Projected Climate Scenarios and Potential Impacts on Vegetation and Fire Vulnerability

Prepared by Kai Henifin, Fire and Climate Resilience Coordinator, Pepperwood
Prepared for Golden Gate Biosphere Network Climate Vulnerability Assessment
December 2023
Goals

1) Provide a range of viable scientific projections suitable for this vulnerability assessment.

2) Support ongoing conservation planning by partners.

3) Scope potential collaborative climate resilience project opportunities.
1. Lot of uncertainty about impacts of climate change on watersheds and ecosystems, recommend "ensemble approach" to climate projections.

2. Analyzing scenarios representing different degrees of change in projected temperature and rainfall, each scenario is treated as a distinct physical "simulation".

3. Scenarios simulate potential change in climate conditions in the future, not intended to project precise timing of how impacts unfold.

4. Models are based on monthly average values; complementary analyses may be required to capture extreme events.

5. The full suite of data is available on Data Basin and ArcGIS Online.
Approach

1. Identify a subset of scenarios to use that capture end members and central tendency of ensemble.

2. Use most recent models (CMIP 6) but augment with (CMIP5) to include drought scenario.

3. Utilize USGS Basin Characterization Model inputs (PPT and TEMP) to ecologically relevant hydrology indictors: AET (productivity), PET, CWD (drought stress), runoff and recharge (270m).

4. Query vegetation distribution and fire hazard models that build on Basin Characterization Model, outputs or equivalents (30m).
1. Review of climate model selection including summaries of downscaled temperature and rainfall trends.

2. Review of hydrology outputs and summaries.

3. Discussion on implications of climate for vegetation, Ackerly model.

4. Discussion on implications of climate for fire hazard.

5. Highlighting landscape-scale and collaborative project opportunities for planning.
Overview and Methods
Late-century values were calculated for climate projections that span a range of temperature and precipitation conditions for California.
Basin Characterization Model (BCM)  
Translating climate to watershed response

BCM INPUT
- Temperature
- Solar Radiation
- Precipitation
- Topography
- Soils
- Geology

Potential Evapotranspiration
Actual Evapotranspiration
= Climatic Water Deficit

UNIQUE BCM OUTPUT
Downscaled Temperature Inputs Derived from Global Climate Models
# Temperature

## SUMMARY OF SCENARIOS COMPARED TO HISTORIC BASELINE

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Average (AVG) °C</th>
<th>Winter Minimum (DJF) °C</th>
<th>Summer Maximum (JJA) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recent Historic (1981-2010)</strong></td>
<td>14.3</td>
<td>4.9</td>
<td>25.9</td>
</tr>
<tr>
<td><strong>Scenario</strong></td>
<td><strong>Warm/High Rainfall</strong></td>
<td><strong>Warm/Moderate Rainfall</strong></td>
<td><strong>Hot/Low Rainfall</strong></td>
</tr>
<tr>
<td><strong>Late-Century (2070-2099)</strong></td>
<td>16.6</td>
<td>16.6</td>
<td>19.4</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td>2.2</td>
<td>2.2</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Recent Historic (1981-2010)

- Mean = 4.9 °C

Late-Century (Warm/Moderate Rainfall)

- Mean = 5.9 °C

Change from Recent Historic (Warm/Moderate Rainfall)

- Average Change: +1.1 °C

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Temperature | SUMMER MAXIMUM (JUN, JUL, AUG), RECENT HISTORIC VS PROJECTED

Recent Historic (1981-2010)

**MEAN = 26.0 °C**

Late-Century
(Warm/Moderate Rainfall)

**MEAN = 29.3 °C**

Change from Recent Historic
(Warm/Moderate Rainfall)

**Average Change**

**+3.3 °C**

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Hotter Summers
Temperatures are projected to be between +3.1 to 7 °C hotter

Milder Winter Weather
Temperatures are projected to be between +0.6 to 4.1 °C hotter

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Watershed Hydrology
Average Annual Precipitation (mm/year)

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Recent Historic (1981-2010)</th>
<th>Late-Century (2070-2099)</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1027mm</td>
<td>1423mm</td>
<td>+38%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1084mm</td>
<td>+5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>818mm</td>
<td>-20%</td>
</tr>
</tbody>
</table>
ALL MODELS

HOT/LOW RAINFALL

WARM/HIGH RAINFALL

WARM/MOD RAINFALL

Decreased precipitation

Increased precipitation

Greatest % Change in Annual Precipitation (mm)
TOP 20%, BY MODEL

Greatest % Change in Summer Precipitation (mm)
TOP 20%, BY MODEL

Greatest % Change in Winter Precipitation (mm)
TOP 20%, BY MODEL

Data Source: Flint & Flint v8 (2021) & v6 (2014)
## Hydrology | QUANTITATIVE SUMMARY

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Average Annual Runoff (mm/year)</th>
<th>Average Annual Recharge (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent Historic (1981-2010)</td>
<td>366mm</td>
<td>147mm</td>
</tr>
<tr>
<td>Scenarios</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm/High Rainfall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm/Moderate Rainfall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot/Low Rainfall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm/High Rainfall</td>
<td>717mm</td>
<td>181mm</td>
</tr>
<tr>
<td>Warm/Moderate Rainfall</td>
<td>419mm</td>
<td>145mm</td>
</tr>
<tr>
<td>Hot/Low Rainfall</td>
<td>235mm</td>
<td>170mm</td>
</tr>
<tr>
<td>Late-Century (2070-2099)</td>
<td>+96%</td>
<td>+23%</td>
</tr>
<tr>
<td>Percent Change</td>
<td></td>
<td>0%</td>
</tr>
</tbody>
</table>

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Recent Historic Runoff

MEAN = 366MM

Runoff (mm/yr)
30-YEAR MEAN 1328

Recent Historic Recharge

MEAN = 147MM

Recharge (mm/yr)
30-YEAR MEAN 779

Recent Historic Water Supply

MEAN = 513MM

Water Supply (mm/yr)
30-YEAR MEAN 1453

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Hydrology | CHANGE IN WATER SUPPLY WARM/MODERATE RAINFALL (2070-2099)

Change in Runoff from Recent Historic

Change from Recent Historic (mm/yr)

MEAN = +53 MM

Change in Recharge from Recent Historic

MEAN = -3 MM

Change in Water Supply from Recent Historic

MEAN = +51 MM

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Climatic Water Deficit (CWD) is a metric of drought stress. It increases with most projected climate scenarios and correlates with vegetation and fire risk, as well as drought. This metric integrates the effects of temperature and rainfall.
## CLIMATIC WATER DEFICIT QUANTITATIVE SUMMARY

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Average Annual Climatic Water Deficit (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent Historical (1981-2010)</td>
<td>660mm</td>
</tr>
<tr>
<td>Scenarios</td>
<td>Warm/High Rainfall</td>
</tr>
<tr>
<td>Late-Century (2070-2099)</td>
<td>724mm</td>
</tr>
<tr>
<td>Percent Change</td>
<td>+10%</td>
</tr>
</tbody>
</table>

Data Source: Flint & Flint v8 (2021) & v6 (2014)
### Recent Historic Climatic Water Deficit Variability

**Mean** = 689 MM  
**Mean** = 69.7 MM

**Annual Average CWD (mm/yr)**  
**Mean** = 689 MM  
**Mean** = 69.7 MM

**30-Year Mean**

**Standard Deviation (mm/yr)**  
**Mean** = 1328  
**Mean** = 231

**Recent Historic CWD (1981-2010)**

**Standard Deviation (1981-2010)**

**Calculating Change in CWD Variability**

\[
\text{Change (in Standard Deviation Units)} = \frac{\text{Projected 30yr mean} - \text{RH 30yr mean}}{\text{RH 30yr Standard Deviation}}
\]

**RH (Recent Historic 1981-2010)**  
**Projected (Late Century 2070-20999)**

Source: Thorne et al. 2015

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Hydrology | CHANGE IN CLIMATIC WATER DEFICIT FROM HISTORICAL (1981-2010)

Warm/High Rainfall

Warm/Moderate Rainfall

Hot/Low Rainfall

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Temperature and CWD increased for all scenarios. Precipitation, recharge, and runoff projections differed by scenario.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>TREND</th>
<th>Warm/High Rainfall</th>
<th>Warm/Moderate Rainfall</th>
<th>Hot/Low Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Average Temperature</td>
<td>▲</td>
<td>△</td>
<td>△</td>
<td>△△</td>
</tr>
<tr>
<td>Winter minimum (Dec, Jan, Feb)</td>
<td>▲▲▲</td>
<td>△△△</td>
<td>△△</td>
<td>△△</td>
</tr>
<tr>
<td>Summer maximum (Jun, Jul, Aug)</td>
<td>▲</td>
<td>△</td>
<td>△</td>
<td>△△</td>
</tr>
<tr>
<td>Annual Precipitation</td>
<td>▲</td>
<td>△△△</td>
<td>△</td>
<td>△△△</td>
</tr>
<tr>
<td>Seasonal Precipitation (Jun, Jul, Aug)</td>
<td>▲</td>
<td>△△△</td>
<td>△△</td>
<td>△△△</td>
</tr>
<tr>
<td>Seasonal Precipitation (Dec, Jan, Feb)</td>
<td>●</td>
<td>△△△</td>
<td>—</td>
<td>△△△</td>
</tr>
<tr>
<td>Recharge</td>
<td>●</td>
<td>△△△</td>
<td>—</td>
<td>△</td>
</tr>
<tr>
<td>Runoff</td>
<td>●</td>
<td>△△△</td>
<td>△</td>
<td>△△△</td>
</tr>
<tr>
<td>Climatic water deficit</td>
<td>▲</td>
<td>△</td>
<td>—</td>
<td>△△</td>
</tr>
</tbody>
</table>

**PROJECTED TREND**

- **Increase** (+5, +20, +50)
- **No change**
- **Decrease** (-5, -20, -50)

![Diagram showing % change by mid-century](Diagram.png)

- ● Varies by model
Landscape Units are geographic divisions based on physiographic features and inform the vegetation vulnerability model.

*Factors, excluding climatic-biotic, and edaphic conditions, affecting prevailing habitat conditions and biotic distributions (e.g. topography, drainage, erosion)*

1 - Northern Mayacamas Mountains
2 - Russian River Valley
3 - Sonoma Coast Range
6 - Southern Mayacamas Mountains
7 - Santa Rosa Plain
10 - Sonoma Valley
11 - Sonoma Mountain
12 - Coastal Grasslands
16 - Marin Coast Range
17 - Point Reyes
25 - San Francisco
30 - Santa Cruz Mountains North
Temperature | SEASONAL (WINTER & SUMMER) AVERAGE TEMPERATURE BY LANDSCAPE UNIT

- Northern Mayacamas Mountains
- Russian River Valley
- Sonoma Coast Range
- Southern Mayacamas Mountains
- Santa Rosa Plain
- Sonoma Valley
- Sonoma Mountain
- Coastal Grasslands
- Marin Coast Range
- Point Reyes
- San Francisco
- Santa Cruz Mountains North

### Summer
(Jun, Jul, Aug)

### Winter
(Dec, Jan, Feb)

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Precipitation | ANNUAL AVERAGE PRECIPITATION BY LANDSCAPE UNIT

Data Source: Flint & Flint v8 (2021) & v6 (2014)
Climatic Water Deficit | AVERAGE NUMBER OF STANDARD DEVIATIONS FROM RECENT HISTORIC (1981-2010)

Data Source: Flint & Flint v8 (2021) & v6 (2014)
WILDFIRE PROBABILITY
## Wildfire Hazard
*Potential for causing damage to vulnerable resources*

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>METRIC</th>
<th>INPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wildfire Hazard</td>
<td>Burn Probability of a fire in one year period (frequency)</td>
<td>U.S. Forest Service FSim 120m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single Year Conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Existing fuels + historic weather)</td>
</tr>
<tr>
<td></td>
<td>Fire Intensity (severity)</td>
<td>Pyrologix WildEST utility</td>
</tr>
<tr>
<td></td>
<td>- Flame length</td>
<td>Multiple Simulations</td>
</tr>
<tr>
<td></td>
<td>- Fireline intensity</td>
<td>(dynamic fuels + weather)</td>
</tr>
</tbody>
</table>
Annual Burn Probability (Frequency)

Flame length >11 ft. and Fireline (Intensity)

Wildfire Hazard

Data Source: Region et al. (2021), Dillon et al. (2015, 2018)
Fire | WILDFIRE HAZARD PROBABILITY AND GOLDEN GATE BIOSPHERE NETWORK LANDS

ACR | Audubon Canyon Ranch
BMR | Bodega Marine Reserve
CCSP | China Camp State Park
FPNHS | Fort Point National Historic Site
GGNRA | Golden Gate National Recreation Area
GGNPC | Golden Gate National Parks Conservancy
JRPB | Jasper Ridge Biological Preserve
MWNNM | Muir Wood National Monument
PBCS | Point Blue Conservation Science
PRNS | Point Reyes National Seashore
PP | Pepperwood Preserve
PT | Presidio Trust
SPTSP | Samuel P. Taylor State Park
SFPUC | San Francisco Public Utilities Commission
TBSP | Tomales Bay State Park

Data Source: Regional et al. (2021), Dillon et al. (2015 & 2018)
## FIRE | WILDFIRE HAZARD BY ECOSYSTEM

<table>
<thead>
<tr>
<th>Ecosystems</th>
<th>Total Acres</th>
<th>Acres Ranked for Wildfire Hazard</th>
<th>Urban &amp; Non-burnable fuel</th>
<th>Percent Area by Wildfire Hazard Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Coastal Dunes</td>
<td>5,780</td>
<td>4,922</td>
<td>15.5%</td>
<td>85%</td>
</tr>
<tr>
<td>Coastal Prairie</td>
<td>395,485</td>
<td>341,278</td>
<td>14%</td>
<td>75%</td>
</tr>
<tr>
<td>Coastal Redwood Forest</td>
<td>162,675</td>
<td>154,309</td>
<td>4.4%</td>
<td>42%</td>
</tr>
<tr>
<td>Coastal Scrub</td>
<td>111,650</td>
<td>105,502</td>
<td>6.6%</td>
<td>82%</td>
</tr>
<tr>
<td>Freshwater Marshes</td>
<td>20,375</td>
<td>12,162</td>
<td>39.9%</td>
<td>57%</td>
</tr>
<tr>
<td>Maritime Chaparral</td>
<td>13,377</td>
<td>11,860</td>
<td>11%</td>
<td>24%</td>
</tr>
<tr>
<td>Mixed Evergreen Forests</td>
<td>61,122</td>
<td>57,922</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Open Oak Woodlands/Savanna</td>
<td>206,996</td>
<td>180,438</td>
<td>13%</td>
<td>31%</td>
</tr>
<tr>
<td>Riparian Forests/Woodlands</td>
<td>130,116</td>
<td>119,981</td>
<td>15%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Data Source: Regional et al. (2021) and Marin County Fine-scale vegetation, Golden Gate Parks Conservancy and Tukman Geospatial LCC (2021)
**Mean Annual Fire Probability**
Warm/Moderate Rainfall (2026-2050)

Data Source: Park et al. (2021)
Vegetation Vulnerability Assessment

Ackerly et al. Probabilistic Vegetation Model
The Probabilistic Vegetation Model (PVM)

Ackerly et al. (2015) modeled the distribution of 22 major vegetation types, most defined by a single dominant woody species, across the San Francisco Bay Area.

Results can be used to facilitate landscape scale analyses

- Project biotic responses to future climate change
- Evaluate responses of individual species along with the overall responses of communities and ecosystems

22 Vegetation Types

Climatic Variables (1951-1980 historic norms)

- Summer maximum temperature (°C)
- Winter minimum temperature (°C)
- Annual precipitation (mm)
- Climatic water deficit (mm)

Ackerly DD, Cromwell WK, Weiss SB, Flint LE, Flint AL. 2015. 
*A Geographic Mosaic of Climate Change Impacts on Terrestrial Vegetation: Which Areas Are Most at Risk?* PLoS ONE 10(6)
Modeled frequency of 22 vegetation types

The model was projected for 54 future climate scenarios, spanning a representative range of temperature and precipitation.

18 climate projections $\times$ 3 time periods = 54 scenarios

This figure shows the relative frequency of 22 vegetation types, parameterized for the historical baseline period and then projected for 54 possible futures.
General trend: Increase in relative distribution of **chamise chaparral**

Ackerly et al. 2015
Species-specific potential responses to climate change

- Higher rainfall
  - Warm < 4°C more rain
  - Hot > 4°C more rain

- Lower rainfall
  - Warm < 4°C less rain
  - Hot > 4°C less rain

% CHANGE (FROM CURRENT):
- Dramatic Decline:
  - -75%
- Moderate Decline:
  - -50%
- Relative Stability:
  - -25%
- Increase:
  - +25%

Current distribution:
- Tolerance (stable or increase) across all scenarios
- Decline (moderate or dramatic) across all scenarios
The direction and magnitude of change was projected for each vegetation type across the four types of climate scenarios …for each of the 12 Landscape Units.

Projected habitat suitability was projected for each vegetation type was represented as a set of four squares, for example:

Redwoods
**Vegetation** | **SUITABLE CLIMATE SPACE IS DECLINING**

**Vulnerable oaks**

Decline *(moderate or dramatic)* across all scenarios

Dying blue oaks, especially on south-facing slopes

Miniature leaves during drought

2015-16 drought
San Luis Obispo county

Normal leaves

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Sonoma Coast Range</th>
<th>Russian River Valley</th>
<th>Northern Mayacamas Mountains</th>
<th>Southern Mayacamas Mountains</th>
<th>Sonoma Valley</th>
<th>Sonoma Mountains</th>
<th>Santa Rosa Plains</th>
<th>Coastal Grassland</th>
<th>Marin Coast</th>
<th>Point Reyes</th>
<th>San Francisco</th>
<th>Santa Cruz Mountains North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black oak <em>(Quercus kelloggii)</em></td>
<td></td>
<td>-</td>
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<tr>
<td>Blue oak <em>(Quercus douglasii)</em></td>
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<td>-</td>
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<tr>
<td>Canyon live oak <em>(Quercus chrysolepis)</em></td>
<td></td>
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<tr>
<td>Oregon oak <em>(Quercus garret</em>)</td>
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</tbody>
</table>
Vegetation | SUITABLE CLIMATE SPACE IS EXPANDING

Resilient oak

Tolerance (stable or increase) across all scenarios

May expand under warmer climates. While sensitive to warmer summers, it may be favored by increasing winter temperatures.
Stable and Expanding Chaparral

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Sonoma Coast Range</th>
<th>Russian River Valley</th>
<th>Northern Mayacamas Mountains</th>
<th>Southern Mayacamas Mountains</th>
<th>Sonoma Valley</th>
<th>Sonoma Mountains</th>
<th>Santa Rosa Plains</th>
<th>Coastal Grassland</th>
<th>Marin Coast</th>
<th>Point Reyes</th>
<th>San Francisco</th>
<th>Santa Cruz Mountains North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamise (Adenostoma fasciculatum)</td>
<td>-</td>
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<tr>
<td>California Bay (Umbellularia california)</td>
<td>-</td>
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<tr>
<td>Coyote brush (Baccharis pillars)</td>
<td>-</td>
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</tr>
</tbody>
</table>
Sensitive Redwoods

Mixed (increase, stable or moderate) across all scenarios

Vulnerable redwoods should be prioritized for protection and stewardship

Sensitive to water deficit and high temperatures. Likely to persist best in cool north-facing slopes, riparian and moist valleys, and areas of persistent fog, where summer drought is reduced.

<table>
<thead>
<tr>
<th></th>
<th>Sonoma Coast Range</th>
<th>Russian River Valley</th>
<th>Northern Mayacamas Mountains</th>
<th>Southern Mayacamas Mountains</th>
<th>Sonoma Valley</th>
<th>Sonoma Mountains</th>
<th>Santa Rosa Plains</th>
<th>Coastal Grassland</th>
<th>Marin Coast</th>
<th>Point Reyes</th>
<th>San Francisco</th>
<th>Santa Cruz Mountains North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redwood (Sequoia sempervirens)</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Photo: Gary Kazanjian
TAKE AWAYS

1.) **Temperature increases across all scenarios**, does not indicate direction or rate of change

2.) **Precipitation is highly variable across all the scenarios**, trending toward extreme events

3.) **New models project more rainfall**, particularly in northwestern portion of Sonoma County

4.) **Water deficits are likely to increase across all scenarios**, which in turn increase fire hazard locally and may reduce suitable habitat for non-drought tolerant species
Golden Gate Biosphere Climate Adaptation Project

About
The goal of this project is to integrate existing, best available science with an expert elicitation process to improve understanding of whether and how important natural resources in the Golden Gate Biosphere Network (GGBN) region may be vulnerable to changing climate conditions and what management actions can be implemented to reduce vulnerabilities and/or increase resilience of those resources.

Tags
- golden gate biosphere
- adaptation planning
- climate
- bcm
- north bay
- basin characterization model

Gallery contains
- 15 Folders
- 46 Datasets

Usage
- bookmarked by 1 member
Kai Henifin
khenifin@pepperwoodpreserve.org
APPENDIX
## Probabilistic Vegetation Model (PVM) | Landscape Unit

<table>
<thead>
<tr>
<th>Species</th>
<th>Sonoma Coast Range</th>
<th>Russian River Valley</th>
<th>Northern Mayacamas Mountains</th>
<th>Southern Mayacamas Mountains</th>
<th>Sonoma Valley</th>
<th>Sonoma Mountains</th>
<th>Santa Rosa Plains</th>
<th>Coastal Grassland</th>
<th>Marin Coast</th>
<th>Point Reyes</th>
<th>San Francisco</th>
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<tbody>
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<td>Black oak (Quercus kelloggii)</td>
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Data Source: Ackerly et al. 2015
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<tr>
<th>Probabilistic Vegetation Model (PVM)</th>
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</thead>
<tbody>
<tr>
<td><strong>Interior live oak</strong> (Quercus wislizeni)</td>
<td>Sonoma Coast Range</td>
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<td><strong>Knobcone pine</strong> (Pinus attenuata)</td>
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<td><strong>Madrone</strong> (Arbutus menziesii)</td>
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<td><strong>Monterey cypress</strong> (Hesperocyparis macrocarpa)</td>
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<td><strong>Oregon oak</strong> (Quercus garrana)</td>
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<tbody>
<tr>
<td><strong>Redwood</strong> <em>(Sequoia sempervirens)</em></td>
<td><img src="image1" alt="Redwood - Sonoma Coast Range" /></td>
<td><img src="image2" alt="Redwood - Russian River Valley" /></td>
<td><img src="image3" alt="Redwood - Northern Mayacamas Mountains" /></td>
<td><img src="image4" alt="Redwood - Southern Mayacamas Mountains" /></td>
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<td><strong>Valley oak</strong> <em>(Quercus lobata)</em></td>
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