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Climate Variability and Drought in the Southern Sierra Nevada: 2002 to 2015

1. Healthy Forests and Drought

Role of the Sierra Nevada and surface water supply

Healthy forests and tree dieoff

2. History of California Drought

The current drought in California brings up many questions about water supply and future environmental conditions. This is not the first major drought California has faced. California has encountered 5 previous megadroughts since 832 AD. A megadrought is considered to be a drought that has lasted 10 years or more. The previous megadrought was from 1918 to 1934 and the current megadrought started in 2000 and continues today. Although we have had megadroughts in the past, 2005-2015 is the driest 10 year period on record in the Tulare Lake Basin since 1894 (Austin, 2015). However, not all years within a megadrought are created equal, some are drier than others. For example, within the current megadrought there have been wet years like 2006 and 2011, where annual precipitations were nearly twice as much as the long-term average precipitation. In contrast, annual precipitation during 2007, 2014, and 2015, the driest three years in the current megadrought, were only half of the long-term average precipitation. Given this extreme variability in climate, many natural resource managers are facing the challenges of managing ecosystems and providing clean water for downstream uses. The most significant source of surface water in California comes from the Sierra Nevada. The Kings River Experimental Watersheds (KREW) located in the southern Sierra Nevada was established to better understand the function of water and forest ecosystems and develop best management practices. The study, conducted by the Forest Service, was designed to characterize the variability of watershed attributes to better understand processes and health of headwater streams and forest watersheds, evaluate forest restoration treatments (mechanical tree thinning and understory prescribed fire), and address climate change effects on the ecosystem. KREW has collected data from 2003 to the present and thus has measured temperature, precipitation, and streamflow variability during the current megadrought.

3. **Location**

The KREW is located on the headwaters of the Kings River that drains into the Central San Joaquin Valley, Tulare Lake Basin. Eight watersheds are located at two sites and are fully instrumented to monitor ecosystem changes; the Providence Creek site is located in mixed-conifer forest and in the rain-snow transitional zone between 4920 and 6950 ft (1500-2120 m) elevation. The Bull Creek site is located in red fir/mixed-conifer and in the seasonal snow zone with an elevation of 6720-8150 ft (2050-2480 m). Evaluating the two sites at different elevation gradients can help determine the future conditions. With rising temperatures and the changing climate, the Bull Creek site may transition to a rain-snow dominated zone similar to the Providence Creek Site rather than a seasonal snow dominated zone.

4. What is a Drought and What were the Effects at KREW?

Generally society terms a long dry period as a drought. Scientists refer to this period as a *meteorological drought*, meaning a period of below-average precipitation that lasts two or more successive years. The end of a drought occurs when precipitation returns to average or above average for at least a year or more (Austin, 2015). Since 2002, KREW has

been measuring streamflow, water chemistry, soils, vegetation, stream biology, sediment loads, etc., to observe effects from climate change and forest restoration treatments.

Figure 1 illustrates KREW precipitation record compared to the 100-year record of two nearby mountain precipitation stations (Huntington Lake and Grant Grove). Notice that KREW has measured precipitation as high as in the historic record (1965 and 1982) and almost as low as in the early 1920s and 1968.

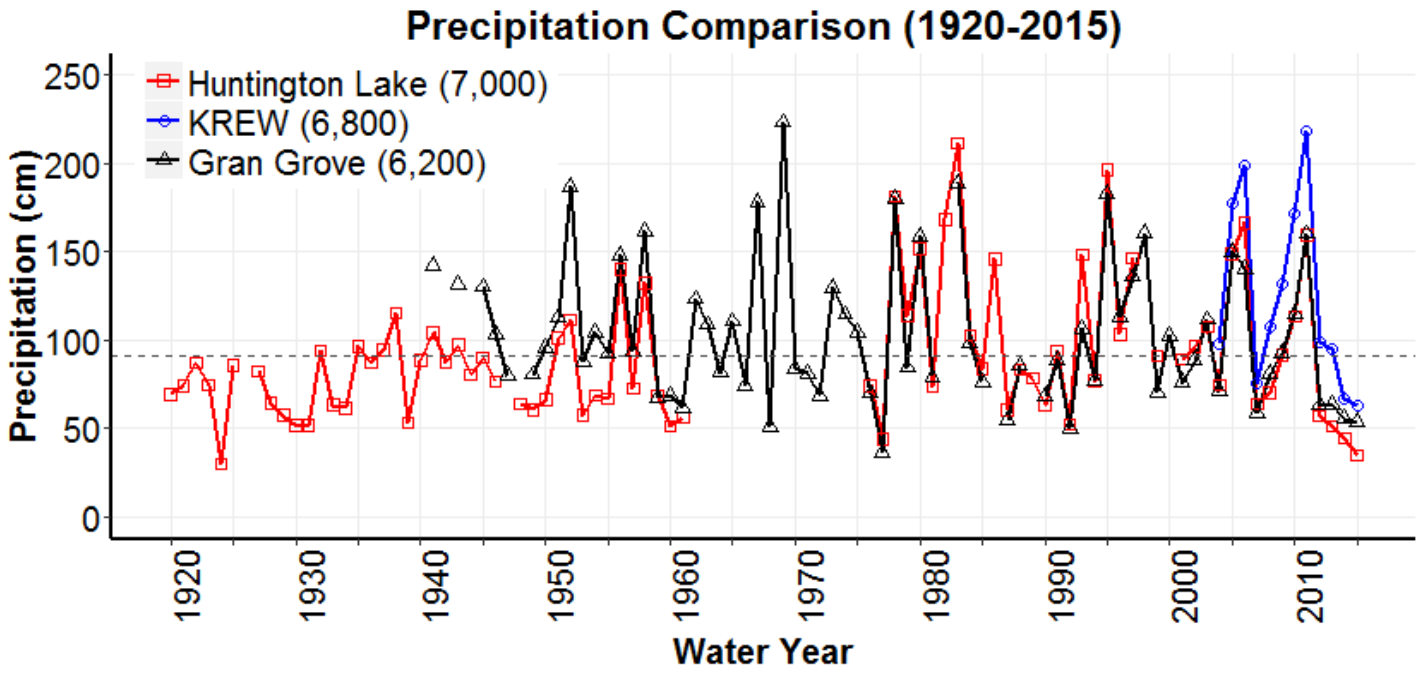

Figure 1: A one hundred year comparison of three precipitation stations, Huntington Lake (7,000 ft), KREW (6,800 ft), and Grant Grove (6,200 ft) around similar elevations found in the southern Sierra Nevada.

5. Temperature

One of the effects of climate change is the increase in global temperature due to the increase in greenhouse gases. Studies have shown there is a correlation between an increase in temperature and drought (Austin, 2015). With an increase in temperature, there is a reduction in snowfall vs rain and an increase in rate of snowmelt. This relationship causes a decrease in soil moisture, an increase in evaporation and ultimately an increase in intensity of dry seasons. KREW has been collecting temperature at two elevation gradients, Providence Creek site and Bull Creek site, for a 12 year period and has seen high variability and change. Figure 2 show the correlation between precipitation and temperature at each site. Notice that Providence Creek site has higher temperatures with more rainfall while the Bull Creek site has lower temperatures with less rainfall but more snow.

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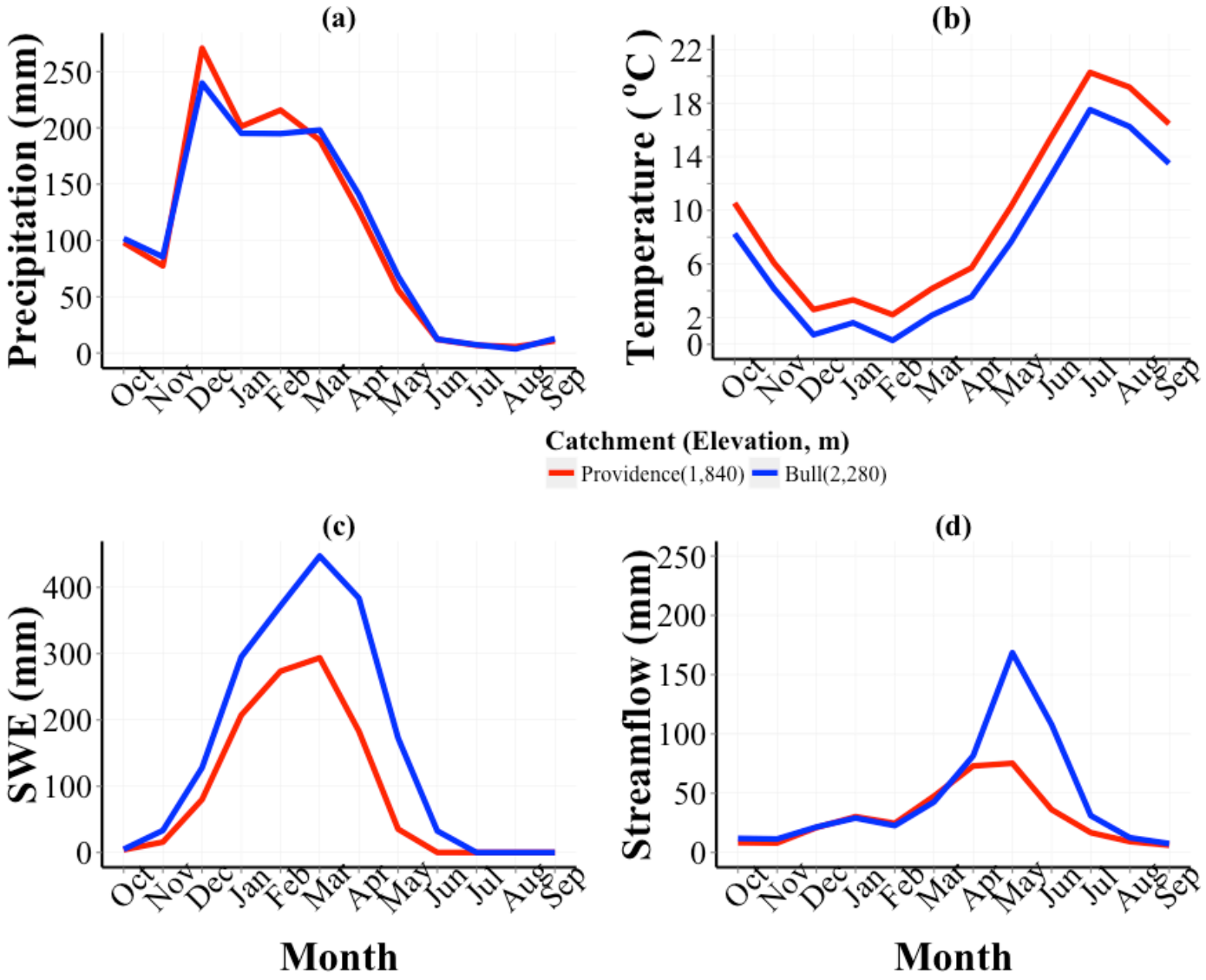

Figure 2: (a) Average monthly precipitation of Providence Creek and Bull Creek in a water year (millimeters).
(b) Average monthly temperature of Providence Creek and Bull Creek in a water year (degrees Celsisus).
(c) Average snow water equalivance of Providence Creek and Bull Creek in a water year (millimeters).
(d) Average streamflow of Providence Creek and Bull Creek in a water year (millimeters).

6. Snow Pack

Scientists believe that a rise in temperature will cause an increase in the number of drought years and their intensity due to the lack of snowpack. During the dry summer months, water is released from the melting of the snowpack stored during the wet cold winters. In the southern Sierra, more than 75% of precipitation falls during the months of December through April (fig. 2 A and B). Snowpack is a naturally occurring above-ground reservoir, and the variability in snowpack at KREW is also high. Because snowmelt occurs over several weeks, there is a lag in runoff from the mountains until late spring into summer supplying California with water for much of the year. In order to know the amount of water

in the snowpack, KREW measures snow water equivalent (SWE). KREW has two meteorology sites located at Bull Creek and at Providence Creek to compare elevation differences in SWE. Comparing the April 1st SWE readings from Upper Bull Creek and Upper Providence Creek shows a strong relationship with precipitation. With high precipitation there was greater SWE. The concerns that Californians are facing is that there has not been a significant snowpack since 2011. During the drought years the snowpack was reduced by 63 percent at the high elevation and by 88 percent at the low elevation (fig. 3 A and B). Thus if the higher elevations were to become more like lower elevations due to temperature changes, there would be a significant decrease in the amount of snowpack and less water in streams.

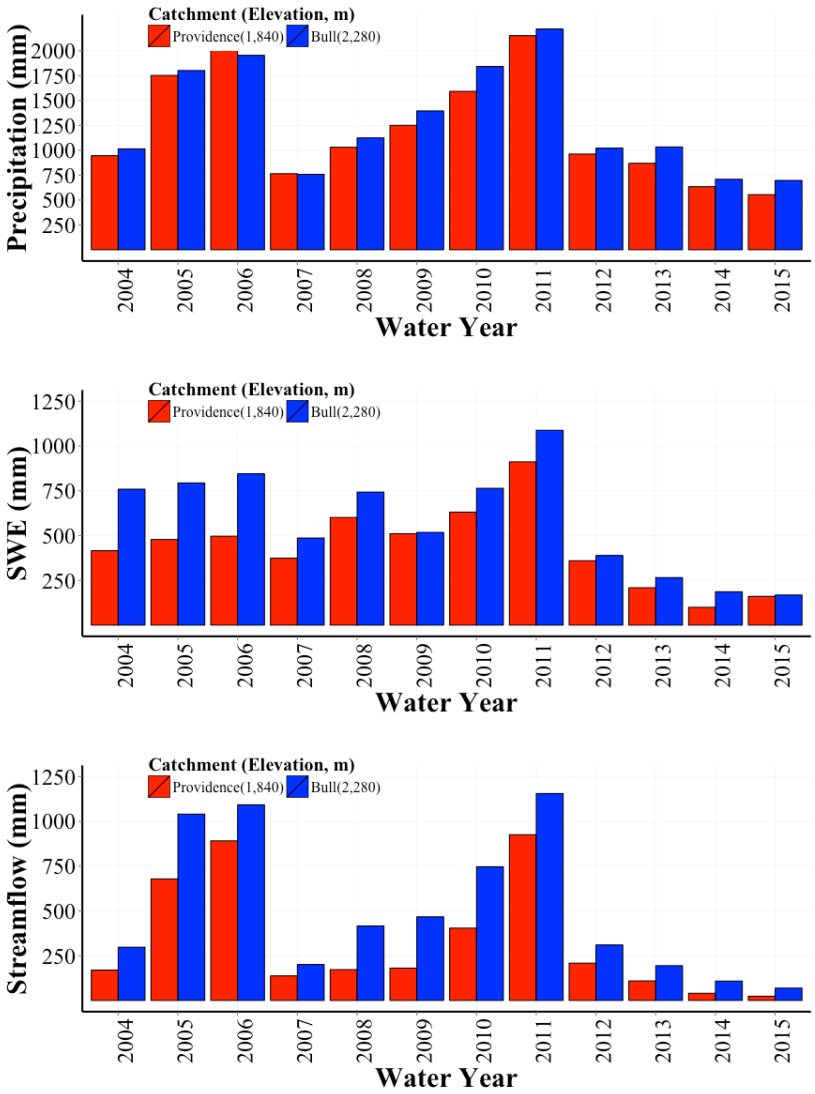

Figure 3: Average annual precipitation, snow water equalivance, and streamflow of Providence Creek and Bull Creek in a water year (millimeters).

7. Soil Moisture

Soil moisture is an important factor for climate, soil properties, plant growth, regulating soil temperatures, streamflow and overall health of a forest. (Bales, 2011) Factors that affect soil moisture include precipitation patterns, soil texture/ drainage properties, plant water use, and evaporation.

Note Data will be added here.

8. Streamflow

Streamflow is the amount of water leaving each watershed within the stream channel. This value can also be variable depending on the season and precipitation. As the effects of climate change are better understood, scientists predict that there will be less water available for the rest of California if soils and plants are absorbing and using more water. As shown previously, the Bull Creek site has a higher SWE and therefore more water available creating more streamflow. Over a 12 year period, KREW has measured the streamflow between the two sites and has shown a substantial decrease in the amount of stream flow after 2011 (Figure 4). Data show that there is less water produced at the Providence Creek site compared to the Bull Creek site because Bull has more snow, a higher SWE, and vegetation.

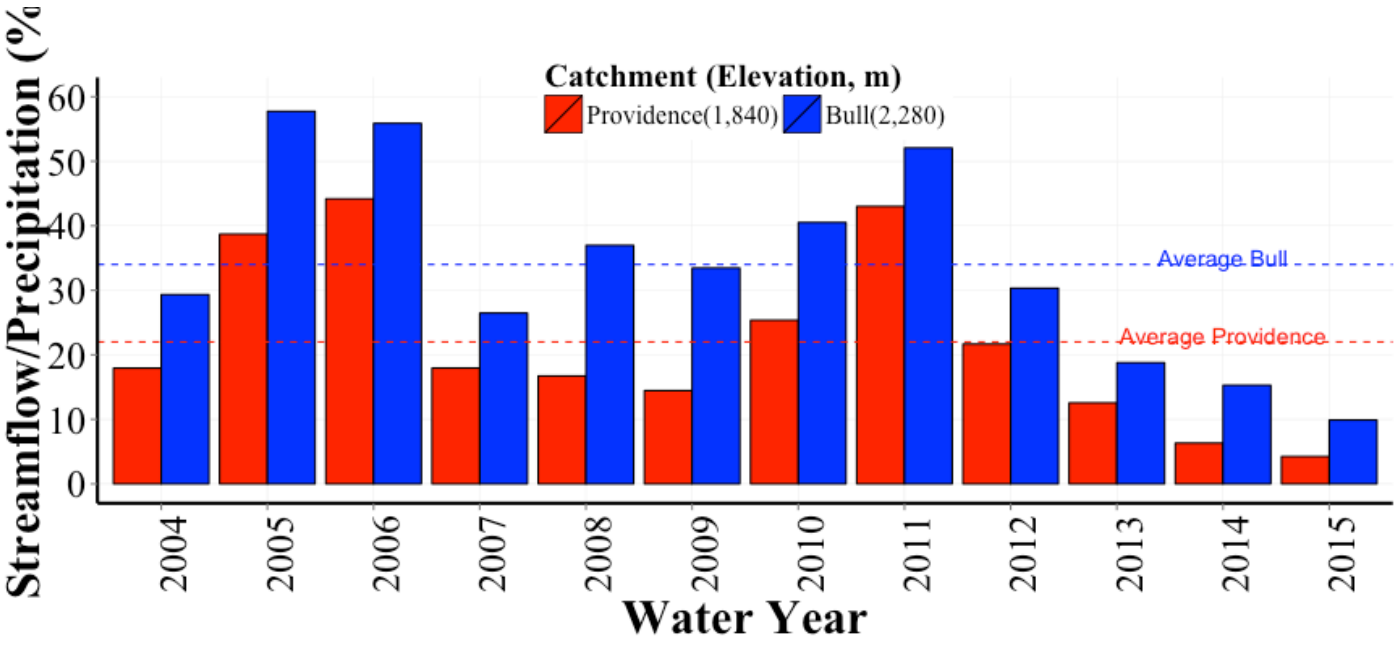

Figure 4: Average Annual streamflow of Providence Creek site and Bull Creek site with the average percent precipitation illustrated as the dotted line.

We need a strong ending here—something like.

Forests provide important ecosystem services. For example, vegetation slows water flow over soils and thus reduces erosion and sedimentation in streams, lakes and reservoirs; it also uses nutrients deposited by air pollution and thus protects water quality.

References

Austin, J.T. 2015. Floods and Droughts in the Tulare Lake Basin, 2nd edition. Sequoia Parks Conservancy, Three Rivers, California.