The microclimate effects and responses of Mormon tea (*Ephedra californica*)

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The Mad Tea Party

Introduction

Mormon Tea and Microclimates

- Mormon tea (*Ephedra californica)* is a shrub species dominant in the deserts of California (Figure 1 and 2).
- They contribute crucial ecosystem services to local biodiversity, such as providing shelter to the endangered blunt-nosed leopard lizard (*Gambelia sila)* (Nobel 2017).
- Mormon tea is also important for anthropogenic uses. It is commonly used in medicine, oil and production, bioenergy, and agriculture (Lortie et al. 2018). Therefore, it is harvested frequently in its ecological range.
- Despite heavy harvest, it has been observed that some shrubs grows back larger after harvest or herbivory, increasing protection area for leopard lizards, and local harvest (Dangerfield and Modukanele 1996; Wandera et al. 1992).

Figure 1. Mormon tea (*Ephedra californica)* shrub in one of the deserts of California.

- Increased shrub volume can also influence the microclimate. When the shrub canopy expands, it shades the underlying soil, cooling it down and increasing the moisture content (Charles et al. 2020). This in turn alters microbial community dynamics and hence nutrient availability (dos Santos et al. 2020; Michopoulous et al. 2020).
- With larger canopy cover, the area that is subject to these effects is also enlarged.

Gaps in Knowledge and Biological Questions

- Since Mormon tea is used by society and natural ecosystems for a wide range of purposes, it is important to understand how harvest across regions impacts its growth, its microclimates and the habitats within them.
- We investigated soil moisture and temperature data collected under and 1m away from Mormon tea canopies in California to understand the effect of canopy growth on microcanopy characteristics.
- To investigate differences due to harvest, we examined the effects of artificial and natural canopy coverage on microclimates, where artificial treatments include clipped and unclipped shrubs, and natural observations include measurements taken under and 1m away from grown shrubs.

Figure 2. Map generated in R of the study area displaying 6 sites where shrub data was collected.

- Our data also provide insight to the geographical variability in canopy growth between sites and microsites, and differences in shrub growth due to harvest (clipped shrubs).
- Because our geographical variables are limited to moisture, temperature, latitude, and longitude, we use an external digital elevation model to account for topographical differences.
- These geographical variables may change over time and space, depending on the season and geographic region. Thus, recommended resource harvest and management regimes may differ between sites and/or microsites.

Methods

Data Wrangling

- The dataset for this project was provided by Dr. Christopher Lortie (Lortie et al. 2020).
- Temperature (°C) and soil moisture (VWC) data were obtained from 6 Mormon tea (*Ephedra californica*) shrub sites in the Cuyama Valley, California (Figure 1).
- Shrubs were subjected to one of two treatments: clipped (and allowed to regrow), or unclipped.
- Temperature and soil moisture measurements were taken from paired shrub and open microsites.
- Elevation data was outsourced from a 90m digital elevation model from the NASA Shuttle Radar Topographic Mission (SRTM), clipped to the study area.

Filter columns — Kept only columns needed for analyses

↓

Summary statistics — Mean temperature and soil moisture measurements over time for each shrub in each environment

↓

Calculate shrub volume

$$V = \frac{2}{3}\pi r^3 = \frac{2}{3}\pi\left(\frac{x}{2}\right)\left(\frac{y}{2}\right)(z)$$

↓

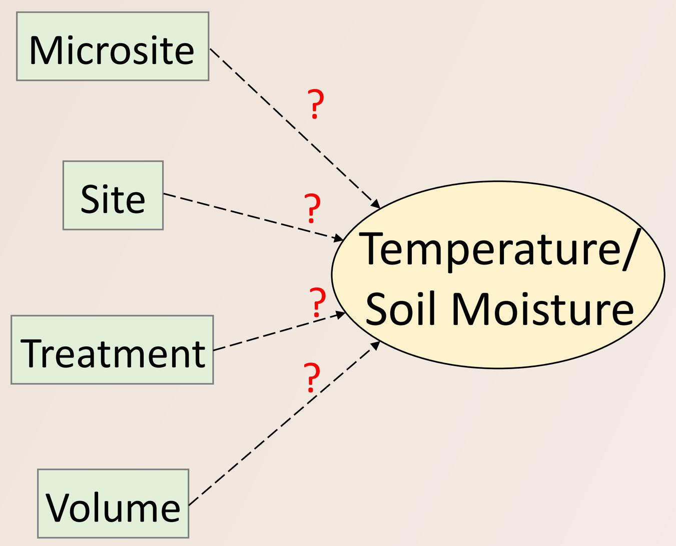
Remove unrealistic values — Negative soil moisture values and extreme outliers (shrub 164) were removed

Figure 3. Flow chart for data wrangling approach. Data was organized and additional columns calculated using the dplyr package.

Research Questions and Approach

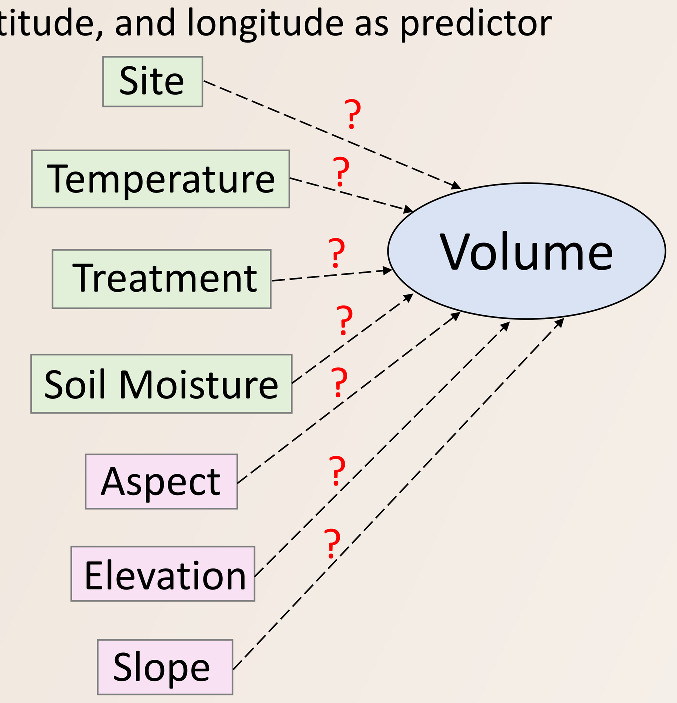
1) Do latitude, longitude, shrub volume, and treatment affect microsite temperature and soil moisture? If so, how does this vary over time?

- We ran a general linear model (GLM) in R with mean temperature as the response variable and latitude, longitude, shrub volume, microsite, and treatment as predictor variables.
- Latitude and longitude are included in "site"
- We repeated this analysis with mean soil moisture as the continuous response variable.
- To assess the changes in microclimate over time, we created time series visualization using the ggplot2 and lubridate packages. Mean soil moisture and mean temperature were graphed against time measured as months, days, and hours.



2) Does the effect of treatment on shrub volume vary geographically?

- We used a GLM to test the relationship between shrub volume as a response variable and treatment, soil moisture, temperature, latitude, and longitude as predictor variables.
- Due to small sample sizes, we ran separate GLMs for the following predictors:
  1. Site, treatment, and soil moisture
  2. Treatment, temperature, and soil moisture
  3. Temperature and site
  4. Site and soil moisture
  5. Temperature and soil moisture
- We repeated this analysis with elevation, slope and aspect as external predictors.



Digital Elevation Model (DEM)

- In order to account for geographical differences in topography, we used a DEM, from which we calculated elevation, aspect, and slope values.
- Because we only had coordinates for each site and none for individual shrubs, we created a 100m buffer around each site to calculate the mean slope, aspect, and elevation value, which we then assigned to every shrub within a site.

Model Selection

- For Q1 and Q2, initial GLMs included all predictors and their interactions.
- Model selection was conducted using *α=0.05* as a threshold to obtain final models with only statistically significant predictors of response variables.

Results

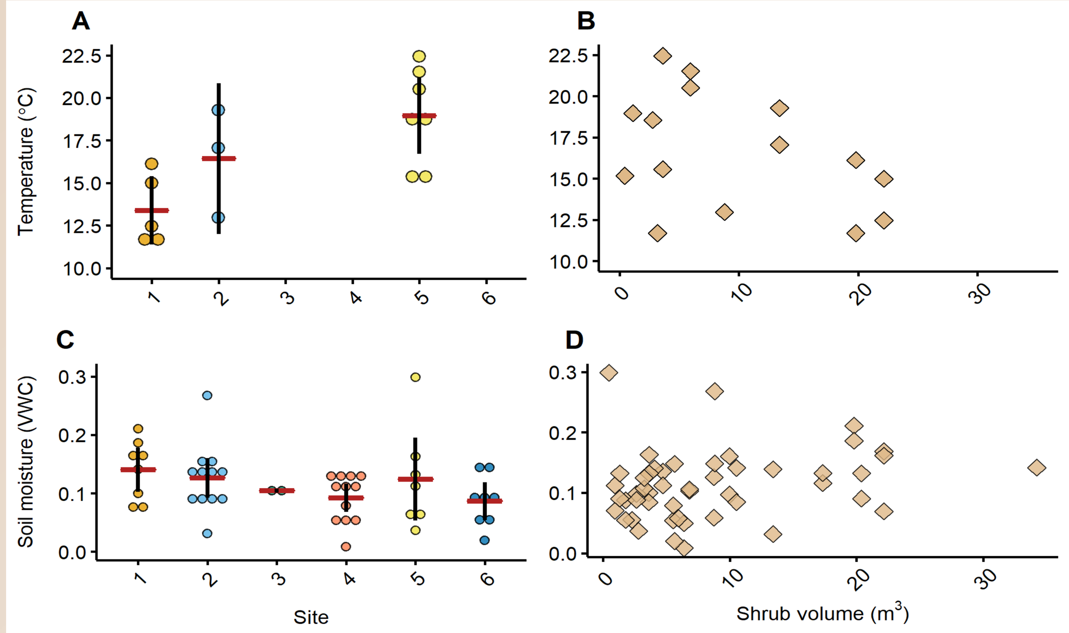


Figure 4. A) Although the relationship is not significant at α=0.05 (p=0.092, $F_O(2,2)=9.90$, $F_C=19.0$), air temperature (°C) tends to increase as site number increases. Site number is positively related to latitude of all sites, and negatively related to longitude in sites 1, 2 and 5. Thus, temperature shows a positive relationship with increasing latitude and decreasing longitude. B) In contrast, air temperature decreases as shrub volume (m^3) increases. There is high variation in this relationship and a small sample size. Therefore, the relationship between shrub volume and temperature is not significant (p=0.126, $F_O(1,2)=6.45$, $F_C=18.5$). C) Site number and D) shrub volume did not have a distinct effect on soil moisture (SWC) (site: p=0.318, $F_O(5,24)= 1.31$, $F_C=2.62$), volume: p=0.61, $F_O(1,24)=0.274$, $F_C=4.26$).

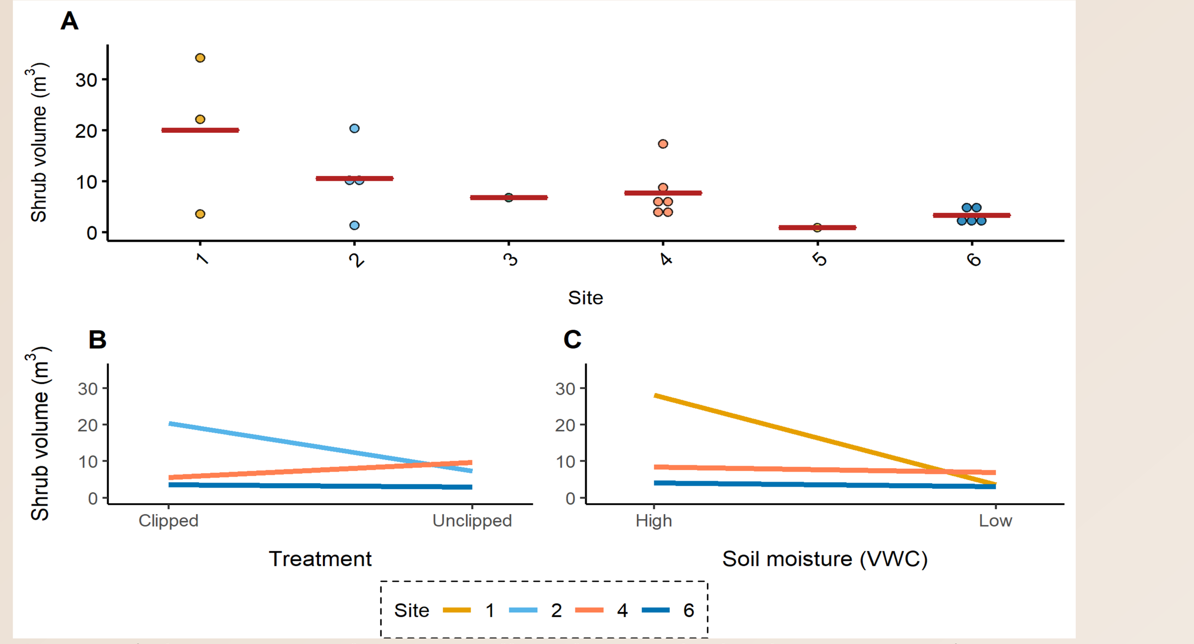


Figure 5. A) There was a significant main effect of site on shrub volume at α=0.05 (p=0.016, $F_O(5,7)=8.98$, $F_C=3.97$). Shrub volume (m^3) decreases as site number increases. Since site number is positively related to the latitude of all sites, shrub volume decreases as latitude increases. This main effect should be treated with caution due to small sample sizes and the significant interaction between site and treatment (B) (p=0.019, $F_O(5,7)=9.65$, $F_C=3.97$), and between site and soil moisture (C) (p=0.023, $F_O(5,7)=8.14$, $F_C=3.97$). The response of shrub volume to treatment depended on site, with clipped shrubs having higher mean volume than unclipped in sites 2 and 6, and unclipped having higher mean volume than clipped in site 4. Mean shrub volume was largest in sites with high soil moisture, however the strength of the response of volume to soil moisture was greater in site 1 than sites 4 and 6.

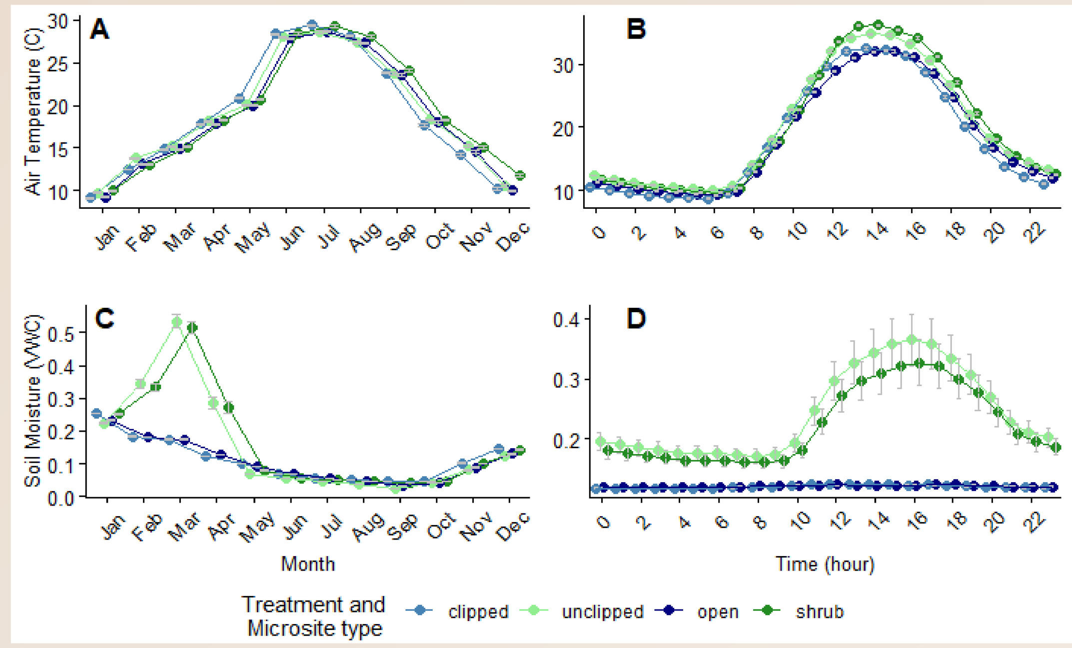


Figure 6. Environmental conditions of artificial (clipped and unclipped treatments) and natural (open and shrub) microsites, with associated 95% confidence intervals. Time series visualizations by date revealed differences. When microsite conditions were then averaged by month (A and C) and hour (B and D), there were visual differences in soil moisture between treatments and microsite types, but no obvious difference in air temperature. Soil moisture in open and clipped plants peaks in March and April (C), and around 3 PM (D). In unclipped and shrub treatments, soil moisture is highest in January, but constant when averaged by hour. Air temperature follows expected patterns in all microsite types (A and B). In all time measurements we see that open and clipped, and unclipped and shrub follow similar trends. This indicates harvest created microsites may not differ from natural counterparts.

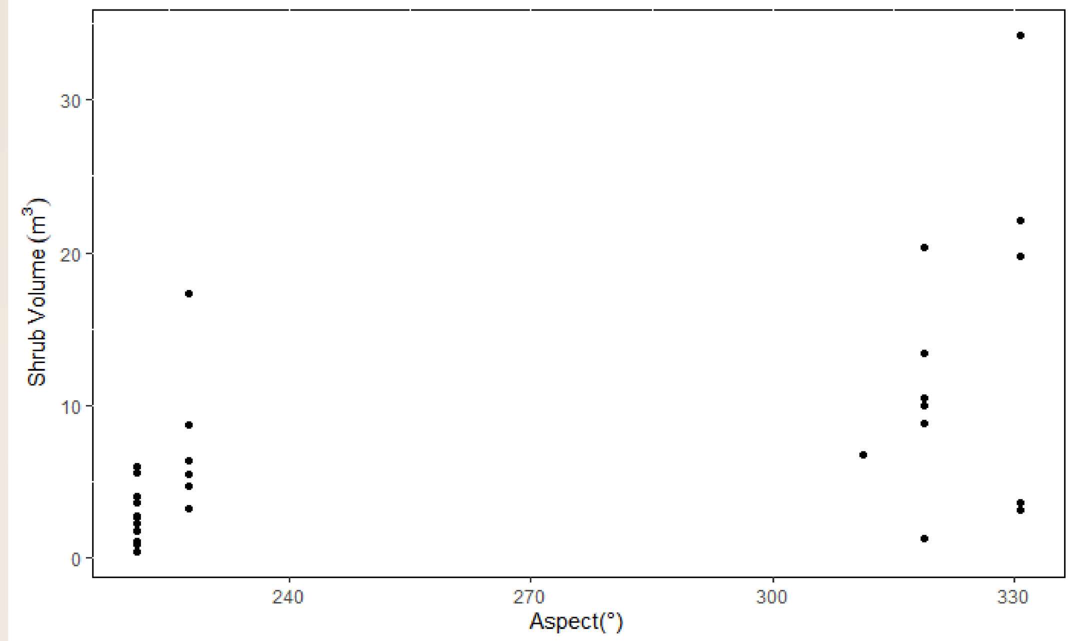


Figure 7. Shrub expansion is controlled by aspect of the shrub. Northwestern facing shrubs (310°-340°) have a higher potential to increase their shrub volume compared to shrub facing the south-west (200°-230°). This is because south-facing slopes received enhanced shortwave radiation in the northern hemisphere. Therefore, northern facing shrubs are more protected in harsh desert conditions. However, facing the northern face of the Cuyama valley does not guarantee enhanced shrub growth as other variables such as soil texture have a greater influence on moisture conservation. These other variables could clarify some reasons that our final model explained such little of the variation in shrub volume ($R^2 = 0.32$; P = 0.002). The effect could be displayed more accurately if geographical data was collected for each individual shrub.

Take Home Messages

•Our goal was to determine how harvest and location affects Mormon tea shrub's health, future harvests, and microclimate conditions.

•When averaged over the sampling period, mean temperature and soil moisture was not significantly affected by site nor shrub volume (Figure 4). Further model results indicated that there were no obvious effects of treatment or microsite type on microsite conditions.

•Contrary to averaged microsite conditions, time series visualizations revealed possible differences over time. When microsite conditions were then averaged by month and hour (Figure 6), there were visual differences in soil moisture between treatments and microsite types. Artificial open microsites (clipped treatments) may not greatly differ from their natural open microsite counterparts.

•Site had a statistically significant effect on shrub volume. Significant interactions between site with soil moisture and site with treatment indicate that location may play a large role in growth (Figure 5). Aspect was determined to be one of the many possible significant effects of location on shrub volume (Figure 7), however other factors like nutrient availability, soil porosity and type should be considered. Small sample sizes and model assumption fits should also be taken into consideration.

•Harvest and use (clipped shrubs) of Mormon Tea did not significantly impact regrowth. Shrubs did not grow back larger, but may regrow to their original size. Further investigation into geographic factors and microsite changes over time are recommended for management.

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