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Root distributions predict shrub–steppe responses to precipitation intensity

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Supplement S1: Description of precipitation intensity treatments

Water was applied to plots via a sprinkler system once enough water was collected in the tanks to create a precipitation event of a certain size (which varied by treatment). The target precipitation event sizes (i.e., tank sizes) were calculated using historical precipitation data and the Clausius-Clapeyron relation. For example, for the 2 mm treatment associated with 1 °C of warming, the following steps were used to calculate the target tank size:

1. Historical observed daily precipitation was put in descending order.
2. A curve was fit to this distribution of historical precipitation events to create a model of the precipitation distribution.
3. Precipitation events in this generalized distribution were multiplied by 1.07 to create a new distribution of larger events.
4. Enough of the smallest precipitation events were removed from this new distribution so that the sum of annual precipitation was equal to the sum of the original distribution (since all events were increased by 7%, if the smallest events were not 'removed' then total annual precipitation would necessarily also increase by 7%). This created a new distribution with fewer larger precipitation events, but the same total annual precipitation.
5. The smallest precipitation event size from this new distribution was used as the tank size for the treatment.

The above sequence of steps was repeated to calculate tank sizes for the treatments meant to reflect increased precipitation intensity associated with 2 °C, 3 °C, 5 °C and 10 °C of warming.

Rain water was applied to the plots in a way that can be described as a tipping bucket model. That is, once the 'bucket' (a water tank in our case) filled from water collected off the shelter roof it would 'tip' (in our case that means water would be applied to the plot via an electric pump and sprinklers). Because a tank can fill and empty multiple times during a storm this tipping bucket model was applied to historical precipitation to calculate the mean daily precipitation event size that results from the treatments. That is, the mean amount of precipitation received on days when there was > 0 mm of precipitation. The mean daily event sizes were calculated using only precipitation data from April to November because those are snow-free months when our pumps would be installed and running, and therefore they are the months during which the tipping bucket model most accurately represents the way treatments were applied. However, when year-round precipitation data is used results remain very similar. Mean event size of the treatment in which additional 1 mm precipitation events were added, were calculated by 'removing' 1 mm of precipitation from larger natural events and re-depositing it on days no natural precipitation occurred. This led to a range of mean daily event sizes of 4.8, 5.3, 6.2, 7.2, 8.4, 10.8, and 19.4 mm, for the 1, control, 2, 3, 4, 8, and 18 mm treatments, respectively. Note that the mean precipitation event size for a given treatment varies from year to year (Figure S1) and these numbers are the mean event sizes across years in the historical record. The mean daily event sizes for the 1 mm, control, 2, 3, 4, 8 and, 18 mm treatments fall into the 43rd, 61st, 81st, 96th, 100th, 100th, and 100th percentiles of historical annual daily mean precipitation event sizes. This means that no year on record had mean daily event sizes as large as the mean daily event sizes of the 4, 8 and, 18 mm treatments. The mean daily event size of the control plots (61st percentile) was above the 50th percentile because a small amount of water needed to be collected in the tanks before the float switches would automatically trigger. While the mean event sizes of the extreme treatments were outside the historical range of annual mean precipitation event sizes, they were within the range of precipitation event sizes that can occur on any given day. Meaning, the treatments didn't receive more water on a single day than can naturally occur. The mean daily event sizes for the 1 mm, control, 2, 3, 4, 8 and, 18 mm treatments fall into the 66th, 69th, 73rd, 77th, 81st, 86th, and 96th percentiles of historical daily precipitation event sizes. For example, this means that historically on days with precipitation, about 4% of days received more than 19.4 mm (the mean event size of the 18 mm treatment). Note that the distribution of daily precipitation events is strongly right skewed (many small events, few large) causing even the 1 mm and control treatments to have mean event sizes well above the 50th percentile of daily event sizes.

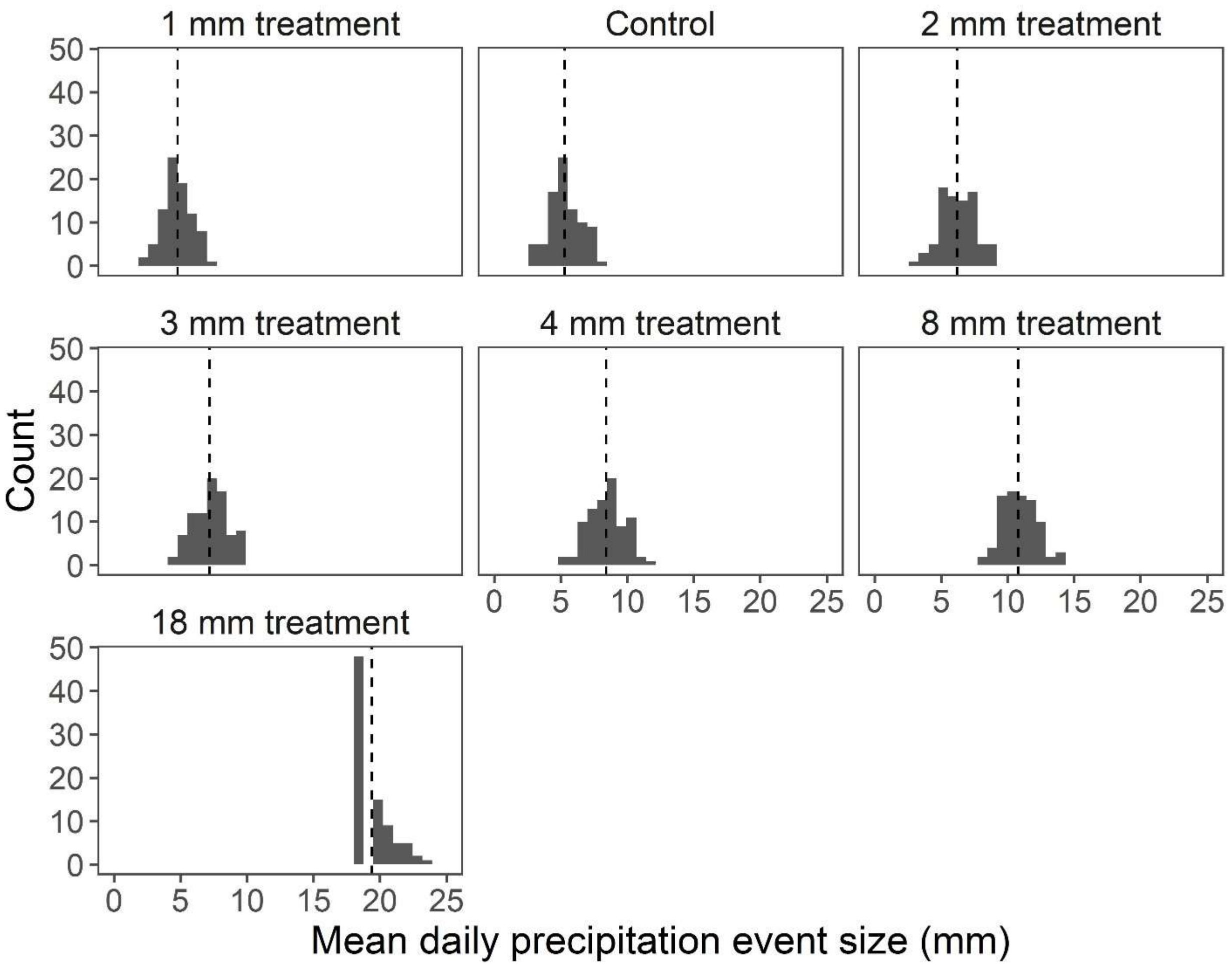

Figure S1. A tipping bucket model was applied to the historical precipitation record (daily precipitation from 1928-2018) to simulate the effects of applied treatments and to determine the mean daily precipitation event sizes for each year. The figure shows the distribution of mean daily event sizes for the 90 years. Dotted line shows distribution mean. Annual precipitation is the same in each treatment.

In addition to increasing precipitation event sizes, the treatments also increased the coefficient of variation of daily precipitation (Figure S1). The increase in the coefficient of variation reflects the fact that treatments increased the number of days with zero precipitation, and increased the amount of precipitation on the remaining days it did rain, thus increasing the standard deviation of daily precipitation. The coefficient of variation of daily precipitation in the 1, control, 2, 3, 4, 8, and 18 mm treatments were 321, 326, 327, 330, 337, 359, and 446%, respectively.

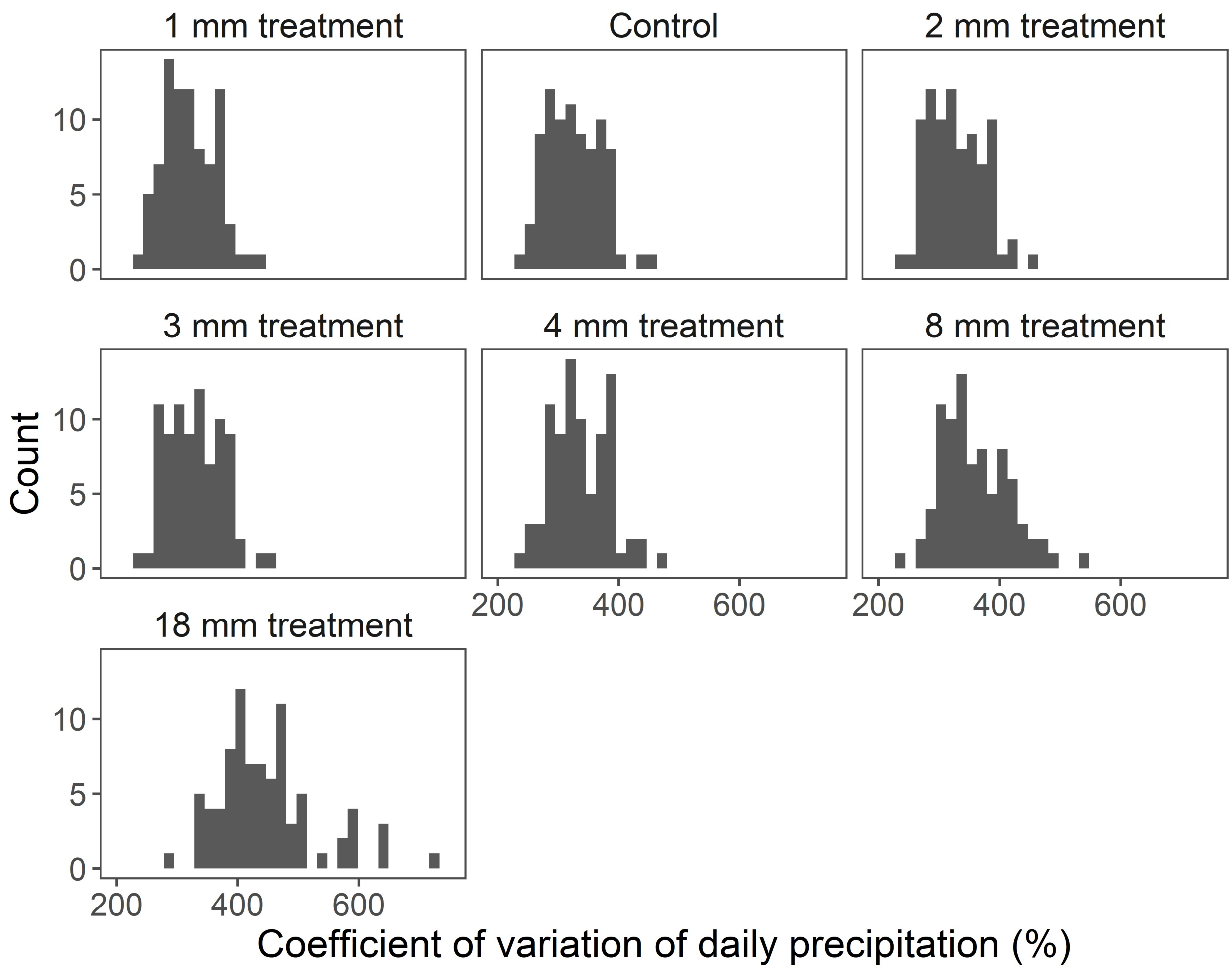

Figure S2. Coefficient of variation (CV) of daily precipitation by treatment. Each panel is a histogram of the CV of daily precipitation event size for a given treatment. A tipping bucket model was applied to the historical precipitation record to calculate daily precipitation for each treatment. That is, for each year on record the CV of daily precipitation event size was calculated as if treatments had been applied for each of those years, and the resulting histogram shows how CV varies between years.

The target number of snow events to be applied for a given treatment was calculated using a similar methodology described above for rain. However, for snow, instead of calculating a target 'tank size', the target number of snow events for the winter was calculated. The actual number of snow events for a given treatment varied depending on the actual number of natural snow events in that winter. That is, if there were fewer naturally occurring snow events during a given winter, all treatments received fewer snow additions.