Paired Watershed Study to Track Soil Moisture and Alluvial Water Response Before and After Brush Treatments in the Gila Watershed Region, New Mexico

FINAL REPORT, 2009

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This project encompasses two study areas, in the Burro Mountains and at Stiver Canyon in the Gila River headwaters. This report accompanies the CD containing all data collected through April 2009 since the project's start in November 2007. An outline of all project activities since that time was provided on the Interim Report, 2009. A copy of that report is included on the CD. Report contents are organized as shown below.

BURRO MOUNTAINS SITE

- Map
- Table of data collection sites
  - Soil moisture
  - Vegetation
  - Climate
  - Alluvial groundwater
  - Soils sampled
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  - Alluvial groundwater (piezometers)
  - Climate
  - Vegetation data

STIVER CANYON SITE

- Map
- Table of data collection sites
  - Soil moisture
  - Vegetation
  - Climate
  - Alluvial groundwater
  - Soils sampled
  - Other
- Sample data graphs and explanatory notes
  - Soil moisture stations
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  - Climate
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STATUS OF TREATMENTS PLANNING

FUTURE WORK

BURRO MOUNTAINS STUDY AREA

All instrumentation planned for the study area in the Burros Mountains has been installed. Sensors and other instruments are downloaded at least quarterly. Table 1 summarizes the data collection sites and data collection periods since study inception in November 2007. Soil moisture data collection sites, identified by letters, are shown on the map below. The map also shows thinning treatment zones established in conjunction with Gila National Forest staff. Treatments are scheduled to begin October 2010.

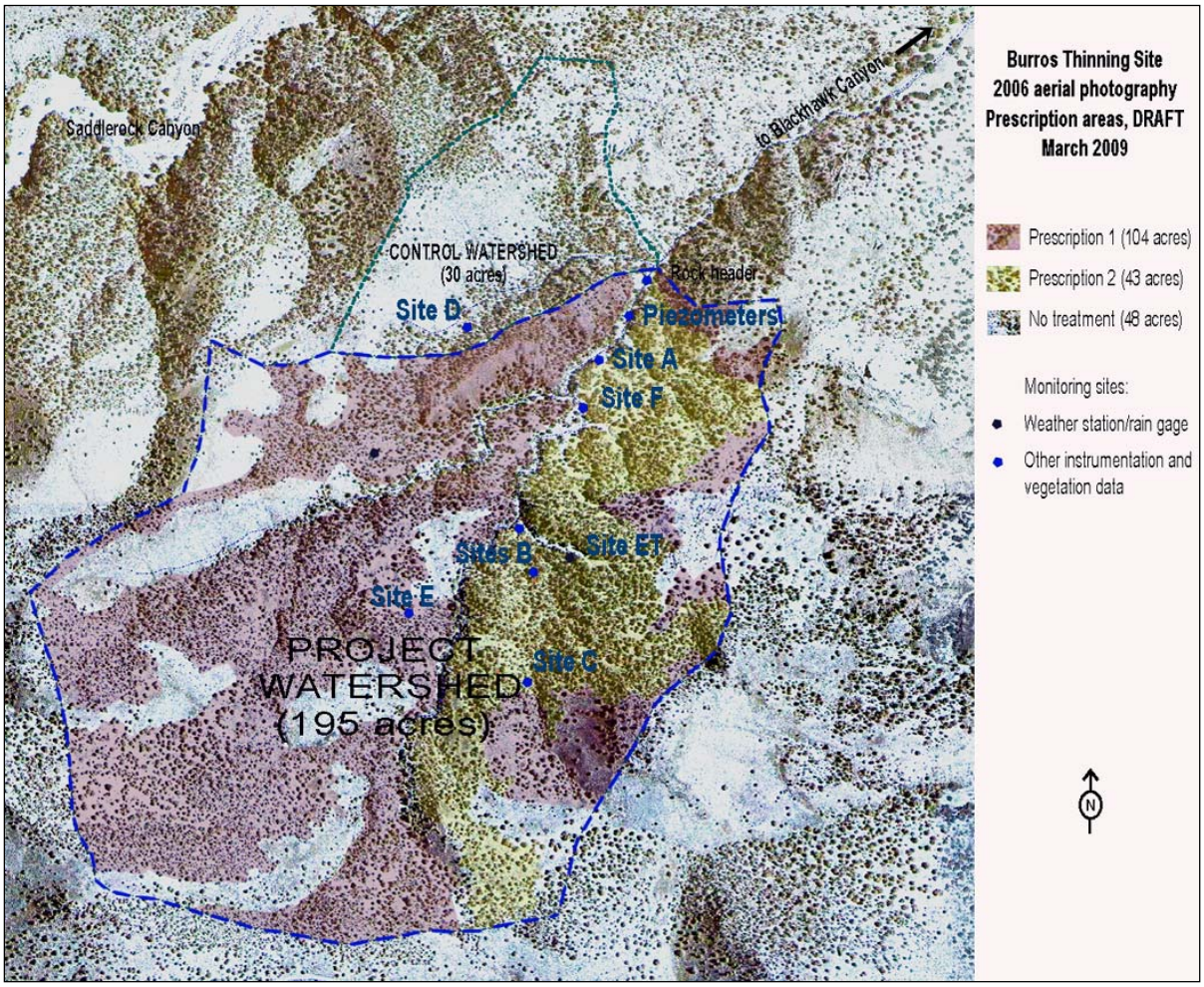


Table 1. Data collected at Burro Mountains project area since project start, November 2007.

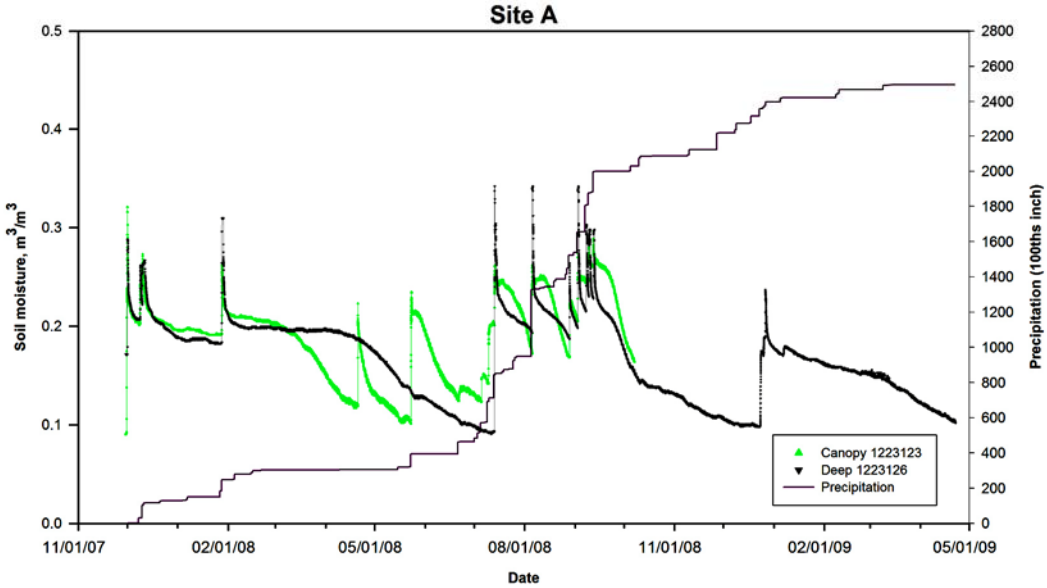
	Archived data			
Site	**Alluvial and soil moisture**	**Vegetation**	**Climate**	**Other**
Site A:				
Deep	11/2007-4/2009			
Canopy	11/2007-10/2008			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Soil samples (sensor calibration)				11/2007
Site B1 (upper)				
Canopy	11/2007-4/2009			
Open	11/2007-4/2009 (gap 8/2008)			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Site B2 (lower)				
Deep	11/2007-4/2009			
Open	11/2007-4/2009			
Soil samples (sensor calibration)				11/2007
Site ET				
Veg. transects		4/2008		
Veg. biomass		3/2009		
Temperature/RH/ wind speed/soil temperature/solar radiation/ precipitation			12/2008-4/2009	
Site C				
Deep	11/2007-4/2009			
Canopy	11/2007-4/2009			
Dripline	11/2007-7/2008; 9/2008-4/2009			
Open	11/2007-4/2009			
Veg. transects		4/2008		
Veg. biomass		3/2009		
Veg. richness		11/2008		
Temperature			11/2007-4/2009	
Soil temperature			11/2007-4/2009	
RH			11/2008-4/2009	
Soil samples (sensor calibration)				11/2007

Table 1 continued.

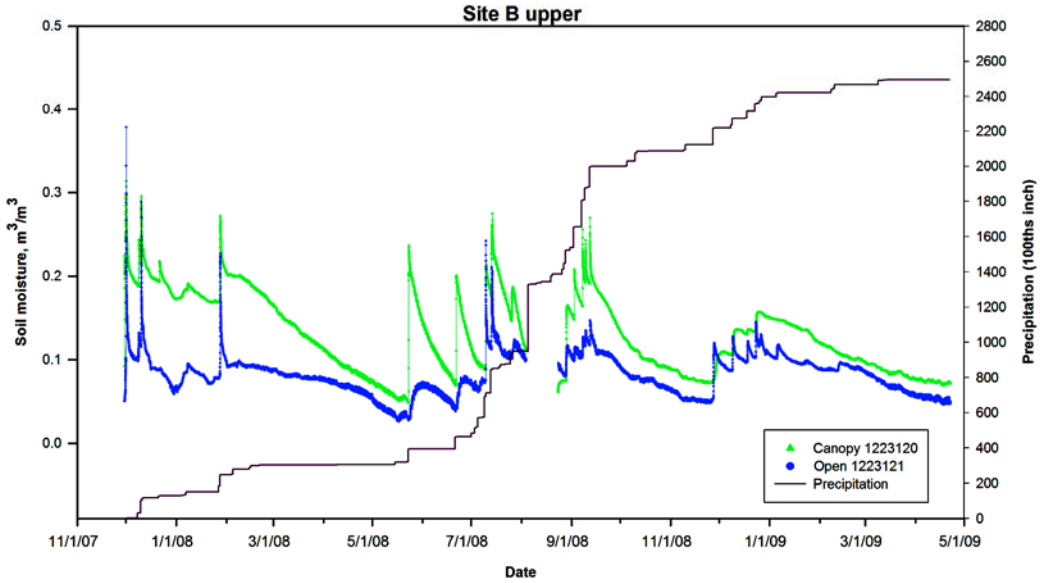
Site D (control)				
Deep	1/2008-4/2009			
Open	1/2008-4/2009			
Canopy	1/2008-4/2009			
Site E				
Deep	5/2008-6/2008;			
Canopy	9/2008-4/2009			
Dripline	(all sensors)			
Open				
Veg. transects		4/2008		
Veg. biomass		3/2009		
Soil samples (sensor calibration)				8/2008
Site F				
Deep				
Canopy	5/2008-4/2009			
Dripline	(all sensors)			
Open				
Veg. richness		11/2008		
Soil samples (sensor calibration)				8/2008
Site UV				
Veg. transects		4/2008		
Piezometers				
01 (below spring)	12/2007-4/2009			
02 (above spring)	12/2007-4/2009			
Precipitation				
Recording rain gage			11/2007-4/2009	
Snow gage			--	
Bird count (Audubon)				4/2009
Bird survey (Hawks Aloft)				1/2009; 5/2009

Graphed data: *Recording soil moisture sensors*

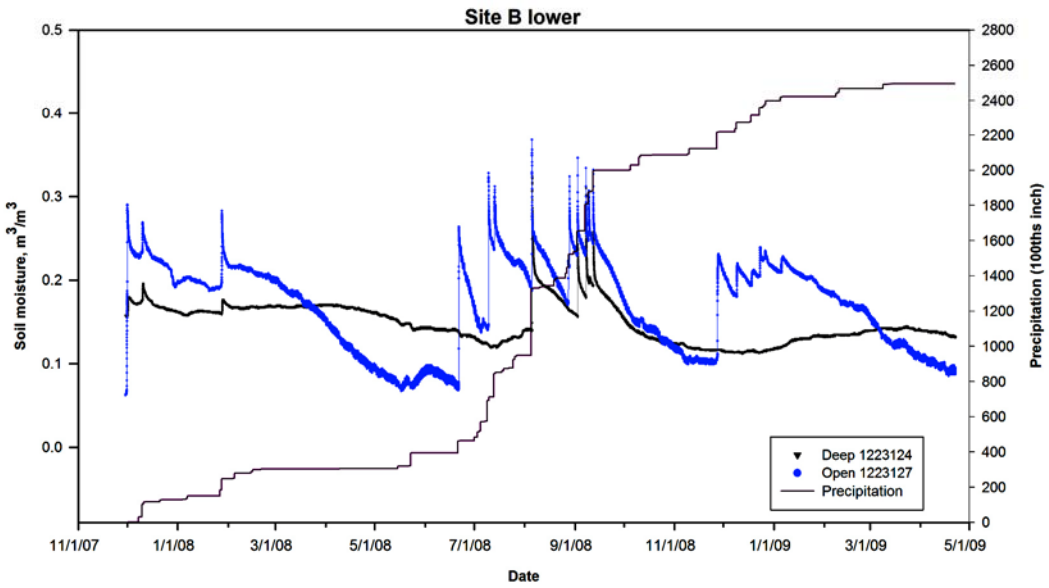
The final data download for the project period to date occurred in April 2009. Soil moisture data collected at 5-min time steps were filtered into averaged 15-min data. The resulting data sets were evaluated for sensor errors (i.e., during frozen soil conditions) and damage; invalid data were removed. Usable data collected by the recording soil moisture sensors and rain gage since the start of the project in November 2007 are shown graphically below. Site locations are shown on the map. Refer to the figure captions for details on data gaps and calibration notes.



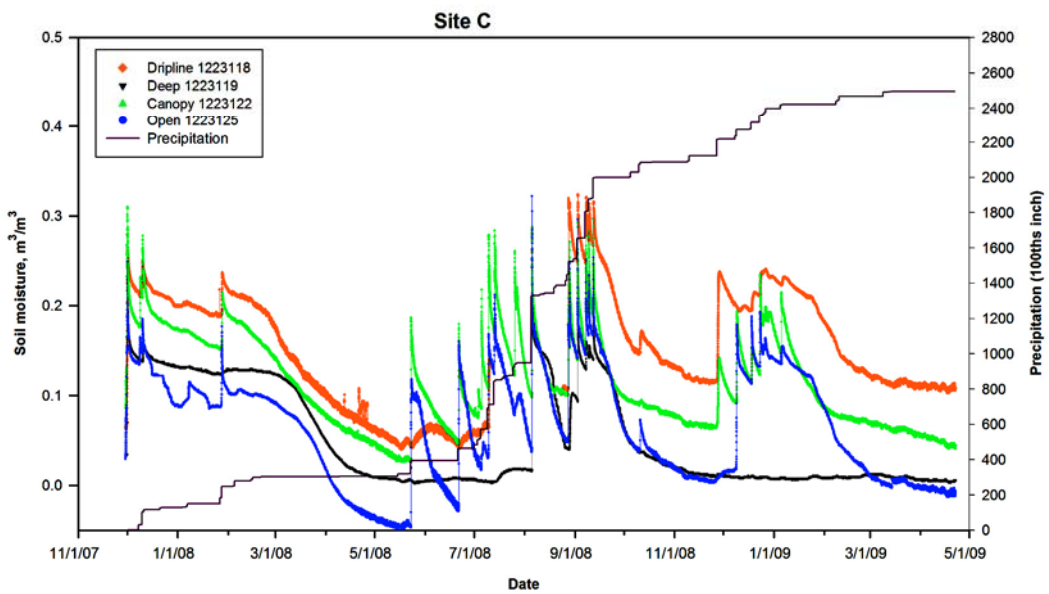
Site A. Recording soil moisture sensors collect data beneath tree canopy (0.5-ft depth) and at the toe of slope to main drainage (1.5-ft depth). The canopy sensor failed in late October 2008 and will be replaced. Results are generally in good agreement with most other sensors of these types (see Sensor Regressions, below).



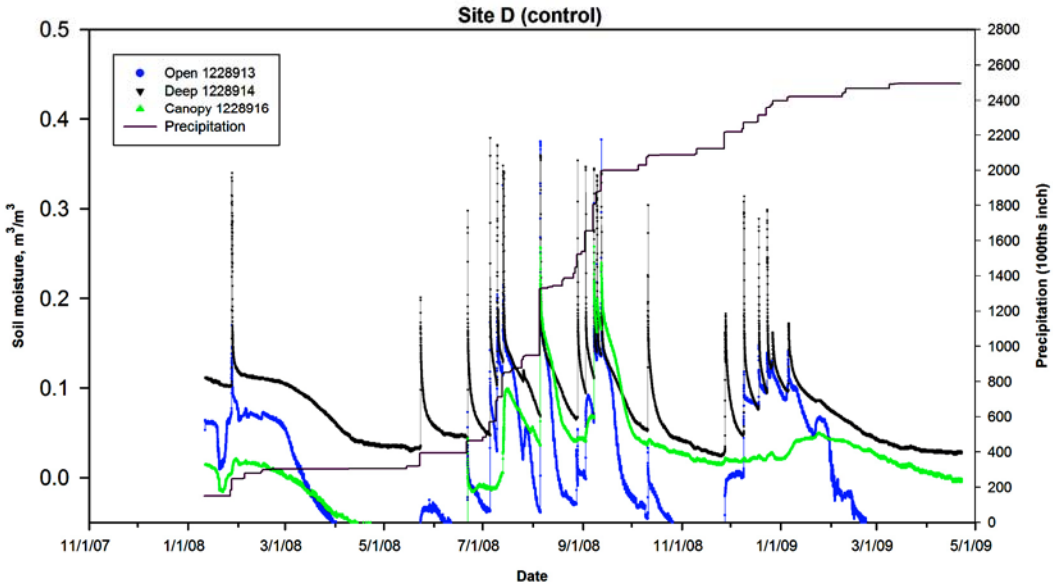
Site B (upper). Recording soil moisture sensors collect data beneath and beyond the tree canopy (0.5-ft depth). A data gap occurred during August 2008. Results are generally in good agreement with most other sensors of these types (see Sensor Regressions, below) .



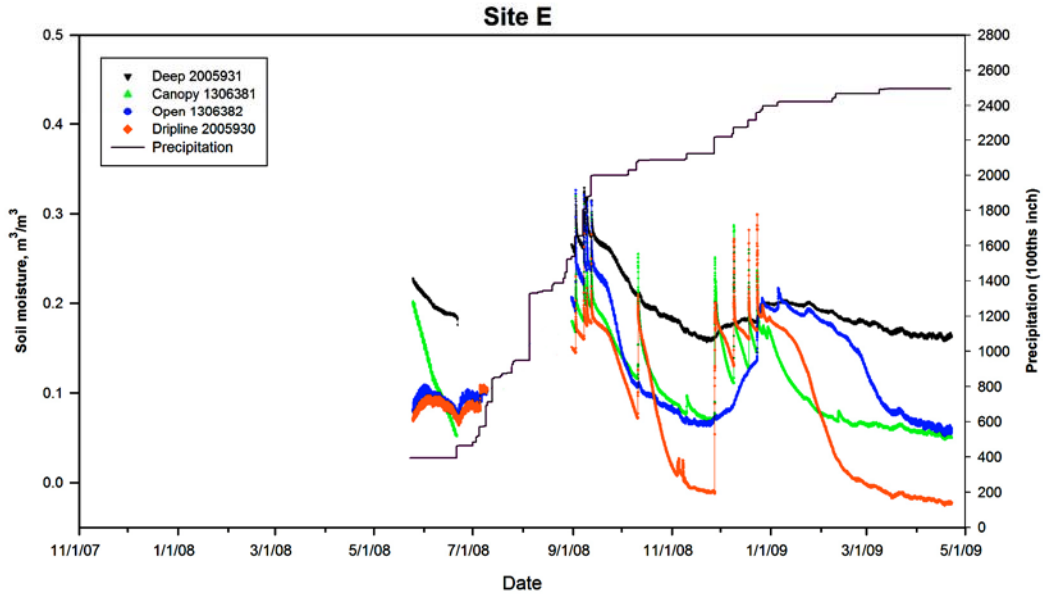
Site B (lower). Recording soil moisture sensors collect data beneath tree canopy (0.5-ft depth) and at the toe of slope to main drainage (1.5-ft depth). Results are generally in good agreement with most other sensors of these types (see Sensor Regressions, below).



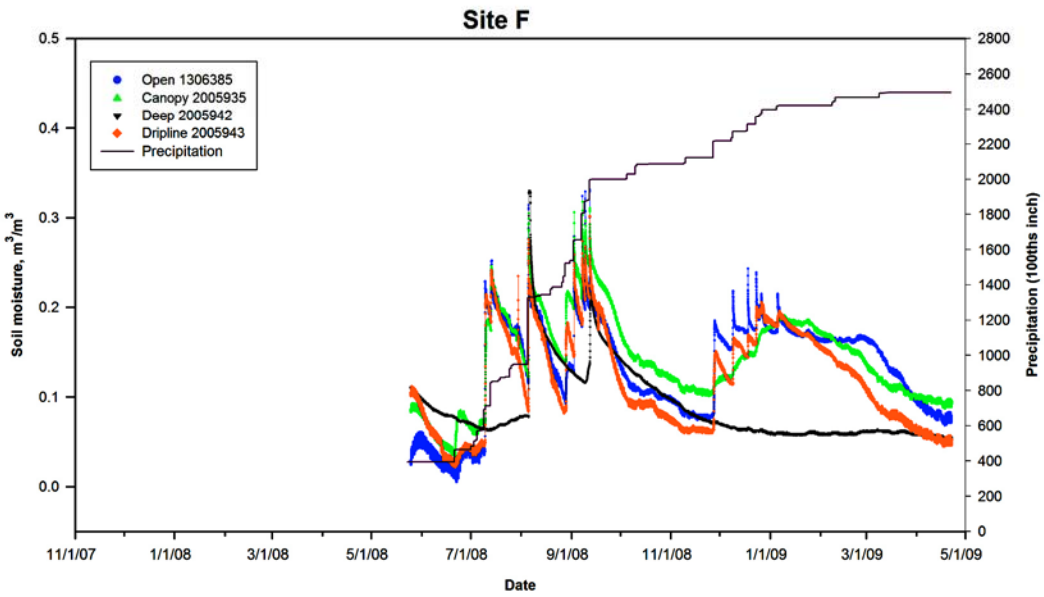
Site C. Recording soil moisture sensors collect data beneath the tree canopy and dripline and outside of tree cover (each at 0.5-ft depth), and at the toe of slope to main drainage (1.5-ft depth). The dripline sensor was damaged in July 2008 and replaced September 2008. Results from three of the sensors are generally in good agreement with most other sensors of these types (see Sensor Regressions, below). Values from the deep sensor suggest additional calibration of the sensor. Potential calibration of all sensors is being evaluated by the results of regression analysis, and will utilize gravimetric analysis of additional soil samples to be collected at varying degrees of soil moisture.



Site D. Recording soil moisture sensors collect data beneath the tree canopy and beyond tree cover (each at 0.5-ft depth), and at a deeper placement beyond tree cover (1.5-ft depth). Data recording began January 2008. All sensors at this site record negative values during dry periods and will require calibration. Sensor calibration for soil type is being evaluated by the results of regression analysis (see Sensor Regression Analysis, below), and will utilize gravimetric analysis of additional soil samples to be collected at varying degrees of soil moisture.



Site E. This site was added in May 2008. Recording soil moisture sensors collect data beneath the tree canopy and dripline, and beyond tree cover (each at 0.5-ft depth). The "deep" placement is also beyond tree cover (1.5-ft depth). All sensors were damaged in June 2008 and replaced August 2008. Results are generally in good agreement with most other sensors of these types (see Sensor Regressions, below), but will continue to be evaluated given the sensors' abbreviated period of record.



Site F. This site was added in May 2008. Recording soil moisture sensors collect data beneath the tree canopy and dripline, and beyond tree cover (each at 0.5-ft depth). The "deep" placement is at the toe of slope to main drainage (1.5-ft depth). Results are generally in good agreement with most other sensors of these types (see Sensor Regressions, below), but will continue to be evaluated given the sensors' abbreviated period record.

Sensor regression analysis

Eventual data analysis will seek to combine data from as many sensors of each type as possible, in order to increase the robustness of the data set's applicability across the project area. Correlations among the usable data from each soil moisture sensor collected through April 2009 were evaluated by a preliminary regression analysis. Sensor data were grouped by type (e.g., "canopy," "open") and the mean values for all sensors of each type were calculated for each 15-minute time step. A simple regression curve was used to compare the data collected by individual sensors of each type and the mean for all sensors of that type. Results are shown in Table 2. Variations in the intercept value are particularly important, suggesting needed calibration, when they indicate sensor readings of << 0 during very dry periods.

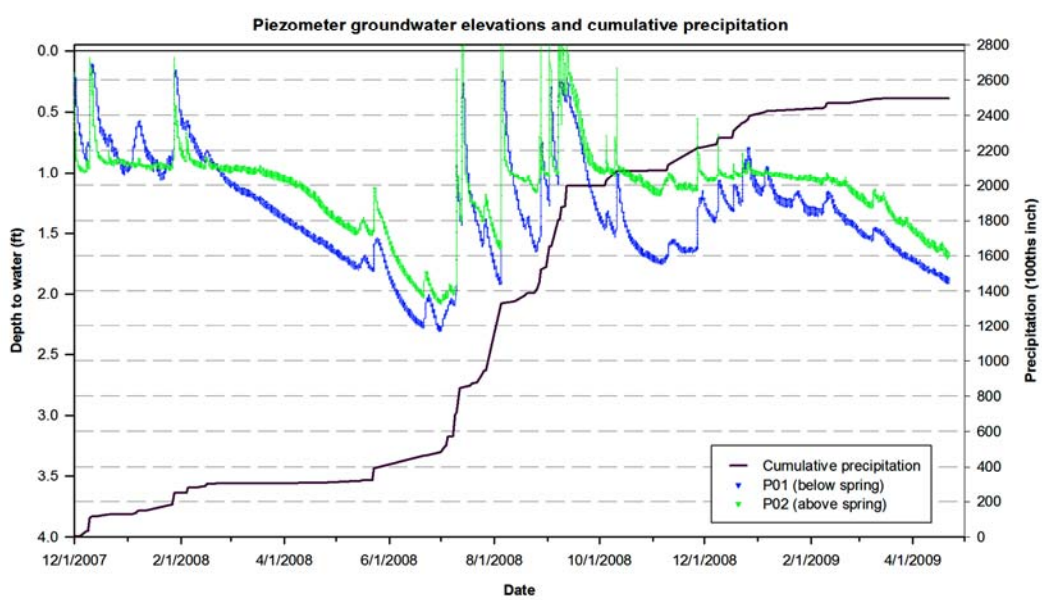
Initial soil samples were collected at a number of sites (Table 1) and soil moisture contents were estimated by bulk density and gravimetric analysis (DB Stephens and Associates). Lab results are included on the data CD. Soil moisture sensor data will be re-evaluated by regression analysis after the 2009 monsoon season to identify sites where intensive soil sampling will be conducted for additional gravimetric analysis of moisture content under varying soil moisture conditions to refine the sensor calibrations where possible.

Table 2. Results of preliminary regression analyses of soil moisture data by sensor "type." Where no sensor of a particular type occurs at the site, the field is blank.

Location	Sensor "type"							
	Canopy		Dripline		Open		Deep	
	r^2	intercept	r^2	intercept	r^2	intercept	r^2	intercept
Site A	0.804	0.101					0.683	0.038
Site B upper	0.843	0.032			0.814	0.081		
Site B lower					0.881	0.081	0.624	0.083
Site C	0.851	0.003	0.865	0.033	0.895	-0.039	0.877	-0.135
Site D	0.565	-0.800			0.848	-0.118	0.476	-0.027
Site E	0.739	0.006	0.779	-0.048	0.829	0.030	0.940	0.078
Site F	0.755	0.033	0.879	0.012	0.704	0.041	0.694	-0.031

Alluvial groundwater

The most recent data downloaded from the two site piezometers were collected in April 2009. All piezometer data were checked against manual water level measurements made during site visits. Variance between manual measurements and levels recorded by transducer were < 0.05 ft. Graphs of all piezometer data collected since the project began in November 2007 are plotted with cumulative precipitation data below.

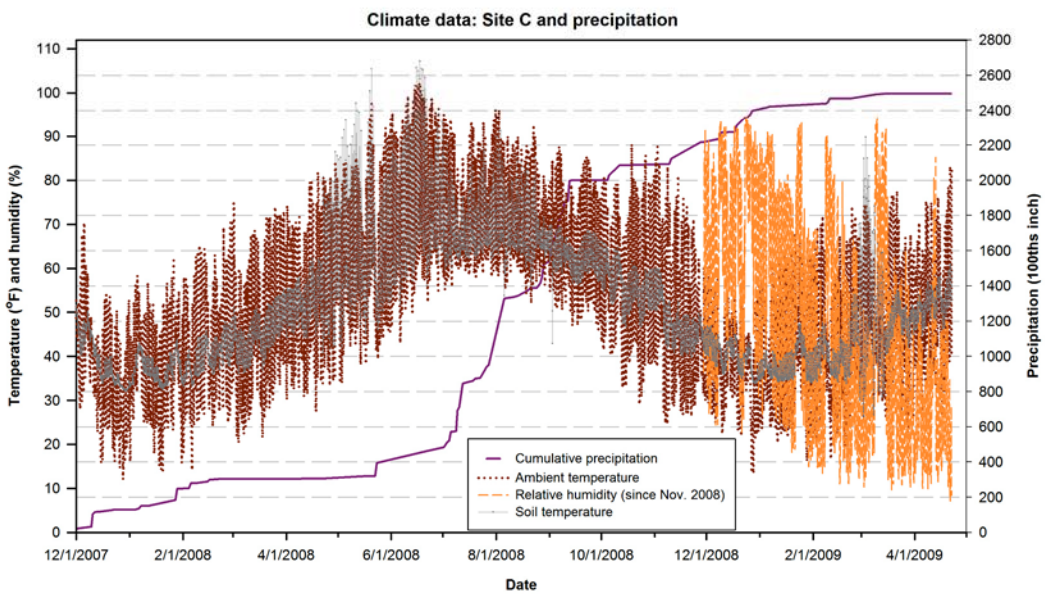


Alluvial groundwater data. Hourly data collected from the two piezometers are plotted relative to channel bottom surface ("0 depth to water") where they are installed. Response to rainfall is rapid and short-lived; above-surface flow of enough duration to be recorded by the pressure transducers (minimum ~1 hr) has occurred only at the piezometer above the spring.

Soil temperature and climate data

Hourly soil and ambient temperatures have been collected at Site C since December 2007. A recording relative humidity sensor was added at the site in November 2008. Data from these sensors are plotted below with cumulative precipitation from the recording rain gauge. Eventually, the Site C data will be used with similar data collected by the weather station (Site ET). Variances in climate data and soil temperatures across the project area will be evaluated and the Site C data used to help refine weather station data to a more site-specific level (i.e., for areas within the project site that are similar to Site C in slope and aspect).

Data collected by the weather station between December 2008 and April 2009 are included on the project report CD but are not plotted here.

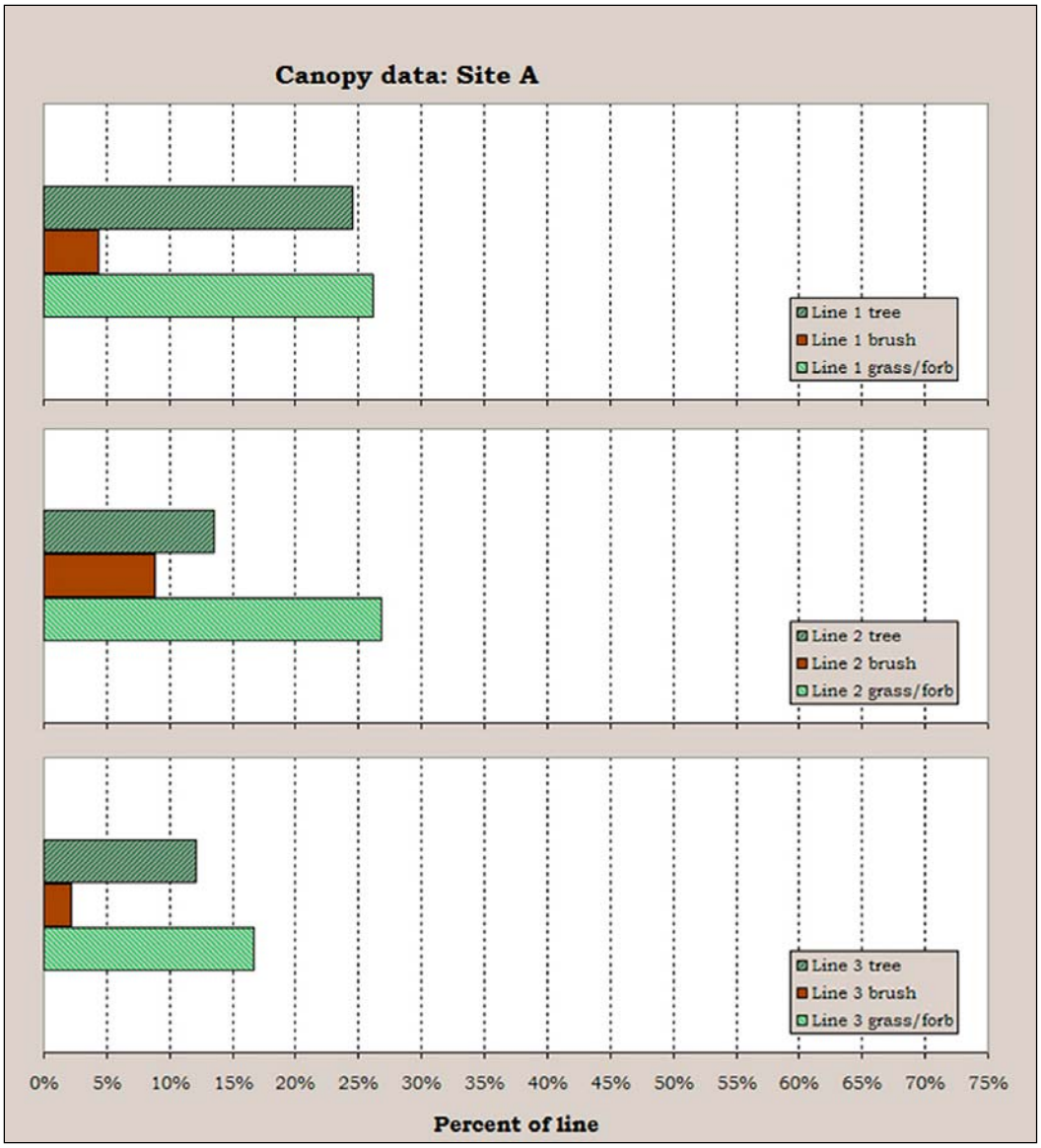


Climate and soil temperature data from Site C plotted with cumulative precipitation for the project area.

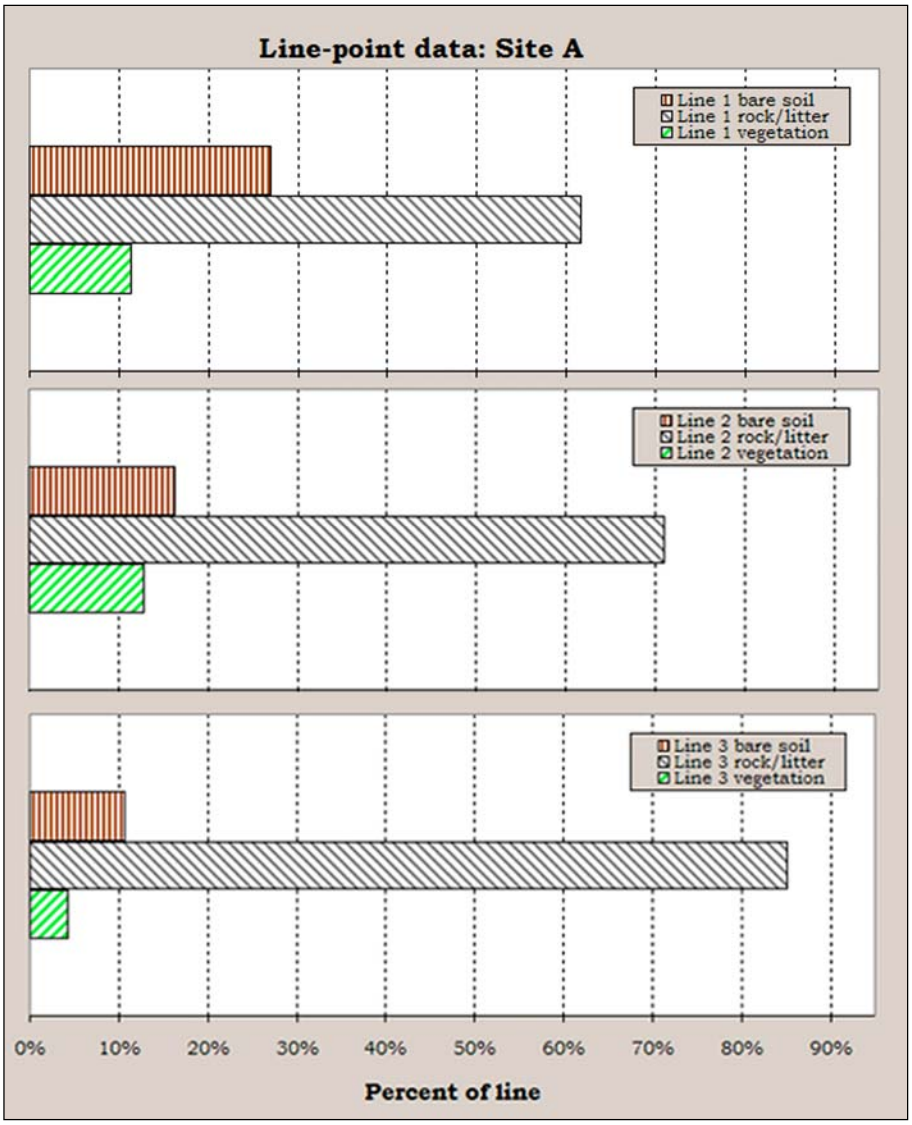
Vegetation transects and biomass plots

Detailed ground and canopy cover data have been collected throughout the project area (Table 1). These sites will be re-measured immediately following treatment and periodically thereafter in order to 1) document vegetation response to treatment and 2) provide representative vegetation data against which estimates of evapotranspiration can be calibrated. A representative set of graphs of the vegetation data appear below;

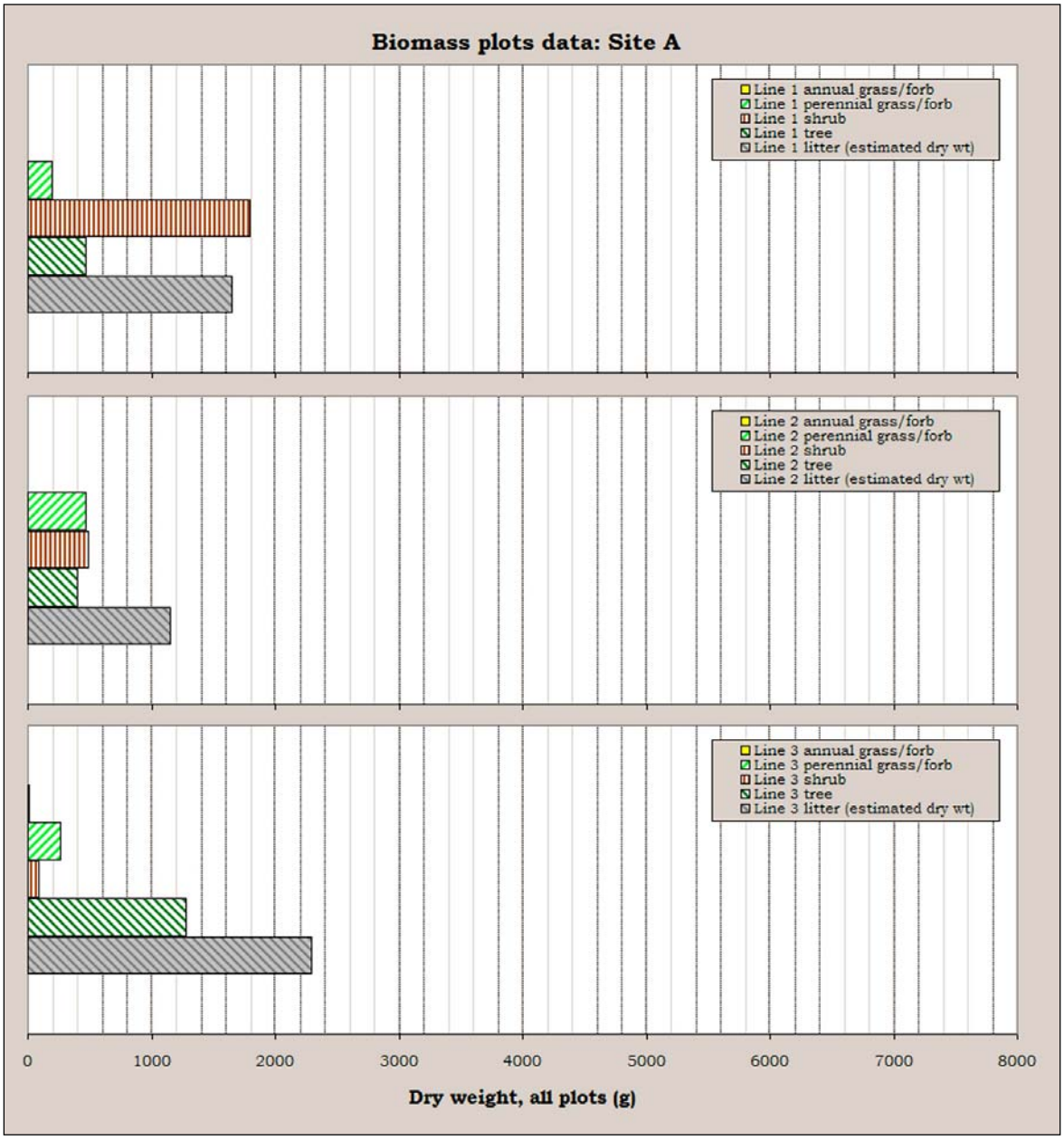
remaining graphs and data are on the data CD. (Because of the large number of data sets, not all are reproduced here.) All vegetation transects and richness plots were also documented photographically; photos are included on the data CD.



Canopy cover data collected from three vegetation transects at Site A. Similar data sets were collected at Sites C, E and B/ET (the last two are grouped by proximity). An additional vegetation data site (UV) was established in the upper part of the treatment watershed.



Line-point intercept surface cover and vegetation data collected from three vegetation transects at Site A. Similar data sets were collected at Sites C, E and B/ET (the last two are grouped by proximity). An additional vegetation data site (UV) was established in the upper part of the treatment watershed, unassociated with any soil moisture data collection site.



Vegetation data from biomass plots established on three transects at Site A. Similar data sets were collected at Sites C, E, and B/ET (the last two are grouped by proximity). Biomass data will also be collected following treatment at the upper watershed vegetation data site (UV).

STIVER CANYON STUDY AREA

We completed final installations of the Stiver Canyon study area instrumentation in April, 2009. Nearly all soil moisture sensors were installed before December, 2008. The weather station was constructed during the April 2009 site visit. Final corrections to the wiring diagram for the weather station were received from the instrument manufacturer and the station was re-wired and operational as of June 2009. The rain gage installed in November 2008 was re-located from its initial placement to the weather station location once the weather station was functioning correctly.

Installed instrumentation has been downloaded periodically, as access conditions allowed. The final data collection run was on April 25, and the resulting data sets for the project period to date are included on the data CD. A number of data gaps have been caused by rodent or other animal disturbance and instrument malfunctions. Table 1 summarizes the data collection sites and valid data periods since study inception in November 2008. Soil moisture and climate data collection sites are shown on the map below. Vegetation transects are located at the soil moisture sites.

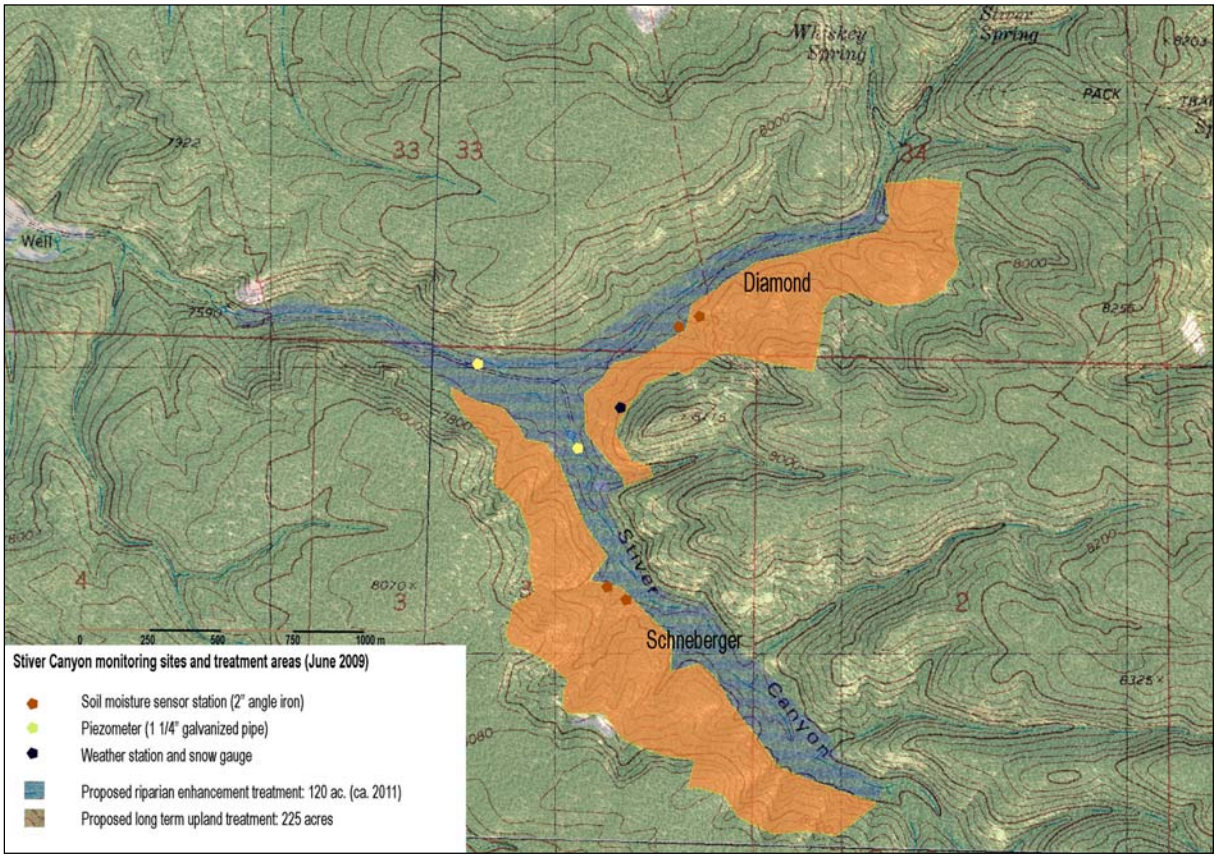


Table 3. Data collected at Stiver Canyon project area since project start, November 2008.

	Archived data			
Site	**Alluvial and soil moisture**	**Vegetation**	**Climate**	**Other**
Diamond control				
Canopy	12/2008-4/2009			
Open	12/2008-4/2009			
Dripline	12/2008-4/2009			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Diamond treatment				
Canopy	12/2008-4/2009			
Open	12/2008-4/2009			
Dripline	12/2008-4/2009			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Schneberger control				
Canopy	12/2008			
Open	12/2008-4/2009			
Dripline	12/2008-4/2009			
Deep	12/2008-4/2009			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Soil samples (sensor calibration)				11/2008
Schneberger treatment				
Canopy	12/2008-4/2009			
Open	*4/2009			
Dripline	12/2008-4/2009			
Deep	*4/2009			
Veg. transects		11/2008		
Veg. biomass		4/2009		
Temperature			2/2009-4/2009	
Soil temperature			11/2008-4/2009	
RH			2/2009-4/2009	
Soil samples (sensor calibration)				11/2008

Table 3 continued.

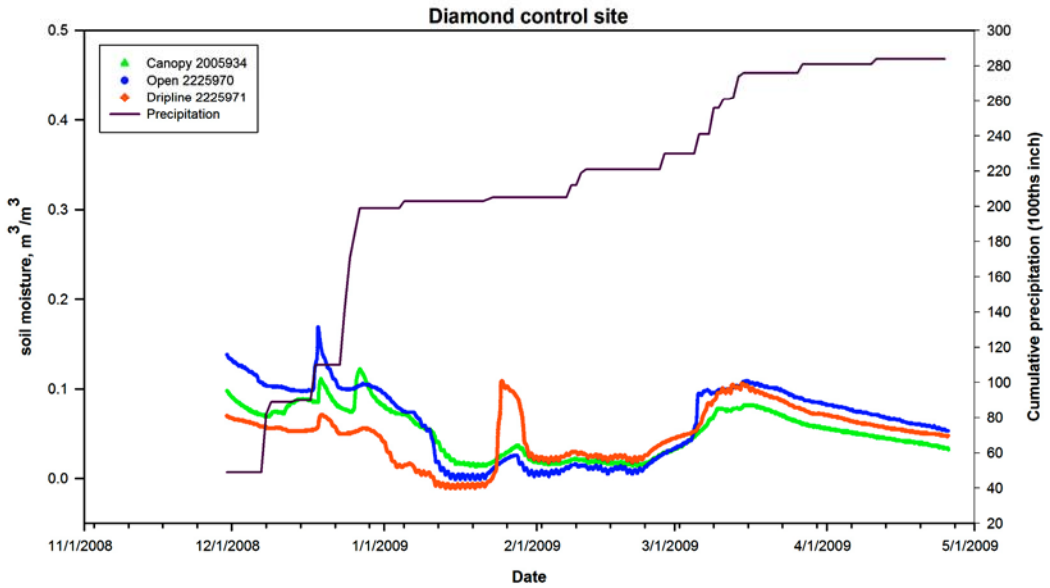
Site ET (weather station)			
Temperature/soil temperature/RH/wind speed/solar radiation/ precipitation			4/2009*
Piezometers			
DS (below confluence)	11/2008-4/2009		
US (Schneberger)	11/2008-4/2009		
Precipitation			
Recording rain gage			11/2008-4/2009
Snow gage			11/2008-4/2009
Riparian vegetation mapping (*populus/salix*)		4/2009	

* Data collection began 4/2009. No data from this sensor included on CD.

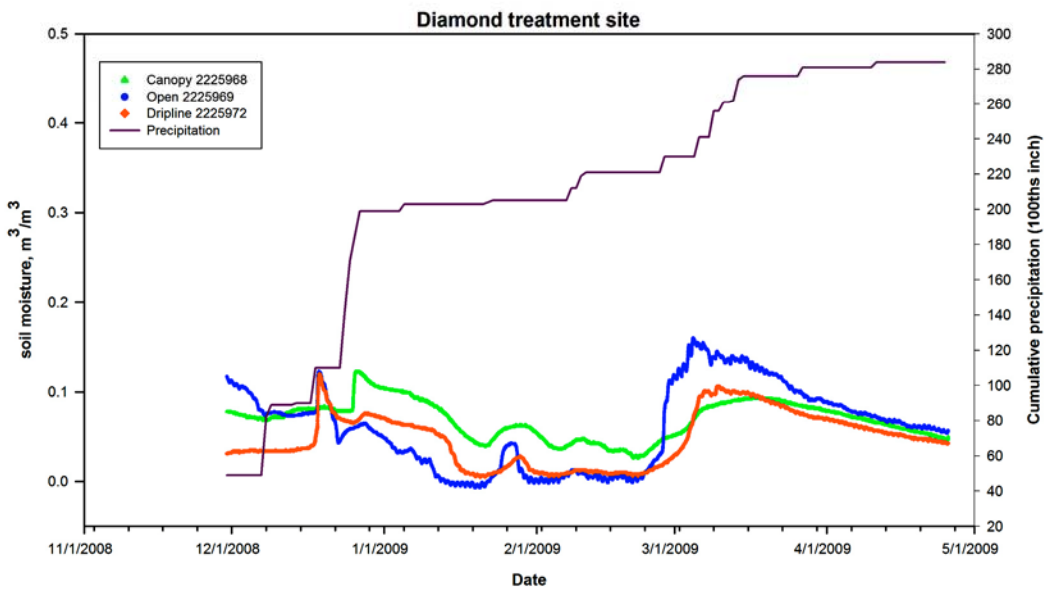
Data graphs: *Recording soil moisture sensors*

Soil moisture sensor site locations are shown on the map above. The final site visit in the project period occurred in April 2009. This was the first site visit when ground conditions allowed us to place the "open" and "deep" soil moisture sensors at the Schneberger treatment site; during prior trips the ground in those areas was frozen. Therefore data from those sensors will first be collected sometime in August 2009.

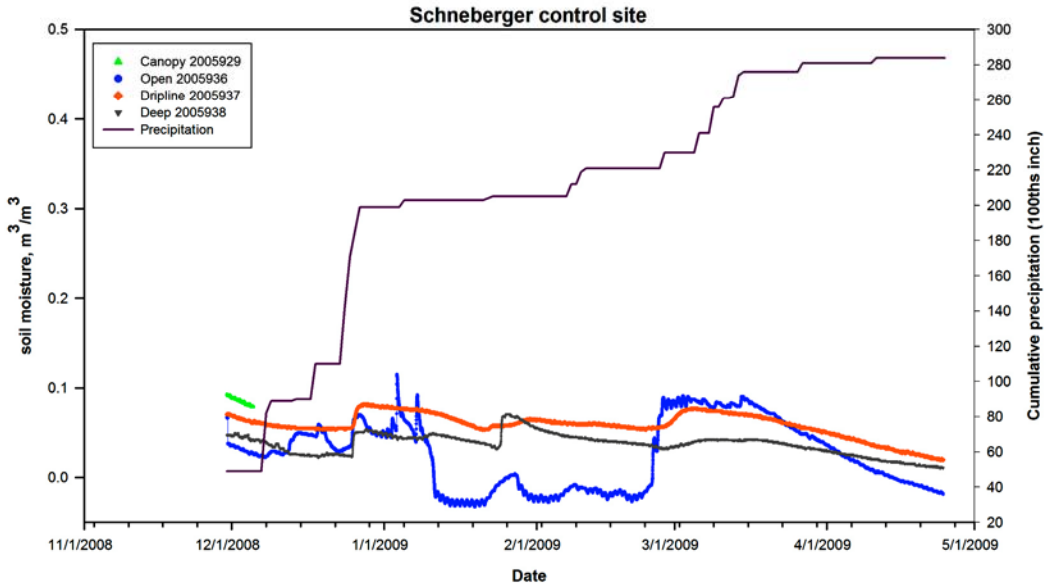
Soil moisture data collected at 5-min time steps were filtered into averaged 15-min data. The resulting data sets were evaluated for sensor errors (i.e., during frozen soil conditions) and damage. The cable for the "canopy" sensor at the Schneberger control site was apparently destroyed almost immediately after placement; all data from December 5 on were removed from this data set. The sensor was replaced in April 2009. Usable data collected by the recording soil moisture sensors and rain gage since the start of the project in November 2008 are shown graphically below. Refer to the figure captions for details on data gaps and calibration notes.



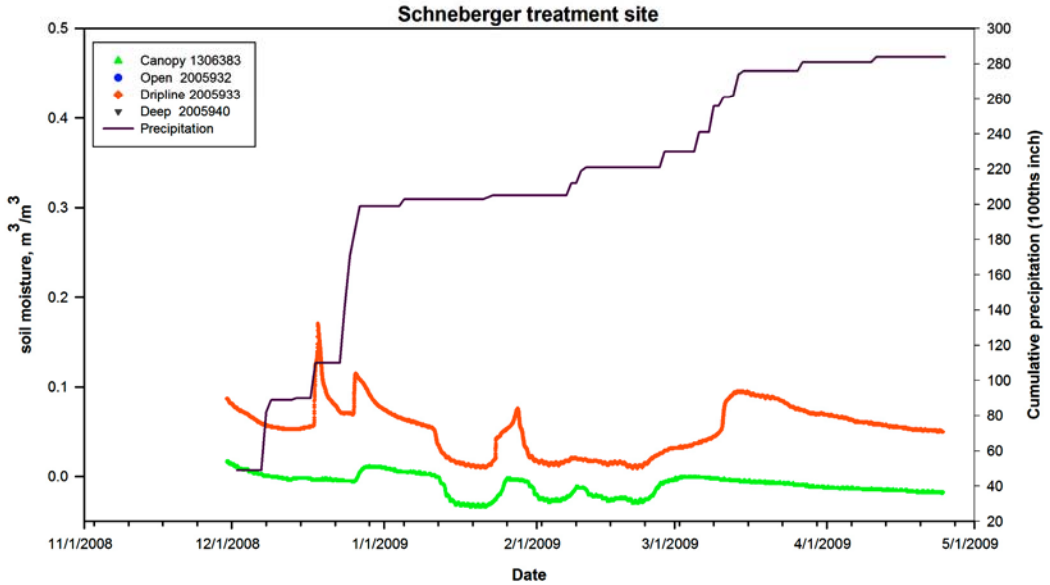
Diamond control. Recording sensors are placed beneath the tree canopy, dripline, and beyond the canopy at 0.5-ft. depth. All sensors appear to be functioning properly. Soil samples were collected and submitted for analyses of moisture content; results will be used to calibrate the sensors if necessary after data collected during the 2009 monsoon are evaluated.



Diamond treatment. Recording sensors are placed beneath the tree canopy, dripline, and beyond the canopy at 0.5-ft. depth. All sensors appear to be functioning properly. Soil samples were collected and submitted for analyses of moisture content; results will be used to calibrate the sensors if necessary after data collected during the 2009 monsoon are evaluated.



Schneberger control. Sensors are placed beneath the tree canopy, dripline, and beyond the canopy at 0.5-ft. depth; a fourth sensor is located beyond canopy at a depth of 1.5 ft ("deep"). The canopy sensor was damaged almost immediately after placement and data collected after that point were removed from the file; the sensor was replaced in April 2009. Data from the "open" sensor may also be unreliable. This sensor will be replaced in August 2009 and data collected prior to that point will be evaluated relative to the new sensor data. after the 2009 monsoon season. Soil samples were collected and submitted for analyses of moisture content; results will be used to calibrate all sensors, as necessary, after data collected during the 2009 monsoon are evaluated.



Schneberger treatment. Only the "canopy" and "open" sensors could be installed prior to April 2009. Placements as are for other sensors of these types. The two sensors appear to be functioning properly. Soil samples were collected and submitted for analyses of moisture content; results will be used to calibrate all sensors, as necessary, after data collected during the 2009 monsoon are evaluated.

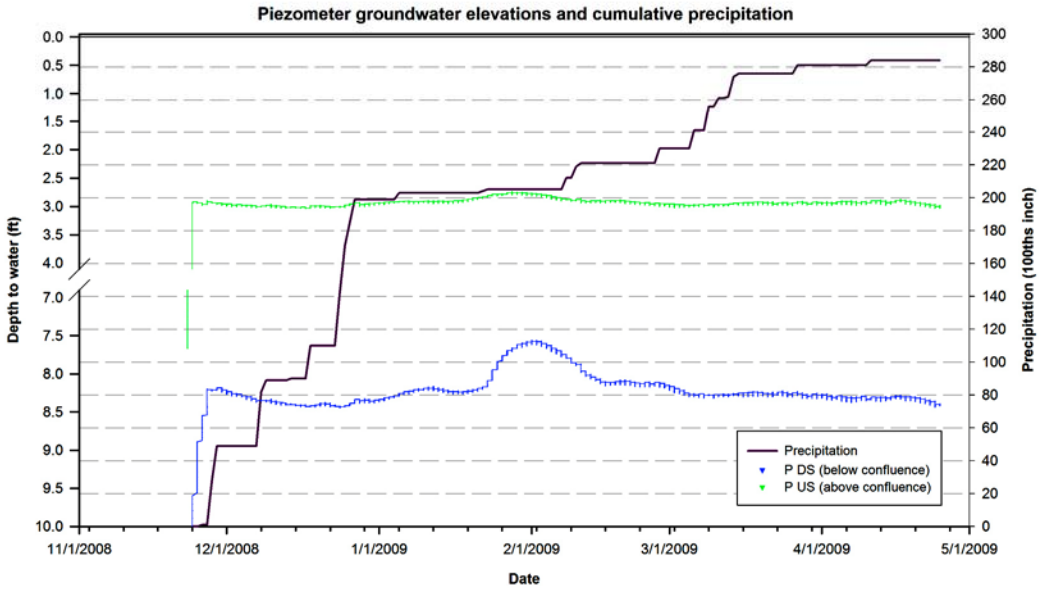
Sensor regression analysis

Correlations among the usable data from each soil moisture sensor will be evaluated by a preliminary regression analysis after data are collected for the 2009 monsoon period. The regression analysis will follow the method described for the Burro Mountain soil moisture sensor data.

Initial soil samples were collected at all sites (Table 3) and soil moisture contents were estimated by bulk density and gravimetric analysis (DB Stephens and Associates). Lab results are included on the data CD. Intensive soil sampling will be conducted for additional gravimetric analysis of moisture content under varying soil moisture conditions to refine the sensor calibrations where indicated.

Alluvial groundwater

Data from transducers in the two site piezometers were collected in April 2009. A third transducer will be installed in an old well downstream of the project area after the well is unsealed. All piezometer data were checked against manual water level measurements made during site visits. Variance between manual measurements and levels recorded by transducer were < 0.05 ft. Graphs of all piezometer data collected since the project began in November 2008 are plotted with cumulative precipitation below.

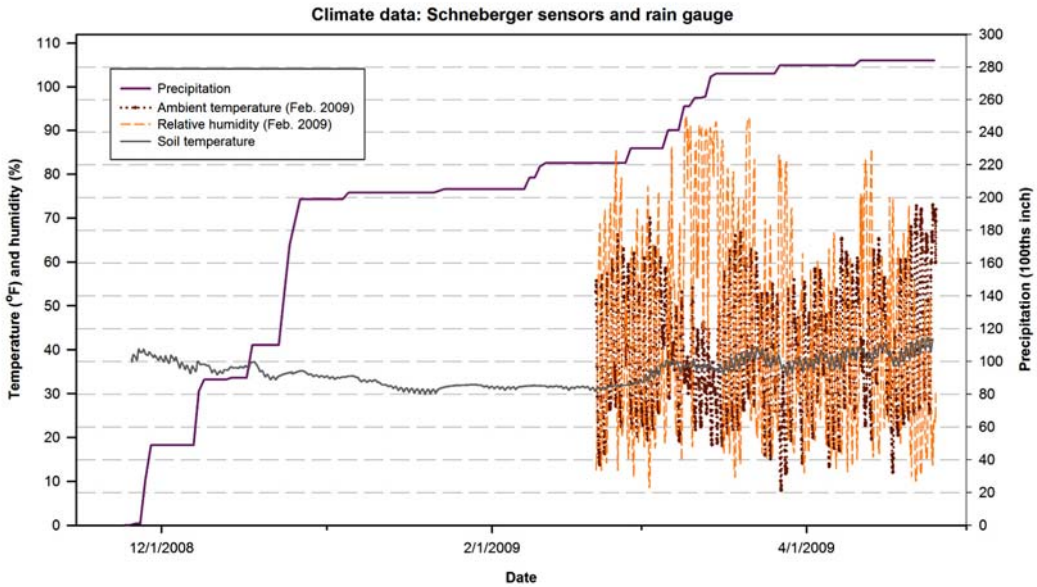


Data from the Stiver piezometers installed on the active channel floodplain. Groundwater elevations beneath the floodplain have remained well below ground surface although groundwater response to precipitation in December may have occurred about one month later. Note that water levels are relative to the ground surface at each piezometer and not between piezometers.

Soil temperature and climate data

Instrumentation was placed near the Schneberger treatment soil moisture sensor in November 2008 to record hourly soil and ambient temperatures and relative humidity. The temperature/RH sensor failed and was re-initialized in February 2009. The available data from the three sensors are plotted below with cumulative precipitation from the recording rain gauge. These data will provide a means of validating data collected by the weather station to help refine weather station data to a more site-specific level (i.e., for areas within the project site more similar to the soil moisture data sites).

The weather station was finalized in April 2009 and is currently collecting data. No data from the station are included with this report.

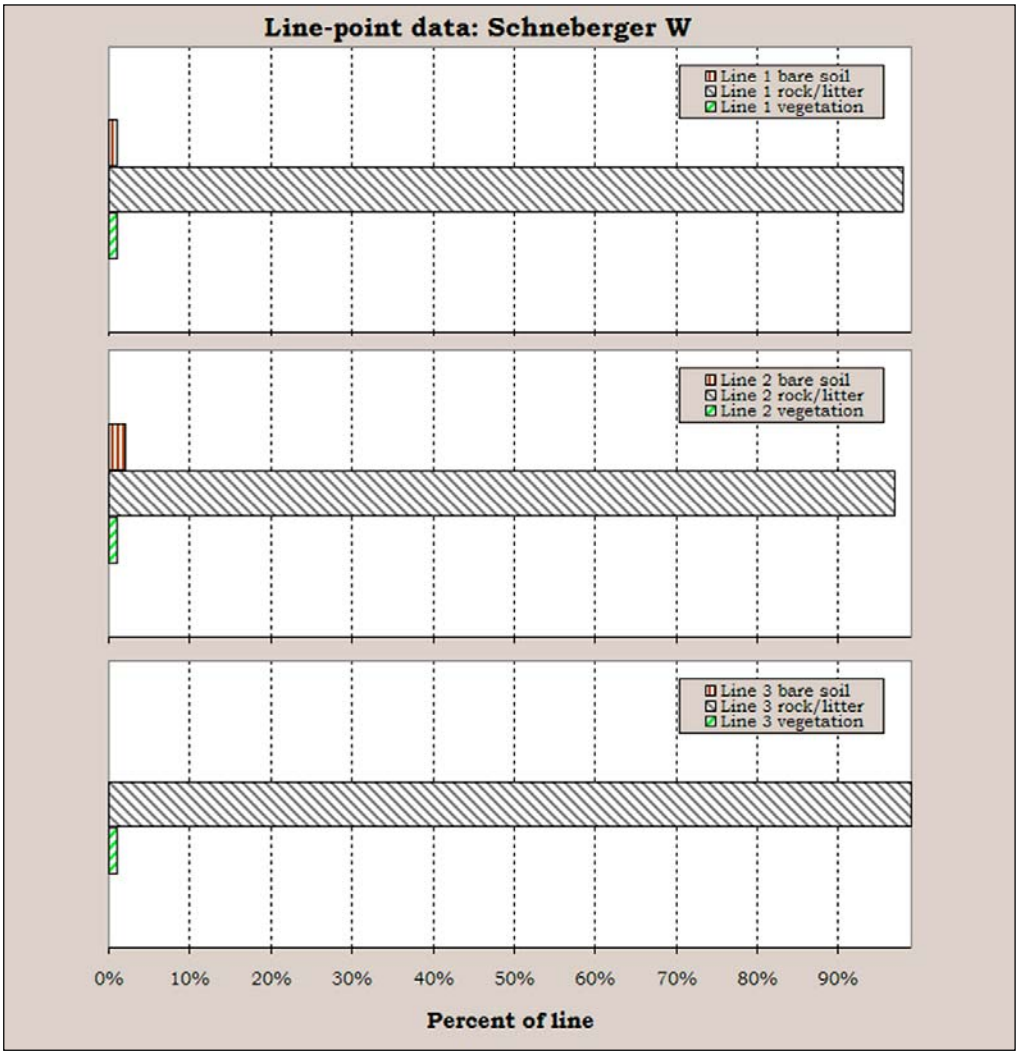


Data from temperature and RH sensors installed at the Stiver project area.

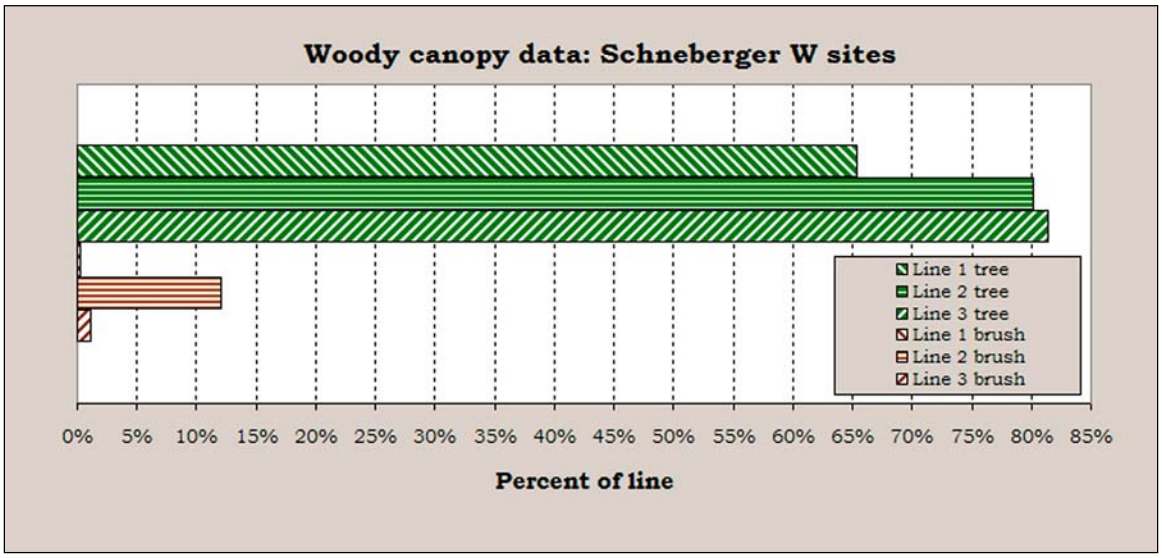
Vegetation transects and biomass plots

Detailed ground and canopy cover data have been collected at each of the soil moisture data sites (Table 3). Vegetation transects were established in November 2008, and we completed all vegetation mapping, including biomass plots along the transects, in April 2009. These sites will be re-measured immediately following treatment and periodically thereafter in order to 1) document vegetation response to treatment and 2) provide representative vegetation data against which estimates of evapotranspiration can be calibrated. A representative set of graphs of the vegetation data appear below; remaining graphs and data are on the data CD. (Because of the large number of data sets, not all are reproduced here.) All vegetation transects were also documented photographically; photos are included on the data CD. All existing riparian vegetation (e.g., *salix, populus*

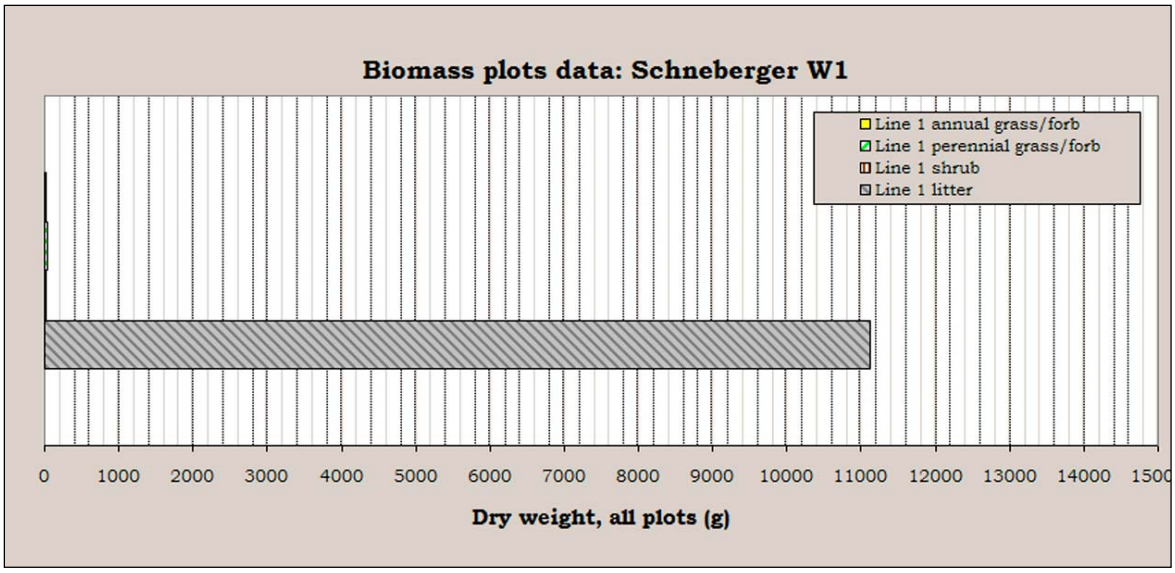
tremuloides) were also mapped by high-accuracy GPS and will be added to the project GIS file.



Line-point intercept vegetation data collected from three vegetation transects at the Schneberger soil moisture station. Similar vegetation data are collected at all soil moisture data collection sites at Stiver.



Combined woody canopy data from three vegetation transects at the Stiver soil moisture data collection site. Ground canopy cover along the vegetation transects is not measured at the Stiver project area.



Biomass measured from five plots on one of three vegetation transects at the Schneberger soil moisture data collection site. Five plots are established on each line and similar data are collected at all soil moisture stations. No tree canopy biomass is estimated at the Stiver project area.

STATUS OF TREATMENTS PLANNING

Burro Mountains site

Details of the two thinning treatments for the site have been developed by coordination among the Grant SWCD, Silver City District Office of the Gila National Forest, NM State Forestry, and the project researchers. The scoping letter was released in late May 2009 and a Decision Memo is pending. Archaeological clearances are forthcoming. Gila National Forest staff will complete thinning within the intensive cut zone, and Grant SWCD will release an RFP to contract the remaining thinning work in late summer 2009. Specifications for the contracted treatments are under development in conjunction with the Gila N.F. A committee will be appointed by the Grant SWCD to review the proposals and award the treatment contract. Treatments are scheduled to be completed between October, 2010 and March 2011 under a workplan and contract between Grant SWCD and NM State Forestry.

Stiver Canyon site

A plan for funding and completing NEPA for the site is being developed in coordination with the Black Range Ranger District of the Gila N.F. A proposal for funding NEPA activities through the Collaborative Forest Restoration Program has been drafted. The proposal will be revised with guidance from the Gila N.F. during the coming months and submitted in early 2010. Completing the details needed for this proposal will lay the groundwork for the treatment specifications. NEPA will be completed during 2011 and thinning would begin as soon thereafter as possible. Ideally, this schedule will allow us to collect nearly three full years of baseline data. Grant SWCD will again manage the RFP for thinning treatments, under their existing workplan and contract with NM State Forestry.

FUTURE WORK

Data reliability

The project instrumentation generally produces consistent and reliable results. Data recorded by a few soil moisture sensors suggests that intensive soil sampling and calibration of sensors will improve consistency among and within the final data sets. In addition, deep soil moisture sensor placement required soil profile disturbance. These sensors are crucial for measuring soil water gravity movement during or after saturating events. Additional soil testing and mapping of site-specific topography to quantify variations in surface slope among these sensor sites will be conducted during the next year. More frequent site visits, particularly to the Stiver site, will be scheduled in order to locate and replace damaged sensors as quickly as possible.

Evapotranspiration modeling

The Burro Mountains weather station will be a permanent fixture at this site, enabling the NMSU Climate Center to continue to collect weather data for its construction of a regionally-specific evapotranspiration model. Soil moisture retention, temperature, and

plant diurnal extremes will be examined in addition to the extremes based on soil physical properties. Vegetation transects and both richness plots will be periodically measured for percent bare ground, percent ground cover, and ground cover types. As the data sets incorporate greater variability in seasonal climate, the relationships between vegetation type and cover and diurnal moisture use may become clearer. After thinning treatments are completed, we anticipate that the ability to estimate changes in diurnal use and rates of evaporation will be paramount in comparing tree canopy environments to shifting herbaceous environments. For example, evaporation is expected to increase with brush clearing due to less canopy and associated mulch removal while total plant transpiration may decrease.

Groundwater sources evaluation

Standard sampling for stable isotopes of water will be conducted at the Burros Mountains site, in order to estimate the relative contributions of recent precipitation and older groundwater on emissions at the spring outlet and sub-channel groundwater. This will provide some insight into the time lag, if any, on precipitation traveling from higher elevations of the watershed to these drainage features.

Data analysis

Multivariate or cluster analysis of the data sets from each study area will begin near the end of the three-year baseline data collection period (September 2010 for the Burro Mountains site; September 2011 for the Stiver site). Preliminary analysis will be directed at identifying specific climate factors with the strongest influence on rates of soil moisture loss.

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