Monitoring Hydrological Changes Related to Western Juniper Removal: A Paired Watershed Approach

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Abstract

Since 1934, western juniper has increased its hold on eastern Oregon rangelands. U.S. Forest Service reports that juniper acreage has increased from 1.5 million acres to over 6 million acres in 1999. Previous studies have shown that water use by juniper can exceed 30 gallons per day when adequate soil moisture is present. Increased juniper dominance has been implicated in the desertification of Oregon's rangelands. Groundwater mitigation, reintroduction of steelhead into the upper Deschutes River basin, and changes in laws affecting surface water right allocations have driven public policy to look at how water is currently being used and how changes in water use (water law) could affect water availability. Vegetative modeling has shown that 9 to 35 trees per acre are enough to utilize all the precipitation delivered to a site in a 13-in annual precipitation zone. Earlier studies suggest that a minimum of 17 in of annual precipitation is required to measure a water yield response associated with vegetative manipulation. In 1993, the Camp Creek Watershed study area was established to monitor the effects of juniper removal on hydrologic processes. In 2005, following 12 yrs of pretreatment monitoring in the 2 watersheds (Mays and Jensen) all post-European aged juniper (juniper <140 years of age) were cut from the treatment watershed (Mays). Analysis indicated that juniper reduction significantly increased late season spring flow by 225 percent (alpha > 0.05), increased days of recorded groundwater by an average of 41 days (alpha > 0.05), and increased the relative availability of late season soil moisture at soil depths of .76 m (27 in) (alpha > 0.1). Ephemeral channel flow did not show a predictable trend following 2 yrs of post treatment measurements. The Camp Creek project illustrated that, for this system, managing vegetation for water yield may be obtainable at a much lower precipitation threshold than what was previously understood.

Keywords: paired watershed, water yield, western juniper, range restoration

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Introduction

According to U.S. Forest Service publication PNW-GTR-464, "Western Juniper in Eastern Oregon," western juniper's dominance in eastern Oregon has increased 5-fold since 1934 (420,000 acres to 2,200,000 acres) (Gedney et al. 1999). The result of this significant shift in plant community dominance has been reduced forage production, increased soil erosion, and reduced infiltration rates. Based on individual tree water use models and field observations, it has been speculated that the expansion of western juniper has been, at least in part, responsible for the desertification of these landscapes. Based on water use models for individual trees, the U.S. Forest Service estimates that mature western juniper tree densities, ranging from 9 to 35 trees per acre, are capable of utilizing all of the available soil moisture on a given site. Research has shown that soil loss from sites with higher than the natural variation of western juniper cover is an order of magnitude greater than similar sites that are still within their natural range of variation (Buckhouse and Gaither 1982).

Established in 1993, the Camp Creek Watershed Study Area was created to monitor water quantity and timing associated with juniper control. Channel morphology, hill slope erosion, and changes in vegetation were also monitored. The project involved the use of a paired watershed study format. The paired watershed project is located approximately 60 mi southeast of Prineville, OR.

Two watersheds (Mays and Jensen) were identified in the Camp Creek Drainage, a tributary of the Crooked River. The project consisted of the treatment (cutting juniper) of one of the paired watersheds totaling approximately 250 acres with the other watershed serving as the untreated control. The U.S. Bureau of Land Management (BLM) Prineville District cut approximately 200 acres of western juniper in Mays watershed. The cutting was initiated in October 2005 and was completed in April 2006.

The elevation of the project area ranged from 4,500 to 5,000 ft with an average annual precipitation of 13 in. The historic vegetation type was mountain big sagebrush/Idaho fescue. The site is currently dominated by western juniper with a sparse understory of shallow rooted perennial grasses and forbs. Since 1993, the two watersheds have been monitored for similarities and differences.

Project objectives

- Evaluate hydrologic changes following the cutting of post-European aged juniper (trees established since mid-1800s).
- Evaluate changes in hill slope erosion and channel morphology following the cutting of post-European aged juniper.
- Evaluate changes in plant community composition following the cutting of post-European aged juniper.

The majority of the two watersheds consisted of public land, administered by the BLM Prineville District (75 percent Mays, 86 percent Jensen). The remaining portions of each watershed were owned by the Hatfield High Desert Ranch. The BLM—in cooperation with the Crook County Soil and Water Conservation District (SWCD), the permittee (Hatfields), and the Oregon State University (OSU) Department of Rangeland Ecology and Management—identified the paired watersheds as an area of interest because of the opportunities the study provided to monitor changes in water yields relative to juniper control. Access to the site is from the Camp Creek/Bear Creek road.

Methods

Establishment of the study and initiation of monitoring began in 1993. Each watershed was delineated by the location of a continuous recording flume placed in the channel at the lowest point of each watershed. Flow was measured and recorded with the aid of a data logger. Precipitation inputs were first measured with the use of a Belfort Universal Rain Gauge, and a weather station was added to each watershed in 2004 to record air temperature, precipitation, wind speed and direction, solar radiation, leaf wetness, relative humidity, and snow accumulation.

In 2004, additional monitoring was added to the watersheds (Figure 1). Within each watershed, a spring was improved and flow measured. Six shallow wells were placed across the valley bottoms of each watershed near the flume location for the purpose of measuring depth of groundwater. Soil moisture and soil temperature probes were installed at 2 locations within each watershed and placed at multiple soil depths.

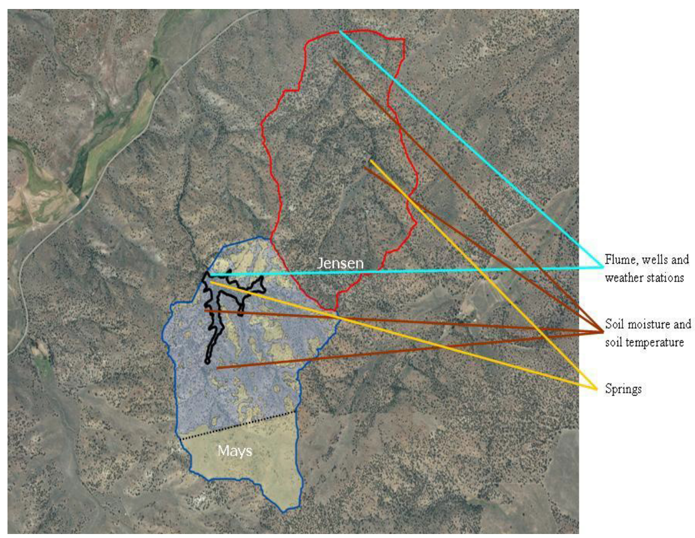


Figure 1. Location of monitoring stations.

All monitoring of weather, spring flow, channel flow, soil moisture, and depth to water was done through satellite uplinks; data is available for viewing on the website http://ifpnet.com.

Results

Spring flow

Figure 2 illustrates the differences in output between the two springs and the differences between years. Spring flow is dependent on timing, type, and amount of precipitation. Base flow, the flow which is least likely to be influenced by a recent precipitation event or snowmelt period, is late season flow. Late season flow is defined as the period between July and November. The first two sets of bars represent the pretreatment years (2004–2005) and the last 3 sets of bars show the changes in flow after treatment (October 2005).

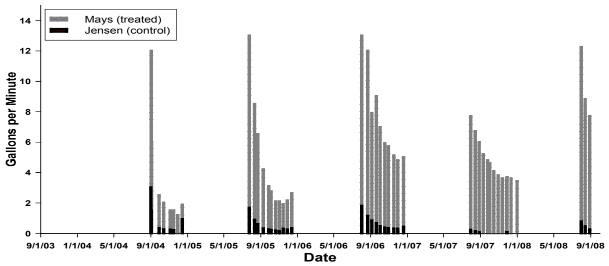


Figure 2. Differences in late season spring flow before and after treatment.

Table 1 shows the t-test results for comparisons of late season flow (lowest flow recorded) between the two watersheds and the years before (2004–2005) and after (2006–2007) treatment. The one tailed P-value is significant at alpha = 0.05**.

Table 1. T-Test for spring flow data, lowest flow recorded (GPM).

Year	Watershed		Diff.	Mean	Variance
	Mays	Jensen			
2004	1.87	0.20	1.67		
2005	1.90	0.13	1.77	1.720	0.00500
2006	4.80	0.23	4.57		
2007	3.6	0.00	3.60	4.085	0.47045
		Difference		2.365	
		Standard error		0.487	
		t-test		4.8505805	
		One tailed P-value		0.019**	

Wells

Well data, in addition to depth measured, provides insight to the timing or availability of subsurface water. The length of groundwater availability could be an indicator of watershed function (Table 2). Increases in length would indicate an improved hydrologic condition. A review of the data (t-test) indicates that changes in the average number of days in which water was recorded in the wells increased in Mays as a result of cutting the trees (p-value = 0.0152). Using a Wilcoxon rank test the wells in Mays post-treatment, recorded a greater increase in the number of days that water was recorded when compared to the control watershed, Jensen (p-value = 0.013).

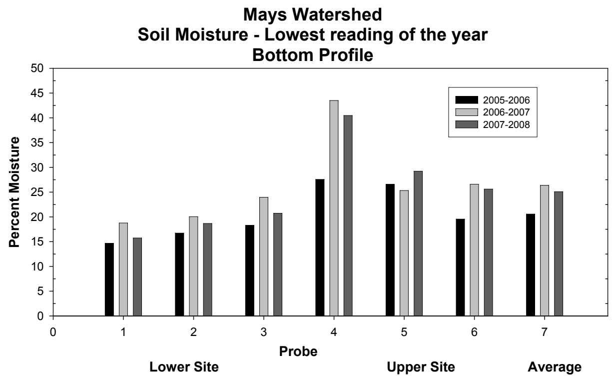
Table 2. Comparison of average number of days of well water for the watersheds. Pre- and post-treatment years consist of 2 yrs each.

Watershed	Well	Pre-treat	Post-treat	Diff.
Mays	1	112.5	128.5	16
	2	119.5	135	15.5
	3	195.5	285	89.5
	4	195.5	209	13.5
	5	156	197	41
	6	269.5	342.5	73
Jensen	1	70	82	12
	2	78.5	89	10.5
	3	283.5	296	12.5
	4	314.5	361.5	47
	5	283.5	296	12.5
	6	167.5	141	-26.5

Soil moisture

Observing the lowest readings of the year within each watershed illustrated the amount of "water savings" that was carried over from one year to the next (Figure 3). Evaluating the change in "water savings" over years helps to see if that change was associated only with precipitation, or if increases might have been due to the lack of deep-rooted vegetation (the cutting of the juniper). If it was due to the removal of deep-rooted vegetation, then excess soil moisture could move through the soil profile and into sub-surface water storage and flow.

Individual probe readings were averaged by location within the soil profile and by site for each watershed. ANOVA (analysis of variance) showed that the observed increase was significant (alpha = 0.1*) for the difference between 2006 and 2005 and for the average increase difference of 2006–07 combined and 2005 when comparing Mays with Jensen. Table 3 shows the results of this test for the combined years 2006–07 compared to 2005.



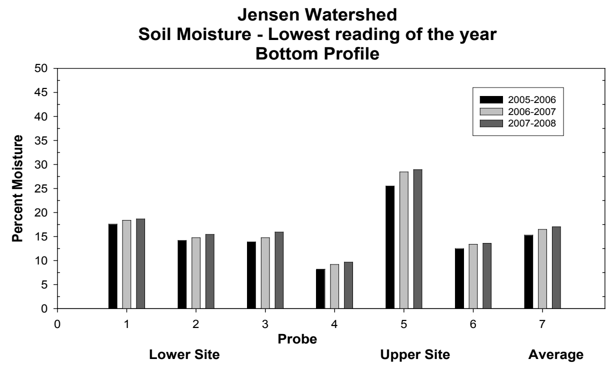


Figure 3. Example of changes in soil moisture. 1 year pre-treatment and 2 years post treatment.

Table 3. Significance of end of year soil moisture accumulation post- vs. pre-treatment.

Year	Probe (Location)	P-value
2006–07 vs. 05	Bottom (0.27 in)	0.1002*
2006–07 vs. 05	Middle (0.18 in)	0.1796
2006–07 vs. 05	Top (0.7 in)	0.6132

Channel flow

Channel flow in the two watersheds is ephemeral. These channels only have flow during periods of snowmelt and extreme summer thunderstorm activity. Ephemeral channels tend to be more influent in relation to the groundwater than perennial flows contributing to groundwater rather than groundwater contributing to channel flow.

Ephemeral channel flows or days of flow did not show a relationship to the treatment. Recorded channel flow occurs during the spring and early summer months and is usually associated with the snow melt period. In 1996 and 2004 total annual days of flow were greater than days of springtime channel flow, a result of late summer thunderstorms and early fall rain. In all years but one, Mays flowed longer than Jensen. In 1998, Jensen flowed for more days when compared to Mays. In 2007, while length of flow was greater in Mays, Jensen's flow as measured in accumulated cubic feet per second was greater than Mays' flow.

Of special note in the observation of these systems was the winter of 2006, following the cutting of juniper in Mays. The snow pack, which began its accumulation in December 2005 was static at approximately 16 in. December and early January rain events saturated the snow pack. While no water content measurements were taken, field notes indicate that the snow was saturated and frozen on top. Field notes also indicated that the snow pack was solid enough for researchers to be able to walk on top of the snow without breaking through. As mentioned earlier, soil temperatures during this period did not drop below 32°F for either watershed. Channel flow in Mays began on 7 January 2006. Flow was recorded through mid-June 2006. In contrast, flow in Jensen did not begin until 1 April 2006 and ceased to flow by early May. During this period, all observations for both watersheds indicated that flow was generated exclusively from bank seepage and that no evidence of overland flow was observed for either watershed.

In contrast, during the winter of 2007, very little snow pack was accumulated. Bare ground was observed in both watersheds (50–70 percent of the landscape) with snow accumulation areas measuring less than 6 in. Soil temperatures in early February were approximately 22°F. An early February storm produced a rain on snow event. Flow was recorded in both watersheds and evidence was observed which indicated the majority of channel flow originated as overland flow. Sediment movement was observed on the hill slopes and in the channels. Sediment deposits had to be removed from both flumes. These two different observations help to illustrate the high variability within these systems and the difficulty in connecting channel flow data to treatment effects, especially during the first two years following treatment.

Management Implications

A healthy, functioning watershed is one that captures, stores and safely releases the precipitation that is delivered to the site. Land management decisions should include looking for ways to increase opportunities for precipitation to infiltrate into the soil profile (vegetation management), moving excess moisture into sub-surface storage and groundwater, slowly releasing that water to minimize the risk of soil loss and channel bank and bed instability (Fisher et al. 2008). Hibbert (1983) and others have suggested that there would be no water yield increase as a result of vegetation manipulation (juniper cutting) in precipitation zones where annual precipitation was less than 4,300 mm (17 in). Any change to the water budget would only yield an increase in soil moisture, improving herbaceous vegetative production.

The 30-yr average annual precipitation at Barnes Station (U.S. Geological Survey weather station) located approximately 10 mi east of the study site is 349 mm (13.75 in). Precipitation over the last 4 yrs on the study site has ranged from 278 mm (10.95 in, 80 percent of average) to 449 mm (17.68 in, 129 percent of normal). Both the high and low precipitation years occurred during the post-treatment phase of the study.

A review of the data collected over the course of the last 13 yrs indicated that the cutting of post-European aged juniper has changed the water balance equation. Analysis of the first 2 yrs following treatment has shown that spring flow, groundwater, and soil moisture have all increased when compared to pre-treatment levels. Comparisons of ephemeral channel flows did not show as clear a trend (data not presented here). Ephemeral channels tend to be more influent in relation to the groundwater, contributing to groundwater rather than groundwater contributing to channel flow.

In the uplands, management implications suggest that with juniper removal, herbaceous vegetation can create a more uniform groundcover across the hillslope. Reduced bare ground results in increased infiltration opportunity and decreased soil erosion. Improved hydrologic function of the uplands can maintain site stability and fertility.

Within the riparian area, management implications point to the opportunity to increase spring flow for livestock, wildlife, and domestic use along with some mitigation of water diversion. Late season low flows limit land management alternatives. Increasing flows by cutting juniper could partially offset this limitation. Changes in groundwater may have downstream effects, delaying the time it takes water move through the system and by adding to channel or perennial stream flow downslope.

By combining the upland and riparian benefits of juniper removal, the system will begin to move toward a watershed that is functional in its ability to capture, store, and safely release water while providing a site that is productive and capable of being managed for sustainable use.

Acknowledgments

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