the cause of the mortality.

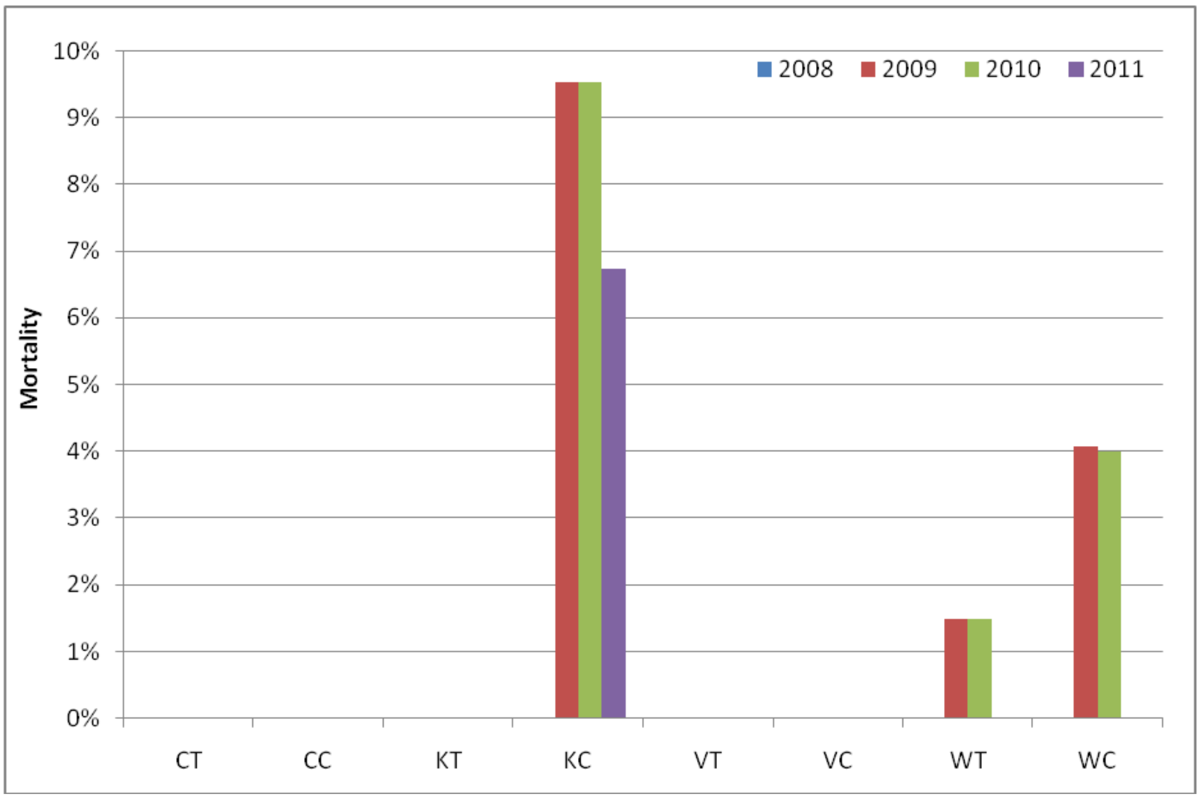


Figure 2.42. Percent tree mortality recorded across all thinning plots from 2008–2011. Percent mortality is recorded in relation to tree status in 2008.

2.6.4 FUELS

Fuel measurements were taken using Brown's transect protocols (Brown 1974) in fall 2010 and 2011 within the four circular tree plots on each paired watershed. Refer to the 2008 Monitoring Plan for detailed monitoring protocols and an explanation of fuel class sizes (SWCA 2008). Figure 2.43 and Figure 2.44 illustrate the percent cover by the various fuel classes on each thinning plot measured in 2010 and 2011, respectively. Figure 2.45 displays the average duff and litter depths at each plot. These data will be used as baseline information with which post-treatment data collected in fall 2011 will be compared.

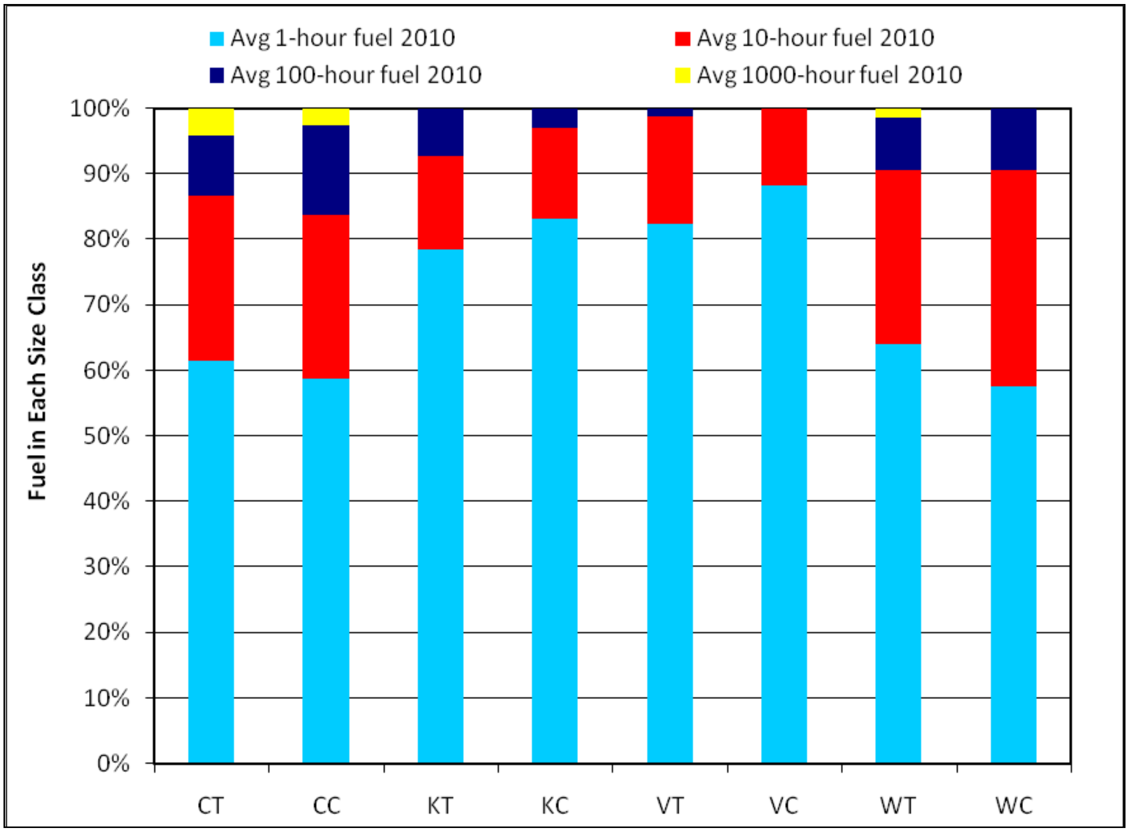


Figure 2.43. Percentage of fuel in each fuel particle size class for 2010 (1-hour, 10-hour, 100-hour, 1,000-hour) on all thinning plots.

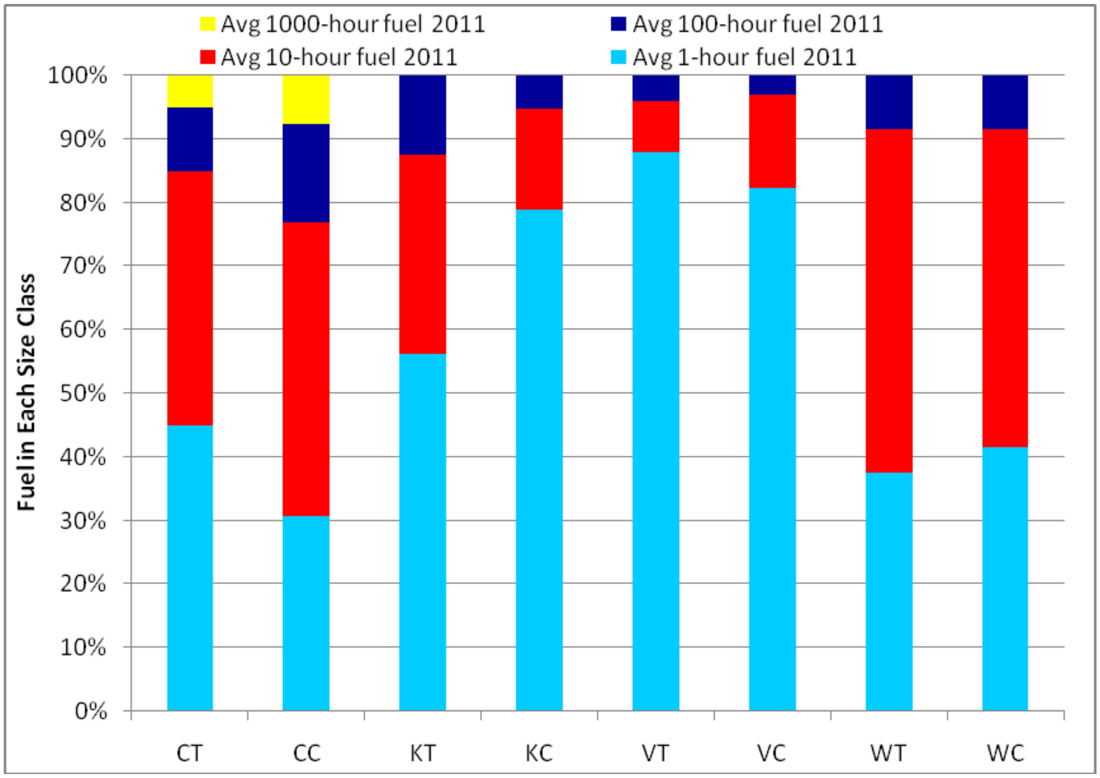


Figure 2.44. Percentage of fuel in each fuel particle size class for 2011 (1-hour, 10-hour, 100-hour, 1,000-hour) on all thinning plots.

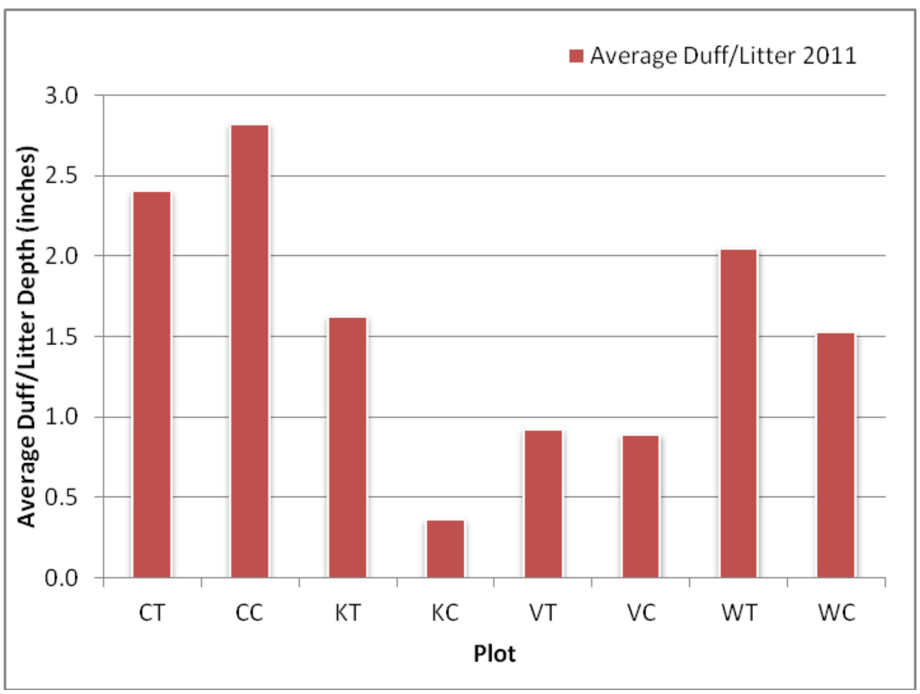


Figure 2.45. Average combined duff and litter depths on all thinning plots, measured in inches.

With reference to Figure 2.43 and Figure 2.44, the piñon/juniper plots tended to have a slightly higher accumulation of 1-hour fuels (fine fuels 0.0–0.6 cm [0.00–0.25 inch] in diameter) compared to the ponderosa plots. Conversely, 100-hour and 1,000-hour fuels (woody debris > 2.5 cm [1 inch] in diameter and > 8 cm [3 inches] in diameter, respectively) were more common at the ponderosa sites. Each paired plot was relatively consistent in terms of fuel loading by size class (see Figure 2.43 and Figure 2.44). Figure 2.45 shows that both Chilili plots had considerably more duff and litter than the other plots. The volume of litter and duff found on the forest floor is related to both productivity and decomposition.

The variation in litter and duff between the Wester and Chilili sites could be related to differing decomposition rates as a result of differences in elevation and moisture regimes. Decomposition has been found to be positively correlated with moisture gradient with greater decomposition on more productive sites (Keane 2008); this would explain the greater depths of duff at Chilili (a higher elevation and more productive ponderosa pine forest) versus Wester (a lower elevation, drier and more open stand ponderosa pine forest). Overall duff and litter depths were higher on the ponderosa sites than the piñon/juniper sites (Figure 2.46), which is to be expected since litter and duff cover in ponderosa pine is almost continuous across the landscape while litter and duff is isolated in patches immediately below the canopies of trees in piñon/juniper woodlands (Figure 2.47).

Figure 2.48 shows the tons/acre of woody dead and downed fuels at each site. The piñon/juniper sites had relatively low fuel loading compared to the ponderosa sites, because the piñon/juniper sites tended to have fewer large-diameter woody fuels. The piñon/juniper sites exhibited greater fine fuel loading, however (see Figure 2.43 and Figure 2.44), likely due to lower canopy cover that permits the growth of graminoids and forbs. Shrub cover was limited at both piñon/juniper sites. The Wester plots also had low loading compared to the Chilili plots; this site was relatively open, and although it exhibited higher levels of 1-hour fuels (see Figure 2.43 and Figure 2.44), there were less 1,000-hour fuels consequently lowering the tons/acre totals (Figure 2.49, see Figure 2.43 and Figure 2.44). Chilili 1 and 2 have noticeably higher fuel loadings than all other sites; these are dense plots with many more 1,000-hour fuels (many downed trees and stumps) (Figure 2.50), which raised their total tons/acre.

Fuel measurements were repeated in fall 2011 following treatment at each plot to determine changes to fuel loading as a result of thinning.

Figure 2.46. Continuous litter and duff cover and accumulations in an arroyo at Chilili 1.

Figure 2.47. Patchy cover of litter and duff at Vigil 1.

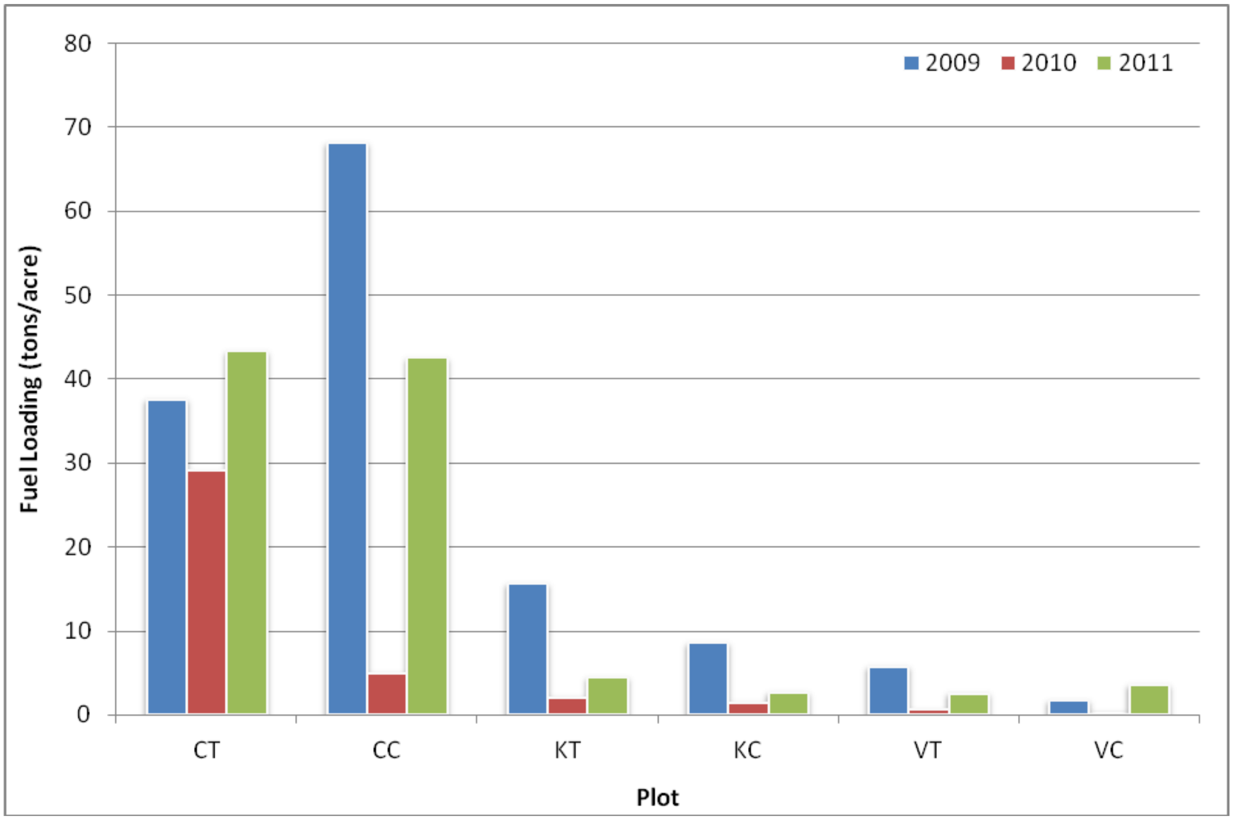


Figure 2.48. Fuel loading (in tons/acre) of dead and downed woody debris for all thinning plots 2009-2011.

Figure 2.49. Wester 2, showing the low fuel loading on the plot and lack of large-diameter dead and downed fuels.

Figure 2.50. Chilili 2, showing high fuel loading with evidence of large-diameter dead and downed fuels.

2.7 Vegetation and Ground Surface Cover and Tree Canopy Structure Monitoring

Herbaceous vegetation was again measured along line intercepts and quadrats from the vegetation and soils plots at each site as presented in the 2009 Annual Report. Additionally, in 2010, SWCA initiated more extensive vegetation measurements on the wildlife plots in order to characterize vegetation composition and structure as habitat for wildlife on those plots and to provide quantitative data to determine how vegetation or habitat changed on the wildlife plots relative to forest thinning treatments. Those vegetation measurements were taken again in 2011 and will be used to characterize vegetation changes on study plots relative to forest thinning treatments. Vegetation was measured from thirty-six 1-m^2 (10.8-square-foot) quadrats located at each of the 36 permanently marked rodent trapping stations on each wildlife plot in a six by six grid, with stations at 10-m (33-foot) intervals (50 × 50–m [164 × 164–foot] plot). All plant species including woody trees and shrubs were measured on each of those square-meter quadrats. The total canopy cover and maximum height in centimeters of each species was measured per quadrat. Vegetation quadrat data were also categorized by growth form (e.g., tree, shrub, cacti, grass, forb) and life-history (annual or perennial). Tree canopy cover was often high above the quadrats and was estimated by visually projecting the dimensions of the quadrat above to minimize optical parallax. In addition to vegetation, soil surface cover categories also were measured on the quadrats, including bare soil, leaf litter (and dead and downed woody material), rock, and cryptobiotic (cryptogam) soil surface crusts. Measures of wood chip coverage on the ground resulting from forest thinning practices were added in 2011.

The vegetation and ground cover data measured from the replicated quadrats on wildlife plots provides the most appropriate data for statistical testing for differences in those cover values resulting from thinning treatments, because there is sufficient sample replication to perform parametric statistical tests. Also, those 36 sampling quadrats were evenly distributed over relative large areas (plots 50 m [164 feet] on a side), providing a good sampling representation of each of the paired study plots. Data from each vegetation and ground cover type were used to test for differences between paired plots using a standard parametric t-test. Ideally, there should be no significant differences between paired plots prior to thinning treatments. If thinning has an effect on any of those cover types, then a significant difference would be expected following thinning treatments.

Tree canopy structure on the wildlife plots was measured by using a standard spherical densiometer for measuring tree upper canopy closure, and vertical structure method as presented below to measure lower tree canopy closure. Tree canopy structure was measured in the fall of 2010 and 2011 when other vegetation measurements were made. Vegetation vertical canopy structure was measured on each of the four vegetation and soils subplots, and on all of the wildlife monitoring plots. The method was adapted from Herrick et al. (2005) and consisted of a 2-m-long (6.6-foot-long), 5-cm-diameter (2-inch-diameter) white polyvinyl chloride (PVC) pipe pole partitioned into three different 2-m (6.6-foot) height layers, each with continuous 10-cm (4-inch) black/white increment markings. The 2-m (6.6-foot) PVC measurement pipe was partitioned into four different vertical 0.5-m (1.6-foot) segments or heights above the ground surface: segment one = 2.0–1.5 m (6.6–4.9 feet), segment two = 1.5–1.0 m (4.9–3.3 feet), segment three = 1.0–0.5 m (3.3–1.6 feet), and segment four = 0.5–0.0 m (1.6–0.0 feet) above the ground surface. An observer recorded vegetation canopy obstruction of the black and white marked areas on the pole, while another person held the pole vertical at three locations across the center line of each 30-m (98-foot) vegetation and soils monitoring subplots, one reading at 10 m (33 feet), one at 20 m (66 feet), and one at 30 m (98 feet). On the vegetation/soils plots, the observer was located 10 m (33 feet) toward the center of the plot from the pole for each canopy measurement. An overall visual obstruction average score was then calculated for each segment of the pole over each of the three lines per subplot, and an overall average score for each segment was then calculated for each plot.

On the wildlife monitoring plots, both vertical structure and densiometer measurements were taken at 11 locations on each wildlife plot at 12 existing vegetation quadrat points, along the middle lines of six quadrats running north-south, and east-west through the middle of each plot, at 10-m intervals. Vertical vegetation structure profiles are not only important for assessing wildlife habitat, but also for fire fuels structure.

Changes in tree canopy cover as measured by a spherical densitometer showed a reduction in tree canopy cover on all of the treatment plots compared to the control plots (Figure 2.51). However, apparently due to large variation values from measurement points, those differences were not statistically different except for the Wester ponderosa pine site where tree canopy cover was significantly less on the plot that was thinned. Changes in tree canopy vertical structure from ground level to a height of 2 m (6.6 feet) also showed a reduction in lower tree canopy density on the plots that were thinned when comparing the treatment to control plots after thinning in 2011 (Figure 2.52). In 2010 prior to tree thinning, paired plots and the two ponderosa pine sites, Chilili and Wester, had significantly different lower canopy structure ($P = 0.006$, $P = 0.02$, respectively), but treatment and control plots at the Kelly and Vigil piñon/juniper sites were not different. In 2011 following tree thinning, lower tree canopy densities were significantly different at the Chilili and Wester ponderosa pine sites, even more than in 2010 (P > 0.0001, P = 0.001, respectively), and significantly different at the Vigil piñon/juniper site (P < 0.0001), but not at the Kelly piñon/juniper site. These findings indicate that forest thinning had a greater effect on lower canopy structure of trees than the upper canopy and that forest thinning did open the tree canopy on thinned plots compared to adjacent non-thinned control plots.

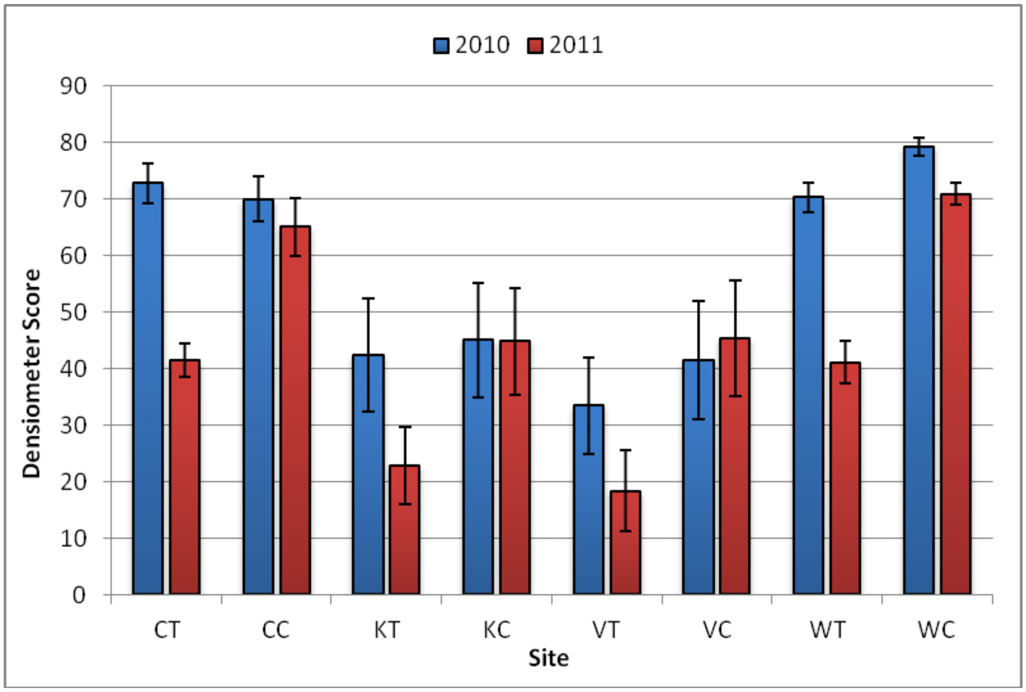


Figure 2.51. Upper tree canopy cover scores as measured from a spherical densiometer on each of the monitoring plots. Densiometer scores range from 0 to 96, similar to percent cover.

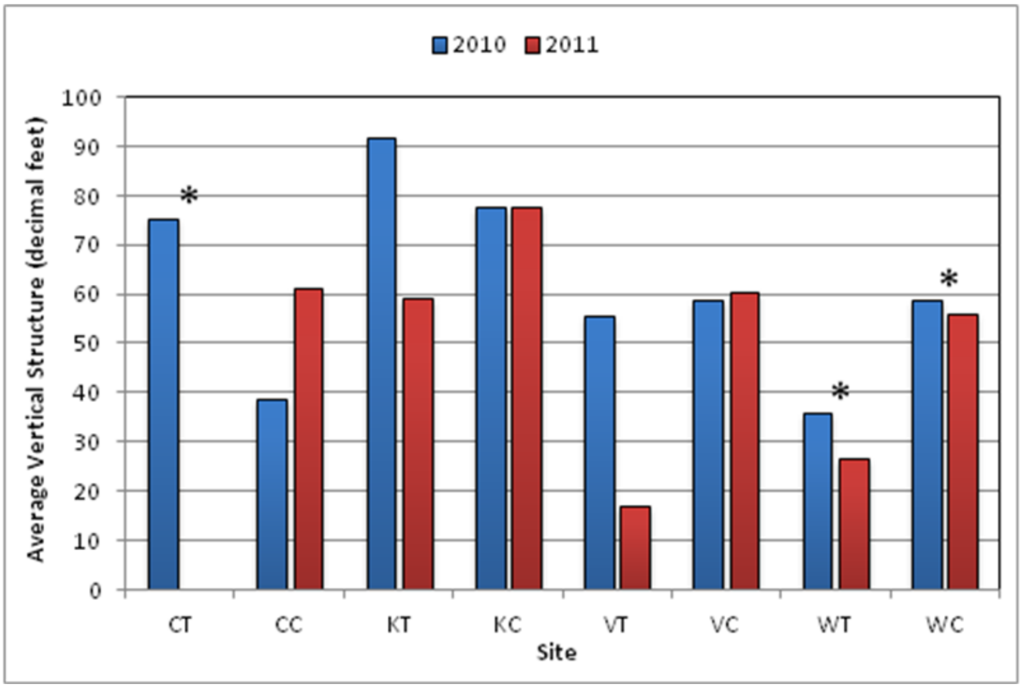
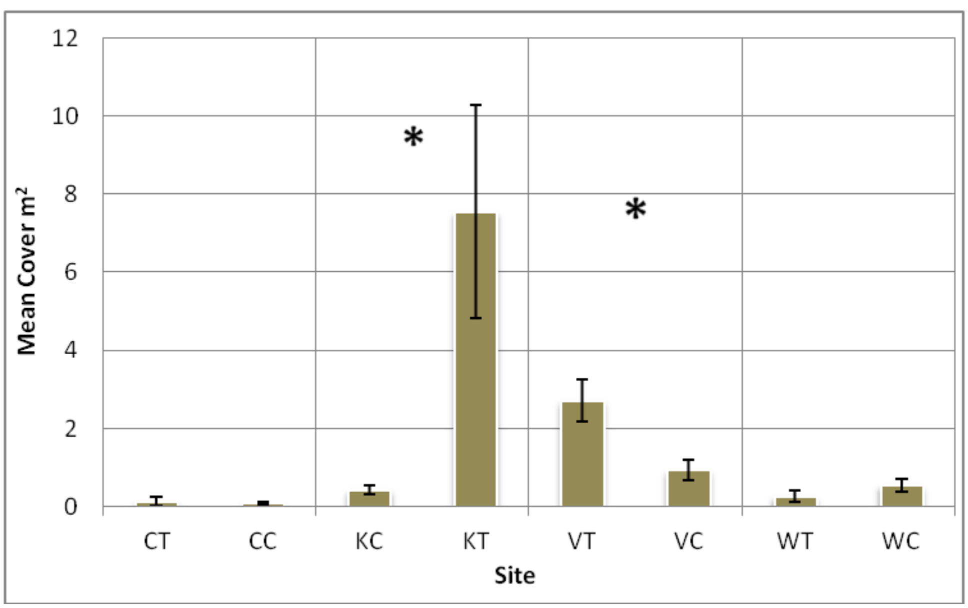
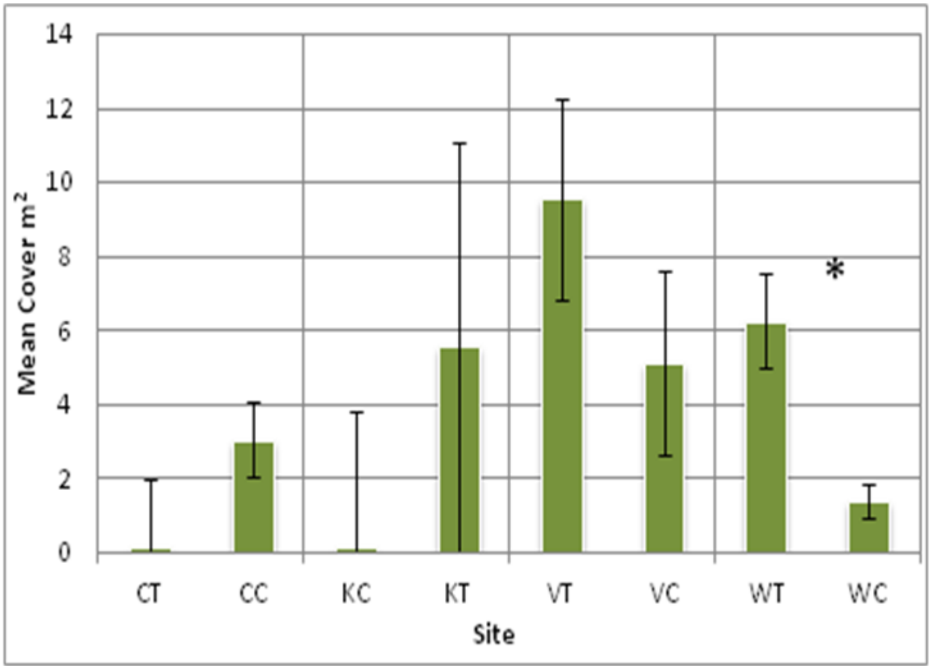


Figure 2.52. Vegetation vertical structure cover from ground level to a height of 2 m (6.6 feet), measured with a vertical structure pole. The higher the score, the denser the canopy cover (note that CT had a value of zero in 2011).

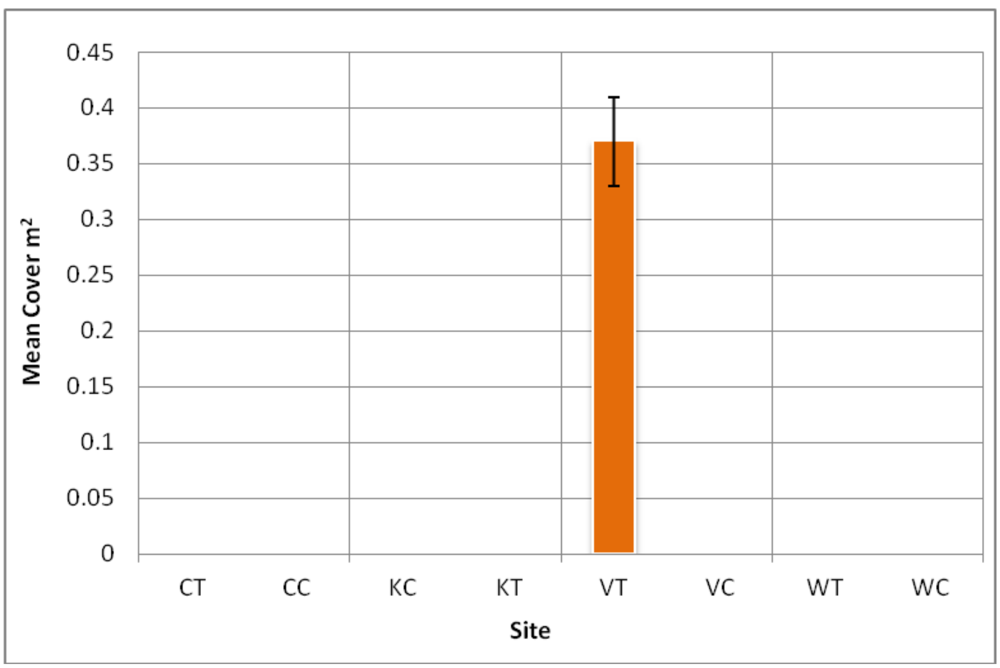
Values for vegetation and ground cover types measured in the fall 2011 are presented in Figure 2.53, providing separate graphs for each ground cover type. The relative percentage of herbaceous vegetation and other types of ground cover at each study plot in 2010 and again in 2011 are presented in Figure 2.54 and Figure 2.55, respectively. Results of statistical t-tests of differences between mean cover values for each of the different vegetation and ground surface cover types are presented in Table 2.10.



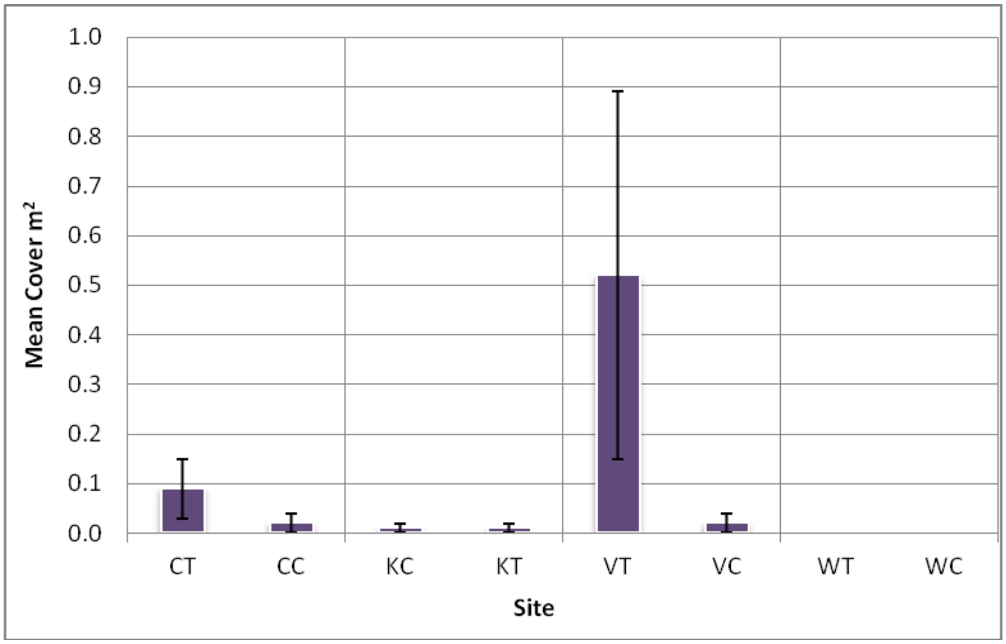
a. Forbs.



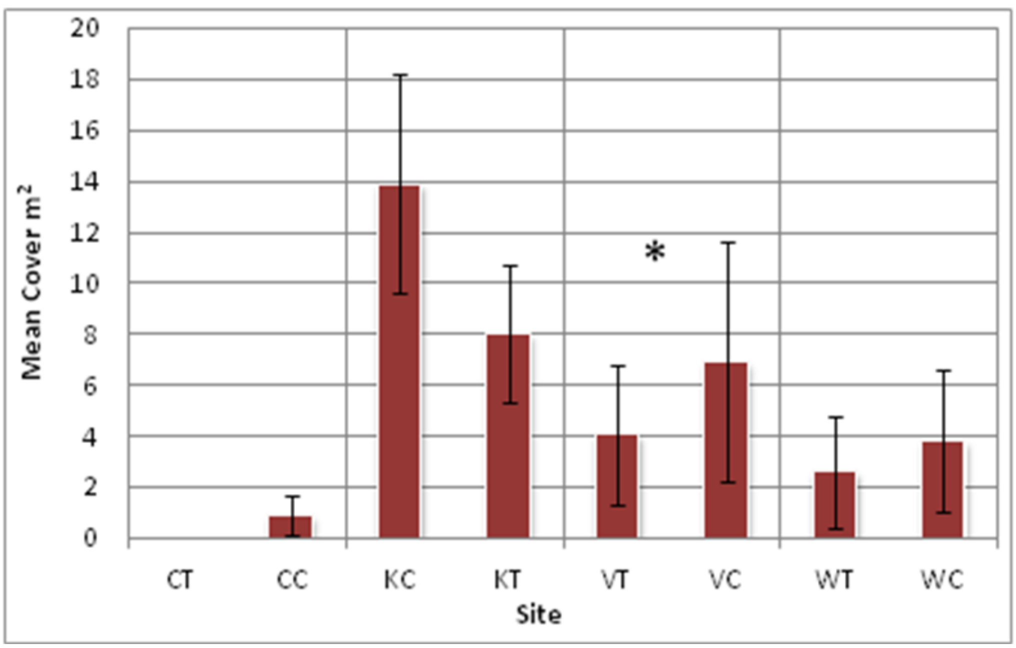
b. Grasses.



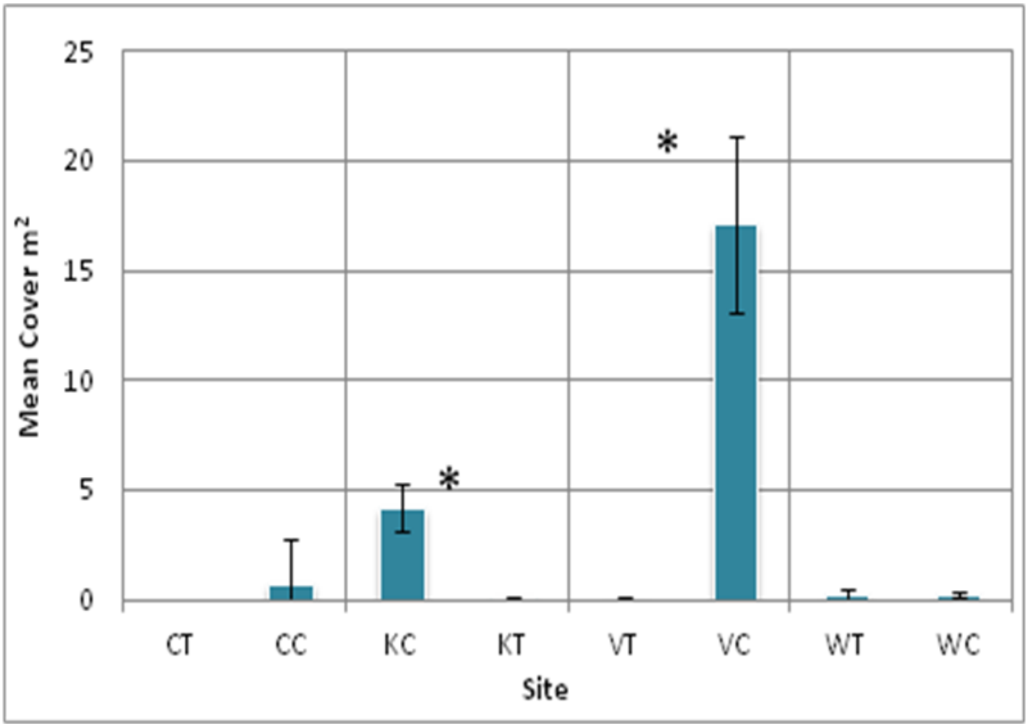
c. Cacti.



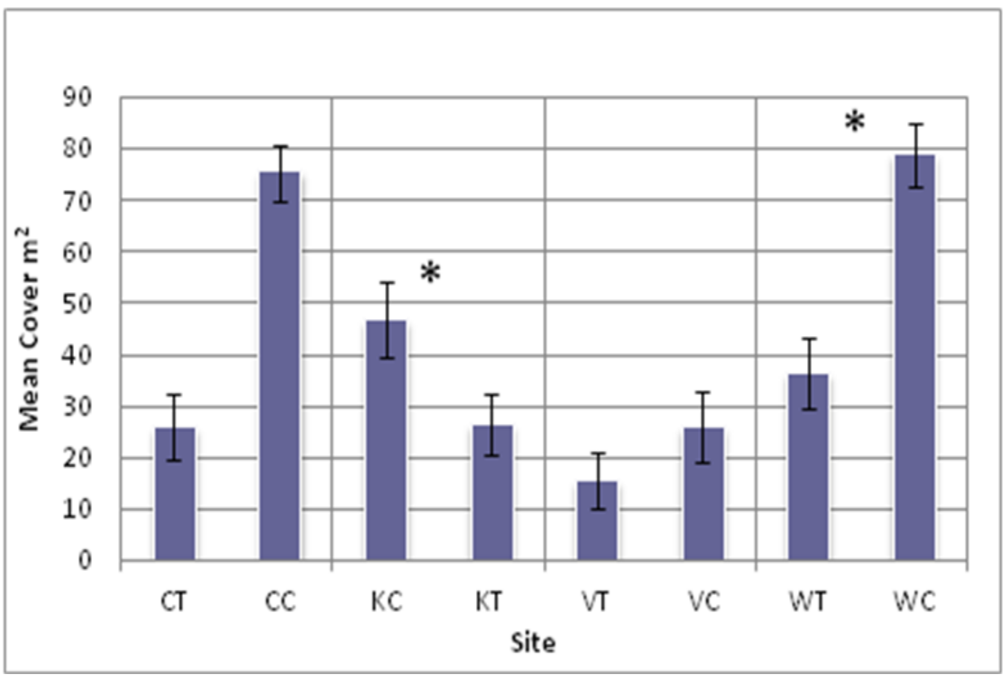
d. Shrubs.



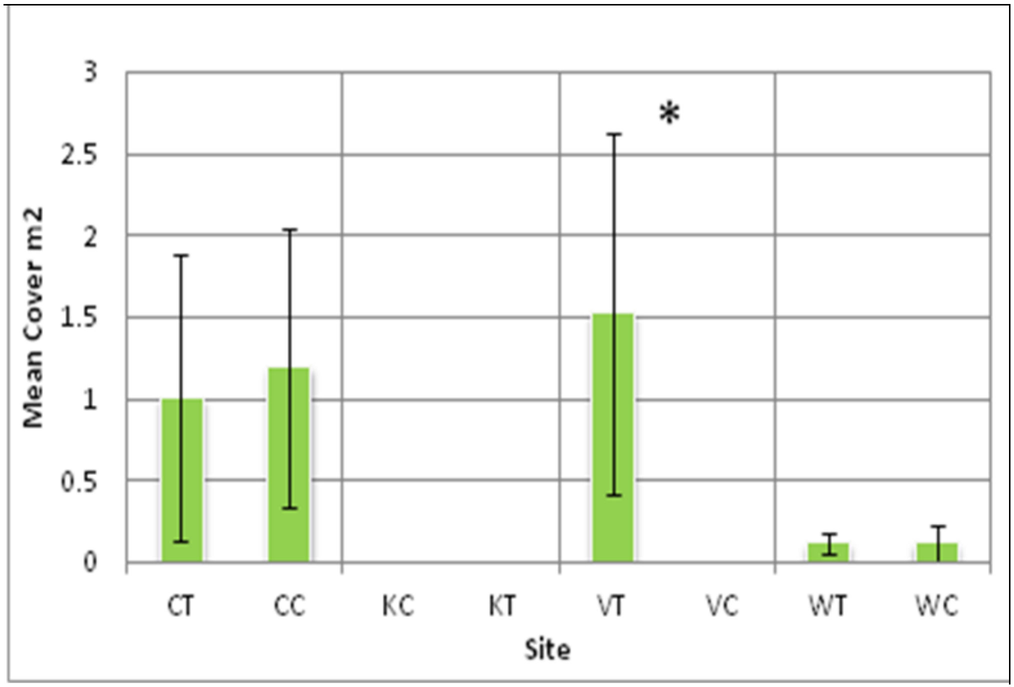
e. Bare soil.



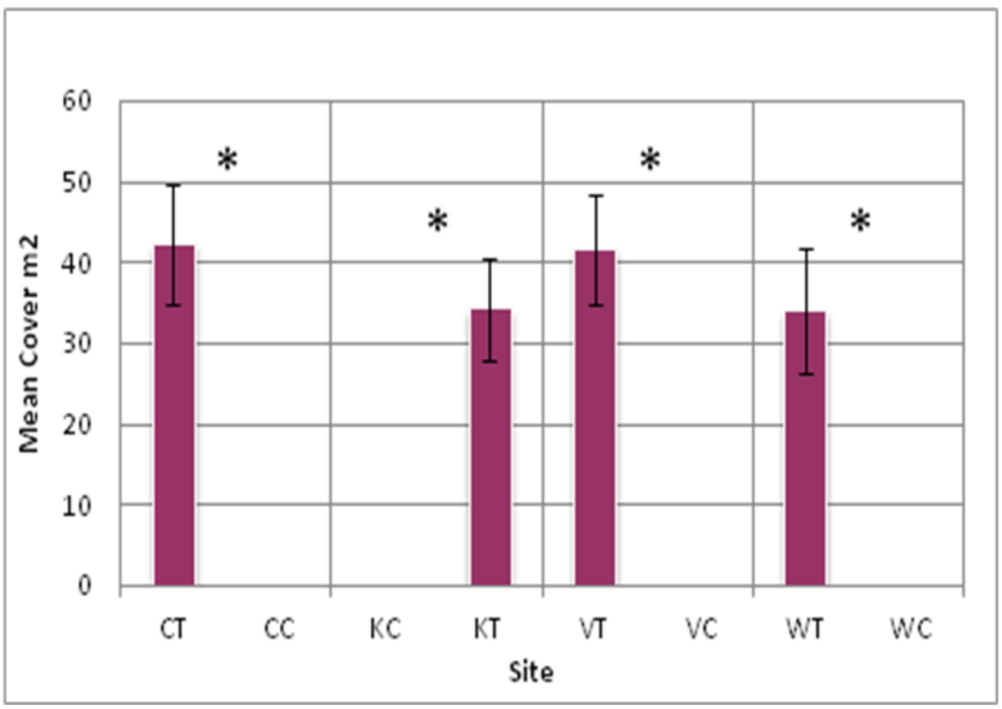
f. Cryptobiotic soil crust.



g. Leaf litter and downed wood.



h. Rock.



i. Wood chips.

Figure 2.53. These graphs illustrate the mean values cover type found across all vegetation quadrats among all of the study sites and paired study plots in fall 2011. Note that the vertical axis scales vary among these graphs in order to best present each cover type. Error bars represent +/- one standard error of the mean.

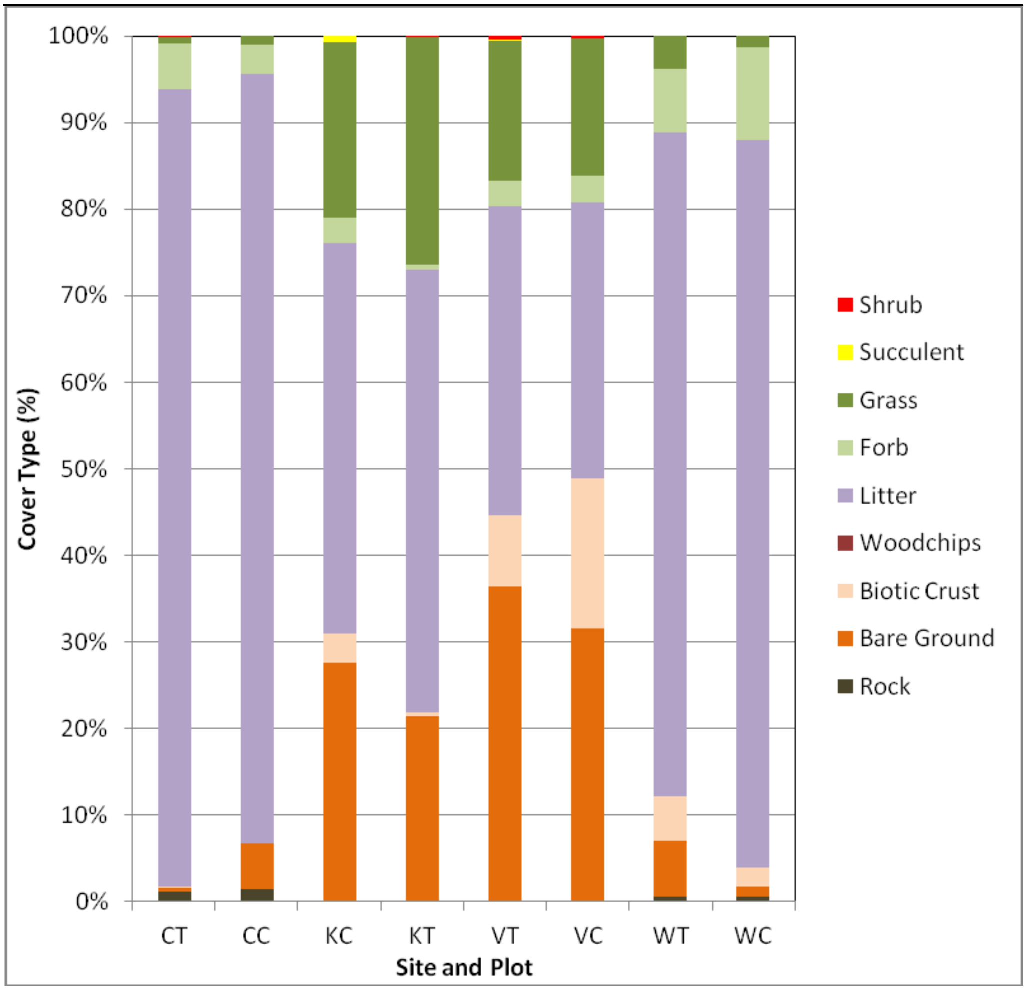


Figure 2.54. Percentages of mean cover of various vegetation and ground surface cover types measured over thirty-six 1-m² (10.7-square-foot) quadrats per wildlife study plot at all of the forest thinning study plots to illustrate relative differences among sites and plots in 2010.

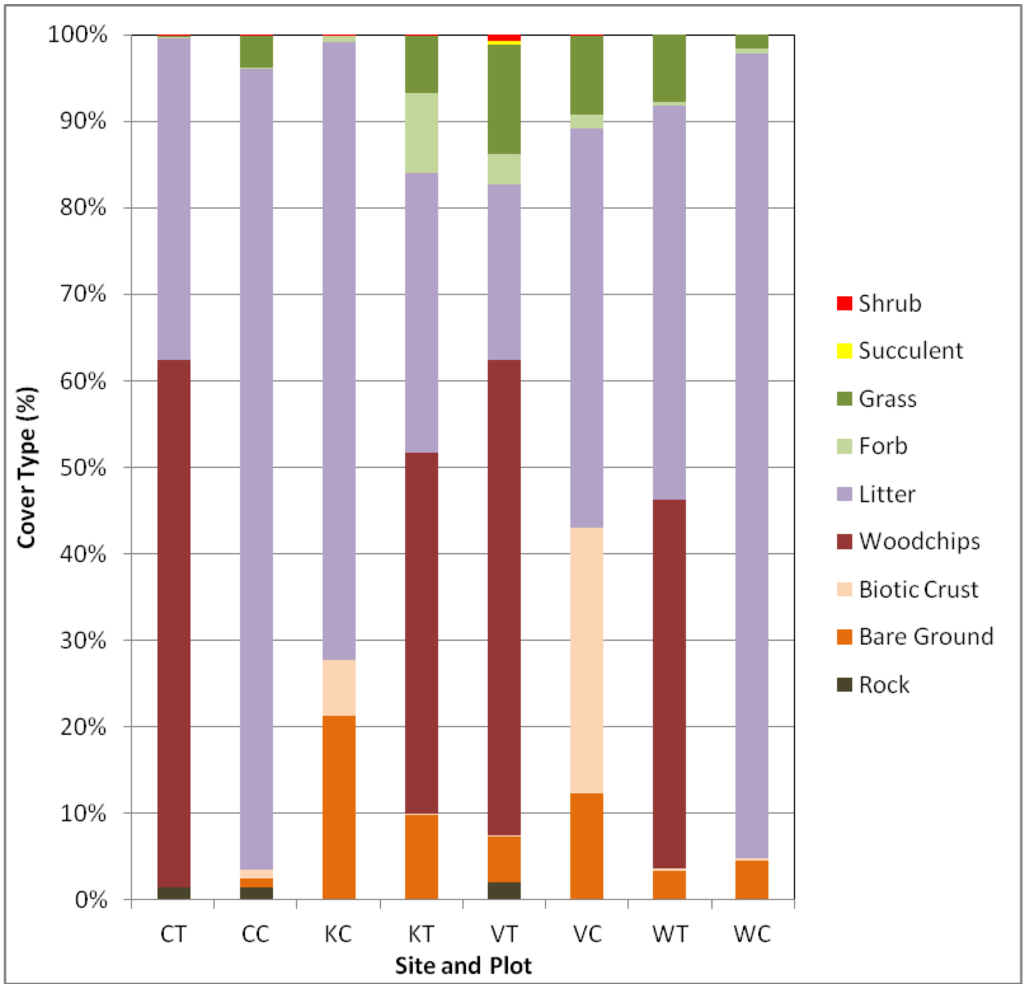


Figure 2.55. Percentages of mean cover of various vegetation and ground surface cover types measured over thirty-six 1-m² (10.7-square-foot) quadrats per wildlife study plot at all of the forest thinning study plots to illustrate relative differences among sites and plots in 2011.

Table 2.10. Test Results for T-tests of No Difference between Mean Values of Vegetation and Ground Cover Types Measured from Vegetation Quadrats on Each Wildlife Study Plot Pair at the Four Study Sites in 2011

Site	Parameter	Treated Mean	Control Mean	P-value (significance)
Chilili	Forbs	0.14	0.08	0.64
	Grasses	2.89	3.04	0.94
	Cacti	–	–	–
	Shrubs	0.09	0.03	0.32
	Bare soil	0.00	0.86	0.27
	Cryptobiotic crust	0.00	2.78	0.16
	Leaf litter	**25.75**	**75.42**	**<0.0001**
	Rock	1.00	1.19	0.87
	Wood chips	**42.22**	**0.00**	**<0.0001**

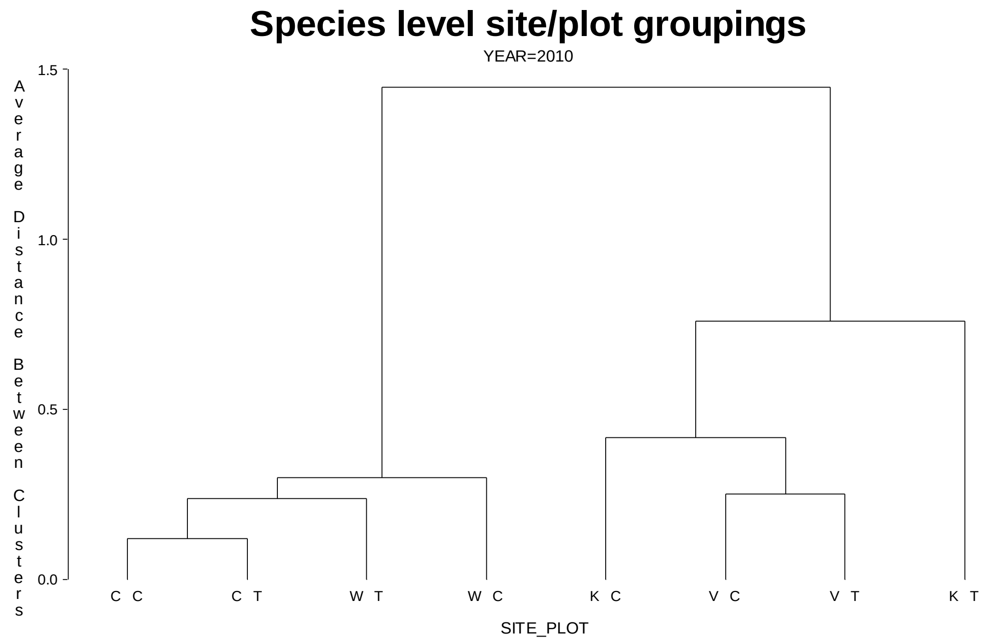
Site	Parameter	Treated Mean	Control Mean	P-value (significance)
Kelly	**Forbs**	**7.55**	0.43	**0.01**
	Grasses	5.55	**12.51**	0.11
	Cacti	0.00	**0**	-
	Shrubs	0.01	**0.01**	1.00
	Bare soil	8.03	**13.89**	0.25
	Cryptobiotic crust	**0.08**	4.22	**0.0004**
	Leaf litter	**26.30**	46.58	**0.03**
	Rock	0.00	**0**	-
	Wood chips	**34.11**	0	**<0.0001**
Vigil	**Forbs**	**2.72**	**0.94**	**0.005**
	Grasses	9.54	5.13	0.23
	Cacti	0.04	0.00	0.32
	Shrubs	0.53	0.03	0.18
	Bare soil	**4.05**	**22.92**	**0.0009**
	Cryptobiotic crust	**0.05**	**17.11**	**0.0001**
	Leaf litter	15.33	25.78	0.23
	Rock	**1.53**	**0.00**	**<0.0001**
	Wood chips	**41.64**	**0.00**	**<0.0001**
Wester	Forbs	0.26	0.55	0.19
	Grasses	**6.25**	**1.39**	**0.0007**
	Cacti	–	–	–
	Shrubs	0.00	0.00	-
	Bare soil	0.28	0.22	0.85
	Cryptobiotic crust	0.28	0.22	0.85
	Leaf litter	**36.25**	**78.81**	**<0.0001**
	Rock	0.11	0.11	1.00
	Wood chips	**33.94**	**0.00**	**>0.0001**

All tests were with sample sizes of 36; p-values of less than 0.05 represent significant differences. Parameters in bold represent those with significant differences between paired plots. Refer to Figure 2.53 for graphical illustrations of differences in mean values. Dashes represent instances where that particular cover type was not found on either of the paired plots.

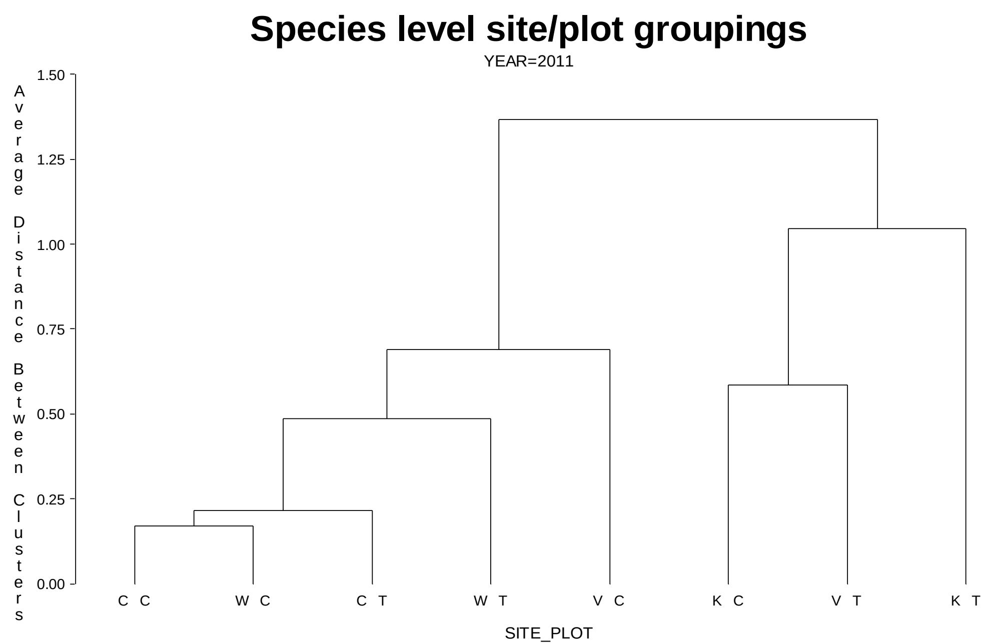
Results of vegetation and ground cover data analysis measured from wildlife plot quadrats show that in general, herbaceous vegetation showed little response to tree thinning, but ground cover variables did change considerably. Forb cover was significantly higher on the treated plot at the Vigil site, and grass cover was significantly higher on the treated plot at the Wester site; otherwise, there were no significant differences in vegetation between treated and control plots. In 2010, prior to thinning treatments, these differences found in 2011 were not present (SWCA 2011). Leaf litter was significantly less on the treated plots than control plots at Chilili, Wester, and Kelly sites, but not at the Vigil site. Bare soil was significantly less on treated plots than untreated plots at the Vigil site, and cryptobiotic soil surface crusts were significantly lower on the treated plots at the Vigil and Kelly sites. However, cryptobiotic crust cover was already greater on those same control plots in 2010 prior to thinning treatments (SWCA 2011), so the difference found in 2011 was not caused by thinning. Wood chips on the ground surface as a result of chipping thinned trees on treatment plots was significantly greater on the treated plots than on control plots at all four sties (see Figure 2.53i, Table 2.10). Wood chips on treatment plots covered other ground surfaces such as bare soil, cryptobiotic crusts, and natural leaf litter.

At a couple of sites herbaceous vegetation cover increased in response to tree thinning, at no sites was there a significant reduction in herbaceous vegetation cover. Overall, these findings show that thinning trees and spreading wood chips reduced natural ground cover as it was replaced by wood chips and enhanced herbaceous vegetation at half of the sites. The severe regional drought of 2011 resulted in decreased plant growth, especially herbaceous plants. Therefore, the effects of tree thinning may have been less on vegetation in 2011 than in a year with typical rainfall amounts.

Measurements of herbaceous vegetation on the thirty-six 1-m² (10.7-square-foot) quadrats also provided information on the canopy cover of each plant species per quadrat. The similarity of plant species composition among all of the study plots over the four-year monitoring period was evaluated with the analytical method called cluster analysis (McCune and Grace 2002). Cluster analysis is useful for evaluating sets of species abundance when many species are involved. Cluster analysis compares sets of species/abundance data and determines how similar those sets are, then graphically represents their similarities as dendrograms or tree diagrams. The closer terminal branches are in those diagrams, the more similar those sets of species are in terms of composition and relative abundance. Cluster analysis dendrograms for all sites and plots for the spring and fall sampling periods for the years 2010 and 2011 are presented in Figure 2.56. Cluster analysis shows that in 2010 (see Figure 2.56a), prior to tree thinning treatments, the ponderosa pine sites (Chilili and Wester) grouped together, the piñon/juniper sites (Kelly and Vigil) grouped together, and the paired plots at each ponderosa site were more similar to each other than to the other site. The Vigil paired plots also grouped together, but the Kelly plots were not as similar to each other as Kelly plot 1 was to the Vigil plots, based on plant species compositions. There were no groupings of treatment versus control plots in 2010. In 2011, those location-based groupings were less pronounced (see Figure 2.56b). The Kelly control plot and Vigil treatment plot grouped together, distinct from all other plots. All other plots showed weak groupings at different levels of similarity, especially the ponderosa site (Chilili and Wester) plots, and no clear patterns were based on treatment versus control plots. These results indicate that the tree thinning treatments altered the location-based patterns found in 2010, but do not reveal particular treatment-based or plant-community–based groupings at this time, less than one year following treatments.



a. 2010.



b. 2011.

Figure 2.56. Cluster analysis results showing the similarity of monitoring sites and paired plots based on similarity of the herbaceous plant community species compositions: a. 2010 and b. 2011.

Results of vegetation and ground cover monitoring showed that forest thinning did affect the physical structure of the woodland from reducing tree canopy and greatly affected the ground surface following the application of wood chips. Also, these findings show that at half of the study sites, herbaceous vegetation increased significantly on plots where trees were thinned, and that the patterns of location-based plant community similarities were altered by forest thinning treatments. These findings are within one year of tree thinning treatments. As vegetation adjusts to the removal of some trees, and the effects of wood chips decomposing on the ground surface, more changes in vegetation and ground cover features are likely in years to come as a response to tree thinning.

2.8 WILDLIFE

Birds and small mammals are being monitored in order to determine if forest thinning affects native wildlife species. Both birds and small mammals were recorded from separate 50 × 50–m (164 × 164–foot) wildlife study plots that are immediately adjacent to each of the two vegetation and soils monitoring study plots at the four study sites. Birds and mammals were measured in late spring (May/June) and early fall (September/October) 2008, 2009, 2010, and 2011 for three consecutive days on each study plot.

2.8.1 BIRDS

The species composition and relative abundance of birds on all study plots were recorded by observing birds by point counts from one location at the center of each wildlife study plot. Each point count was conducted for 20 minutes at dawn for three consecutive mornings on each study plot in both spring and fall. Spring counts are intended to assess breeding bird use of the forest and woodland habitats, and fall counts are intended to assess migratory bird use of the same habitats. Many of the bird observations were based on hearing songs and calls and identifying those to species. Additionally, visual observations were often recorded. A list of all bird species observed across the four study sites and counts of individuals are presented in Appendix A. SWCA encountered a total of 40 bird species from all of the study sites.

Numbers of birds varied considerably from site to site and among plots over the four years of monitoring (Figure 2.57). Bird abundance tended to be highest at the piñon/juniper sites compared to the ponderosa pine sites. Abundance patterns among treatment and control monitoring plots did not change in 2011 following thinning treatments.

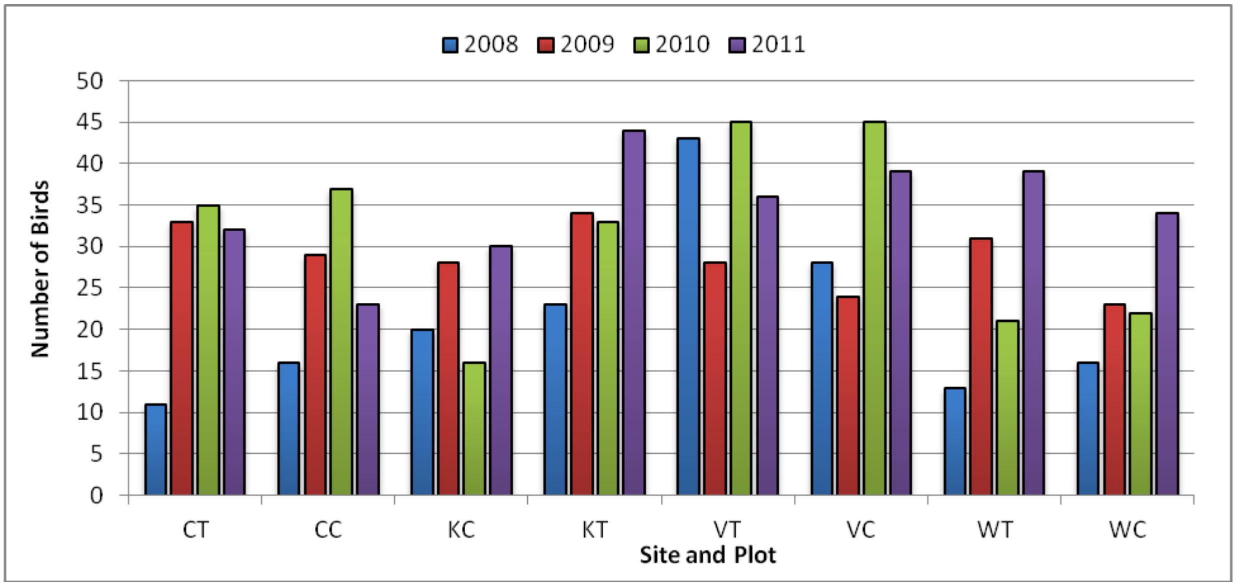
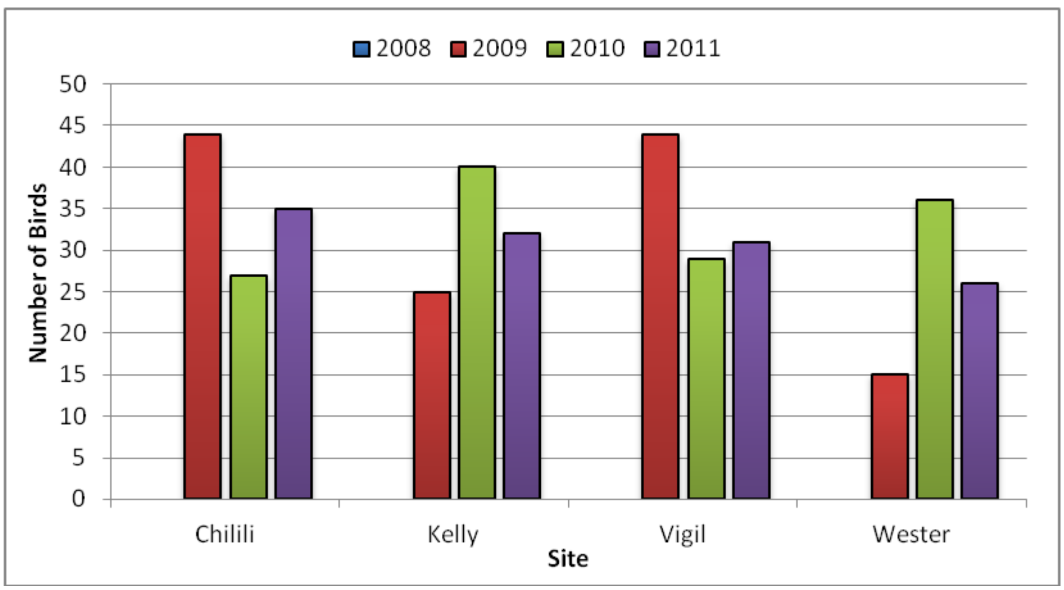
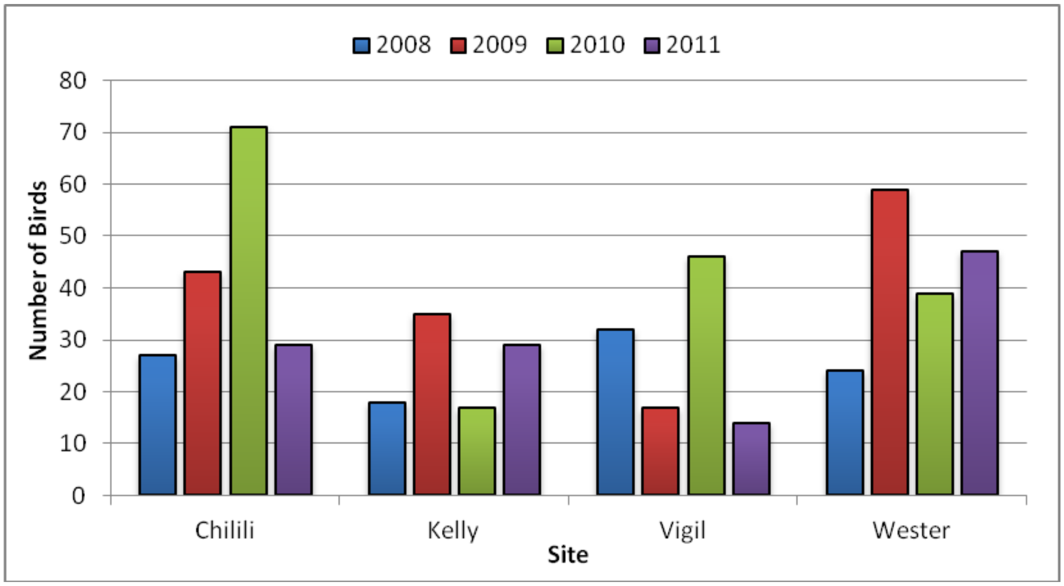


Figure 2.57. Bird abundance across monitoring sites and plots from 2008 through 2011.

Seasonal bird abundance showed different patterns between spring and fall sampling periods, over the four-year monitoring period (Figure 2.58). Spring breeding season counts tended to be similar across all monitoring sites, while fall migration counts tended to be highest at the piñon/juniper sites. Otherwise, there were no clear patterns relative to abundance across sites and years.



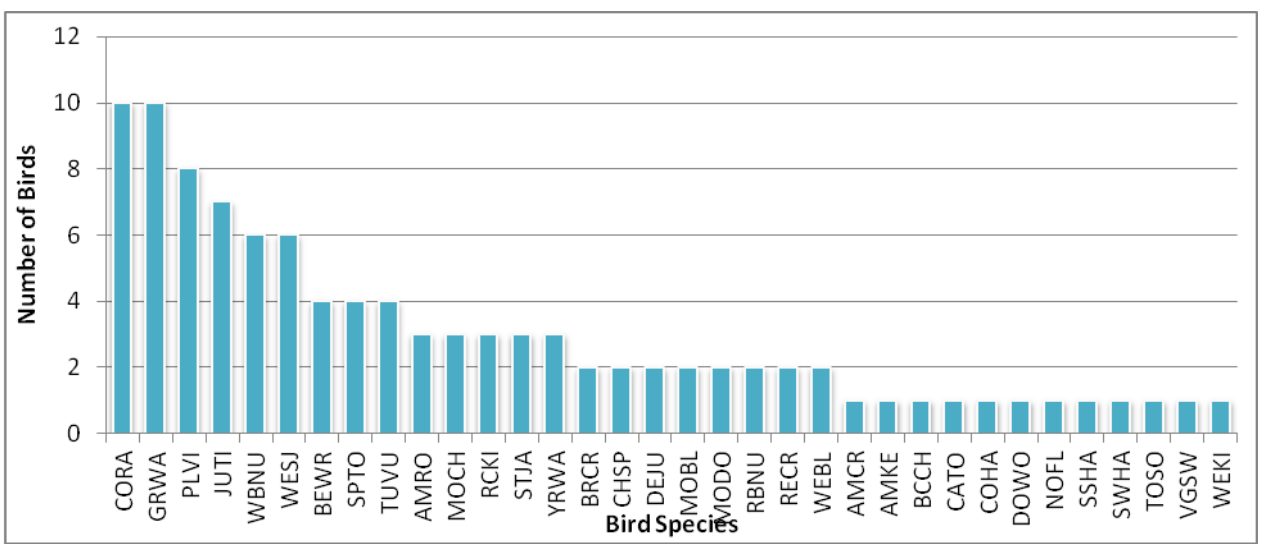
a. Spring.



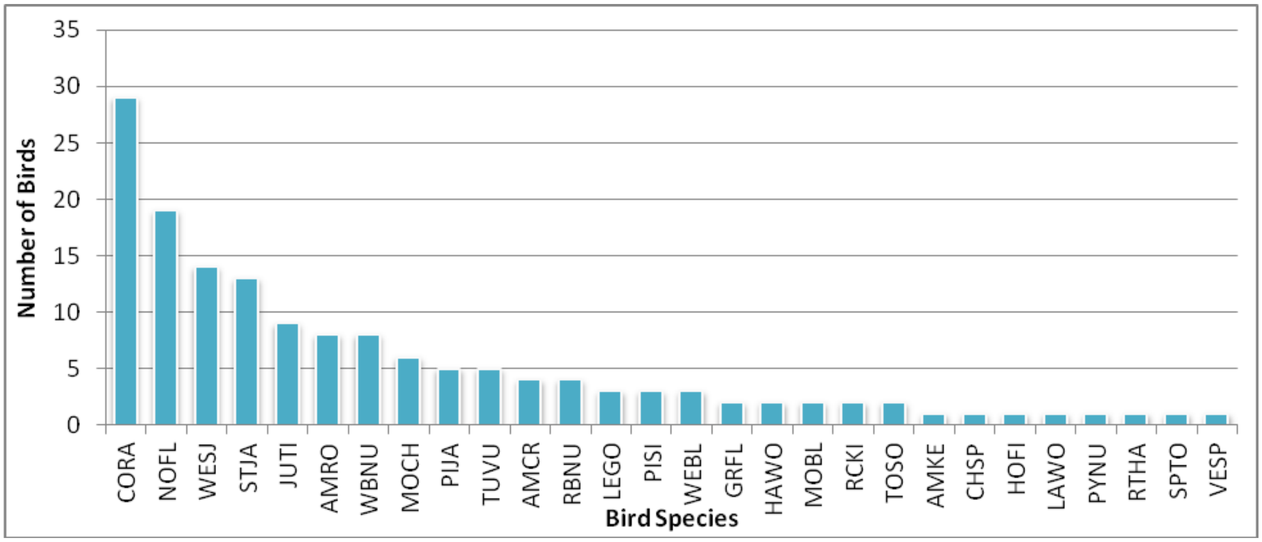
b. Fall.

Figure 2.58. Total numbers of all birds observed at each monitoring site from 2008 through 2011, during a. the spring and b. the fall sampling periods of each year (note that monitoring for birds did not begin until fall of 2008).

The total number of bird individuals by species during the spring and fall monitoring periods of 2011, summed over all sites and plots are presented in Figure 2.59 a and b, respectively, in order of rank abundance (see Appendix A for full names that correspond to the codes). Common raven (*Corvus corax*) was the most abundant bird species during both the spring and fall of 2011. Other common spring breeding season birds included Grace's warbler (*Dendroica graciae*), plumbeous vireo (*Vireo plumbea*), and juniper titmouse (*Baeolophus ridgwayi*), and other common fall bird species included northern flicker (*Colaptes auratus*) and western scrub jay (*Aphelocoma californica*).



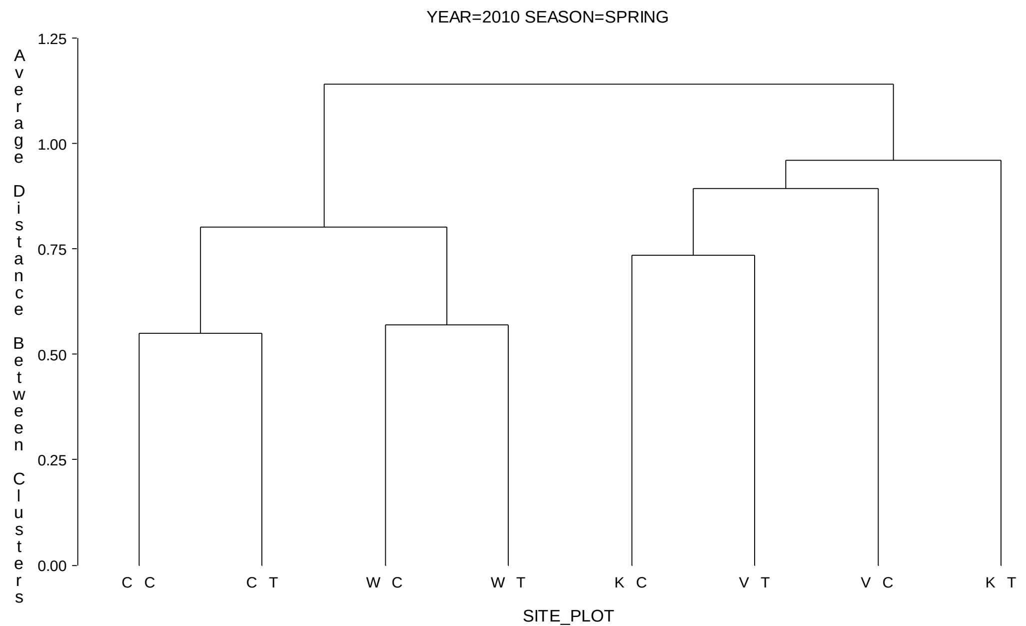
a. Spring.



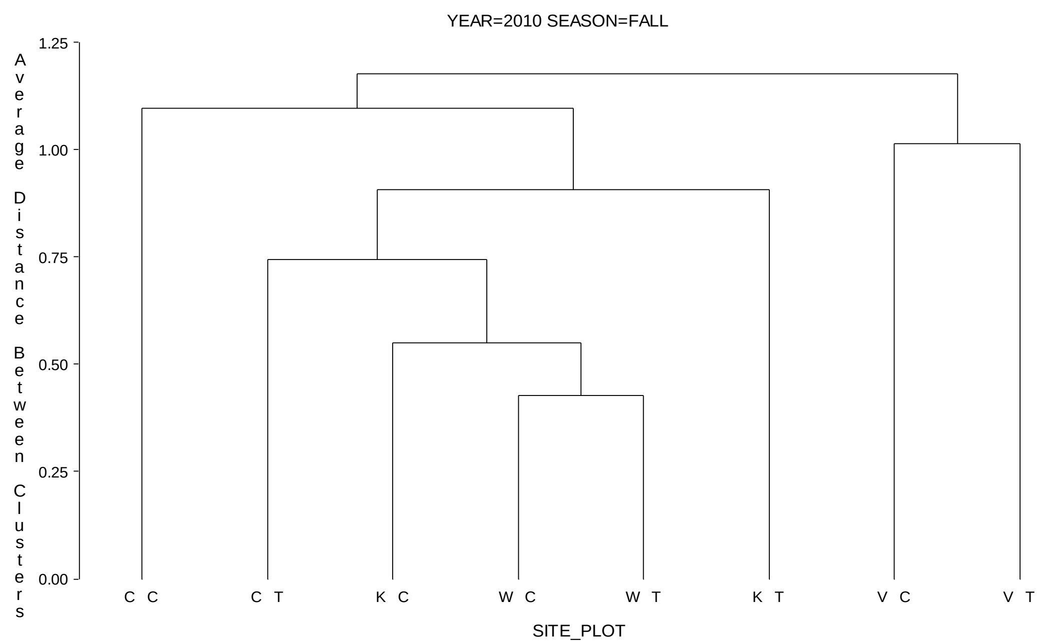
b. Fall.

Figure 2.59. Total number of birds by species for: a. spring and b. fall 2011, on all sites and all plots, from most abundant to least abundant. Refer to Appendix A for full names based on codes.

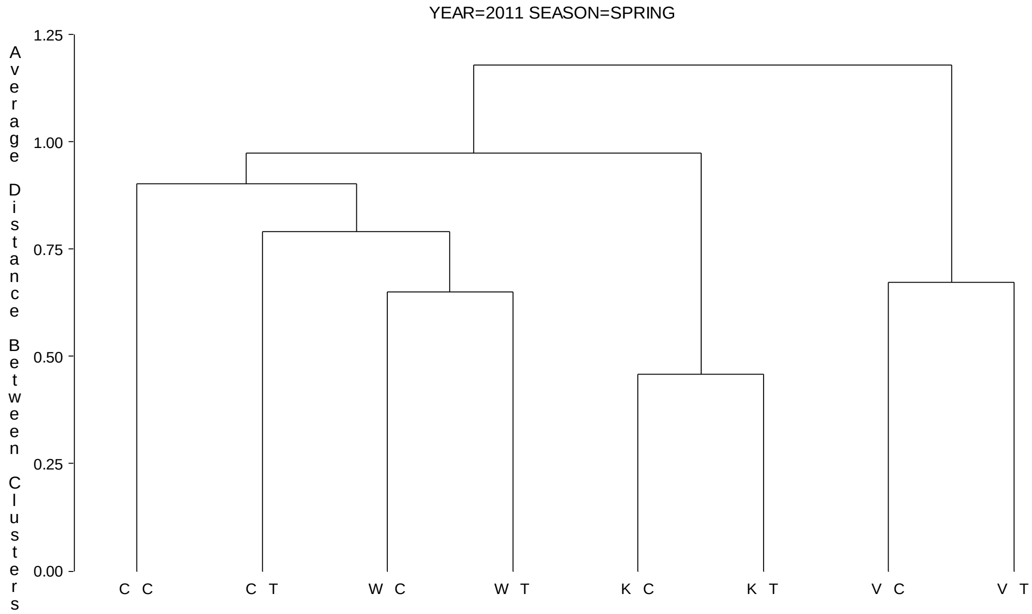
Cluster analysis dendrograms for all sites and plots for the spring and fall sampling periods for the years 2010 and 2011 are presented in Figure 2.60. Cluster analysis shows that over the two-year period, 2010 through 2011, bird communities were most similar to each other based on location. The ponderosa pine sites and plots within sites tended to group together, and the piñon/juniper sites and plots within sites tended to group together. This pattern was especially pronounced during the spring breeding period. As of fall 2011, the bird communities have not shown a response to forest thinning treatments, in which case plots would group together based on treatment status rather than location.



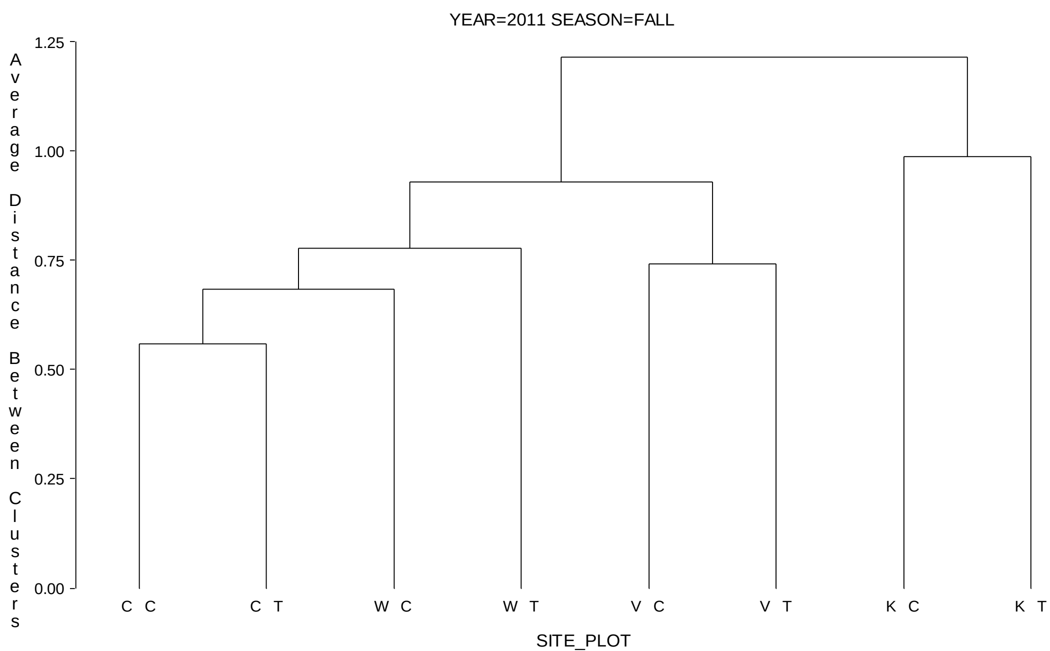
a. 2010, spring.



b. 2010, fall.



c. 2011, spring.



d. 2011, fall.

Figure 2.60. Cluster analysis dendrograms showing similarities of monitoring sites/plots based on bird species composition, spring and fall 2010 prior to tree thinning treatments (a and b) and 2011 following thinning treatments (c and d).

2.8.2 Small Mammals

Small mammals (rodents) were sampled from a single six × six–trap grid (36 traps total) of live-capture rodent traps set at 10-m (33-foot) intervals on each of the wildlife monitoring plots for three consecutive nights in spring and fall, the same dates that birds were sampled in 2008, 2009, 2010, and 2011. Samples from spring and fall are useful to follow trends in adults and juveniles in order to assess breeding status and production over the year, but season species composition generally does not change as with birds.

Rodent abundance over the entire four-year monitoring period is presented in Figure 2.61. Rodent densities peaked in 2009, declined in 2010, and then increased again in 2011.

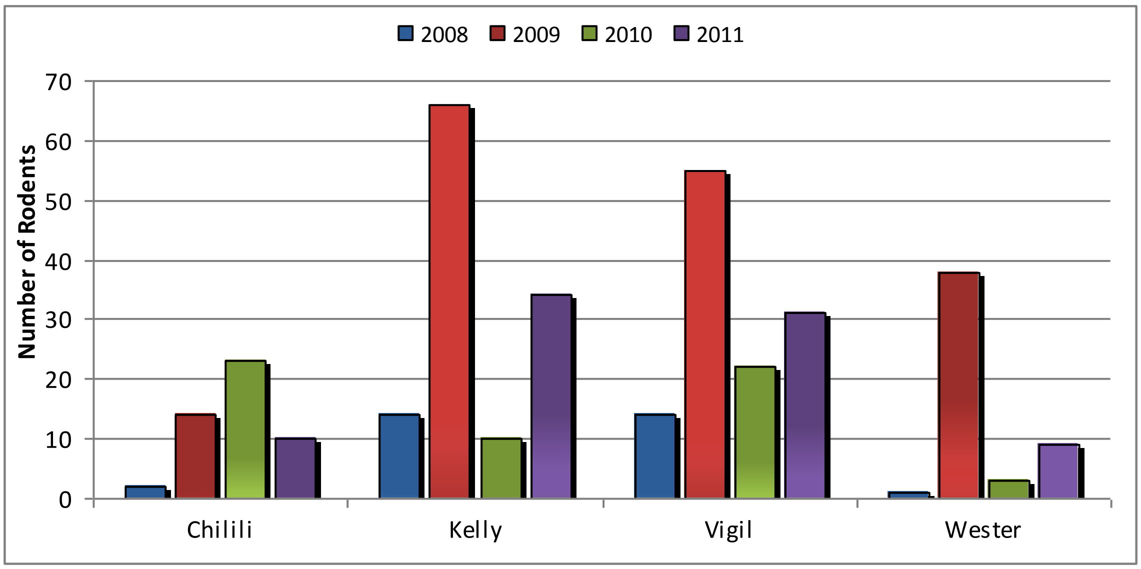
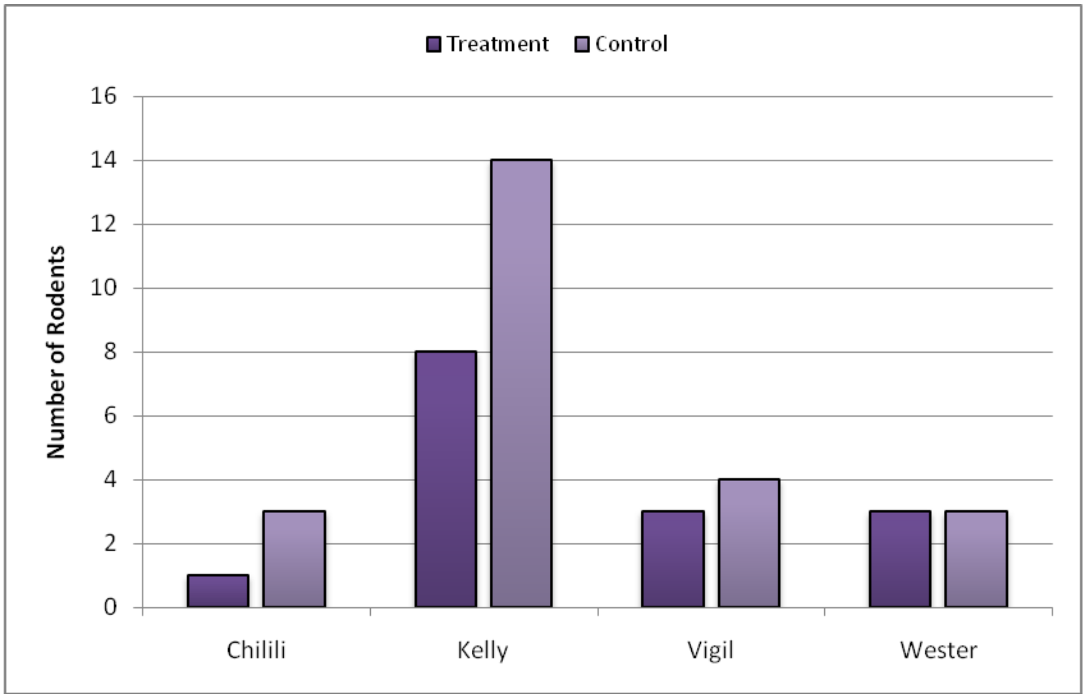
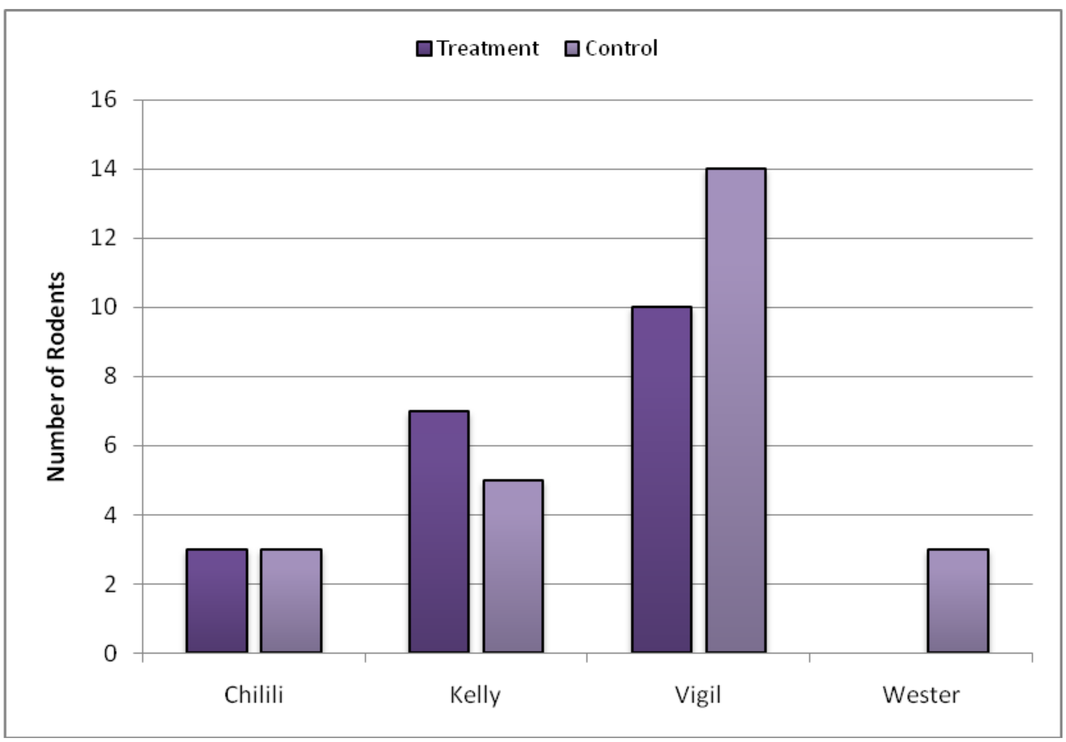


Figure 2.61. Total rodent abundance from 2008 through 2011, summed over all monitoring sites and plots, spring and fall periods.

The total numbers of rodents observed on paired study plots among the sites in spring and fall 2011 are presented in Figure 2.62. The spring data show that rodent densities were in general lower on the treatment plots where trees were removed than on adjacent control plots. The Kelly site had the highest numbers of rodents in the spring, and there were more on the non-thinned control plot than on the thinned plot; those rodents were dominated by piñon mouse (*Peromyscus truei*). Rodent densities were relatively low at all other sites, and there were little differences between treatment and control plots. The Vigil site had the highest rodent densities in the fall, and more rodents were found on the non-thinned control plot than on the treated plot, dominated by piñon mouse. The Kelly site had slightly more rodents on the treated plot than the control plot in the fall. At the Wester site, no rodents were found on the treated plot, and only three were found on the control plot. Those rodents were deer mouse (*P. maniculatus*). Overall, rodent densities tended to be higher on the control plots than the treated plots.



a. Spring.



b. Fall.

Figure 2.62. Rodent abundance from 2011 spring and fall sampling across monitoring sites and paired plots.

Figure 2.63 shows the abundance of each rodent species over the four-year study period. Piñon mouse and deer mouse dominated the species composition, and piñon mouse was dominant at the piñon/juniper sites, while deer mouse was dominant at the ponderosa pine sites. As with overall rodent abundance, individual species abundance varied considerably over the years, peaking in 2009 and declining through 2011.

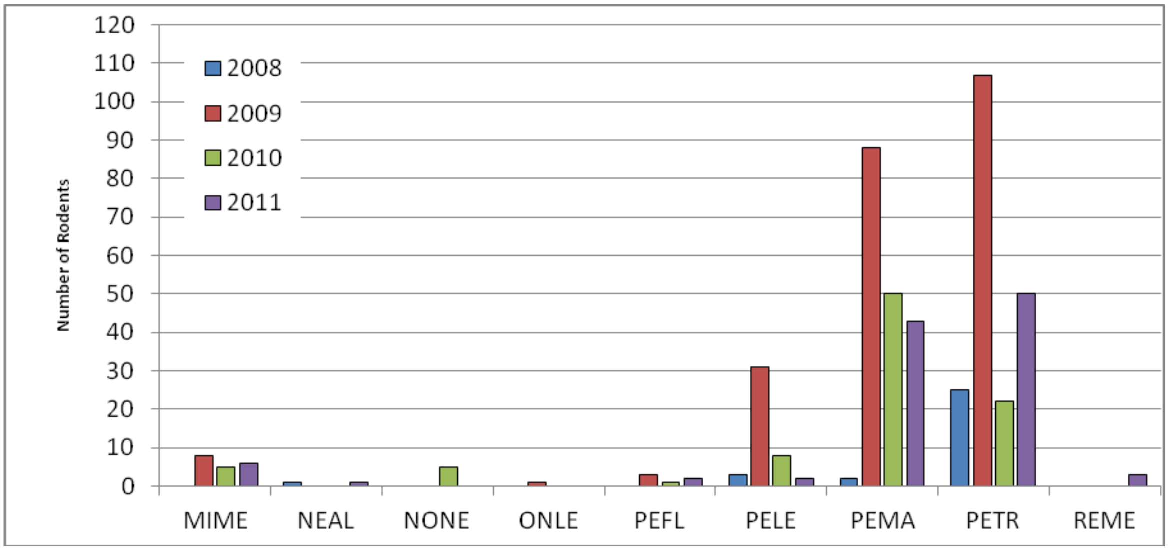


Figure 2.63. Total numbers of individuals of each rodent species across all study plots over the four years of monitoring. Refer to Appendix A for full names based on codes.

Overall, these findings show that rodent abundance decreased on plots where trees were thinned. Also, overall rodent population abundance across the entire study area has been changing over time, with a peak in 2009, and a steady decrease through 2011, coincident with the severe regional drought in 2011.

3.0 POST-FIRE MONITORING

In April 2008 a large area of the Estancia Basin watershed was burned in the 13,709-acre Trigo fire. This burn area encompassed a large portion of the Cibola National Forest and also included 3,712 acres of private land on its eastern fringe. Since three large wildfires (Ojo Peak, Trigo, and Big Spring) have burned a considerable portion of the eastern slopes of the Manzano Mountains, the impacts of wildfire on Estancia Basin watershed health are likely significant. The Steering Committee awarded SWCA funding to develop and implement post-fire monitoring to evaluate wildfire impacts to Estancia Basin watershed health. The Trigo fire was chosen for the monitoring because it was the largest of the three fires and was centrally located within the study region and relative to the existing forest thinning monitoring sites. The full fire monitoring plan for this project was prepared and submitted to the Steering Committee in July 2008 (SWCA 2008), and the first year of monitoring was reported in the 2008 Annual Report (SWCA 2009).

The Trigo post-fire monitoring plots were selected in Arroyo de Cuervo (Cuervo 1 and Cuervo 2) and in the Arroyo de Manzano (Manzano 1) watersheds. Three low-severity (Figure 3.1) and three high-severity (Figure 3.2) plots were identified in each watershed, and three unburned (U) plots were located across the watersheds. With the permission of landowners, the plots were selected on seven different private parcels of land: Bouton (BOU), Sanchez (SAN), Manzano Mountain Retreat (MMR), Salazar (SAL), Candelaria (CAN), Mitchell (MIT), and Neff (NEFF), totaling 21 plots for the entire study (Figure 3.3).

This was the fourth and final year of monitoring for the Trigo fire study. Monitoring on the 21 fire plots has been completed by SWCA in fall 2008, spring and fall 2009, spring and fall 2010, and spring and fall 2011. However, due to safety concerns about falling trees at both the high- and low-severity sites during the fall measurement period of 2011, the Steering Committee and SWCA decided to suspend the current study until sometime into the future when monitoring conditions are safer. However, site monumentation was left in place in anticipation of future studies looking at the long-term effect of this large wildfire.

Figure 3.1. Typical low burn severity plot in the Trigo burn area.

Figure 3.2. Typical high burn severity plot in the Trigo burn area.

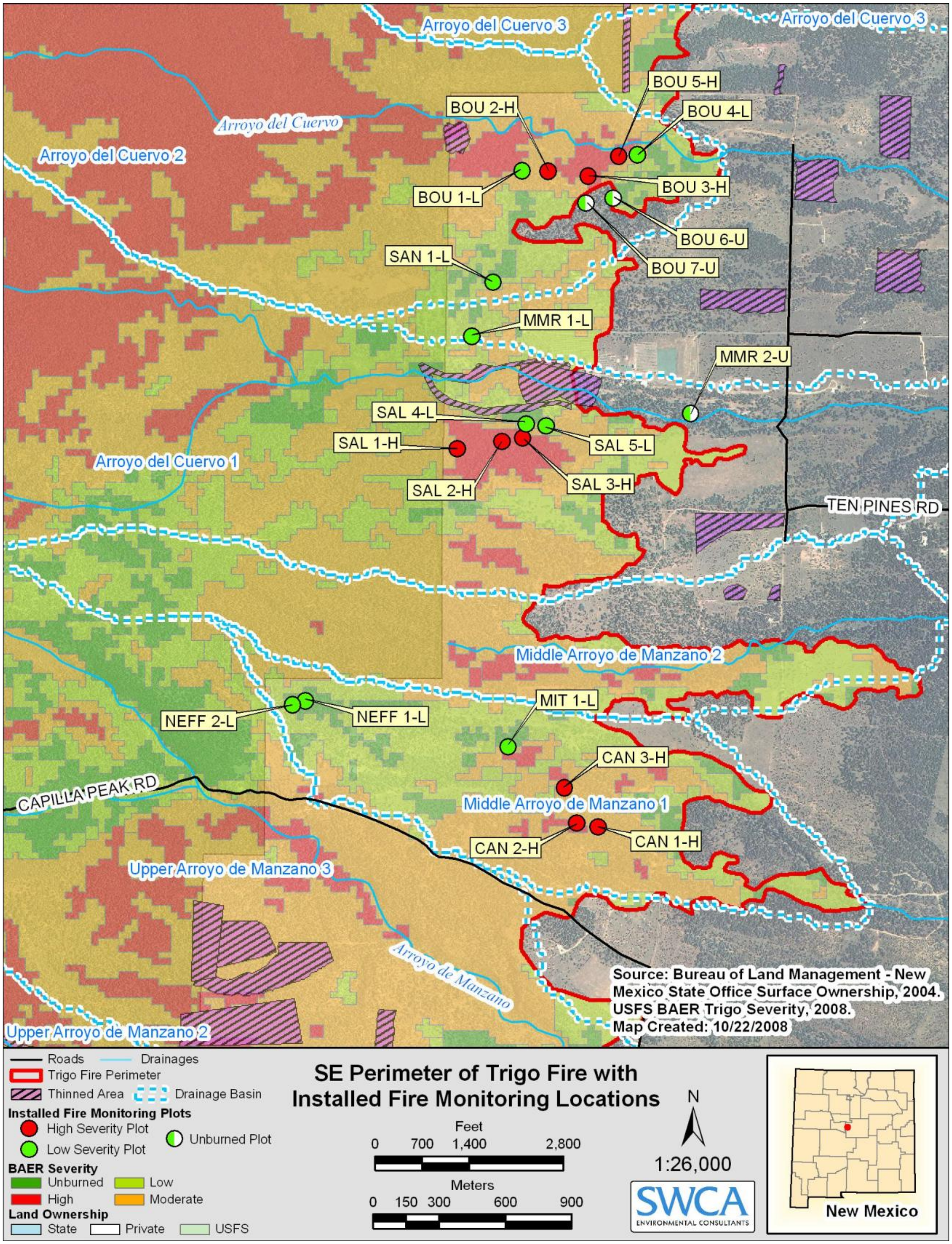


Figure 3.3. Fire monitoring plot locations.

3.1 TREES

Tree monitoring during the 2011 field season included re-measurements of most parameters monitored in 2008. Measurements of diameter at breast height and height were not taken in 2011 because very little change was expected in these parameters on an annual basis.

Of particular interest in 2011 was the recording of live and dead status of tagged trees in order to determine tree mortality compared to 2008, 2009, and 2010 levels. These data were only collected for the low-severity plots because all high-severity plots received 100% tree mortality. Mortality was noted in relation to the degree of scorch that each individual tree received during the fire in 2008. Figure 3.4 illustrates this relationship and the change in status of trees between 2008, 2009, 2010, and 2011. Some of the trees that were killed by the fire in 2008 had also fallen during this period.

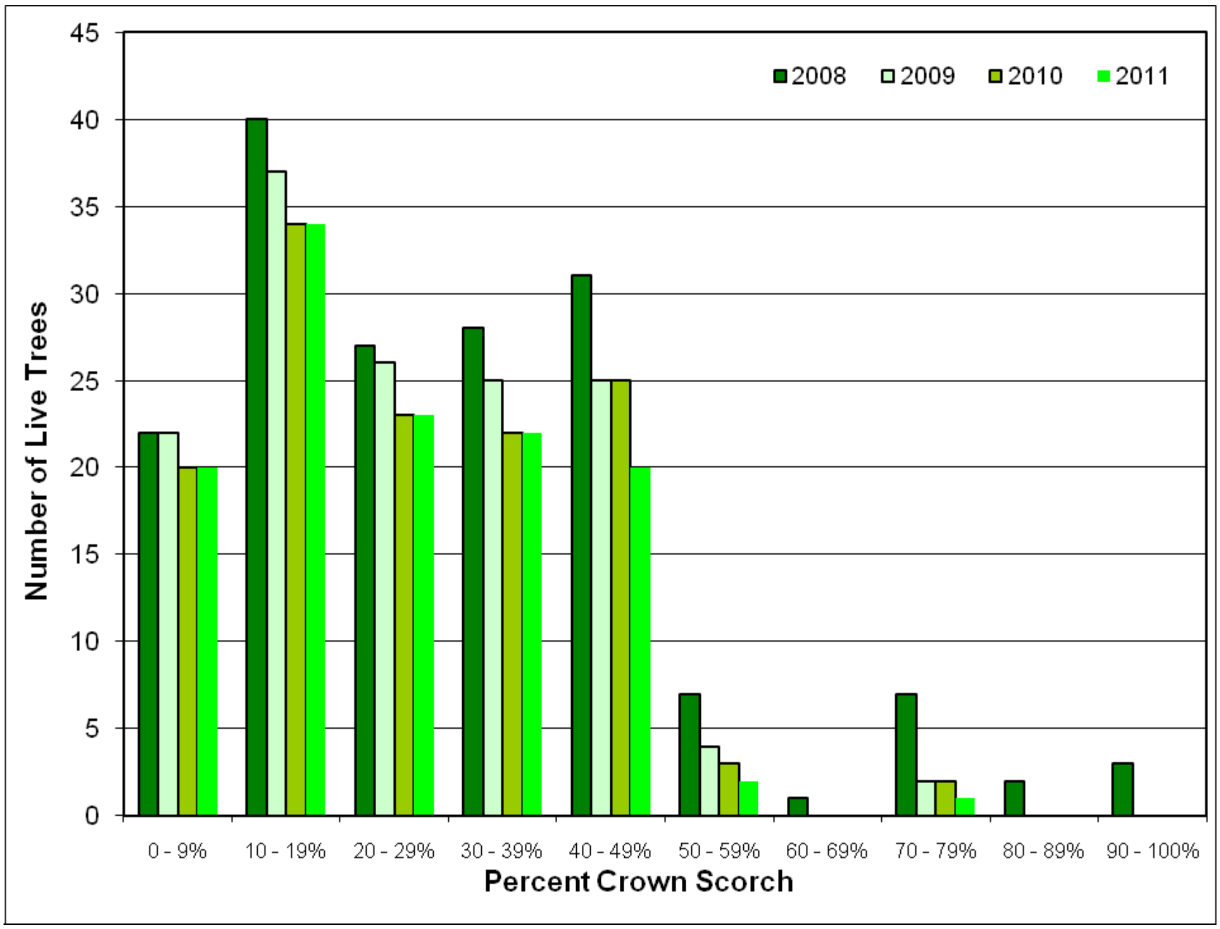


Figure 3.4. Number of live trees in relation to percent crown scorch on all low-severity fire plots.

Figure 3.4 suggests that even if trees survived the first year after the fire, they did not necessarily survive through to 2009 or 2010: 18% of the trees that were live in 2008 were recorded as dead in 2009, and of the trees that were live in 2009, a further 8% had died by 2010. The greatest losses were recorded in the more severely burned trees (> 50% mortality); only six of the 25 trees in these categories in 2008 were still surviving in 2010. Similar high levels of post-fire mortality have been recorded in other studies. Ffolliott et al. (2008) observed that two-thirds of ponderosa exposed to high-severity fire during the Rodeo-Chediski Fire (occurred in Arizona, 2002) were dead two years after the event. Fowler and Sieg (2004) have found that in studies, fire-related mortality was observed from one to three years post fire. The Trigo fire data also show a notable threshold scorch level (approximately 50% of the crown) past which tree survivorship is compromised (see Figure 3.4). Similar findings have been noted on other fires in ponderosa pine forests; for example, Lynch (1959) notes that ponderosa trees with more than 50% crown injury suffered the most mortality.

A number of trees that were tagged in 2008 and standing in 2008 and/or 2009 had fallen by the fall 2010 monitoring period with many more trees coming down during the winter 2010–2011, as is evident in the photo points below. The worst hit trees were the fully consumed small-diameter trees that had received deep basal charring. Crews also observed that many dead trees were being snapped in half at a height of approximately 1.8 m (6 feet), possibly due to strong winds at this level and structural weakness of the bole as the trees decayed (Figure 3.5). The photo series below shows the change in stand trees over time (see Section 3.2). The falling trees were the primary reason for ceasing this study. No tree measurements were taken on high-severity plots during the fall of 2011 because of safety concerns.

Figure 3.5. Salazar high-severity plot showing fallen tagged trees and trees snapped at mid bole.

3.2 HERBACEOUS VEGETATION

Herbaceous vegetation measurements are carried out in spring and fall each year beginning in fall 2008. Dramatic changes in ground cover have been observed over the monitoring period, particularly for the high-severity plots (Figure 3.6–Figure 3.14).

Figure 3.6. CAN 3-H west (fall 2008) showing little to no vegetation cover and considerable bare soil.

Figure 3.7. CAN 3-H west (fall 2009) showing dominance by the deep red forb fetid goosefoot (*Chenopodium graveolens*).

Figure 3.8. Can 3-H west (fall 2010) showing dominance by the seeded grass species tall wheatgrass (*Thinopyrum ponticum)*.

Figure 3.9. Can 3-H west (fall 2011) showing nearly 80% of dead trees downed and the presence of grass species tall wheatgrass (*Thinopyrum ponticum)*.

Figure 3.10. BOU 3-H west (fall 2008) showing little to no vegetation cover.

Figure 3.11. BOU 3-H west (spring 2009) showing increased cover of spring annuals and early colonizers.

Figure 3.12. BOU 3-H west (fall 2009) showing increased vegetation cover dominated by fetid goosefoot.

Figure 3.13. BOU 3-H west (fall 2010) showing greater species diversity, cover, and vertical structure.

Figure 3.14. BOU 3-H west (spring 2011) showing several large trees downed since the fall of 2010.

3.3 Vegetation and Ground Surface Cover Monitoring

Herbaceous vegetation was measured along line intercepts and quadrats at each of the 21 fire plots representing both high and low severities, as well as no burn areas, from the fall of 2008 through the fall of 2011; however, during the fall of 2011 not all high-severity plots were measured because of the danger of falling trees. Line intercept data were taken at each plot on four 23-m (75-foot) transects recording cover by growth form. Vegetation was also measured from thirty six 1-m² (10.7-square-foot) quadrats that are located along the 23-m (75-foot) transects. In addition to vegetation, soil surface cover categories also were measured on the line intercepts and quadrats, including bare soil, leaf litter (and dead and downed woody material), and rock.

3.3.1 Line Intercept Data

The results of the ground cover measurements taken along the line intercept transects types measured in both the fall and spring of 2008–2011 are presented below in Figure 3.15 through Figure 3.20. These figures present all of the different cover types by burn severity and by year. Values in these graphs are presented on the same vertical axis scale to provide a representation of the relative importance of each cover type per plot.

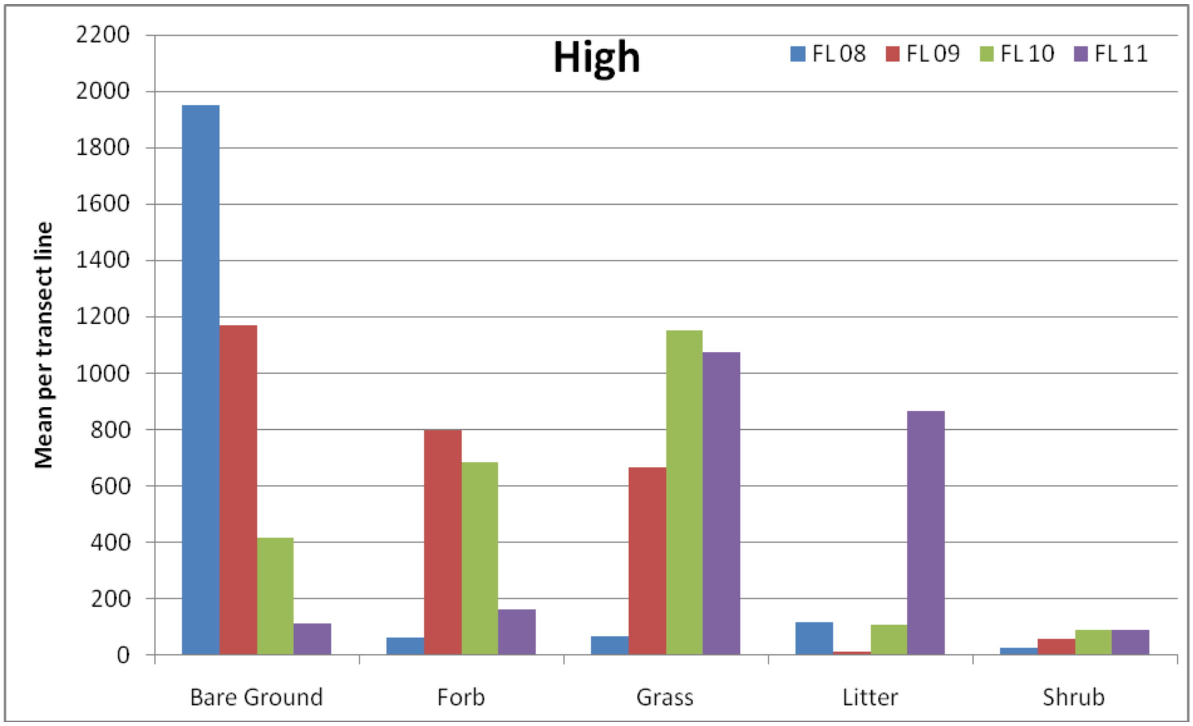


Figure 3.15. Vegetation cover measured along 23-m (75-foot) transects for all high-severity burn plots, fall 2008–2011.

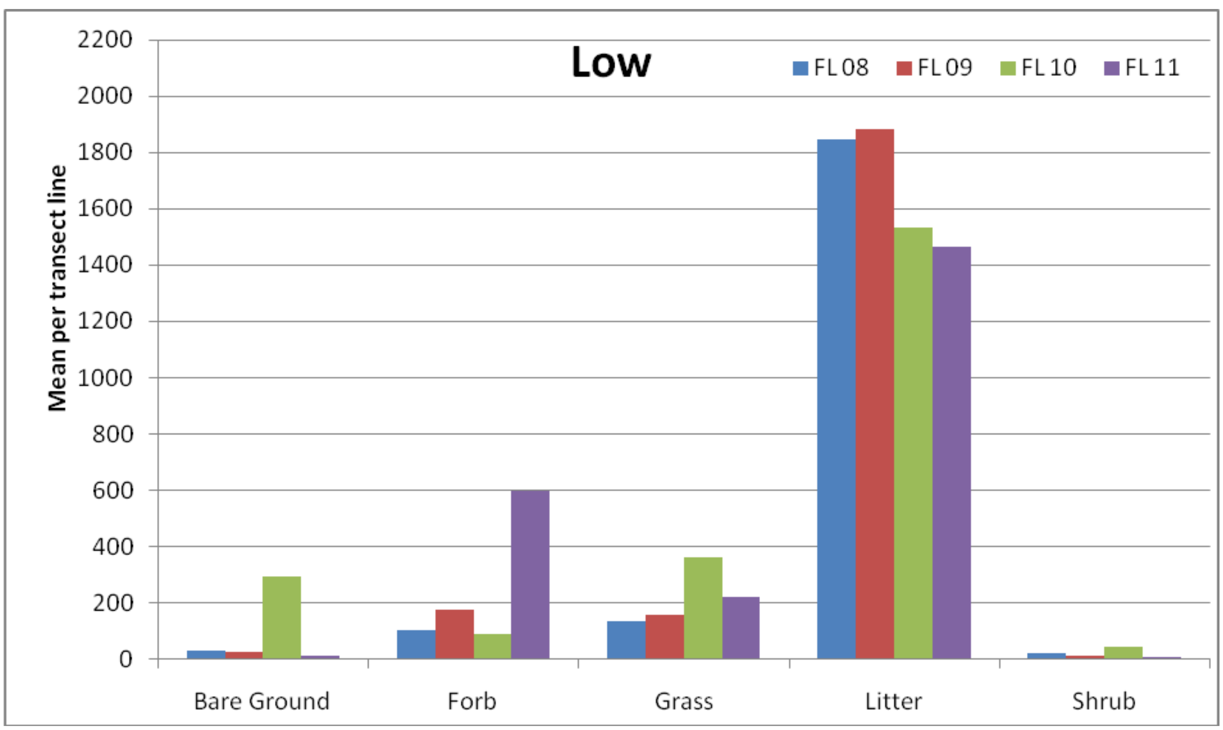


Figure 3.16. Vegetation cover measured along 23-m (75-foot) transects for all low-severity burn plots, fall 2008–2011.

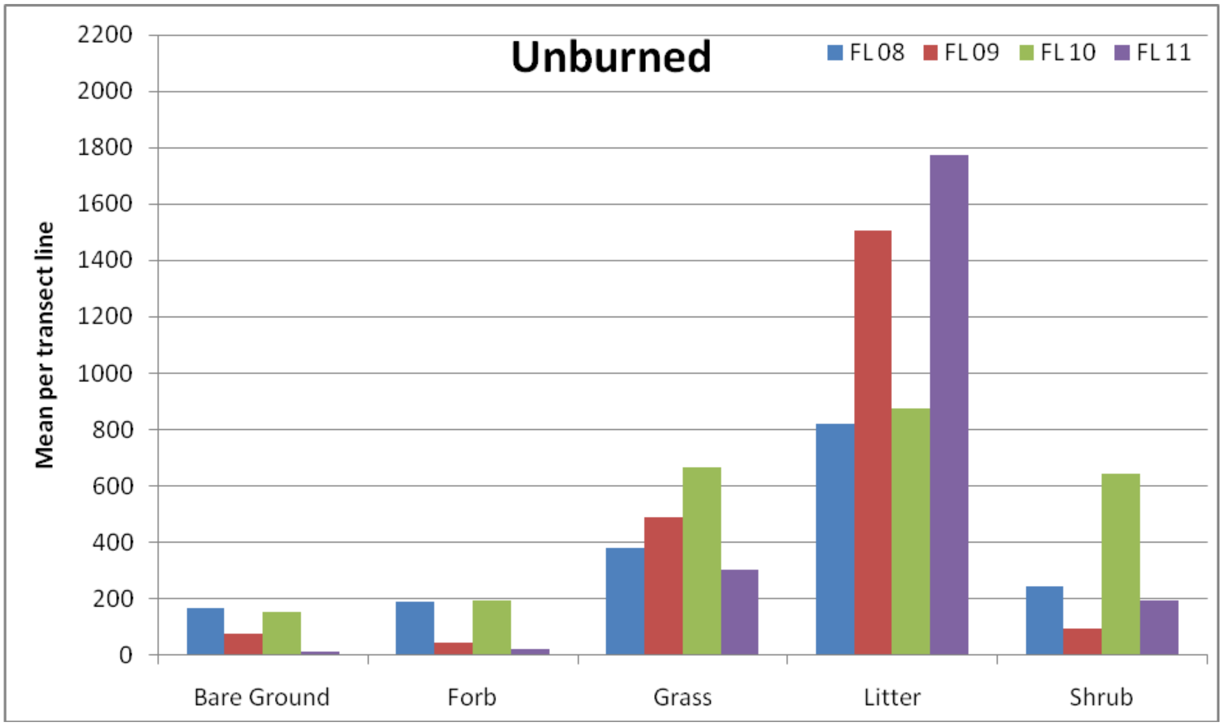


Figure 3.17. Vegetation cover measured along 23-m (75-foot) transects for all unburned plots, fall 2008–2011.

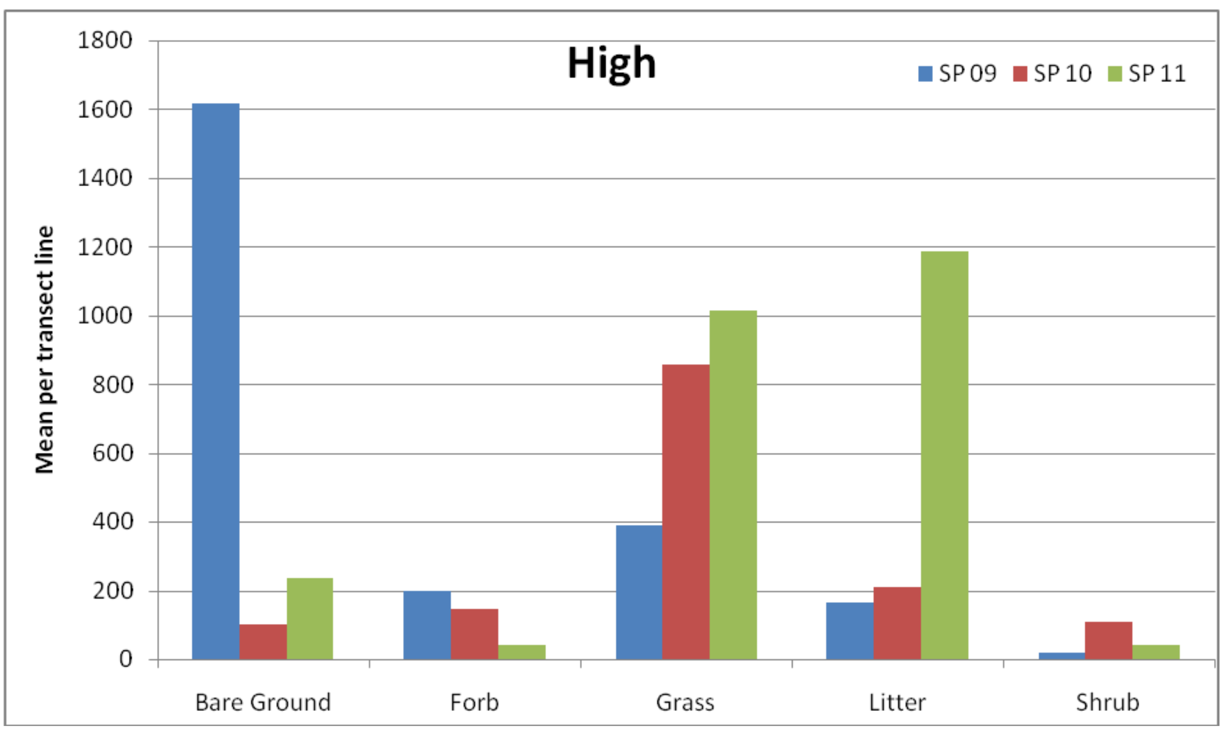


Figure 3.18. Vegetation cover measured along 23-m (75-foot) transects for all high-severity burn plots, spring 2009–2011.

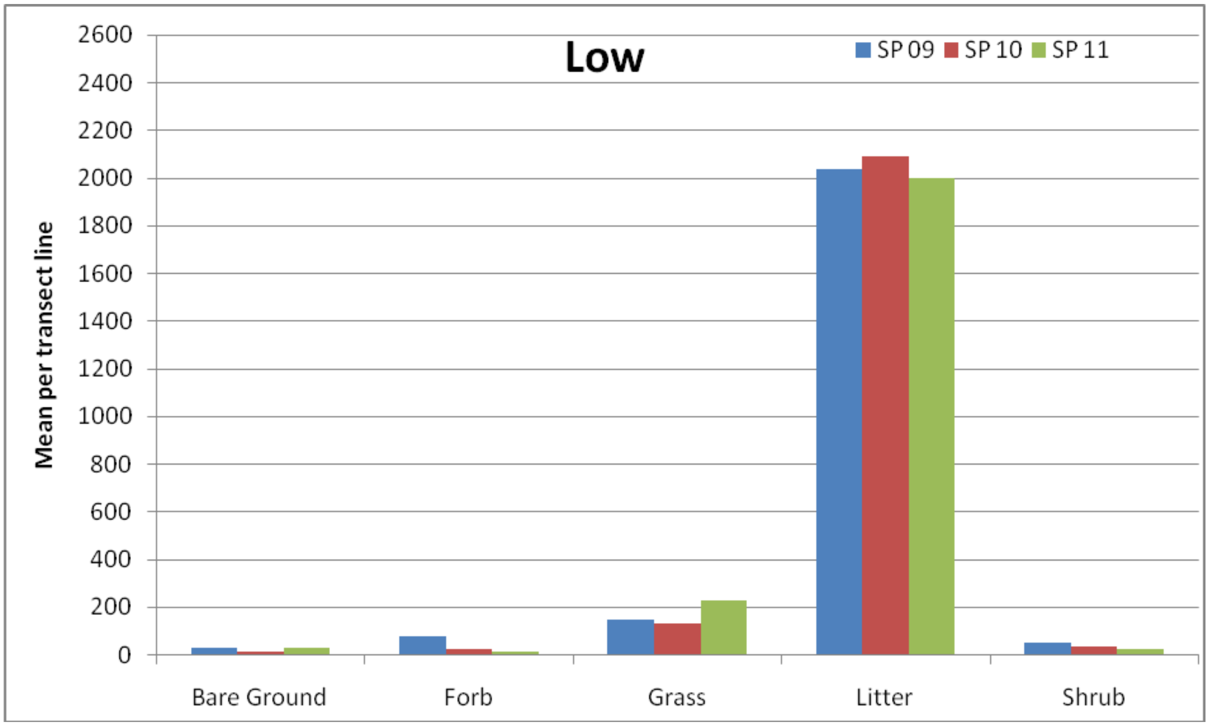


Figure 3.19. Vegetation cover measured along 23-m (75-foot) transects for all high-severity burn plots, spring 2009–2011.

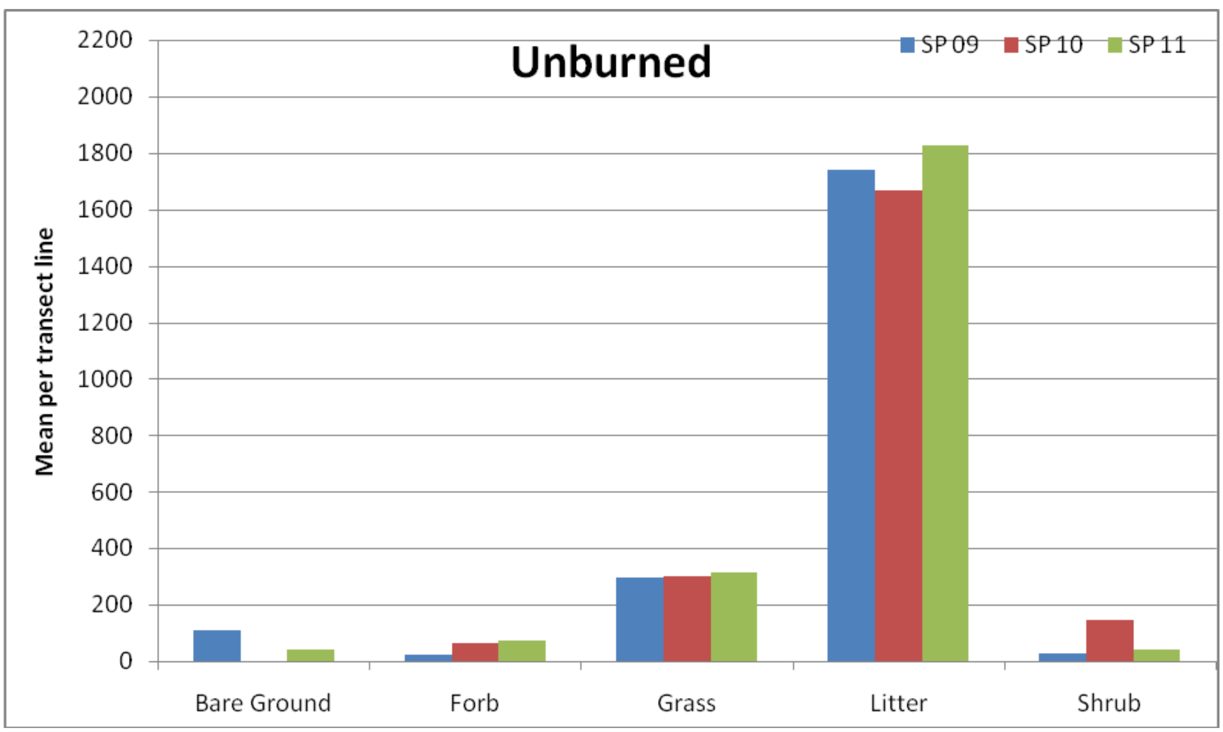


Figure 3.20. Vegetation cover measured along 23-m (75-foot) transects for all unburned plots, spring 2009–2011.

3.3.2 Quadrat Data

Quadrat data were recorded in spring 2009, 2010, and 2011, and fall 2008, 2009, 2010, and 2011. These data are used to determine changes to the major cover types (bare ground, leaf litter, forb, grass) on plots over time. A graph for all fall monitoring periods are presented first (Figure 3.21), followed by spring monitoring results (Figure 3.22).

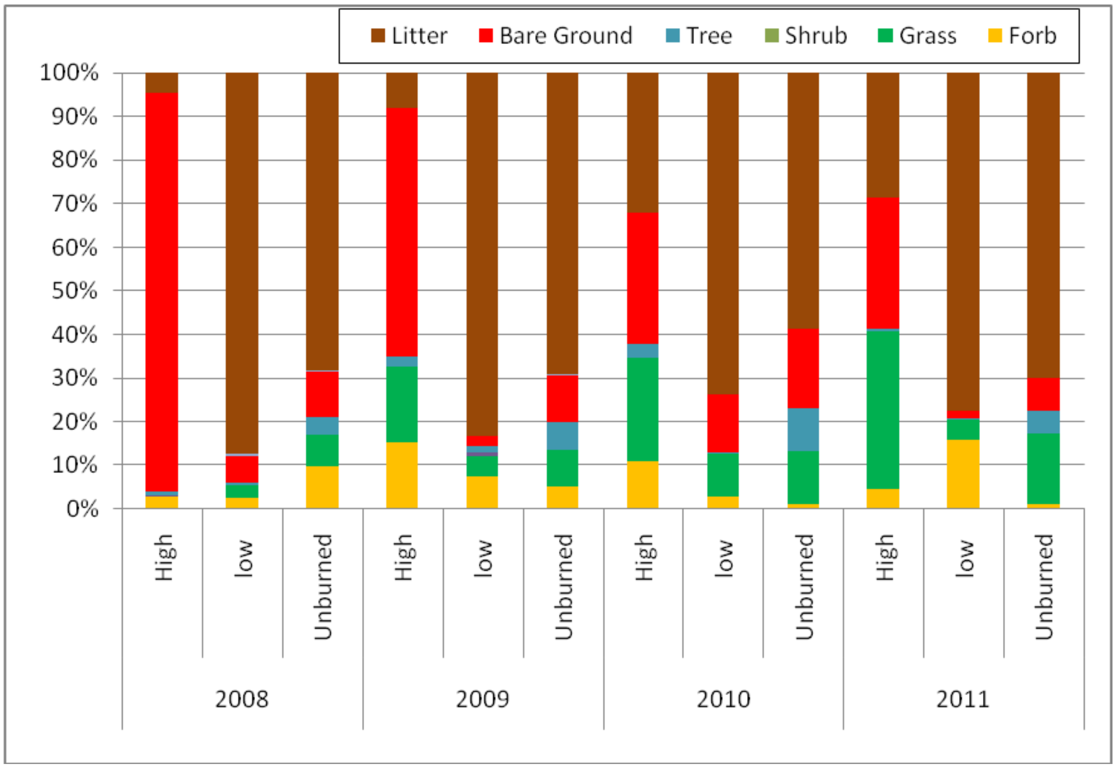


Figure 3.21. Vegetation cover in quadrats for all severity burn plots during the fall measurements of 2008–2011.

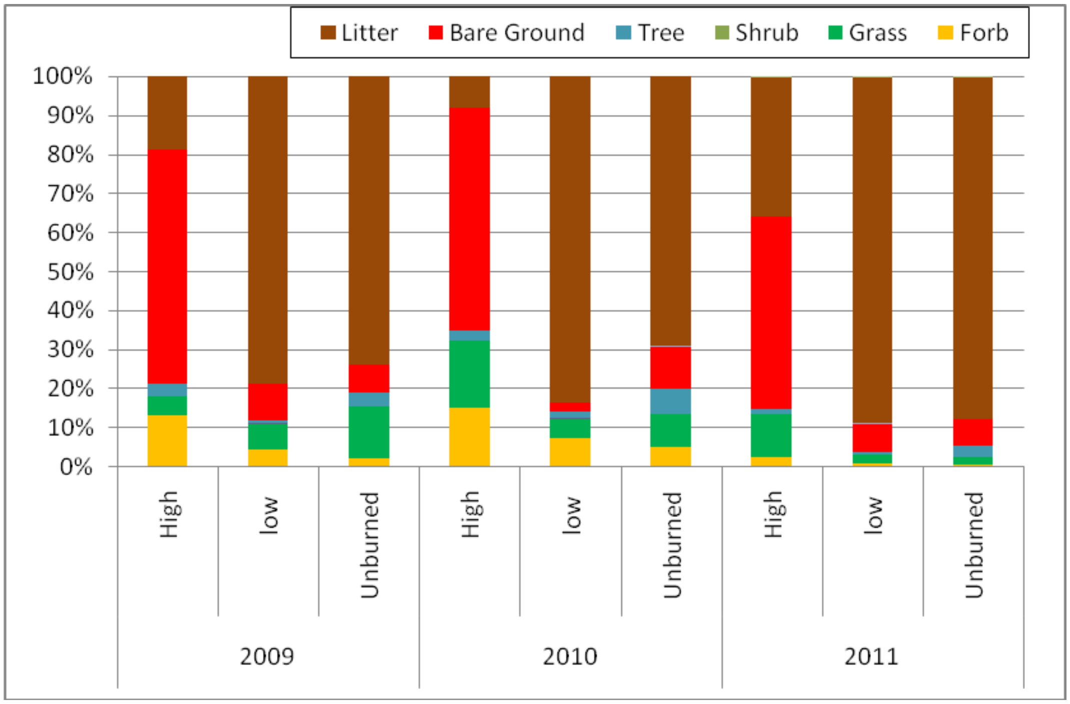


Figure 3.22. Vegetation cover in quadrats for all severity burn plots during the spring measurements of 2009–2011.

The graphs above illustrate the fall and spring data collection in all vegetation quadrats. The most significant results can be seen in the high-severity plots where bare ground has decreased, while grasses have increased. Forbs increased in 2009 over 2008 levels, but then remained relatively constant in 2010 and 2011. Leaf litter increased over the three field seasons but not significantly. The low-severity plots (see Figure 3.20) did not change as significantly as the high-severity plots. The cover of grasses increased between 2008 and 2009 and then remained relatively constant in 2010 and 2011. Bare ground levels declined over the four years as litter and herbaceous material built back up.

The unburned plots reflect some variation in cover between the four years, however, statistical tests determined that the variation in cover types between years is not significantly different.

Table 3.1 provides names and species codes for the more common plants found on the fire plots (see also Appendix B). The most common species across the low-severity plots in all seasons were fetid goosefoot (*Chenopodium graveolens*) and tall wheatgrass (*Thinopyrum ponticum*). Italian ryegrass (*Lolium perenne*) was a dominant species in 2008 through spring 2010 but was not recorded in the fall 2010 monitoring. Both tall wheatgrass and Italian ryegrass are large robust grasses that were present in the seed mix applied following the fire in 2008. Tall wheatgrass is a perennial grass that was expected to increase in dominance since disturbance; Italian ryegrass, an annual grass, was expected to slowly decline as is seen here. Fetid goosefoot, though still dominant in all seasons on both low- and high-severity plots, was seen to decline in fall 2010 and even more so in the fall of 2011. This could be because the species is an annual forb that is most abundant immediately following a disturbance and will decline as a site becomes re-established and perennial species become more dominant (Kuenzi et al. 2008).

Table 3.1. List of the Most Common Plants Found on the Fire Plots

Code	Common Name	Scientific Name	Growth Form	Life History
ARCA14	Littleleaf pussytoes	*Artemisia carruthii*	Forb	Perennial
ARLU	White sagebrush	*Artemisia ludoviciana*	Forb	Perennial
ASNU4	Smallflowered milkvetch	*Astragalus nuttallianus*	Forb	Perennial
BADI	Ragleaf bahia	*Bahia dissecta*	Forb	Annual
BLTR	Pine dropseed	*Blepharoneuron trichophyllum*	Grass	Perennial
BOGR2	Blue grama	*Bouteloua gracilis*	Grass	Perennial
BRAR5	Field brome	*Bromus arvensis*	Grass	Annual
CHFR3	Fremont’s goosefoot	*Chenopodium fremontii*	Forb	Perennial
CHGR2	Fetid goosefoot	*Chenopodium graveolens*	Forb	Annual
CHLE4	Narrowleaf goosefoot	*Chenopodium leptophyllum*	Forb	Annual
CYFE2	Fendler’s flatsedge	*Cyperus fendlerianus*	Grass	Perennial
ELCA4	Canada wildrye	*Elymus Canadensis*	Grass	Perennial
ERDI4	Spreading fleabane	*Erigeron divergens*	Forb	Biennial
ERFL	Trailing fleabane	*Erigeron flagellaris*	Forb	Biennial
ERME	Mexican lovegrass	*Erogrostis Mexicana*	Grass	Annual
ERRA3	Redroot buckwheat	*Eriogonum racemosum*	Forb	Perennial
GECAF	Parry's geranium	*Geranium caespitosum*	Forb	Perennial
GUSA2	Broom snakeweed	*Gutierrezia sarothrae*	Shrub	Perennial
KOMA	Prairie junegrass	*Koeleria macranthus*	Grass	Perennial
LOPE	Italian ryegrass	*Lolium perenne*	Grass	Annual
LOWR	Wright’s deervetch	*Lotus wrightii*	Forb	Perennial
PIMI7	Littleseed ricegrass	*Oryzopsis micrantha*	Grass	Perennial
PHHE4	Ivyleaf groundcherry	*Physalis hederifolia*	Forb	Perennial
QUGA	Gambel oak	*Quercus gambelii*	Shrub	Perennial
QUGR3	Gray oak	*Quercus grisea*	Shrub	Perennial
SPAN3	Copper globemallow	*Sphaeralcea angustifolia*	Forb	Perennial
THME	Hopi tea greenthread	*Thelesperma megapotamicum*	Forb	Perennial
THPO7	Tall wheatgrass	*Thinopyrum ponticum*	Grass	Perennial

Figure 3.23. Tall wheatgrass that was seeded on a high-severity plot, fall 2010.

A number of the dominant species were specific to the high-severity plots, including Wright's deervetch (*Lotus wrightii*), narrowleaf goosefoot (*Chenopodium leptophyllum*), Fremont's goosefoot (*Chenopodium fremontii*), and spreading fleabane (*Erigeron divergens*). These species are typical of early colonizers following disturbance (Wolfson et al. 2005). Blue grama (*Bouteloua gracilis*), a native grass, was only dominant on the low-severity plots but was observed to be increasing in cover on high-severity plots during 2010. As a native perennial blue grama was expected to become more dominant over the coming years since disturbance. Gambel oak (*Quercus gambelii*) was the dominant shrub on both low- and high-severity plots, and its cover has remained relatively constant across the seasons.

As a whole, annual forb and grass dominance is expected to decline in future years, giving way to increased cover by perennial forbs and grasses. This change is anticipated to be most notable on the high-severity plots where perennial species were largely eliminated from the site due to disturbance of the soil and litter layers, and early colonizers were typically annual species (e.g., ragleaf bahia [*Bahia dissecta*], fetid goosefoot, narrowleaf goosefoot, Italian ryegrass). Because the low-severity plots exhibited minimal loss of duff and litter and limited soil erosion, perennial species were better able to survive the fire, and colonization by annual species in comparison was much reduced.

3.3.3 Soil Movement

Soil movement was monitored using soil movement bridges (called soil erosion bridges in the 2008 Annual Report) modeled after White and Loftin (2000). Permanent bridge support posts were installed at consistent, systematically determined, and unbiased locations at the ends of the north and south transects at each plot (refer to the 2008 Annual Report for detailed monitoring protocols and literature associated with soil movement [SWCA 2009]). Soil movement bridges that had been installed in fall 2008 were monitored in spring and fall 2009, 2010, and 2011. Figure 3.24 through Figure 3.26 demonstrate the changes in the soil surface profiles between 2008 and 2011 for three plots in the same watershed burned by differing severities.

The soil profile on the high-severity Salazar site (see Figure 3.24) seems to show a general falling trend (soil loss), suggesting that erosional processes dominated at this site for all seasons. This graph shows the micro-topographic variations across the soil surveying area, where there may be a general erosional trend coupled on a smaller scale with a deposition event. The greatest variation in profile height at this site remains minimal, however, at approximately 20 mm.

The soil profile on the low-severity Salazar site (see Figure 3.25) is more varied than the high-severity site with both erosional and depositional processes occurring throughout the seasons. At soil bridge installation, the low-severity site had more litter accumulation, so the micro-topography across the profile was highly varied, possibly contributing to the variation in soil movement observed across the seasons. The degree of change in the profiles across seasons is higher than the high-severity site, but is still less than 40 mm.

The unburned site at the Manzano Mountain Retreat appears to show a general rising trend (soil gain) in the soil profile (see Figure 3.26), suggesting that depositional processes are dominant at the site. The fall 2010 profile was at some points over 100 mm higher than the fall 2008 profile, suggesting considerable and active soil movement has been occurring.

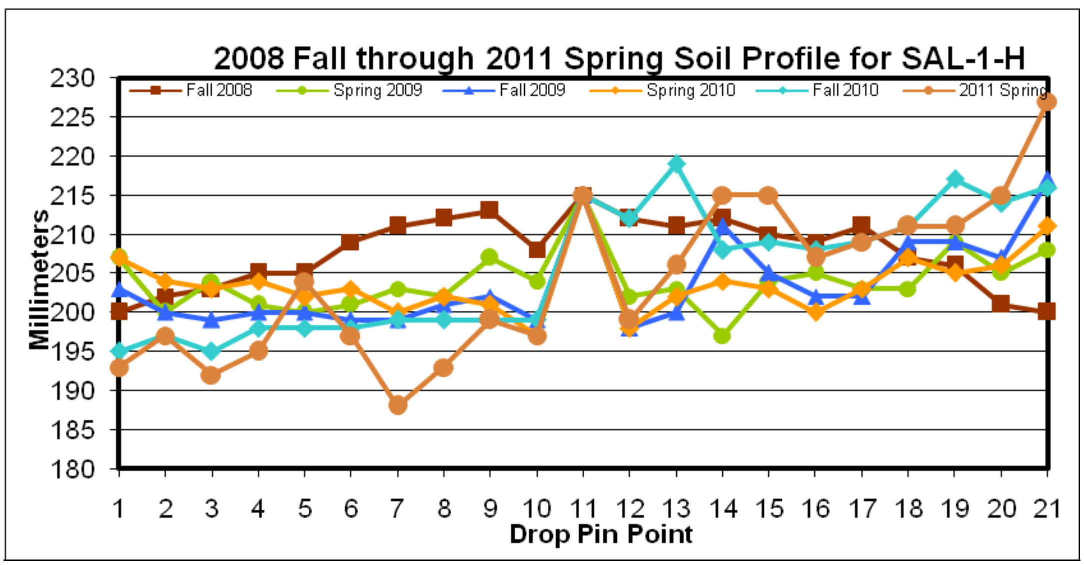


Figure 3.24. Soil movement bridge data on a Salazar high-severity plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

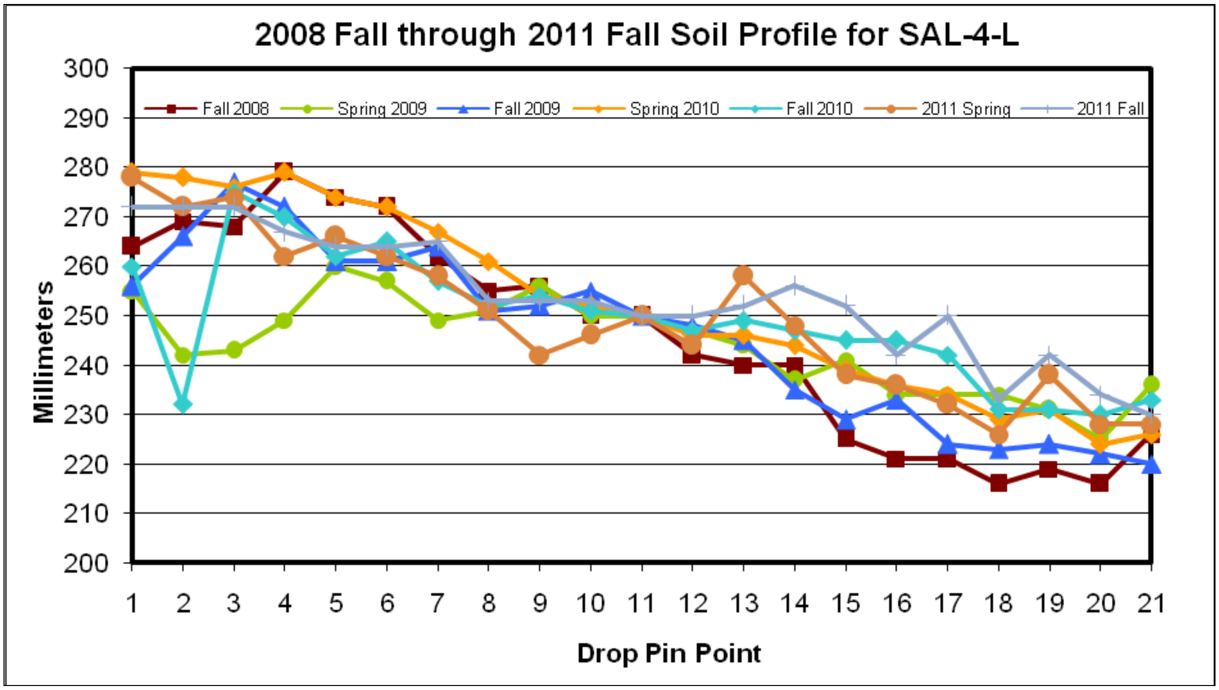


Figure 3.25. Soil movement bridge data on a Salazar low-severity plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

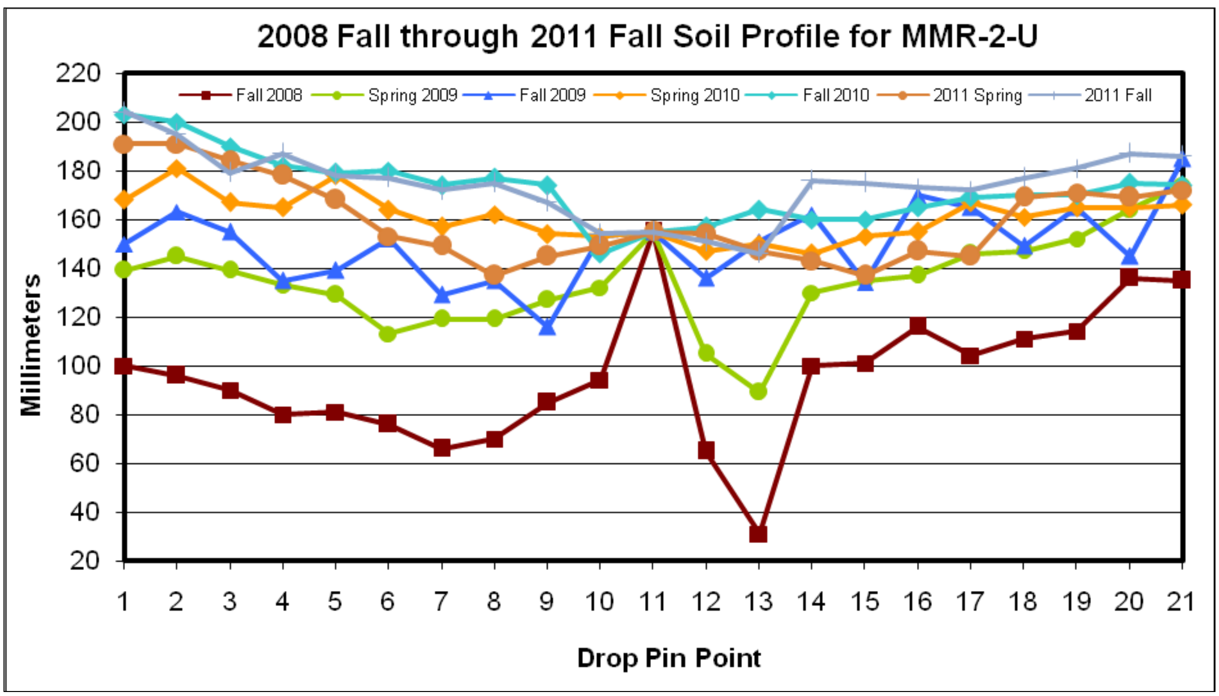


Figure 3.26. Soil movement bridge data on a Manzano Mountain Retreat unburned plot across all monitoring seasons. Each point on the X axis represents one measurement point from the soil surface to the level bridge above the surface.

3.3.4 WILDLIFE CAMERA DATA

Wildlife cameras have been established across the three project watersheds since spring 2009. Until fall 2010 three cameras were rotated between watersheds with one camera in each severity type. In November 2010, six additional cameras were purchased in order to have permanent coverage in each watershed and remove the need for rotation. This provided increased monitoring of wildlife use of all severity types on all watersheds throughout all seasons.

Table 3.2 provides data from wildlife cameras prior to the new camera installs. Because of camera malfunction and irregular offload periods, the cumulative camera days for each severity type vary. This variability was the driving force behind installing permanent cameras on all watersheds.

Table 3.2. 2011 Wildlife Frequency Data for Wildlife Cameras Located at on the Different Burn Severities

2011		High				Low				Unburned			
Species	**Scientific Name**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**	**W**	**Sp**	**Su**	**F**
Abert's squirrel	*Sciurus aberti*	0	0	0	0	0	0	0	3	0	0	0	0
Black bear	*Ursus americanus*	0	0	0	0	0	0	0	4	0	0	0	1
Bobcat	*Lynx rufus*	0	0	0	0	0	0	0	1	0	0	0	0
Coyote	*Canis latrans*	0	0	0	0	0	0	2	0	0	0	0	0
Gray fox	*Urocyon cinereoargenteus*	0	0	0	0	0	0	0	6	0	0	0	0
Hawk sp.	*Buteo* sp.	0	1	0	0	0	0	0	0	0	0	0	0
Black-tailed jackrabbit	*Lepus californicus*	0	0	0	0	0	0	0	6	0	0	0	0
Mountain lion	*Puma concolor*	0	0	0	0	0	0	1	0	0	0	0	0
Mule deer	*Odocoileus hemionus*	43	0	1	4	0	42	70	113	38	3	0	7
Unknown	–	0	0	0	0	0	0	3	4	0	0	0	0
Wild turkey	*Meleagris gallopavo*	0	0	0	0	0	0	0	6	0	0	0	0

The most common species recorded at all sites and across both monitoring years is the mule deer (*Odocoileus hemionus*) which can be seen above in Table 3.2. In 2011 mule deer numbers were consistently higher on the low-severity plots than the high-severity plots; for both, severities frequencies were considerably greater than on the unburned plots. In 2009 species diversity was greatest on the unburned plots. In 2010 and 2011 species diversity was greatest on the low-severity plots, including mule deer (Figure 3.27–Figure 2.28), mountain lion (*Puma* concolorblack bear (*Ursus americanus*) (Figure 3.30), Merriam's wild turkey (*Meleagris gallopavo*), Abert's squirrel (*Sciurus aberti*), cottontail rabbit (*Sylvilagus* sp.), jackrabbit (*Lepus* sp.), and various birds.

Figure 3.27. Family of mule deer at the Salazar low-severity site, 20011.

Figure 3.28. Mule deer in full velvet at the Salazar low-severity site, 20011.

Figure 3.29. Mountain lion at the Salazar low-severity site, 20011.

Figure 3.30. Bear observed at the Neff low-severity site, 20011.

3.4 FIRE MONITORING CONCLUSION

Fourth-year results from the post-wildfire monitoring suggest the area is slowly regenerating with increased herbaceous cover, particularly grass and forb cover and reduced bare ground on the high- and low-severity plots. Aerial seeding efforts were successful on all high-severity plots with dominance of seeded annual grasses. Much of the high-severity plots had experienced 100% mortality of the tree layer, and many of these trees have now begun to fall, particularly as a result of wind throw. The low-severity plots exhibited patchy mortality in 2008; some of the worst-hit trees, those that were more than 50% scorched, have now begun to die as a result of the physiological stress. Soil erosion is highly variable across plots but appears to continue to be dominant on the high-severity plots. Regrowth of the herbaceous layer, dominance of seeded grasses, dead and fallen trees, and increased litter layers will all contribute to the maintenance of the soil layer.

4.0 EPHEMERAL WATERSHED STREAM MONITORING

Background information on the stream piezometers can be found in the 2009 Annual Report. In addition to the paired watershed flumes, piezometers were installed on three nearby streams in order to gauge surface flows on a larger scale (Figure 4.1). The 2011 monitoring season saw very few flows; however, a large flow did occur at the Chilili site and destroyed the stream piezometer (Figure 4.2 and Figure 4.3). Due to the damage caused to the stream piezometer from the flood, the stage was not able to be recorded; however, it was estimated that the peak flow reached nearly 0.6 m (2 feet). A new gauge made of galvanized steel was installed to replace the damaged gauge on a subsequent site visit (Figure 4.4). The other gauges at the Vigil site and Kelly site did not record any flows during the 2011 monitoring season.

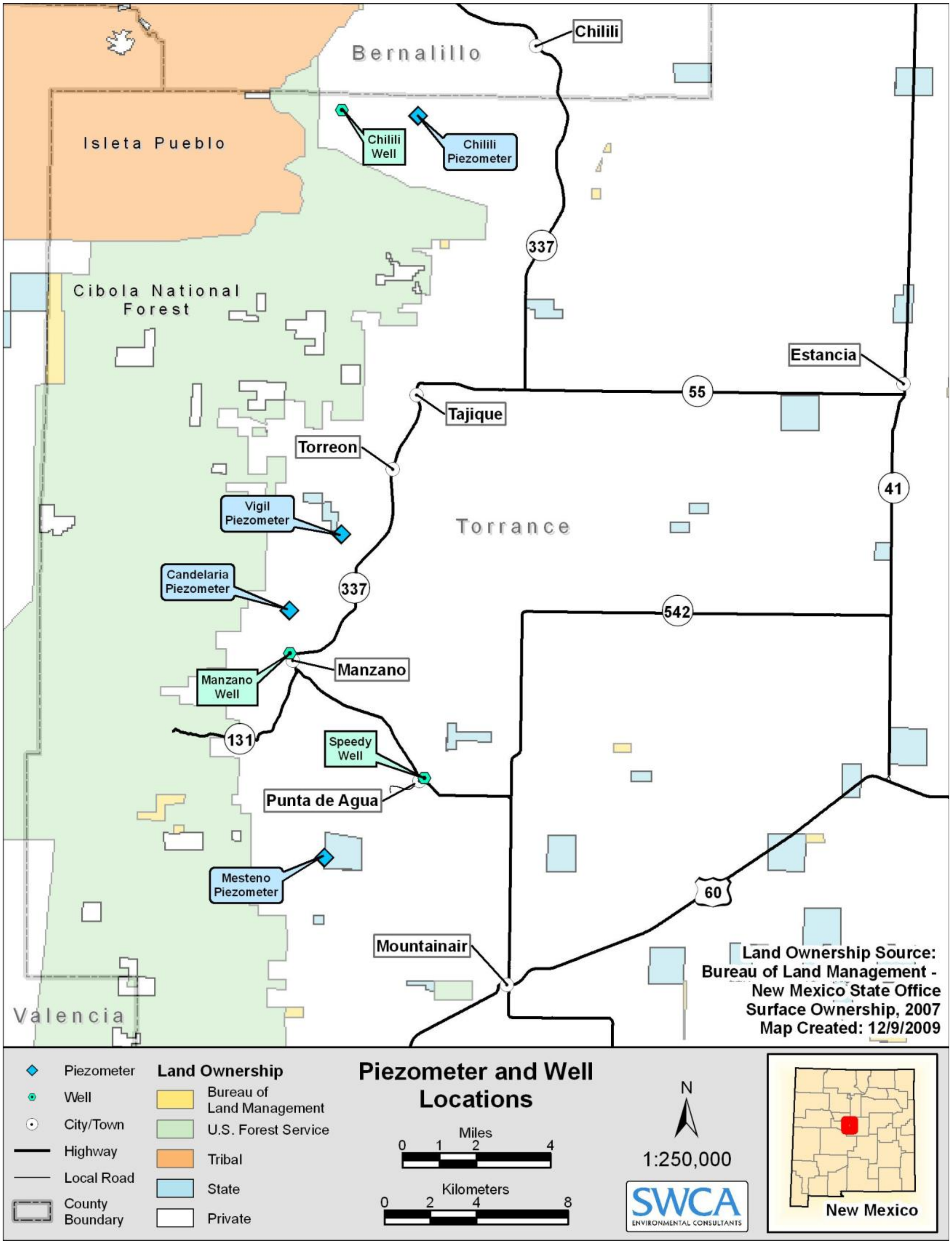


Figure 4.1. Location of the piezometers and wells within the Estancia Basin.

Figure 4.2. The Chilili piezometer in the fall of 2011 after a storm event destroyed the gauge, view facing downstream. The height of the high waterline of this event was determined by the accumulation of debris on the stream banks and within vegetation.

Figure 4.3. The Chilili piezometer in the fall of 2011 after a storm event destroyed the gauge, view facing upstream. The height of the high waterline of this event was determined by the accumulation of debris on the stream banks and within vegetation.

Figure 4.4. The new Chilili piezometer that was installed in the fall of 2011 to replace the storm damaged gauge.

4.1 GROUNDWATER WELL MONITORING

The monitoring study is evaluating infiltration rates in the Estancia Basin by using deep pressure sensors to monitor the level of groundwater in relation to stream flow events. By monitoring the groundwater levels in private wells located close to stream monitoring locations, changes in recharge can be observed, and potentially the impact of thinning and burned areas can be compared to these groundwater levels to asses any changes.

Ideally, this project will evaluate infiltration rates in the control areas versus burned areas and relate this information to nearby groundwater levels. This could be accomplished by monitoring private wells located close to stream monitoring locations. Sandia National Laboratory and the U.S. Geological Survey are currently initiating well monitoring programs. Both entities have been receptive to sharing data when they become available, though neither knows if data would be available near the project's piezometer locations in the immediate future. The monitoring will use deep pressure sensors to monitor the level of groundwater in relation to stream flow events. If these data are available, they will be compared to the collected data from this project.

SWCA installed three well monitoring devices during early to mid June 2009. These well monitoring locations are at Chilili, Manzano, and Punta de Agua (see Figure 4.1). Each monitoring well is equipped with Solinst Levelogger Junior pressure transducers that were programmed to record values hourly. The Chilili site is approximately 30 m (98 feet) from the western flume. The well is approximately 15 m (50 feet) deep, and depth to groundwater when installed is approximately 8 feet (25 feet). The Manzano well is shallow, approximately 8 m (25 feet) deep, and periodically goes dry. The municipal well is nearby and likely contributes to the drawdown in this area. SWCA is looking for an alternative well, but until it is found this well will continue to be monitored. The Punta de Agua well is in "downtown" Punta. The well is approximately 37 m (120 feet) deep, and depth to groundwater is approximately 28 m (91 feet) when installed. SWCA will off-load data quarterly at each well location.

Figure 4.5 through Figure 4.7 display the well data from each of the three locations monitored in the Estancia Basin. During 2011 all wells showed a general decline throughout the year. The well in Punta de Agua and Chilili showed a steady decline through the course of the year, especially the well in Punta, which saw a large draw down being in March. This draw down can likely be attributed to increased pumping for domestic and agricultural use at the Punta site and a lack of a good snowpack and early season precipitation at the Chilili site. The Chilili well did show a small rise in during the month of October, which was the result of several large late season monsoonal storms. The well at Manzano remained dry for the course of the 2011 season.

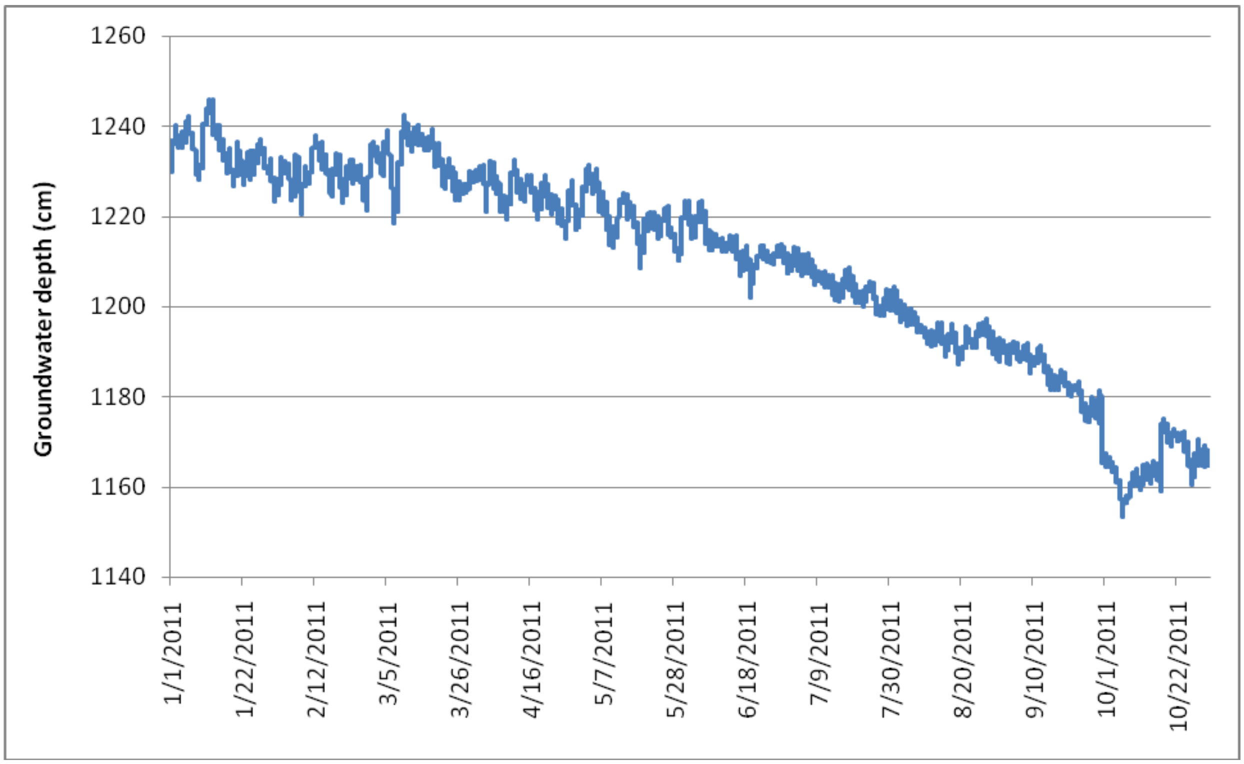


Figure 4.5. Well data from the Chilili site showing a steady decline, which represents the drought conditions that the region faced in 2011.

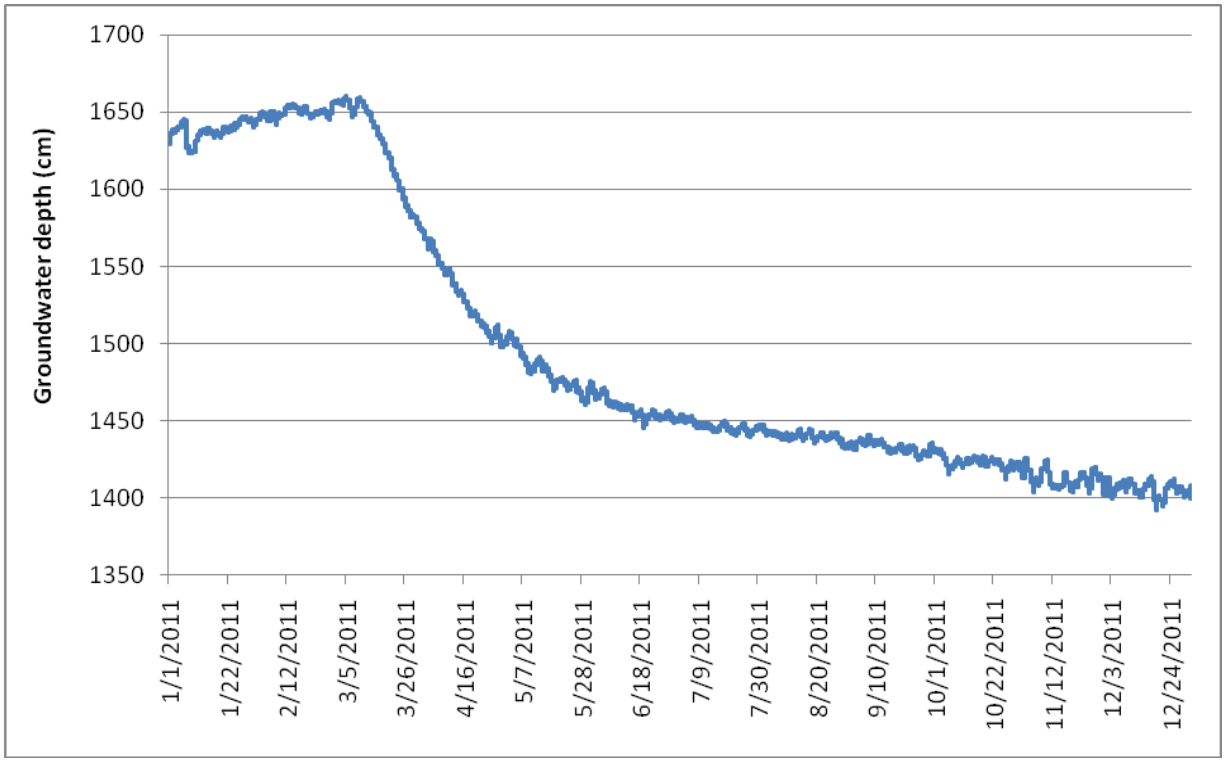


Figure 4.6. Well data from the Punta de Agua site showing steady rise of the groundwater over the summer months.

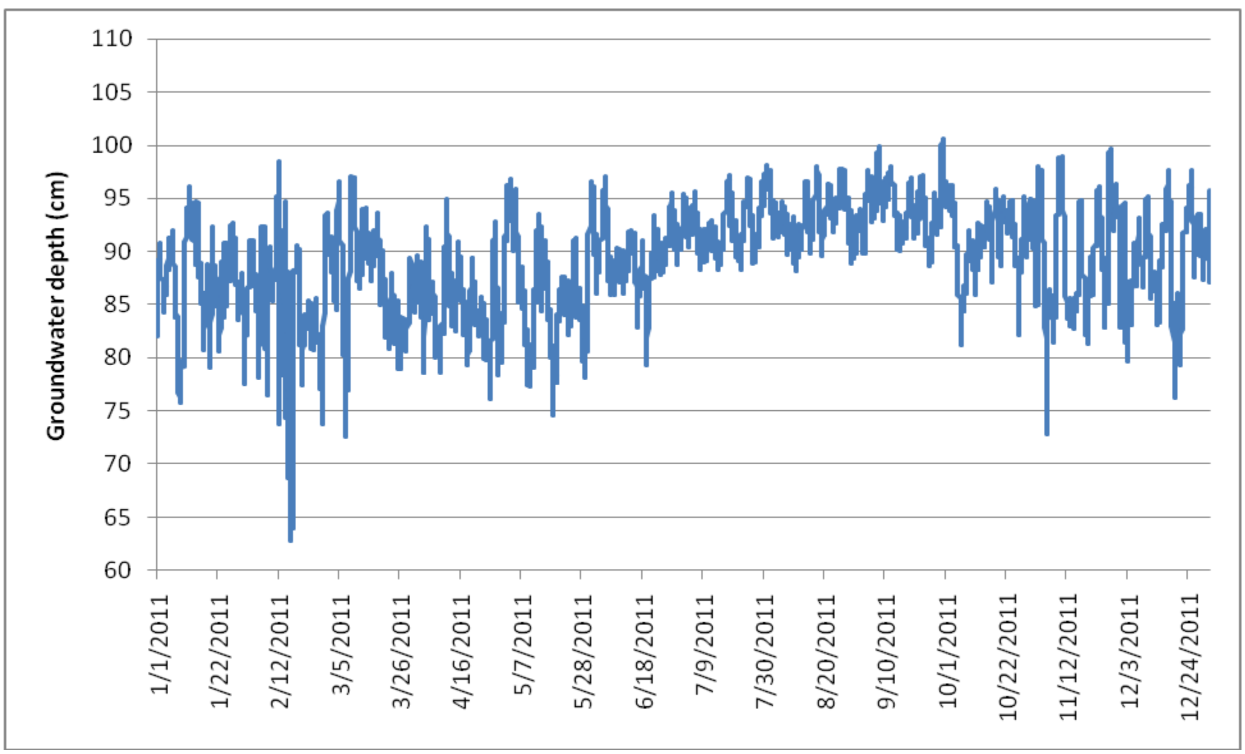


Figure 4.7. Well data from the Manzano site showing the fluctuations in groundwater over the summer months.

5.0 SOUTH MOUNTAIN WEATHER STATION

The South Mountain Weather Station (SMWS) was installed by EnviroLogic to provide meteorological, soil moisture, and temperature data as part of the Estancia Basin Watershed Health and Restoration Program overseen by the Steering Committee. EnviroLogic installed the SMWS in September 2006 to initiate site-specific monitoring of rainfall and soil water content at various soil depths. For details on site selection and monitoring protocols, please refer to the 2008 Monitoring Plan (SWCA 2008). The SMWS is within the Edgewood Soil and Water Conservation District, on the private property, near South Mountain, Santa Fe County, New Mexico, approximately 19 km (12 miles) north of the town of Edgewood (Figure 5.1). The intent of EnviroLogic was to assess water infiltration through soil depths, relate that to meteorological variables, and then compare two measured locations to determine the effects of forest thinning projects on groundwater recharge.

The SMWS measures precipitation, wind speed and direction, air temperature, humidity, and solar radiation. Soil moisture and temperature probes are situated at various depths at two locations with distinct vegetation structure types: one site within a piñon/juniper stand and one site in an adjacent open area consisting of short grasses. EnviroLogic referred to these locations as “Tree” and “Meadow,” respectively. The Tree site is situated approximately 30 m (98 feet) northeast of the SMWS within a grouping of one-seed juniper and piñon pine trees. The Meadow site is situated approximately 11 m (36 feet) northwest of the SMWS, in vegetation dominated by blue grama and broom snakeweed (*Gutierrezia sarothrae*).

SWCA is now responsible for the management of the SMWS and the maintenance, summation, and distribution of the data collected at this station. The following sections summarize the data collected since SWCA assumed responsibility for SMWS in April 2008. SWCA prepared a report, “South Mountain Weather Station: History, Data Summaries, and Continued Operation,” summarizing the data collected from 2006 and 2007 by EnviroLogic, and submitted that report to the Steering Committee. This report is available at the Restoration Institute’s website (http://www.nmfwri.org/).

During the 2011 monitoring season, New Mexico, particular Torrance and Bernalillo counties, were experiencing a severe drought (see Figure 2.7). The affects of the drought can clearly be seen in the result summaries below. The soil moisture measurement at both the Meadow and Tree sites showed long periods of drying, with only the near surface sensors showing variation (Figure 5.2–Figure 5.8). There were also no storms in 2011 that were able to produce deep seepage, which would register with the sensors in the deep bore holes. In fact, over the course of the monitoring period the deep soil moisture sensors at both the Meadow and Tree sites have remained constant with no variation. The effects of the drought can also be seen when looking at Figure 5.8, which displays the monthly averages of relative temperature and relative humidity. This graph shows high temperatures in June and July with low average relative humidity. This combination of high temperatures and low relative humidity is prime fire weather conditions and, therefore, likely a key factor for the occurrence of several large catastrophic wildfires in both New Mexico and Arizona (Los Conchas, Pacheco, and Wallow wildfires).

The following sensors were replaced during the spring of 2011: wind vain, relative humidity, temperature, and solar radiation. A wireless cellular modem was also added to make downloads easier and more efficient. The data displayed below in Figure 5.2 through Figure 5.8 are summarized as monthly averages of relevant meteorological data.

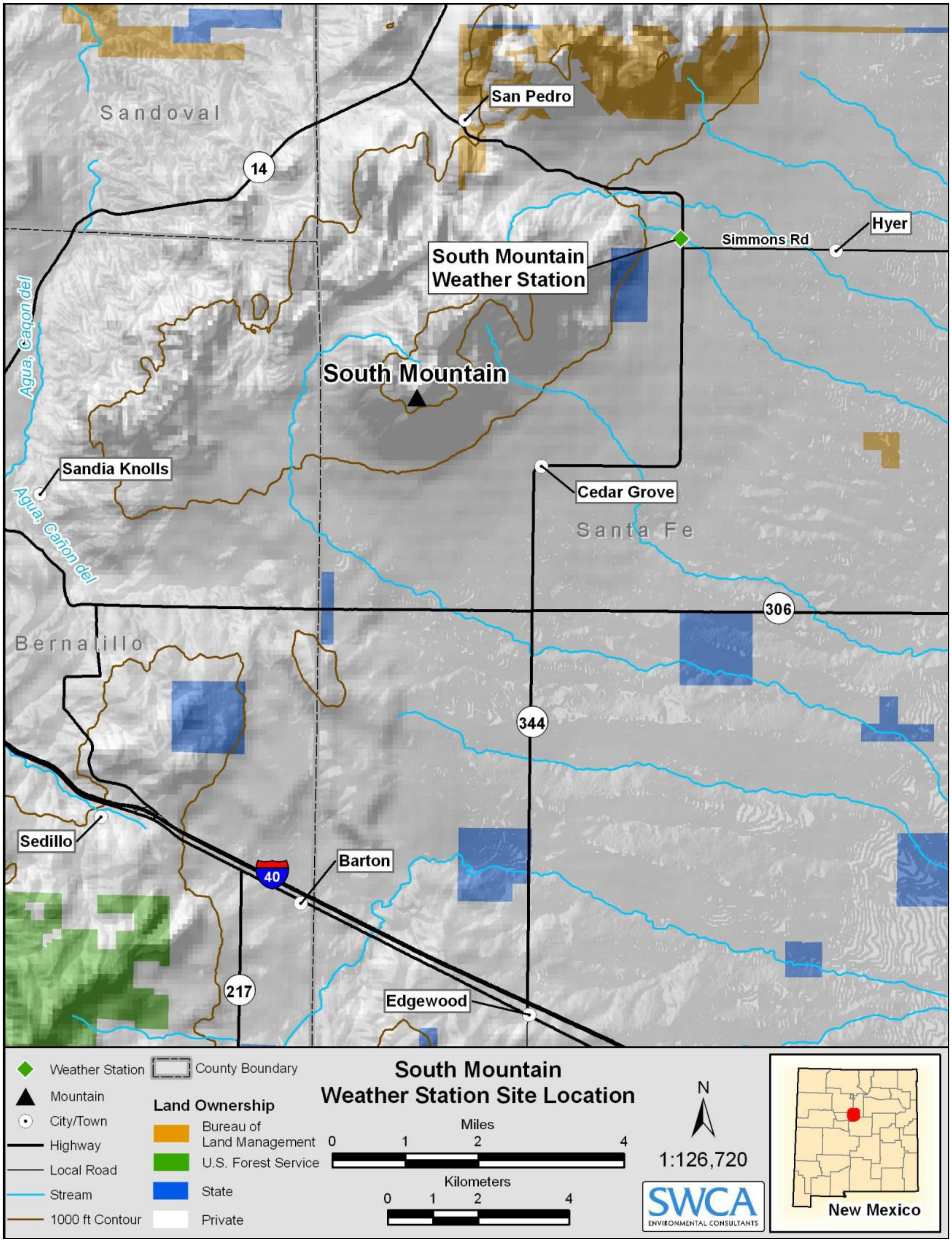


Figure 5.1. Location of the South Mountain Weather Station.

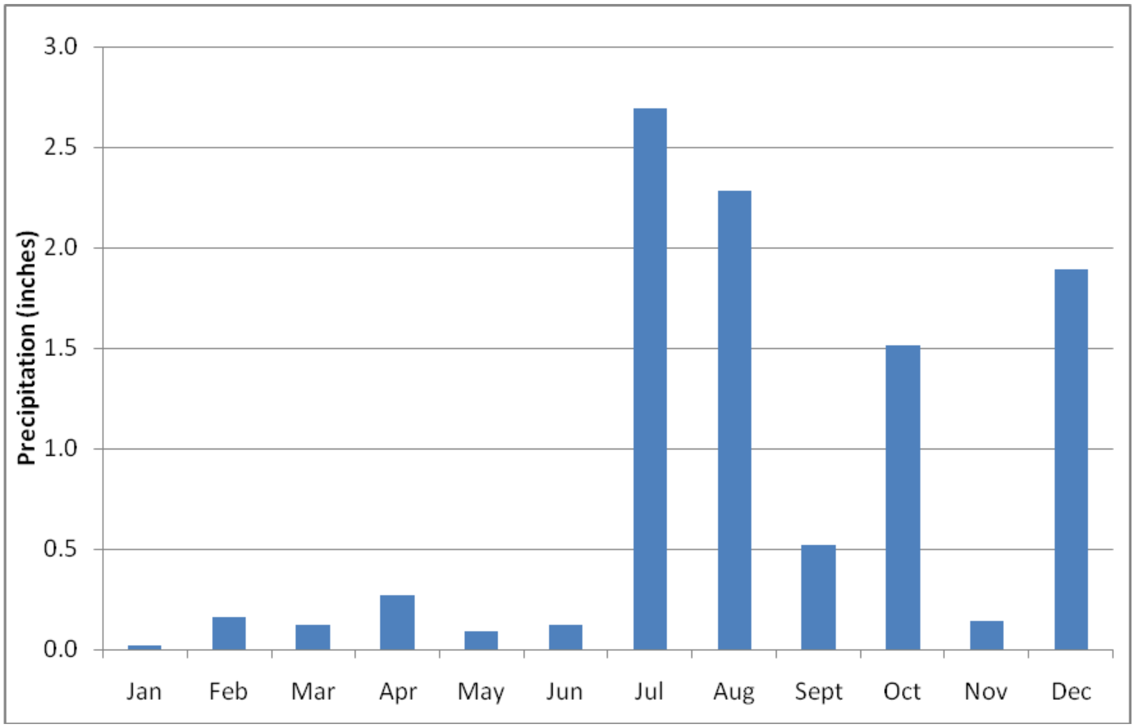


Figure 5.2. Graph showing monthly total rainfall over the course of 2011.

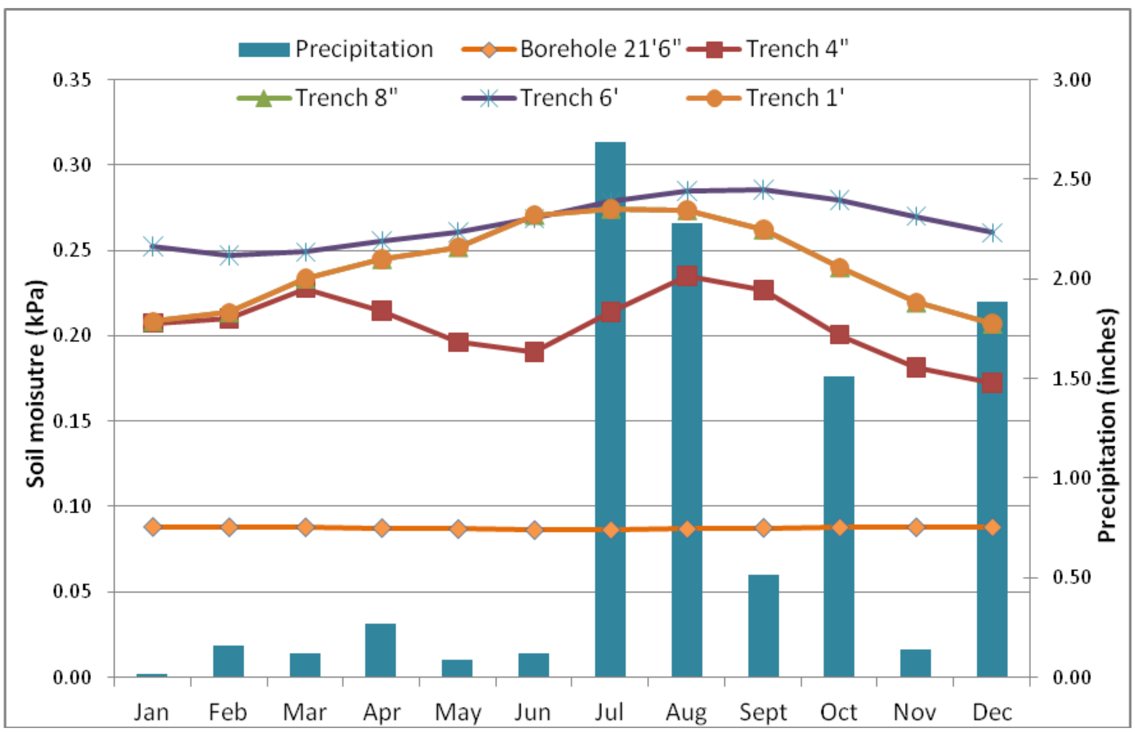


Figure 5.3. Tree site monthly average soil moisture and total precipitation for 2011.

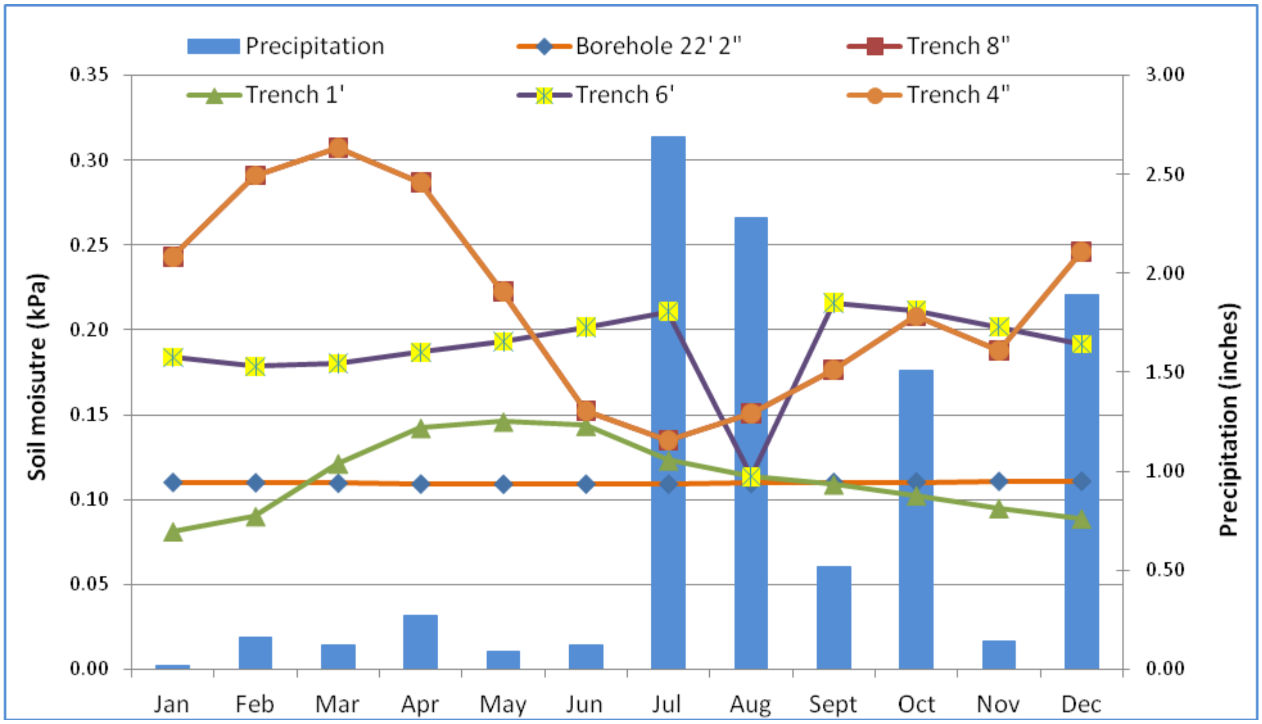


Figure 5.4. Meadow site average monthly soil moisture and total precipitation for 2011.

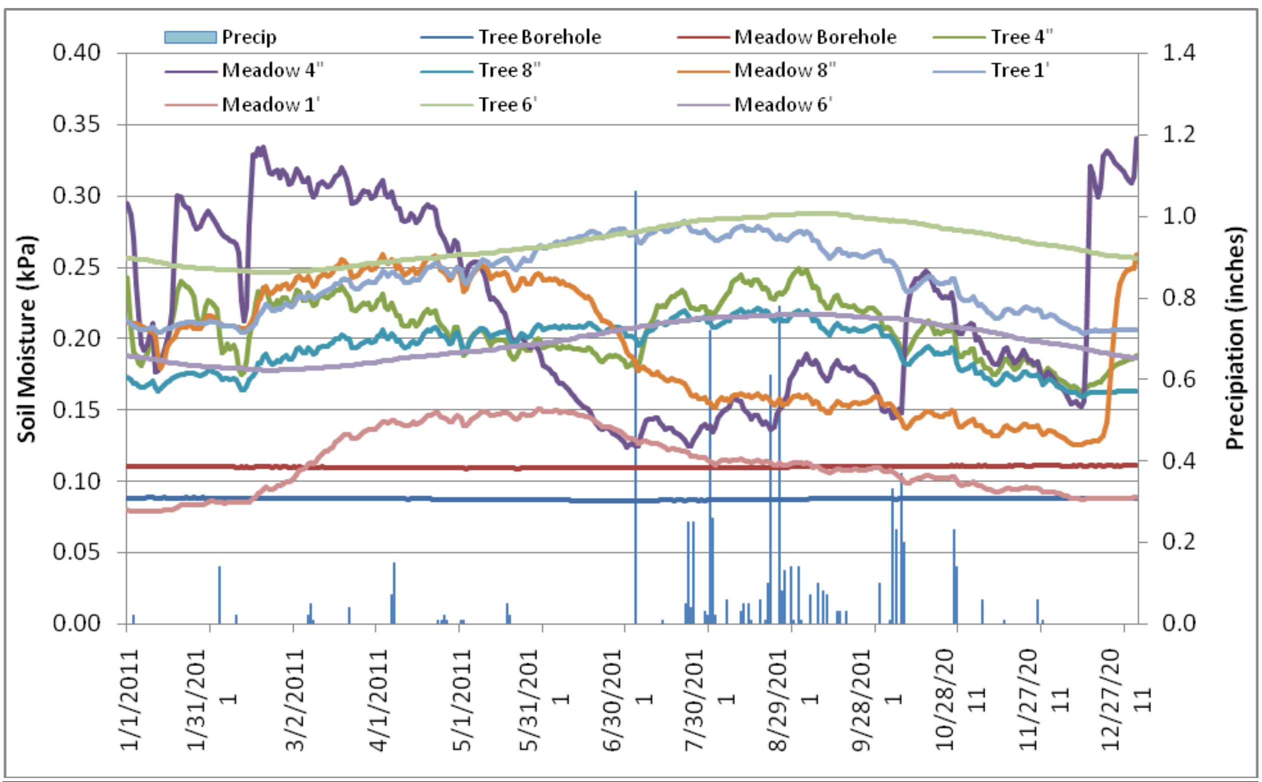


Figure 5.5. Tree and Meadow site average monthly soil moisture and total precipitation for 2011.

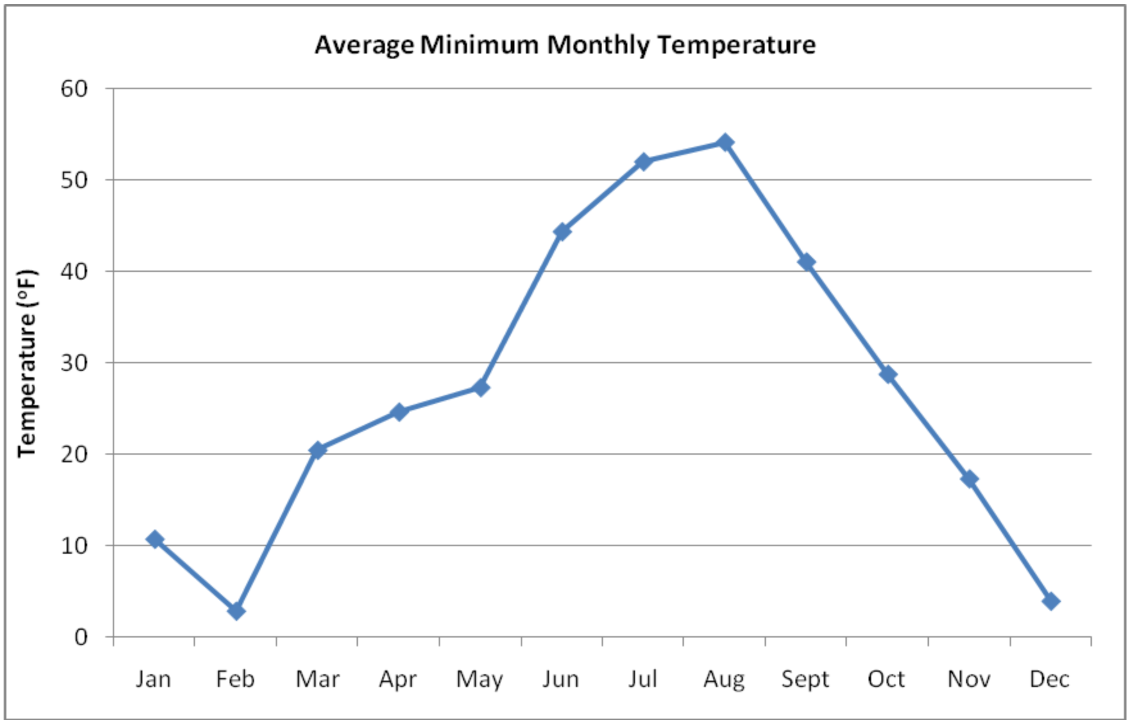


Figure 5.6. Minimum monthly temperature experienced at the SMWS during 2011.

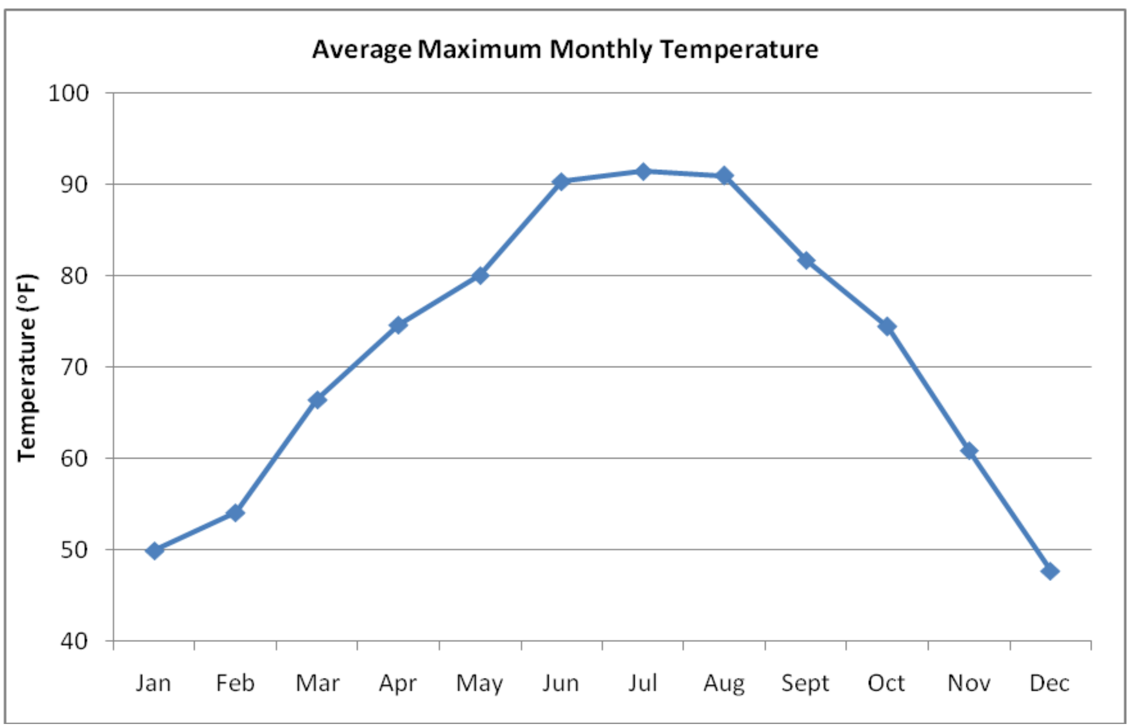


Figure 5.7. Maximum monthly temperature experienced at the SMWS during 2011.

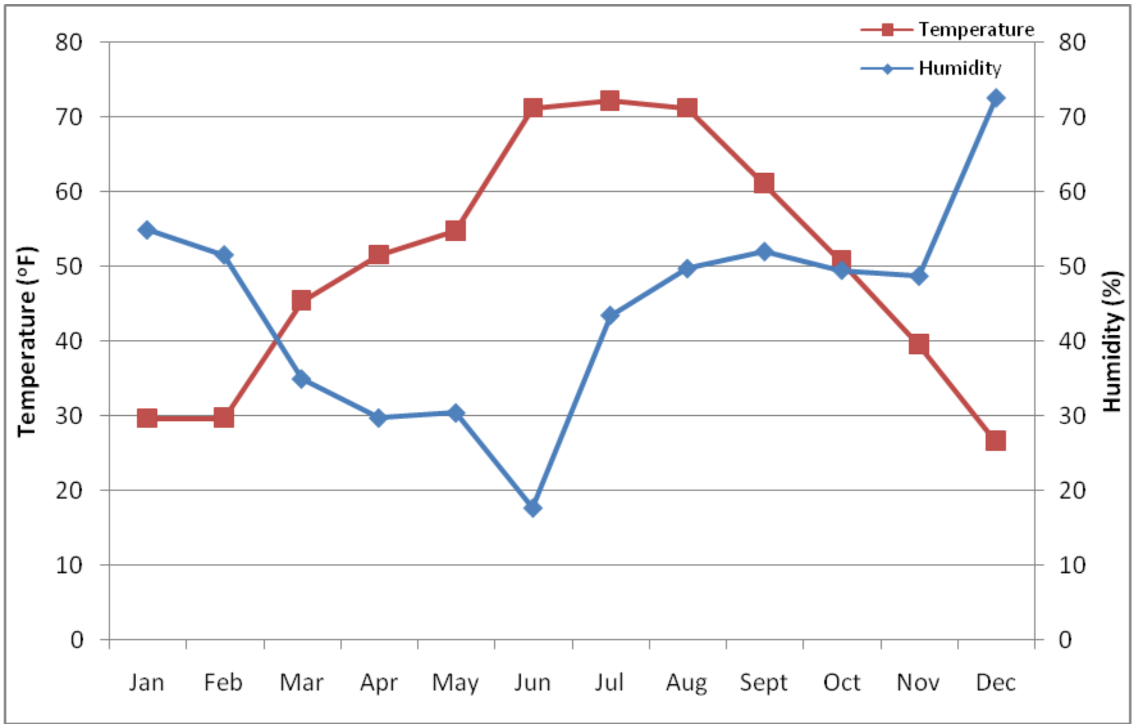


Figure 5.8. Daily average temperature and relative humidity over the course of 2011.

6.0 PLANNED MONITORING FOR 2012 (YEAR FIVE)

SWCA will continue the current monitoring efforts for year five of this project, including the operation of the SMWS. SWCA will monitor post-thinning treatment conditions in late spring and fall 2012 and continue to manage the SMWS and the weather data.

Post-wildfire monitoring has been suspended for 2012 because of safety issues regarding falling dead trees. Post-fire monitoring may commence in a year or two, if sufficiently few dead trees remain at the monitoring sites. At this time, SWCA does not anticipate changes in the current monitoring designs or methods for forest thinning monitoring. Reporting will include regular monthly progress reports and a 2012 Annual Report.

7.0 ACKNOWLEDGEMENTS AND CONTRIBUTORS

The New Mexico Water Trust Board provided funding for this project. The Estancia Basin Watershed Health, Restoration and Monitoring Steering Committee provided oversight and coordination of this project, in cooperation with the New Mexico Forest and Watershed Restoration Institute and New Mexico State Forestry. Deirdre Tarr of the Claunch-Pinto Soil and Water Conservation District and Joe Zebrowski from the New Mexico Forest and Watershed Restoration Institute provided valuable oversight and support. The Bouton, Candelaria, Kelly, Mitchell, Neff, Salazar, Sanchez, Vigil, and Wester families kindly offered access to their land to conduct forest thinning and monitoring research, along with the Chilili Land Grant, Manzano Land Grant, and the Manzano Mountain Retreat. New Mexico State Forestry, the U.S. Forest Service, the U.S. Geological Survey, and the Claunch-Pinto, East Torrance, and Edgewood soil and water conservation districts have all provided advice and support. Vernon Kohler and Kelly Archuleta from the Claunch-Pinto and Edgewood soil and water conservation districts have been assisting with field data collections. Mike Matush from the New Mexico Environment Department, Surface Water Quality Bureau, has been helpful in designing and installing stream monitoring stations. The Estancia Basin Water Planning Committee also contributed funding to install the new Chilili ponderosa pine monitoring study site. Joseph Fluder is the SWCA project manager and provided guidance, oversight, and quality assurance. In addition to the authors, SWCA staff Ryan Trollinger, Justin Elza, and Alayne Szymanski contributed to the preparation of this report.

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APPENDIX A
ANIMAL SPECIES RECORDED FROM FOREST MONITORING WILDLIFE STUDY PLOTS

Appendix A. Animal Species Recorded from Forest Monitoring Wildlife Study Plots

Common Name	Genus	Species	Code
Bird Species			
American crow	*Corvus*	*branchyrhynchos*	*AMCR*
American robin	*Turdus*	*migratorius*	*AMRO*
Ash-throated flycatcher	*Myarchus*	*cinerascens*	*ATFL*
Bewick's wren	*Thryomanes*	*bewickii*	*BEWR*
Black-capped chickadee	*Poecile*	*atricapillus*	*BCCH*
Black-throated gray warbler	*Dendroica*	*nigrescens*	*BTYW*
Broad-tailed hummingbird	*Cynanthus*	*latirostris*	*BTAH*
Chipping sparrow	*Spizella*	*passerina*	*CHSP*
Common raven	*Corvus*	*corvax*	*CORA*
Common nighthawk	*Chordeiles*	*minor*	*CONI*
Cooper's hawk	*Accipiter*	*cooperii*	*COHA*
Dark-eyed junco	*Junco*	*hyemalis*	*DEJU*
Finch sp.	*Carpodacus*	sp.	UNKN
Grace's warbler	*Dendroica*	*graciae*	*GRWA*
Hermit thrush	*Catharus*	*guttatus*	*HETH*
Juniper titmouse	*Baeolophus*	*ridgwayi*	*JUTI*
Orange crowned warbler	*Vermivora*	*celata*	*OCWA*
Mountain chickadee	*Poecile*	*gambeli*	*MOCH*
Mourning dove	*Zenaida*	*macroura*	*MODO*
Northern flicker	*Colaptes*	*auratus*	*NOFL*
Plumbeous vireo	*Vireo*	*plumbeus*	*PLVI*
Pinyon jay	*Gymnorhinus*	*cyanocephalus*	*PIJA*
Pygmy nuthatch	*Sitta*	*pygmaea*	*PYNU*
Red-breasted nuthatch	*Sitta*	*canadensis*	*RBNU*
Red crossbill	*Loxia*	*curvirostra*	*RECR*
Red-tailed hawk	*Buteo*	*jamaicensis*	*RTHA*
Ruby-crowned kinglet	*Regulus*	*calendula*	*RCKI*
Rufous hummingbird	*Selasphorus*	*rufus*	*RUHU*
Sharp-shinned hawk	*Accipiter*	*striatus*	*SSHA*
Spotted towhee	*Pipilo*	*maculatus*	*SPTO*
Stellar's jay	*Cyanocitta*	*stelleri*	*STJA*
Swainson's thrush	*Catharus*	*ustulatus*	*SWTH*
Townsend's solitaire	*Myadestes*	*townsendii*	*TOSO*
Turkey vulture	*Cathartes*	*aura*	*TUVU*
Western bluebird	*Sialia*	*mexicana*	*WEBL*
Western meadowlark	*Sturnella*	*neglecta*	*WEME*
Western scrub jay	*Aphelocoma*	*californica*	*WESJ*
White-breasted nuthatch	*Sitta*	*carolinensis*	*WBNU*
Wild turkey	*Meleagris*	*gallopavo*	*WITU*
Yellow-rumped warbler	*Dendroica*	*coronate*	*YRWA*
Rodent Species			
Colorado chipmunk	*Tamias*	*quadrivittatus*	*TAQU*
Deer mouse	*Peromyscus*	*maniculatus*	*PEMA*
Mexican vole	*Microtus*	*mexicanus*	*MIME*
Ord's kangaroo rat	*Dipodomys*	*ordii*	*DIOR*
Pinyon mouse	*Peromyscus*	*truei*	*PETR*
Silky pocket mouse	*Perognathus*	*flavus*	*PEFL*
White-footed mouse	*Peromyscus*	*leucopis*	*PELE*
White-throated woodrat	*Neotoma*	*albigula*	*NEAL*

APPENDIX B
LIST OF PLANT SPECIES ENCOUNTERED ON FOREST MONITORING STUDY PLOTS

Appendix B. List of Plant Species Encountered on Forest Monitoring Study Plots

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Gymnosperms						
Cypressaceae	*Juniperus*	*deppeana*	JUDE2	alligator juniper	tree	perennial
Cypressaceae	*Juniperus*	*monosperma*	JUMO	one-seed juniper	tree	perennial
Cypressaceae	*Juniperus*	*scopulorum*	JUSC2	Rocky Mountain juniper	tree	perennial
Pinaceae	*Pinus*	*edulis*	PIED	piñon pine	tree	perennial
Pinaceae	*Pinus*	*ponderosa*	PIPO	ponderosa pine	tree	perennial
Angiosperms: Dicotyledons						
Amaranthaceae	*Amaranthus*	*albus*	AMAL	prostrate pigweed	forb	annual
Amaranthaceae	*Amaranthus*	*cruentus*	AMCR	red amaranth	forb	annual
Amaranthaceae	*Amaranthus*	*palmeri*	AMPA	carelessweed	forb	annual
Anacardiaceae	*Rhus*	*trilobata*	RHTR	skunkbush sumac	shrub	perennial
Apiaceae	*Lomatium*	*dissectum*	LODI	fernleaf biscuitroot	forb	perennial
Asteraceae	*Achillea*	*millefolium*	ACMI2	common yarrow	forb	perennial
Asteraceae	*Ageratina*	*herbacea*	AGHE5	fragrant snakeroot	forb	perennial
Asteraceae	*Anaphalis*	*margaritacea*	ANMA	western pearly everlasting	forb	perennial
Asteraceae	*Antennaria*	*microphylla*	ANMI3	forb	perennial	
Asteraceae	*Artemisia*	*carruthii*	ARCA14	littleleaf pussytoes	forb	perennial
Asteraceae	*Artemisia*	*dracunculus*	ARDR4	taragon	forb	perennial
Asteraceae	*Artemisia*	*frigida*	ARFR4	prairie sagewort	forb	perennial
Asteraceae	*Artemisia*	*ludoviciana*	ARLU	white sagebrush	forb	perennial
Asteraceae	*Aster*	*falcatus*	ASFA3	Russian milkvetch	forb	annual
Asteraceae	*Bahia*	*dissecta*	BADI	ragleaf bahia	forb	annual
Asteraceae	*Brickellia*	*eupatorioides*	BREU	false boneset	forb	perennial
Asteraceae	*Brickellia*	*grandiflora*	BRGR	tasselflower brickel	forb	perennial
Asteraceae	*Chaetopappa*	*ericoides*	CHER2	rose heath	forb	perennial
Asteraceae	*Circium*	*undulatum*	CIUN	wavyleaf thistle	forb	annual
Asteraceae	*Conyza*	*canadensis*	COCA5	Canadian horseweed	forb	annual
Asteraceae	*Erigeron*	*divergens*	ERDI4	spreading fleabane	forb	biennial
Asteraceae	*Erigeron*	*flagellaris*	ERFL	trailing fleabane	forb	biennial
Asteraceae	*Erigeron*	*formosissimus*	ERFO3	beautiful fleabane	forb	perennial
Asteraceae	*Erigeron*	*speciosus*	ERSP4	aspen fleabane	forb	perennial
Asteraceae	*Erigeron*	*divergens*	ERDI4	spreading fleabane	forb	biennial
Brassicaceae	*Lepidium*	*alyssoides*	LEAL4	mesa pepperwort	forb	perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Brassicaceae	*Schoenocrambe*	*linearifolia*	SCLI12	slimleaf plainsmustard	forb	perennial
Brassicaceae	*Sisymbrium*	*altissimum*	SIAL2	tall tumblemustard	forb	annual/biennial
Cactaceae	*Cylindropuntia*	*imbricata*	CYIM2	tree cholla	succulent	perennial
Cactaceae	*Echinocereus*	*viridiflorus*	ECVI2	nylon hedgehog cactu	succulent	perennial
Cactaceae	*Escobaria*	*vivipera*	ESVI2	spinystar cactus	succulent	perennial
Cactaceae	*Grusonia*	*clavata*	GRCL	club cholla	succulent	perennial
Cactaceae	*Opuntia*	*engelmannii*	OPEN3	cactus apple	succulent	perennial
Cactaceae	*Opuntia*	*phaeacantha*	OPPH	tulip pricklypear	succulent	perennial
Cactaceae	*Opuntia*	*macrorhiza*	OPMA2	twistspine pricklypear	succulent	perennial
Cactaceae	*Opuntia*	*polyacantha*	OPPO	plains pricklypear	succulent	perennial
Caryophyllaceae	*Cerastium*	*brachypodum*	CEBR3	shortstalk chickweed	forb	perennial
Caryophyllaceae	*Cerastium*	*nutans*	CENU2	nodding chickweed	forb	annual/perennial
Caryophyllaceae	*Pseudostellaria*	*jamesiana*	PSJA2	tuber starwort	forb	perennial
Caryophyllaceae	*Silene*	*scouleri*	SISC7	simple campion	forb	perennial
Chenopodiaceae	*Chenopodium*	*capitatum*	CHCA4	blight goosefoot	forb	perennial
Chenopodiaceae	*Chenopodium*	*fremontii*	CHFR3	Fremont's goosefoot	forb	perennial
Chenopodiaceae	*Chenopodium*	*graveolens*	CHGR2	fetid goosefoot	forb	annual
Chenopodiaceae	*Chenopodium*	*incanum*	CHIN2	mealy goosefoot	forb	annual
Chenopodiaceae	*Chenopodium*	*leptophyllum*	CHLE4	narrowleaf goosefoot	forb	annual
Chenopodiaceae	*Salsola*	*kali*	SAKA	Russian thistle	forb	annual
Euphorbiaceae	*Chamaesyce*	*albomarginata*	CHAL11	whitemargin sandmat	forb	perennial
Euphorbiaceae	*Chamaesyce*	*chaetocalyx*	CHCHC3	bristlecup sandmat	Forb	perennial
Euphorbiaceae	*Chamaesyce*	*fendleri*	CHFE3	threadstem sandmat	forb	perennial
Euphorbiaceae	*Chamaesyce*	*serpyllifolia*	CHSE6	thymeleaf sandmat	forb	annual
Fabaceae	*Astragalus*	*mollisimus*	ASMO7	wooly locoweed	forb	perennial
Fabaceae	*Astragalus*	*nuttallianus*	ASNU4	smallflowered milkvetch	forb	perennial
Fabaceae	*Dalea*	*purpurea*	DAPU5	purple prairie clove	forb	perennial
Fabaceae	*Hoffmannseggia*	*drepanocarpa*	HODR	sicklepod holdback	forb	perennial
Fabaceae	*Lotus*	*wrightii*	LOWR	Wright's deervetch	forb	perennial
Fabaceae	*Lupinus*	*kingii*	LUKI	King's lupine	forb	perennial
Fabaceae	*Psoralidium*	*tenuiflorum*	PSTE5	slimflower scurfpea	forb	perennial
Fabaceae	*Robinia*	*neomexicana*	RONE	New Mexico locust	tree	perennial
Fabaceae	*Vicea*	*americana*	VIAM	American vetch	forb	perennial
Fagaceae	*Quercus*	*gambelii*	QUGA	Gambel's oak	tree	perennial
Fagaceae	*Quercus*	*grisea*	QUGR3	gray oak	tree	perennial

Group/Family	Genus	Species	Code	Common Name	Form	Life History
Fagaceae	*Quercus*	*turbinella*	QUTU2	Sonoran scrub oak	tree	perennial
Geraniaceae	*Geranium*	*caespitosum*	GECAF	Fremont's geranium	forb	perennial
Hydrophyllaceae	*Nama*	*dichotomum*	NADI	wishbone fiddleleaf	forb	annual
Lamiacea	*Agastache*	*pallidiflora*	AGPA	Bill Williams Mountain giant hyssop	forb	perennial
Lamiacea	*Hedeoma*	*drummondii*	HEDR	Drummond's false pen	forb	annual
Lamiacea	*Salvia*	*subincisa*	SASU7	sawtooth sage	forb	annual
Linaceae	*Linum*	*aristatum*	LIAR3	bristle flax	forb	annual
Linaceae	*Linum*	*vernale*	LIVE2	Chihuahuan flax	forb	annual
Malvaceae	*Spheralcea*	*angustifolia*	SPAN3	copper globemallow	forb	perennial
Malvaceae	*Spheralcea*	*coccinea*	SPCO	scarlet globemallow	forb	perennial
Malvaceae	*Spheralcea*	*fendleri*	SPFE	Fendler's globemallow	forb	perennial
Malvaceae	*Spheralcea*	*grossulariifolia*	SPGR2	gooseberryleaf globe	forb	perennial
Malvaceae	*Spheralcea*	*hastulata*	SPHA	spear globemallow	forb	perennial
Monotropaeae	*Monotropa*	*hypopithys*	MOHY3	pinesap	forb	perennial
Nyctaginaceae	*Mirabilis*	*linearis*	MILI3	narrowleaf four o'clock	forb	perennial
Nyctaginaceae	*Mirabilis*	*oxybaphoides*	MIOX	smooth spreading four o’clock	forb	perennial
Oleaceae	*Menodora*	*scabra*	MESC	rough menodora	forb	perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	tufted evening primrose	forb	annual
Oxalidaceae	*Oxalis*	*violacea*	OXVI	violet woodsorrel	forb	perennial
Papaveraceae	*Argemone*	*squarrosa*	ARSQ	hedgehog pricklypoppy	forb	perennial
Onagraceae	*Oenothera*	*caespitosa*	OECA10	tufted evening primrose	forb	annual
Polemoniaceae	*Ipomopsis*	*aggregata*	IPAG	scarlet gilia	forb	annual
Polygonaceae	*Eriogonum*	*alatum*	ERAL4	winged buckwheat	forb	annual
Polygonaceae	*Eriogonum*	*annuum*	ERAN4	annual buckwheat	forb	annual
Polygonaceae	*Eriogonum*	*microthecum*	ERMI4	slender buckwheat	shrub	perennial
Polygonaceae	*Eriogonum*	*racemosum*	ERRA3	redroot buckwheat	forb	perennial
Polygonaceae	*Eriogonum*	*wrightii*	ERWR	bastardsage	forb	perennial
Polygonaceae	*Polygonum*	*douglasii*	PODO4	Douglas' knotweed	forb	annual
Portulacaceae	*Phemeranthus*	*brevicaulis*	PHBR15	dwarf fameflower	forb	perennial
Portulacaceae	*Portulaca*	*oleracea*	POOL	little hogweed	forb	annual
Portulacaceae	*Portulaca*	*pilosa*	POPI3	kiss me quick	forb	annual
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	pygmyflower rockjasmine	forb	annual
Ranunculaceae	*Thalictrum*	*fendleri*	THFE	Fendler's meadow-rue	forb	perennial

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Santalaceae	*Comandra*	*umbellata*	COUM	bastard toadflax	forb	perennial
Primulaceae	*Androsace*	*septentrionalis*	ANSE4	pygmyflower rockjasmine	forb	annual
Scrophulariaceae	*Castilleja*	*integra*	CAIN14	wholeleaf Indian paintbrush	forb	perennial
Scrophulariaceae	*Cordylanthus*	*tenuis*	COTE3	slender birdbeak	forb	annual
Scrophulariaceae	*Cordylanthus*	*wrightii*	COWR2	Wrights bird's beak	forb	annual
Scrophulariaceae	*Penstemon*	*barbatus*	PEBA2	beardlip penstemon	forb	perennial
Scrophulariaceae	*Penstemon*	*jamesii*	PEJA	James' beardtongue	forb	perennial
Scrophulariaceae	*Penstemon*	*oliganthus*	PEOL	Apache beardtongue	forb	perennial
Scrophulariaceae	*Penstemon*	*virgatus*	PEVI4	upright blue beardtongue	forb	perennial
Scrophulariaceae	*verbascum*	*thapsus*	VETH	common mullein	forb	biennial
Solanaceae	*Physalis*	*hederifolia*	PHHE4	ivyleaf groundcherry	forb	perennial
Solanaceae	*Solanum*	*elaeagnifolium*	SOEL	silverleaf nightshade	forb	perennial
Solanaceae	*Solanum*	*triflorum*	SOTR	cutleaf nightshade	forb	perennial
Verbanaceae	*Glandularia*	*bipinnatifida*	GLBIC	Davis Mountain mock vervain	forb	perennial
Verbanaceae	*Verbena*	*macdougalii*	VEMA	MacDougal verbena	forb	annual
Viscaceae	*Phoradendron*	*juniperinum*	PHJU	juniper mistletoe	herb	Perennial/juniper parasite
Viscaceae	*Phoradendron*	*macrophyllum*	PHMA18	Colorado desert mist	herb	perennial
Angiosperms: Monocotyledons						
Agavaceae	*Yucca*	*baccada*	YUBA	banana yucca	succulent	perennial
Agavaceae	*Yucca*	*glauca*	YUGL	soapweed yucca	succulent	perennial
Commelinaceae	*Commelina*	*dianthifolia*	CODI4	birdbill dayflower	forb	perennial
Cyperaceae	*Carex*	*geophila*	CAGE	White Mountain sedge	sedge	perennial
Cyperaceae	*Cyperus*	*esculentus*	CYES	yellow nutsedge	sedge	perennial
Cyperaceae	*Cyperus*	*fendlerianus*	CYFE2	Fendler's flatsedge	sedge	perennial
Liliaceae	*Allium*	*cernuum*	ALCE2	nodding onion	forb	perennial
Poaceae	*Achnatherum*	*robustum*	ACRO7	sleepygrass	grass	perennial
Poaceae	*Alopecurus*	*aequalis*	ALAE	shortawn foxtail	grass	perennial
Poaceae	*Andropogon*	*gerardii*	ANGE	big bluestem	grass	perennial
Poaceae	*Aristida*	*adscensionis*	ARAD	sixweeks threeawn	grass	annual
Poaceae	*Aristida*	*arizonica*	ARAR6	Arizona threeawn	grass	perennial
Poaceae	*Aristida*	*divaricata*	ARDI5	poverty threeawn	grass	perennial
Poaceae	*Aristida*	*purpurea*	ARPU9	purple threeawn	grass	perennial
Poaceae	*Blepharoneuron*	*tricholepsis*	BLTR	pine dropseed	grass	perennial

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Poaceae	*Bouteloua*	*aristidoides*	BOAR	needle grama	grass	annual
Poaceae	*Bouteloua*	*curtipendula*	BOCU	sideoats grama	grass	perennial
Poaceae	*Bouteloua*	*gracilis*	BOGR2	blue grama	grass	perennial
Poaceae	*Bromus*	*arvensis*	BRAR5	field brome	grass	annual
Poaceae	*Elymus*	*canadensis*	ELCA4	Canada wildrye	grass	perennial
Poaceae	*Elymus*	*elymoides*	ELEL5	squirreltail	grass	perennial
Poaceae	*Elymus*	*hystrix L.*	ELHY	eastern bottlebrush	grass	perennial
Poaceae	*Eragrostis*	*cilianensis*	ERCI	stinkgrass	grass	annual
Poaceae	*Eragrostis*	*curvula*	ERCU2	weeping lovegrass	grass	annual
Poaceae	*Eragrostis*	*mexicanus*	ERME	Mexican lovegrass	grass	annual
Poaceae	*Koeleria*	*macrantha*	KOMA	prairie junegrass	grass	perennial
Poaceae	*Lolium*	*perenne*	LOPE	perennial ryegrass	grass	annual
Poaceae	*Lycurus*	*phleoides*	LYPH	common wolfstail	grass	perennial
Poaceae	*Lycurus*	*setosus*	LYSE3	bristly wolfstail	grass	perennial
Poaceae	*Monroa*	*squarrosa*	MOSQ	false buffalograss	grass	annual
Poaceae	*Muhlenbergia*	*minutissima*	MUMI2	annual muhly	grass	annual
Poaceae	*Muhlenbergia*	*montana*	MUMO	mountain muhly	grass	perennial
Poaceae	*Muhlenbergia*	*thurberi*	MUTH	Thurber's muhly	grass	perennial
Poaceae	*Muhlenbergia*	*torreyi*	MUTO2	ring muhly	grass	perennial
Poaceae	*Muhlenbergia*	*richardsonii*	MURI	mat muhly	grass	perennial
Poaceae	*Panicum*	*capillare*	PACA6	witchgrass	grass	annual
Poaceae	*Pascopyrum*	*smithii*	PASM	western wheatgrass	grass	perennial
Poaceae	*Piptatherum*	*micranthum*	PIMI7	littleseed ricegrass	grass	perennial
Poaceae	*Pleuraphis*	*jamesii*	PLJA	James' galleta	grass	perennial
Poaceae	*Poa*	*fendleriana*	POFE	muttongrass	grass	perennial
Poaceae	*Setaria*	*viridis*	SEVI4	green bristlegrass	grass	annual
Poaceae	*Sporobolus*	*cryptandrus*	SPCR	sand dropseed	grass	perennial
Poaceae	*Thinopyrum*	*ponticum*	THPO7	tall wheatgrass	grass	perennial
Non-Vascular Plants						
–	multiple	multiple	MOSS	moss	crypt	perennial
–	multiple	multiple	CRUST	cryptobiotic crust	crypt	perennial

Taxonomy and names follow the U.S. Department of Agriculture (2010) PLANTS Database.

Attachments

DVD with all raw data files along with an electronic .pdf version of the report

Addenda

(SMWS quarterly reports)