Vegetation Vulnerability Assessment

Prepared by Morgan Gray, Ph.D.
Pepperwood

November 2020

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Overview

- Recap and Refresher **30 minutes**
  - Geographic extent
  - Climate assessment results 15 minutes
  - Fire assessment results 15 minutes
- Vegetation vulnerability assessment **50 minutes**
  - Methods 20 minutes
  - Vegetation vulnerability by Landscape Unit 30 minutes
- Questions and discussion **20 minutes**

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Climate vulnerability review

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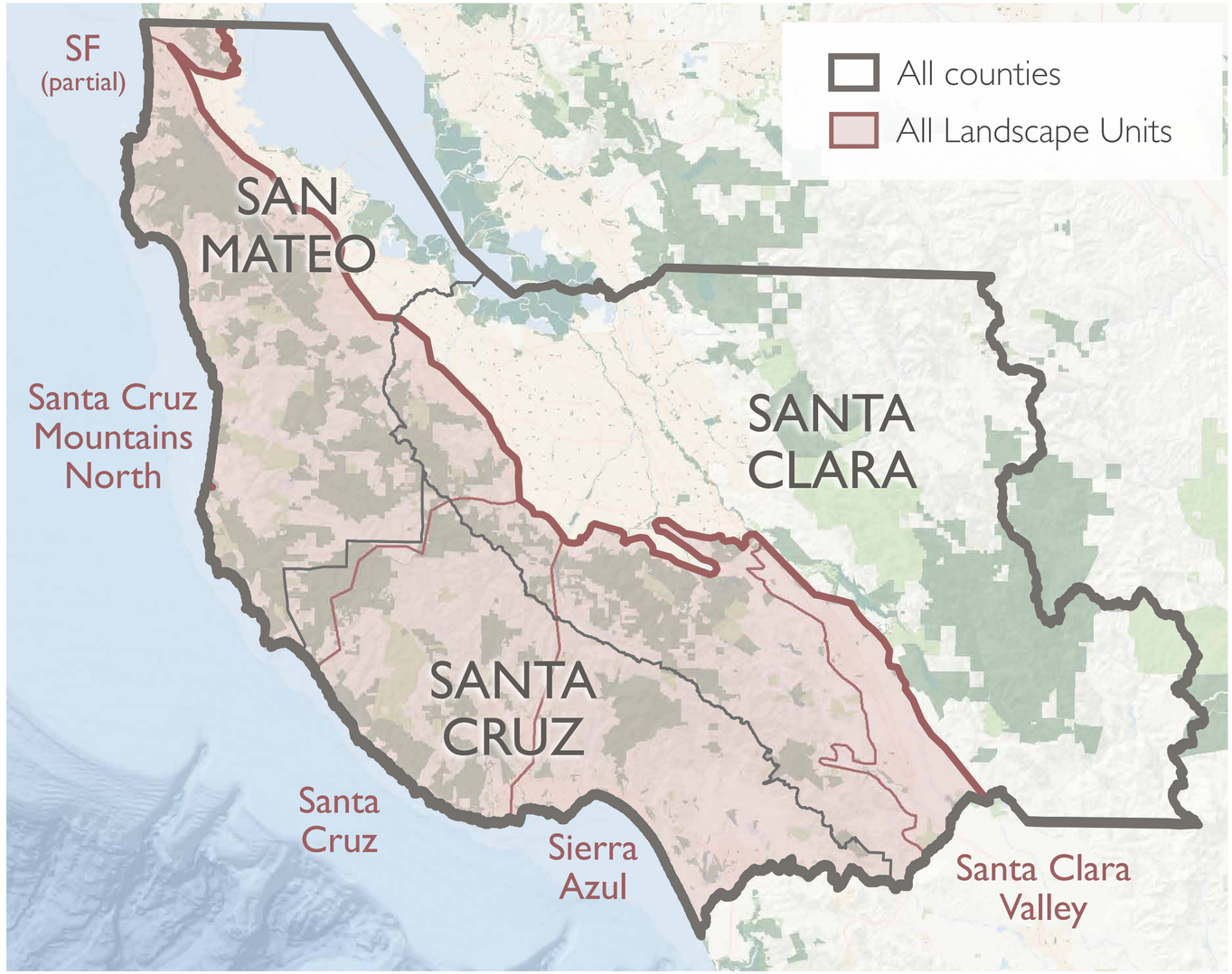
Geographic Extent

We summarized vegetation data for **6 geographic extents** based CLN Landscape Units

Here the Landscape Unit and county boundary extents are overlaid for comparison



Note: *Only the portion of the San Francisco Landscape Unit within San Mateo county was included in the analyses*

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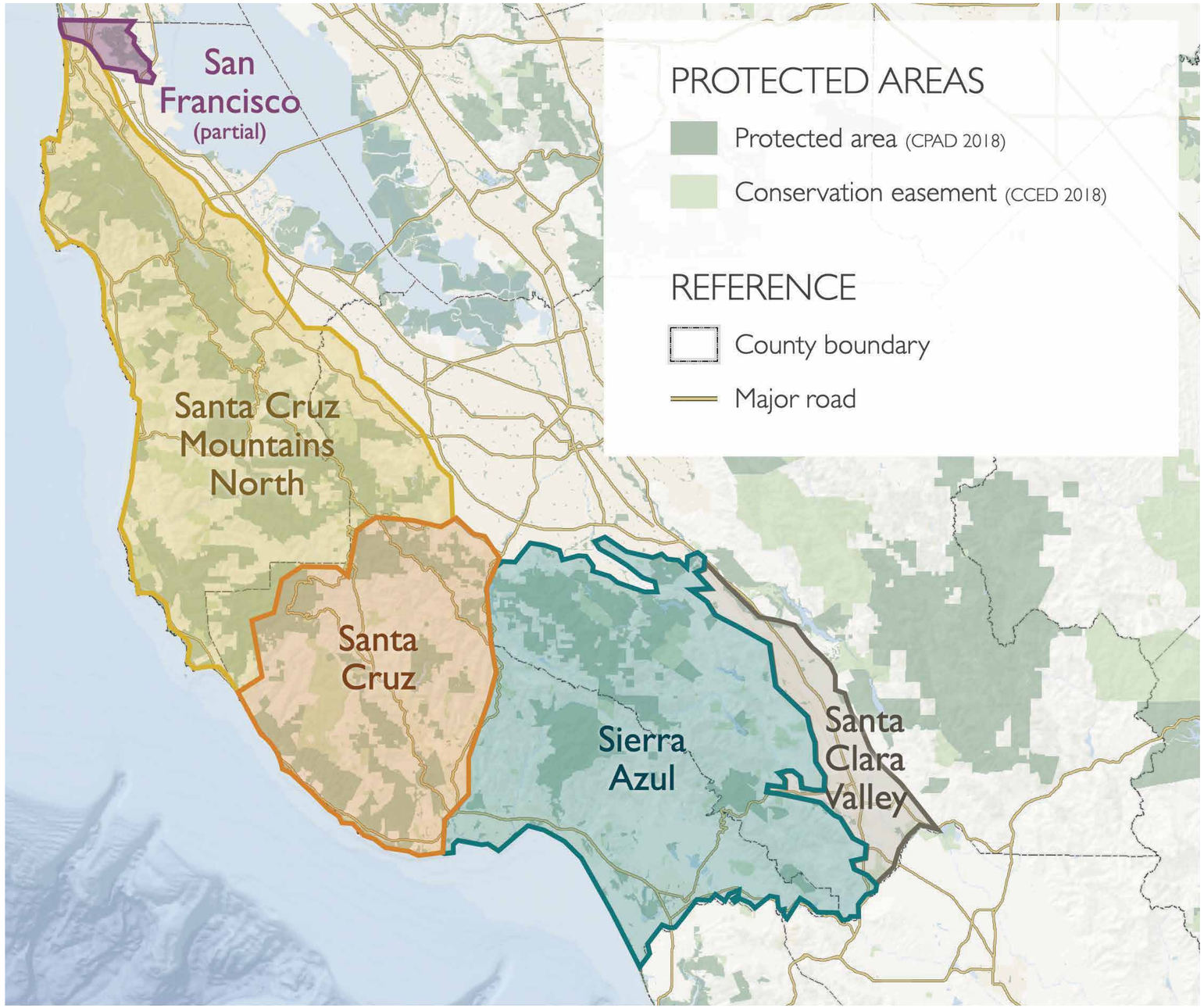

Landscape Units

Conservation Lands Network (CLN)

Landscape Units are geographic divisions based on physiographic* features, and inform the vegetation vulnerability model.

Five Landscape Units in this region are:

- Santa Cruz Mountains North
- Santa Cruz
- Sierra Azul
- Santa Clara Valley
- San Francisco (partial)

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

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We evaluated 7 climate variables and 1 fire metric

VARIABLE	METRIC	ABBREV.
Air temperature	Temperature ANNUAL MEAN	AVG
	Summer maximum temperature MEAN FOR JUN, JUL, AUG	JJA
	Winter minimum temperature MEAN FOR DEC, JAN, FEB	DJF
Hydrology	Recharge	RCH
	Runoff	RUN
	Climatic water deficit	CWD
	Precipitation	PPT
Fire	Wildfire risk	WFR

3 Temperature metrics

4 Hydrologic metrics

1 Fire metric

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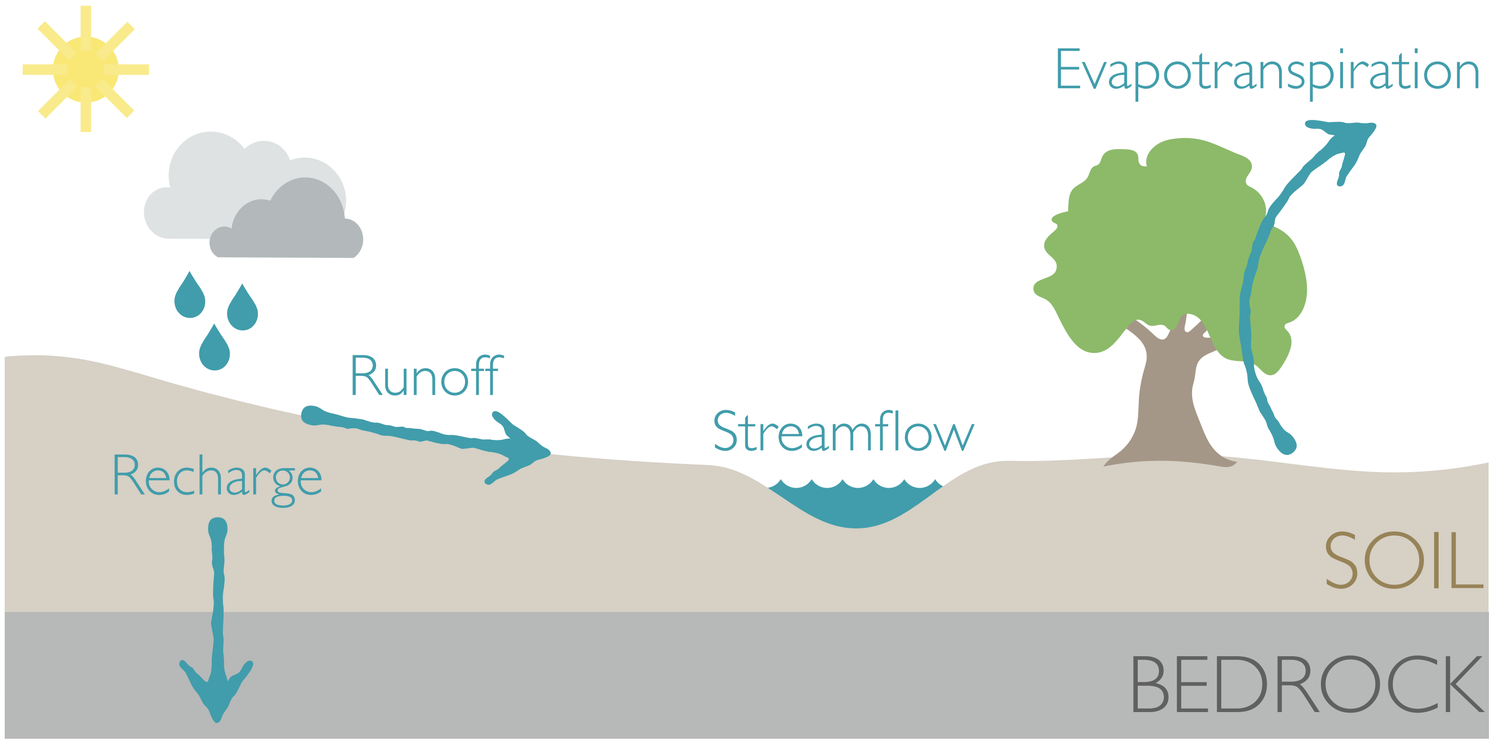
Basin Characterization Model (BCM)

Translating climate to watershed response

BCM INPUT

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



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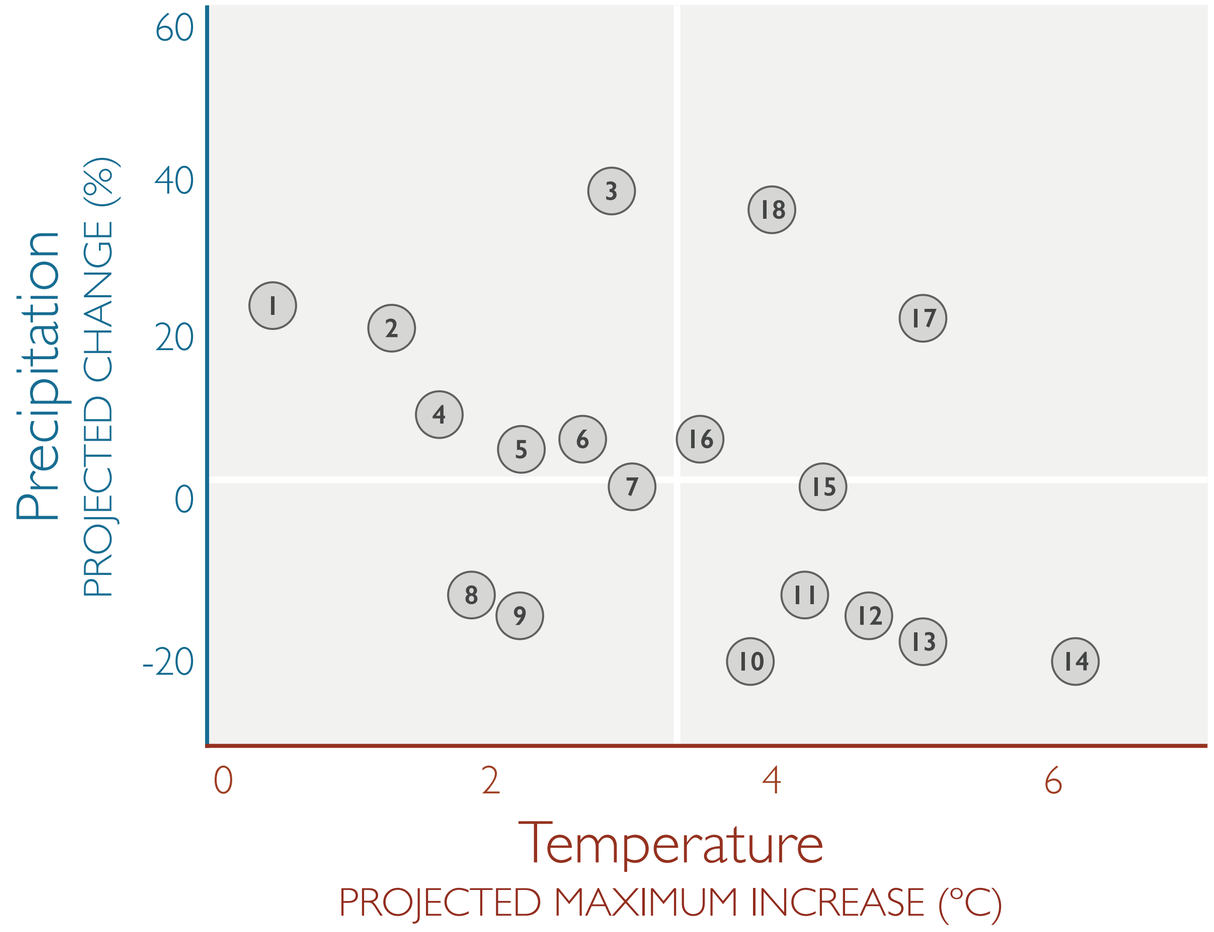
18 climate change projections

Climate Ready North Bay: 2070-2099 relative to 1951-1980

Projected change in **precipitation** and **temperature**



ID	Climate Scenario
1	GISS-E2 rcp2.6
2	MRI-cgm3 rcp2.6
3	CSIRO-mk3.5 A1B
4	PCM B1
5	PCM A2
6	MPI-em rcp4.5
7	GISS-apm A1B
8	MIROC-5 rcp 2.6
9	GFDL B1
10	GFDL A2
11	MIROC-esm rcp4.5
12	MIROC-esm rcp6.0
13	MIROC-2-medres A2
14	MIROC-esm rcp8.5
15	FGOALS-G2 rcp8.5
16	CCSM-4 rcp8.5
17	IPSL-cm5a-In rcp8.5
18	CNRM-cm5 rcp8.5

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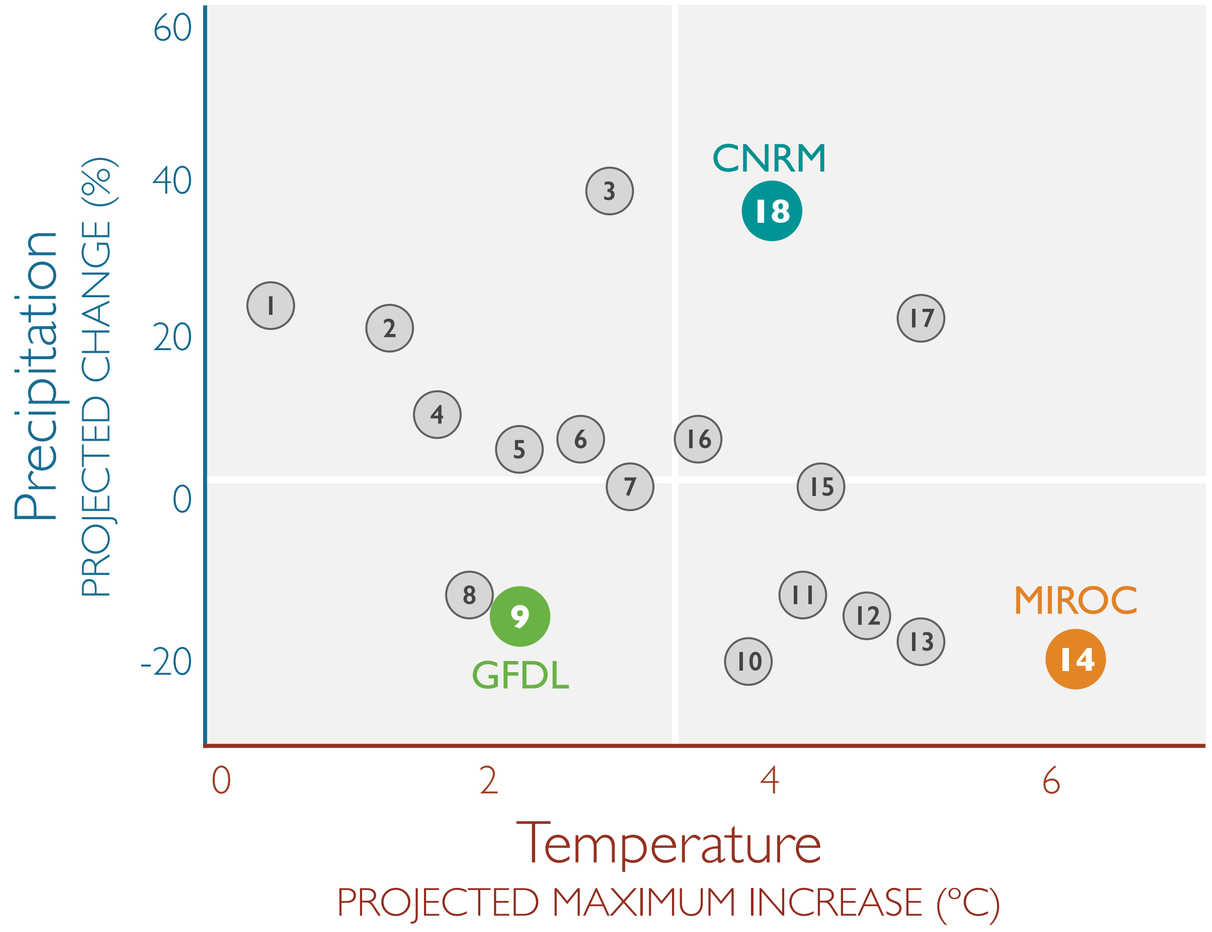
We used 3 of the 18 climate projections in the previous assessment

Projected change in **precipitation** and **temperature**



ID	Climate Scenario
1	GISS-E2 rcp2.6
2	MRI-cgm3 rcp2.6
3	CSIRO-mk3.5 A1B
4	PCM B1
5	PCM A2
6	MPI-em rcp4.5
7	GISS-apm A1B
8	MIROC-5 rcp 2.6
9	**GFDL B1**
10	GFDL A2
11	MIROC-esm rcp4.5
12	MIROC-esm rcp6.0
13	MIROC-2-medres A2
14	**MIROC-esm rcp8.5**
15	FGOALS-G2 rcp8.5
16	CCSM-4 rcp8.5
17	IPSL-cm5a-ln rcp8.5
18	**CNRM-cm5 rcp8.5**

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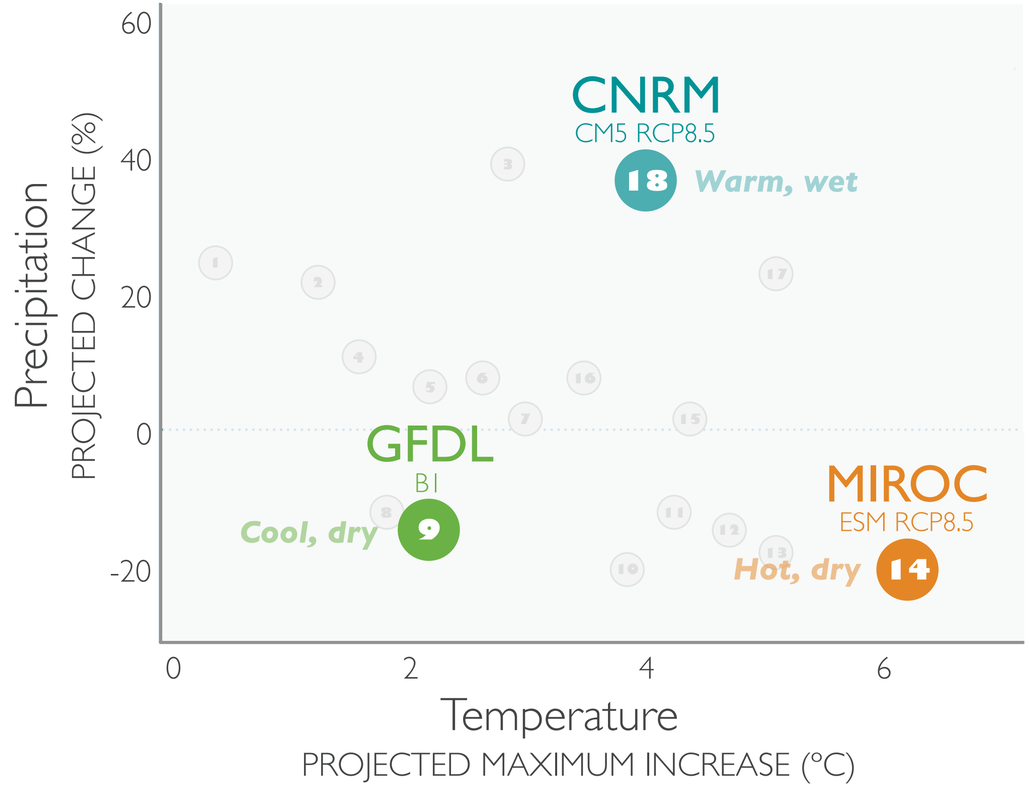
Each climate variable was assessed for **4 climate scenarios** at **2 time periods**: recent (1981-2010) and mid-century (2040-2069)

	SCENARIO		PROJECTION TEMP.	PROJECTION PRECIP.	TIME PERIOD
1	RECENT		—	—	Recent 1981 - 2010
2	CNRM	CNRM rcp 8.5	WARM	WET	Mid-Century 2040 - 2060
3	GFDL	GFDL B1	COOL	DRY	
4	MIROC	MIROC ESM rcp 8.5	HOT	DRY	



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We used **30 data sets** in the climate vulnerability assessment

VARIABLE	METRIC		RECENT	CNRM *Warm, wet*	GFDL *Cool, dry*	MIROC *Hot, dry*
Air temperature	Temperature ANNUAL MEAN	AVG	1981 - 2010	2040 - 2069	2040 - 2069	2040 - 2069
	Summer maximum temperature MEAN FOR JUN, JUL, AUG	JJA				
	Winter minimum temperature MEAN FOR DEC, JAN, FEB	DJF				
Hydrology	Recharge	RCH				
	Runoff	RUN				
	Climatic water deficit	CWD				
	Precipitation	PPT				
Fire	Wildfire risk	WRF	1971-2000			

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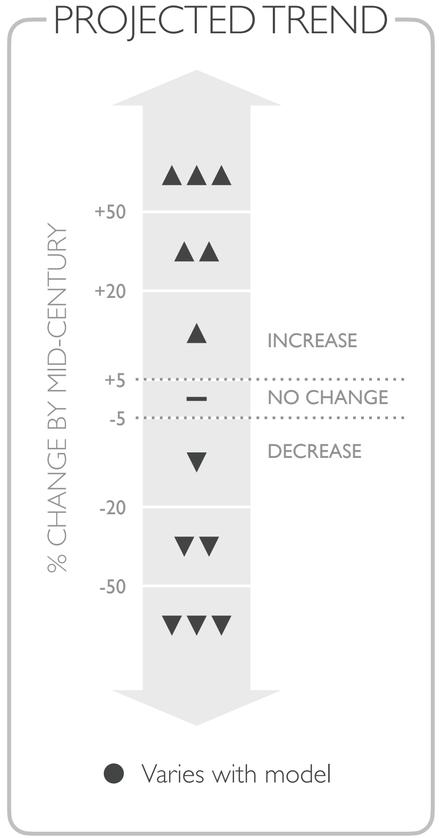
Temperature and CWD increased for all scenarios

Precipitation, recharge, and runoff projections differed by scenario

VARIABLE	TREND	CNRM *Warm, wet*	GFDL *Cool, dry*	MIROC *Hot, dry*
Annual average	▲	△	△	△△
Winter minimum (Dec, Jan, Feb)	▲▲	△△	△△	△△
Summer maximum (Jun, Jul, Aug)	▲	△	△	△
Climatic water deficit	▲	—	—	△
Precipitation	●	△	—	▽▽
Recharge	●	△	—	▽▽
Runoff	●	△△	—	▽▽
Wildfire risk	▲			



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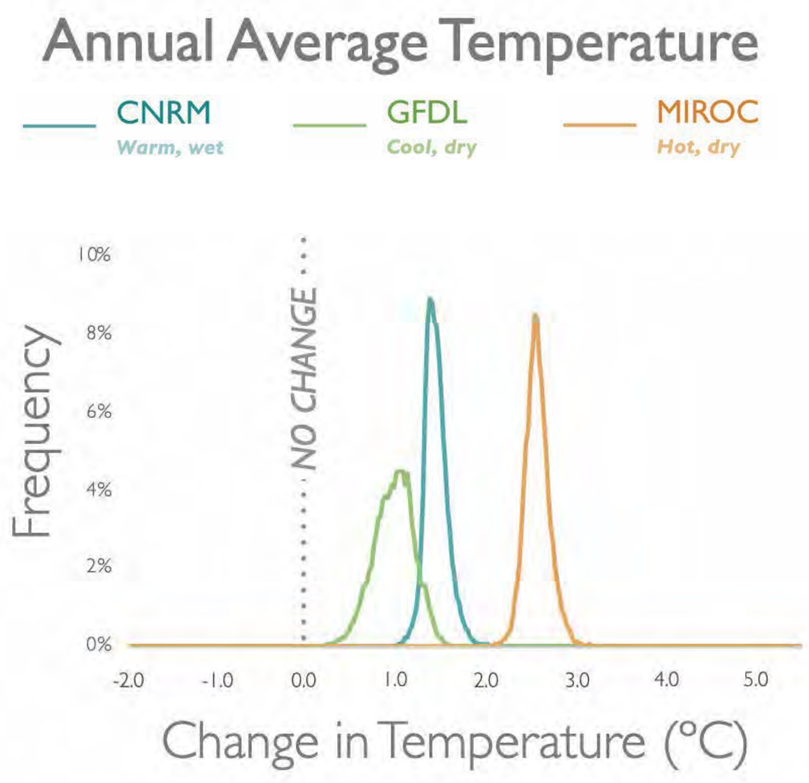
The trend for all models was an **increase** in temperature by mid-century

CNRM (warm model): Intermediate temperature increases for all variables

GFDL (cool model): Smallest increase in temperature for all variables.

Summer predictions show a wide range of temperatures that include modest decreases at a few locations

MIROC (hot model): Greatest increase for all variables, particularly for summer and average temperatures



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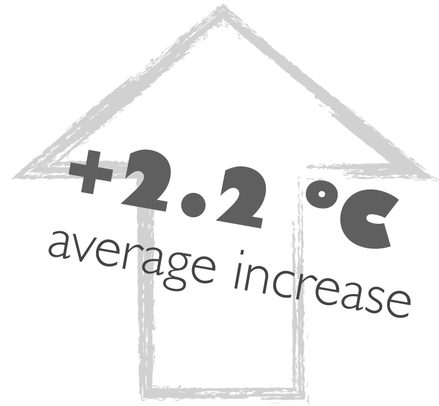
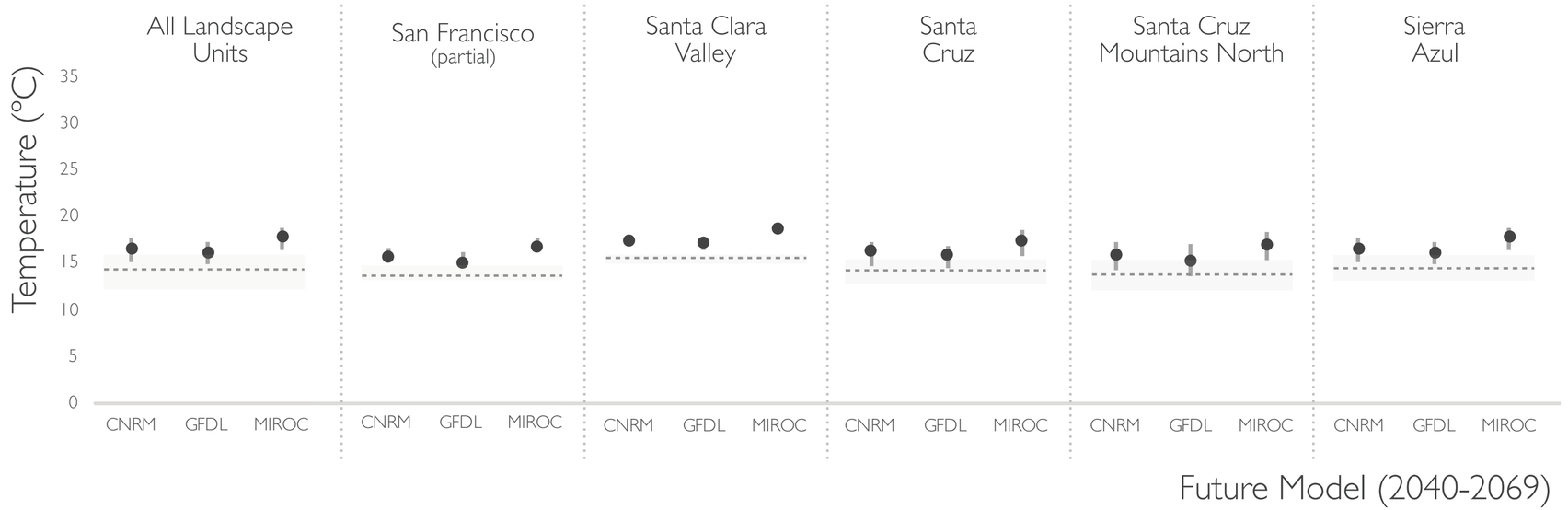
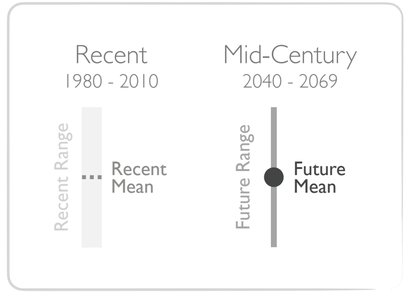
Consistent increase in average temperature

Annual average temperatures are projected to **increase by an average of 15 %** across the five Landscape Units (range: 10 - 21%)

Temperatures are projected to be between **+1.5 - 3.1 °C hotter**, with the regional average increasing from 14.6 to between 16.0 - 17.6°C







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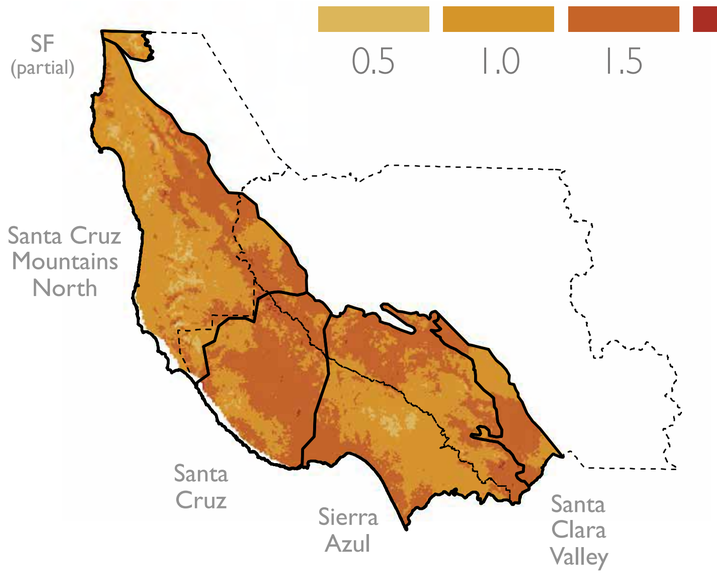
Consistent increase in average temperature

The three models project a change in **AVG temperature** from **+0.2 °C to +3.9 °C** by mid-century.

Although the magnitude of warming varied, **the spatial distribution is consistent** across the three models.

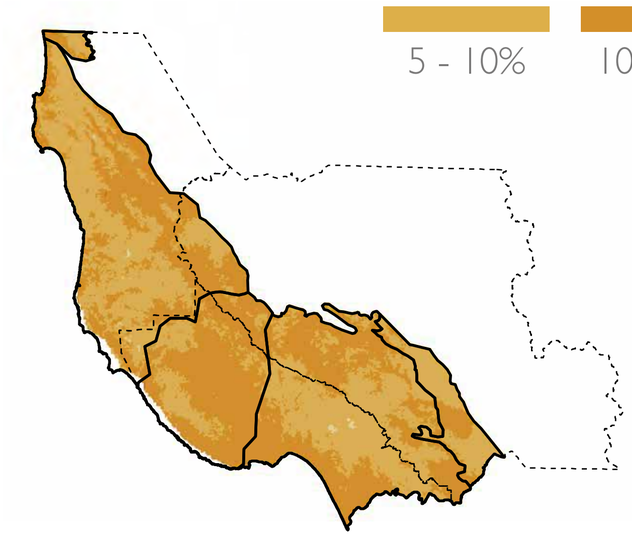
Scenario	Change	Mean
Recent	—	14.5 °C
CNRM	+1.2 °C to +2.8 °C	16.5 °C
GDFL	+0.2 °C to +2.3 °C	16.0 °C
MIROC	+2.3 °C to +3.9 °C	17.6 °C

Minimum Temperature Increase (°C)
CNRM, GFDL, MIROC models



97% of the region will warm by **>1.0 °C**

Minimum Percent Increase
30-YEAR MEAN



99% of temperatures will increase by **>5%**

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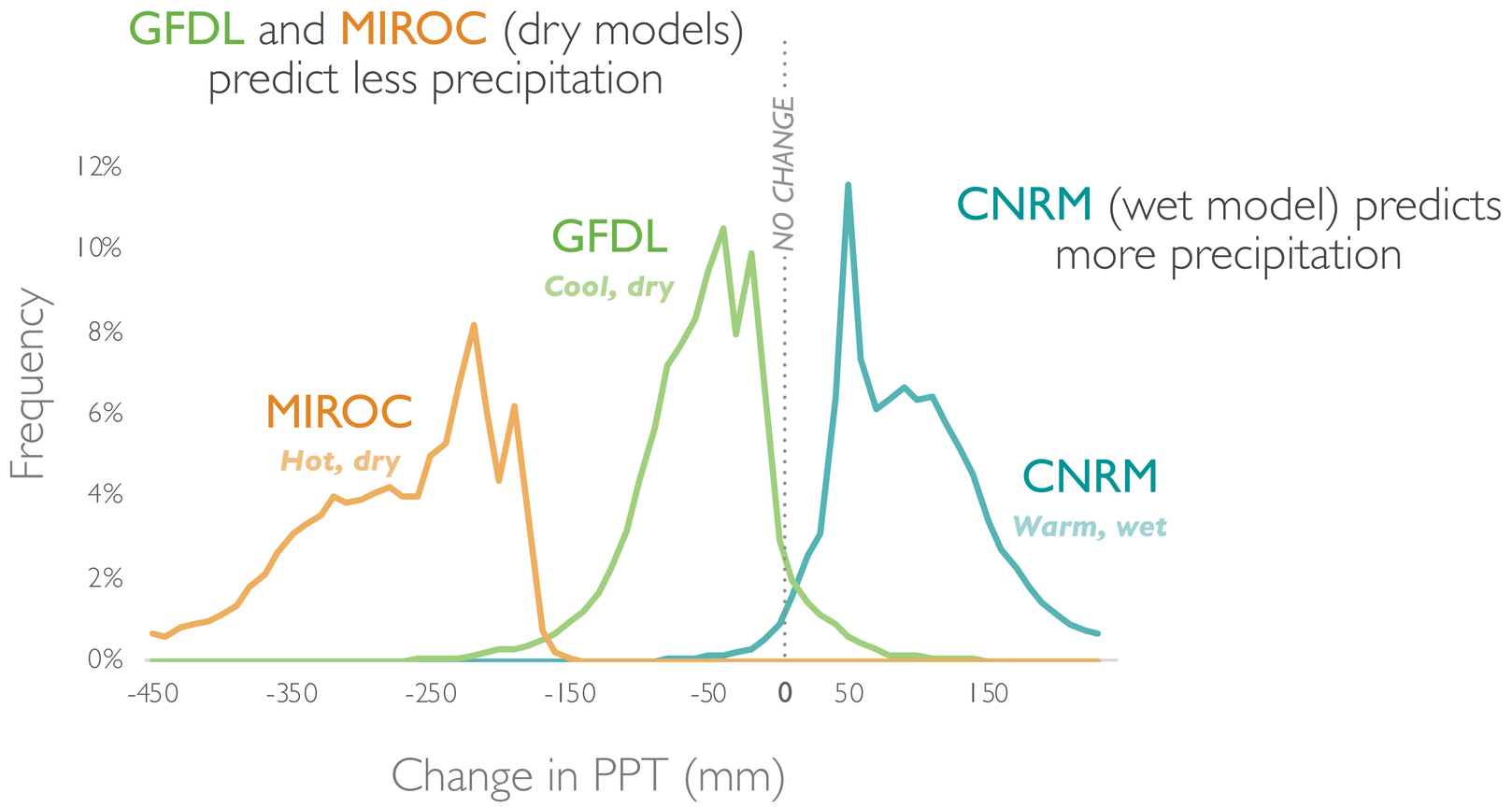
The models differed in their predictions for how precipitation will change



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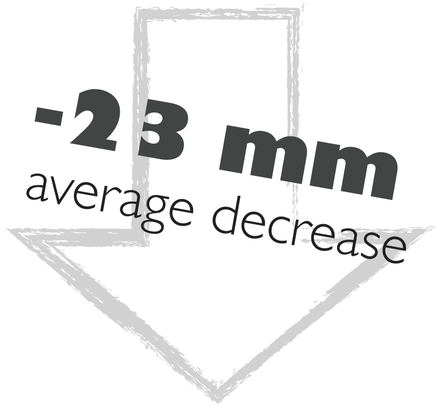
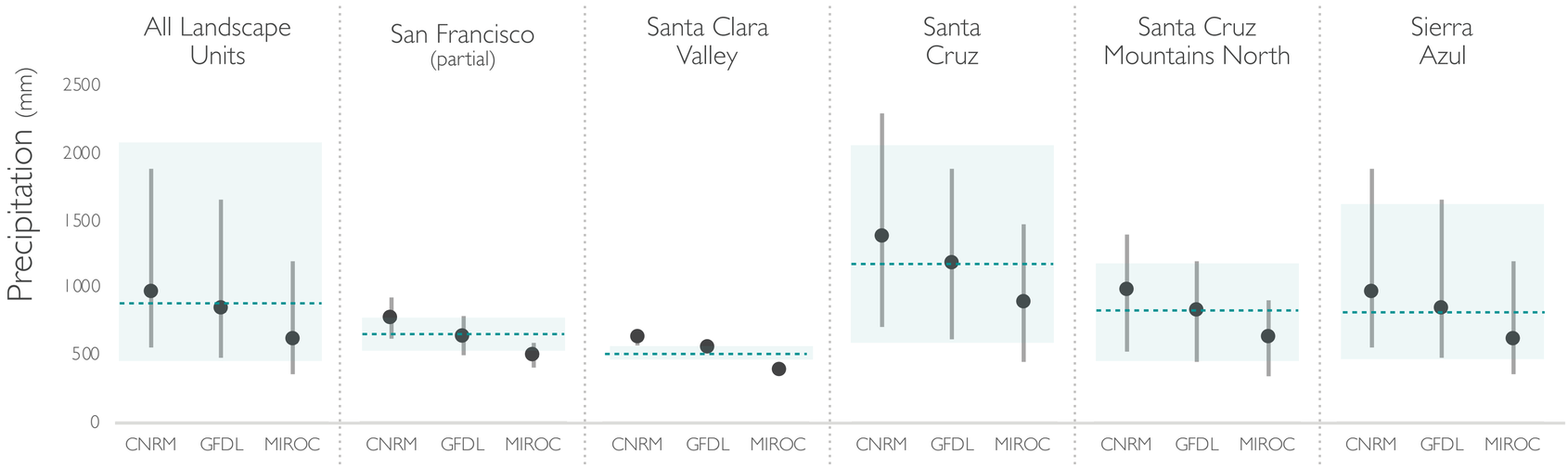
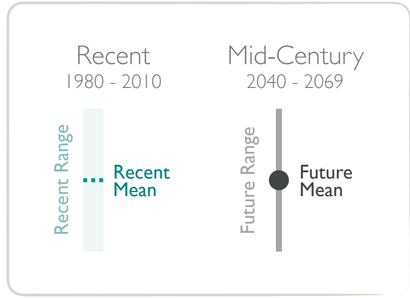
Uncertainties about precipitation

Precipitation is projected to **decrease by an average of 3%** across the five Landscape Units (range: -25 to +17%)

Precipitation is projected to **differ by -223.0 and +151.4 mm**, with the regional average changing from 883.5 to between 660.6 - 1034.9 mm







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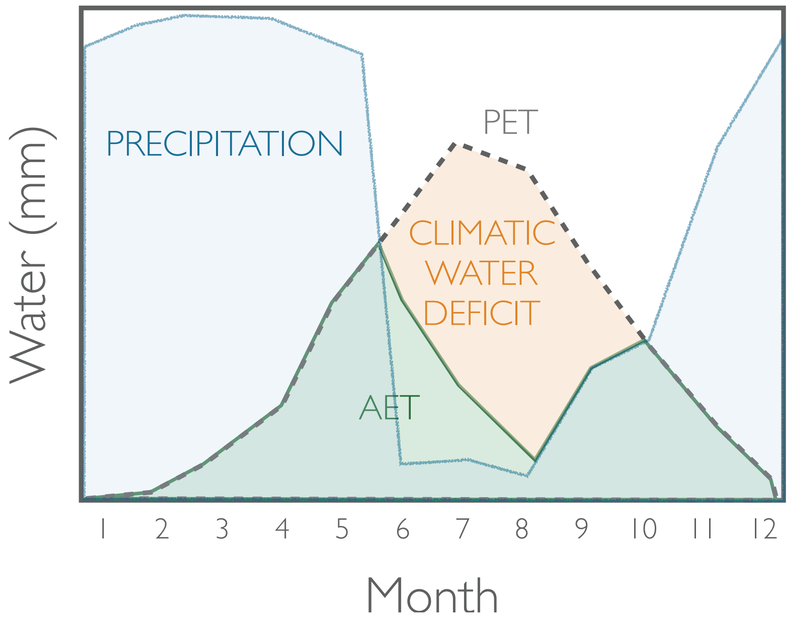
Climatic Water Deficit (CWD)
A METRIC OF DROUGHT STRESS

Climatic Water Deficit = Potential Evapotranspiration − Actual Evapotranspiration



This metric integrates the effects of temperature and rainfall

- CWD increases with all future climate scenarios
- CWD correlates with vegetation and fire risk

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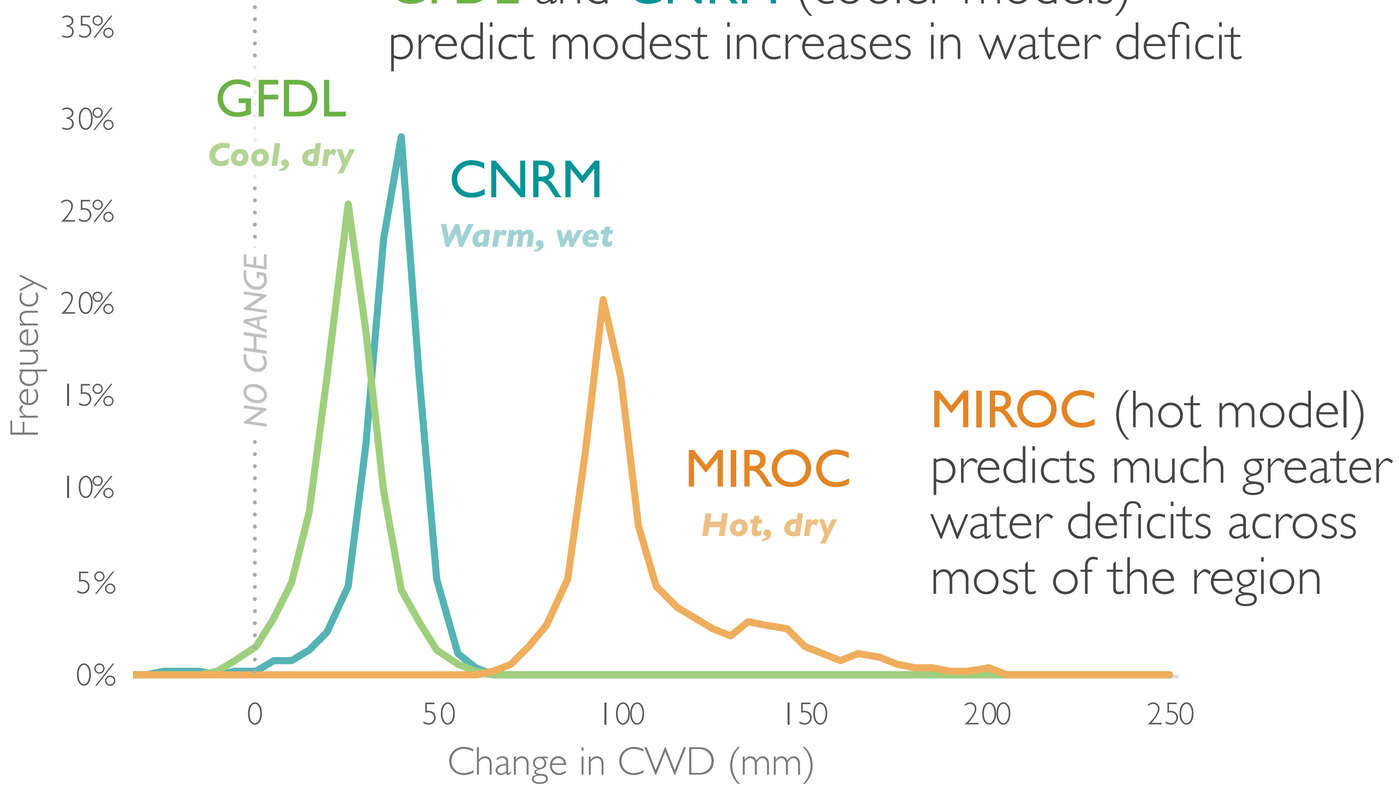
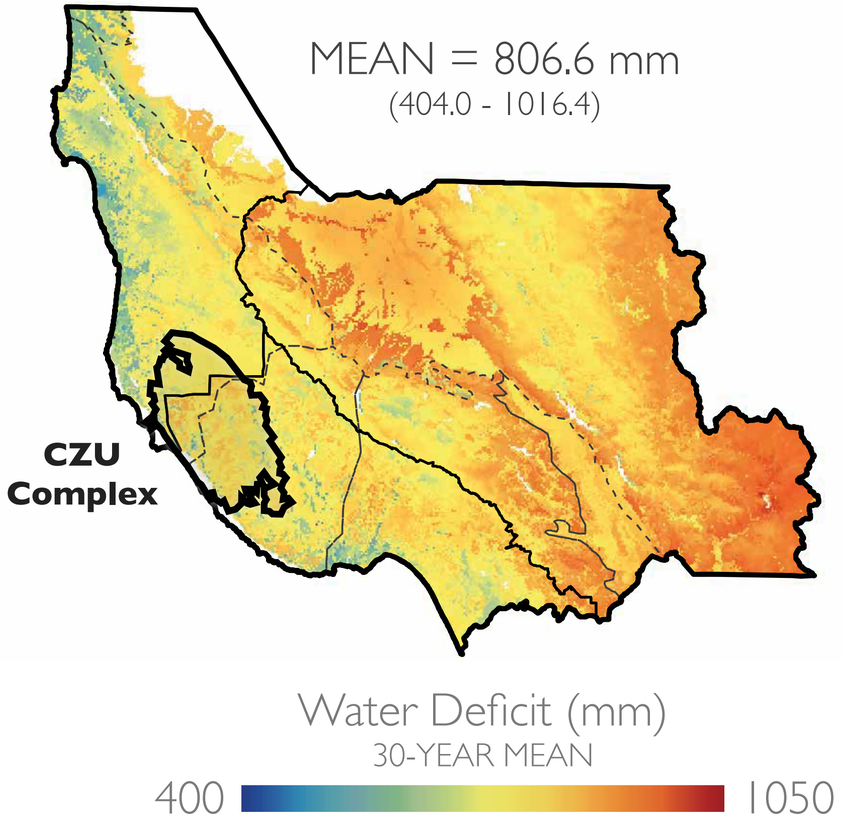
The trend for all models is an **increase** in climatic water deficit





Data Source: Flint & Flint 2014

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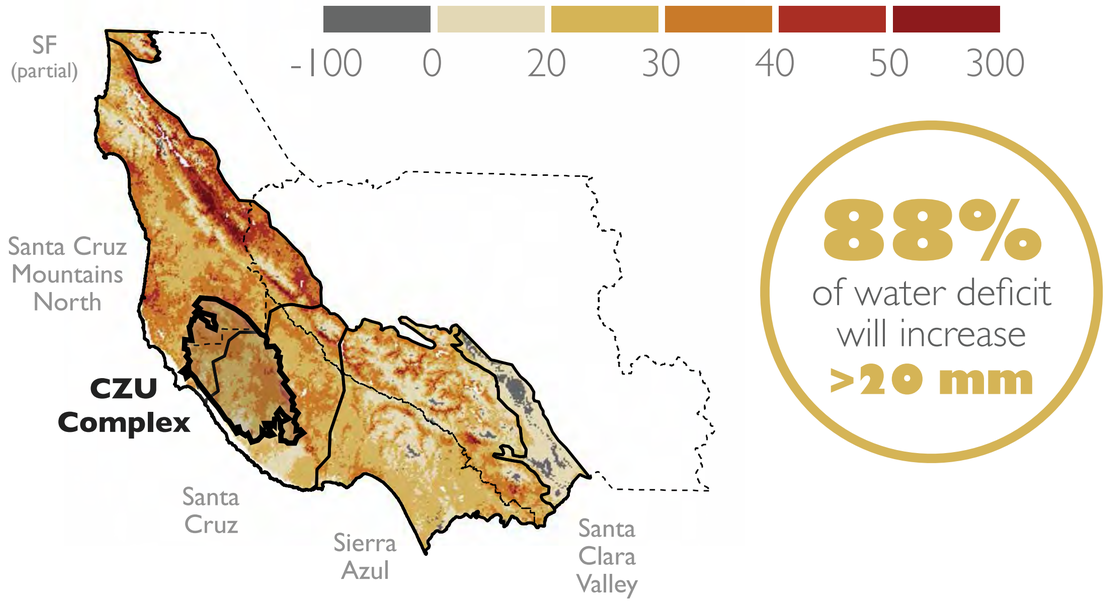
The three models project a change in **climatic water deficit** from **-66.9 mm to +260.6 mm** by mid-century.

Although the magnitude of warming varied, **the spatial distribution is consistent** across the three models.

Scenario	Change	Mean
Recent	—	769.9 mm
CNRM	-66.9 mm to +94.4 mm	808.8 mm
GDFL	-30.2 mm to +115.3 mm	797.6 mm
MIROC	+54.2 mm to +260.6 mm	880.5 mm

Minimum Deficit Increase (mm)

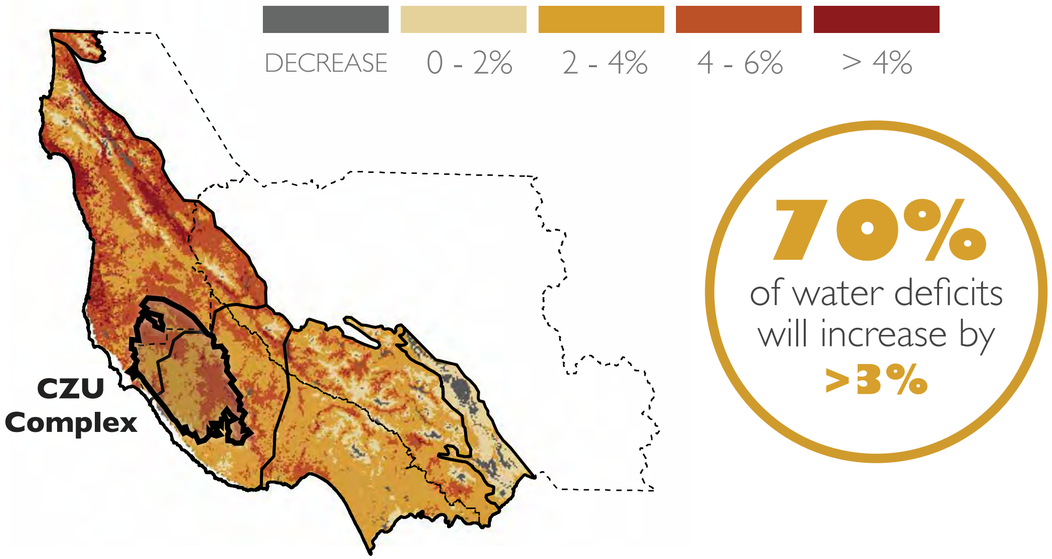
CNRM, GFDL, MIROC models



88%
of water deficit will increase **>20 mm**

Minimum Percent Change

30-YEAR MEAN



70%
of water deficits will increase by **>3%**

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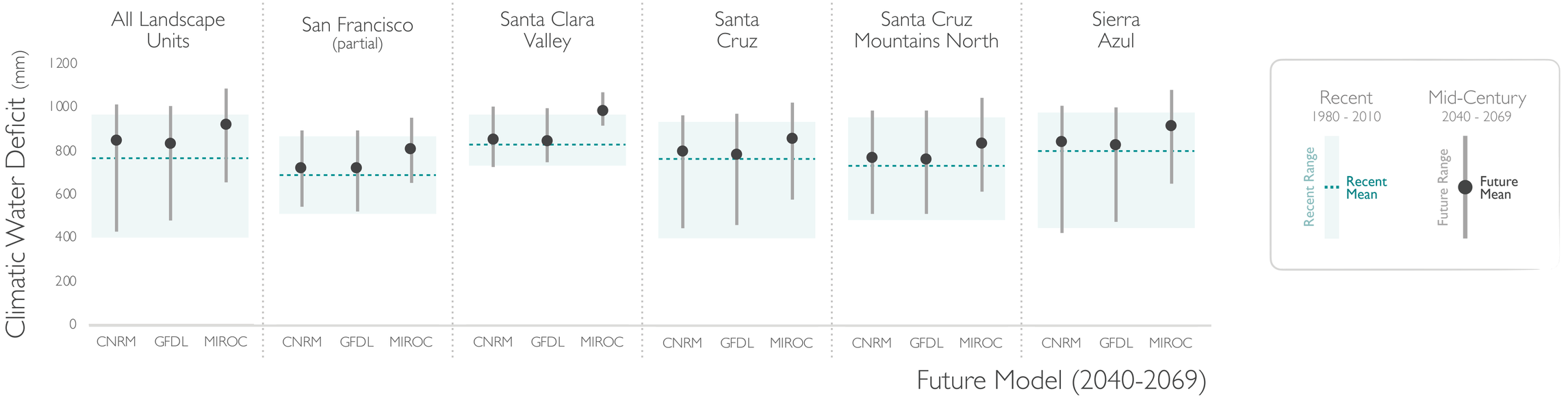
Increased drought stress

Climatic water deficit is projected to **increase by an average of 8%** across the five Landscape Units (range: 4 - 14%)

Deficits are projected to be between **+27.7 - +110.6 mm drier**, with the regional average increasing from 769.9 to between 797.6 - 880.5 mm



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What causes large wildfires?

What do we know about wildfires ***here***?

How do we forecast ***future*** wildfires?

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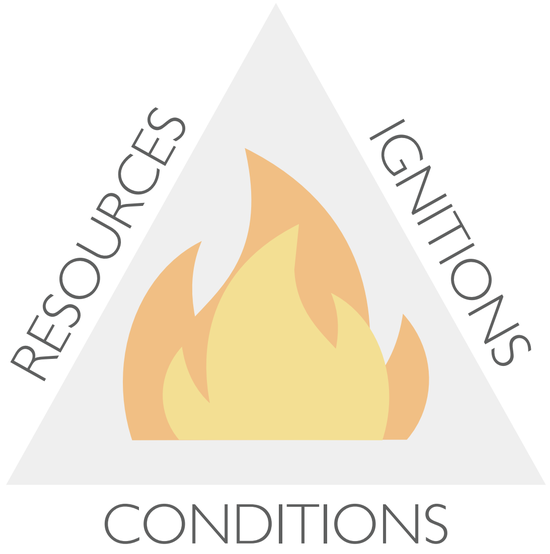
Wildfires are influenced by biophysical factors and human activity



Influence	Resources	Conditions	Ignitions
Biophysical Factors	• Plant characteristics *Species composition* *Spatial distribution* *Traits (e.g., growth rate)* • Herbivory • Decomposition	• Dry season severity • Fire weather episodes	• Lightning • Volcanic activity
Human Activity	• Land management *Fire suppression* *Plant litter accumulation* *Grazing* • Invasive species	• Altered hydrology • Desertification	• Accidents • Arson

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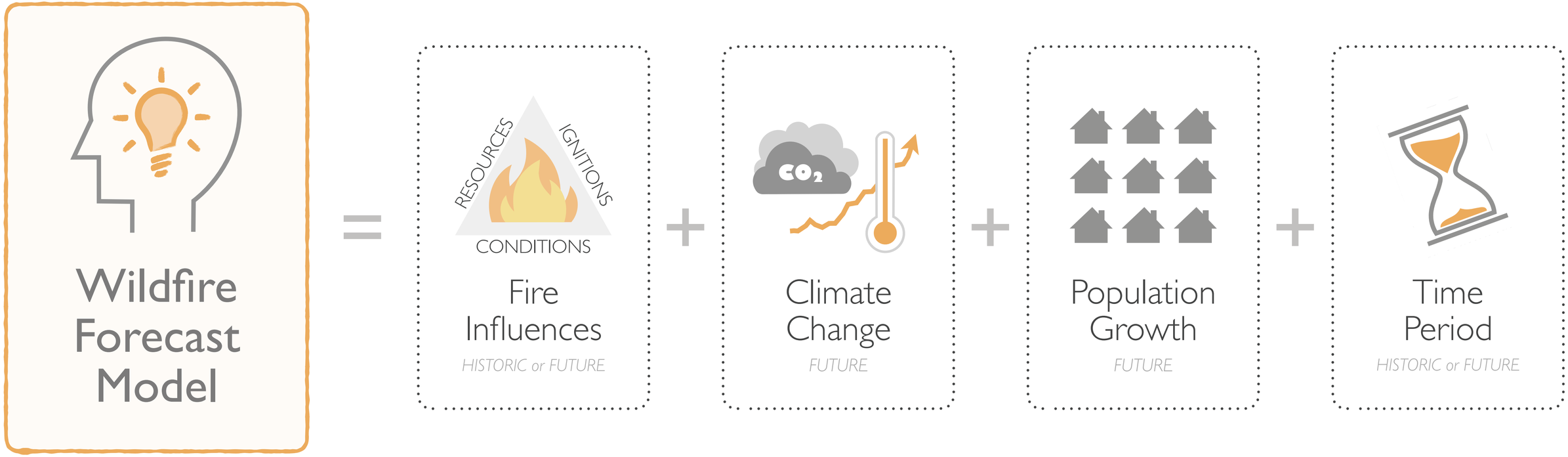
Wildfire forecast models integrate fire influences with future scenarios for climate and human population growth



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We used **wildfire risk** as the fire metric to use for this assessment because the forecast scenario was consistent with the climate metrics

FIRE METRIC	FIRE INFLUENCE VARIABLES (Biophysical, Human)			FORECAST SCENARIOS		
	RESOURCES	CONDITIONS	IGNITIONS	CLIMATE	POPULATION	YEARS
Wildfire risk *Probability of 1+ wildfires in a 30-year time period* Krawchuk & Moritz 2012	—	Actual evapotranspiration (AET) Climatic water deficit (CWD) Potential evapotranspiration (PET) Precipitation (PPT) Temperature (max) Vegetation type	Historic fire counts (30y) Distance to development Urban extent	GFDL A2 **GFDL B1** PCM A2 PCM B1	Business As Usual Smart Growth	**1980-2010** **2040-2069** 2070-2099

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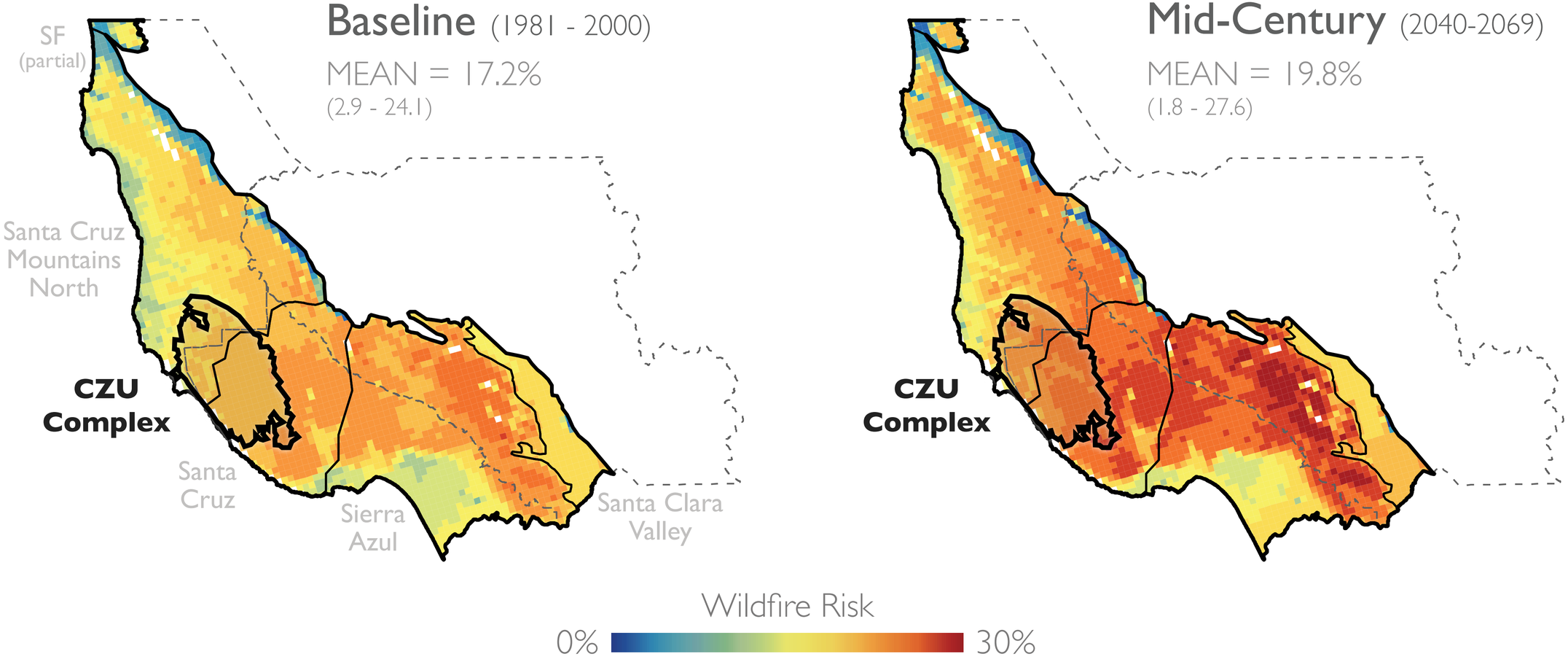
Wildfire risk | 30-year probability of 1+ fires



Data Source: Krawchuk & Moritz 2012

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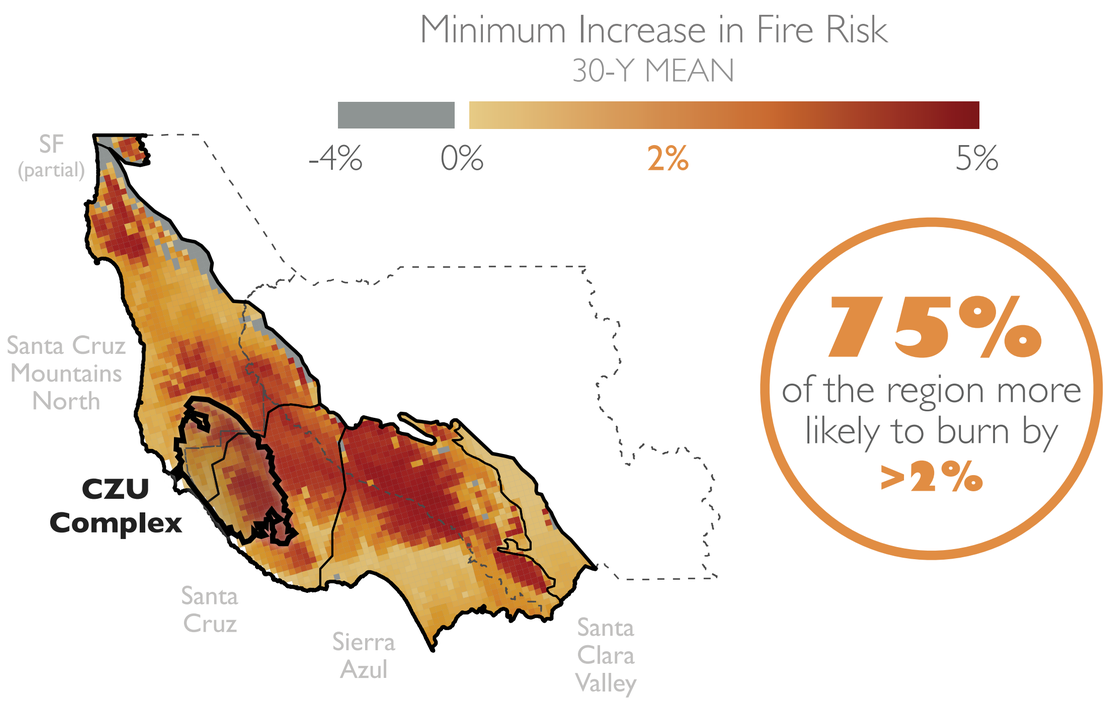
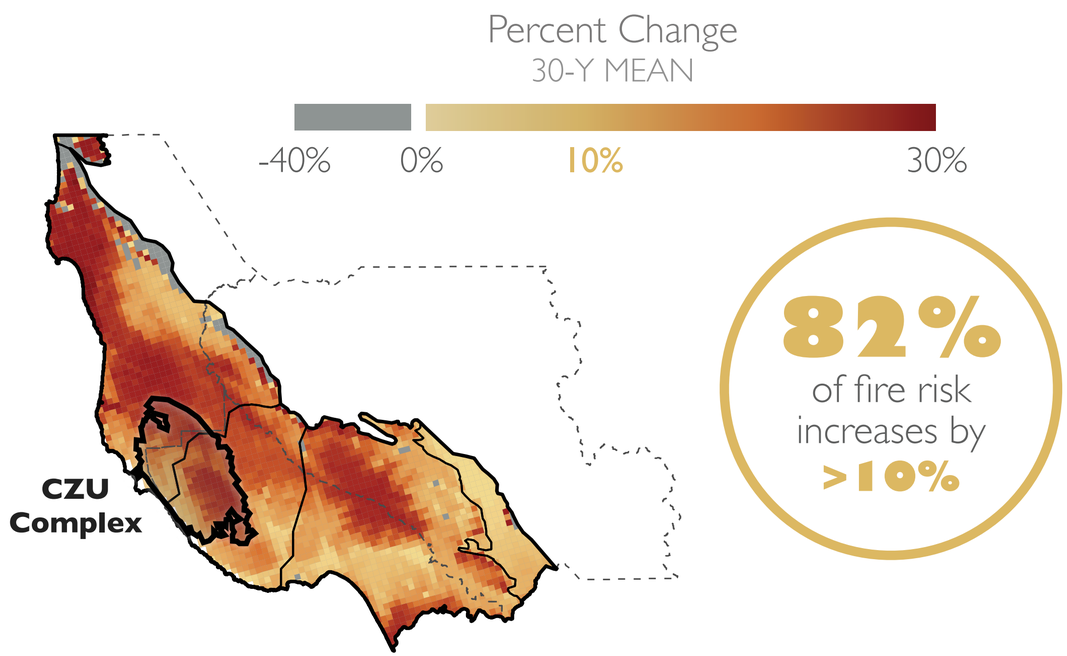
Wildfire risk | 30-year probability of 1+ fires

Mean Wildfire Risk	All LU	SF (partial)	Santa Clara Valley	Santa Cruz	Santa Cruz Mtn. North	Sierra Azul
Recent	17.5%	10.0%	16.8%	19.2%	15.1%	18.7%
Mid-Century	20.4%	10.5%	18.3%	22.3%	17.5%	21.5%
Change	2.8%	0.5%	1.5%	3.1%	2.4%	2.8%
% Change	**16%**	**5%**	**9%**	**16%**	**16%**	**15%**





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TBC3 Forest Health Working Group

www.pepperwoodpreserve.org/tbc3/2020-post-fire-tools

Pepperwood ABOUT US WHAT WE DO THE PRESERVE GET INVOLVED SUPPORT US RESOURCES

Fire and Forest Health

Fire Mitigation and Forest Health

Bridging the gap between science and management

The objective of our work around Fire Mitigation and Forest Health integrates multiple threads of Pepperwood's applied science and management activities into one unified approach for forest management. Our goal is to demonstrate best practices on the preserve and to leverage Pepperwood's role in research, outreach, collaborations, and technical advising to expand these throughout our region.

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Adaptive Management Plan

An operating manual for op

Thanks to funding from the Gordo
peer-reviewed Adaptive Managem
insights into stewarding different
inform our practices. Many expert
Fred Euphrat.

Pepperwood's Adaptive Managem
wildfire that is applicable well bey
incorporates an ongoing cycle of f
guide with others, including our pa

Fire Ecology for Non-Scientists: The Fire Triangle & Fire Behavior

By Sandi Funke & with contributing research from Preserve Ecologist, Michelle Halbur

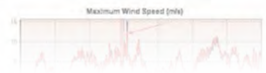
How exactly does wildfire work? Why did our recent fires burn where they did? Once I was able to move out of emergency mode, as an educator and someone who is "science curious", I wanted to learn more about wildfire. Here is what I have found out.

The Fire Triangle

The Fire Triangle

The Fire Triangle is a great way to visualize what is necessary for a fire to start. *Heat*, *fuel*, and *oxygen* in the right proportions are the required components. If any one of these three essentials is not present, fire cannot exist. *Fuel* is any type of material that can burn. In a wild land fire like the Tubbs or Kincade Fires, fuel can be vegetation, branches, needles, snags, and unfortunately, human-built structures like houses. *Heat* is needed to start a fire, and is usually provided by an external source. It could be a lightning strike, or a human-based ignition source such as electrical wiring or arson. *Oxygen*, the third required component, is of course present in varying concentrations in the air we breathe.

The National Park Service explains that *Fire Behavior* is influenced by a myriad of factors including weather and topography (the shape and features of the Earth's surface), as these can affect parts of the fire triangle. The effects of these factors can be cumulative.



Weather can be a major contributing factor to fire intensity. The night of the Tubbs Fire, we recorded wind speeds of up to 33 mph near Pepperwood's Bechtel House. Though high, these speeds are not as

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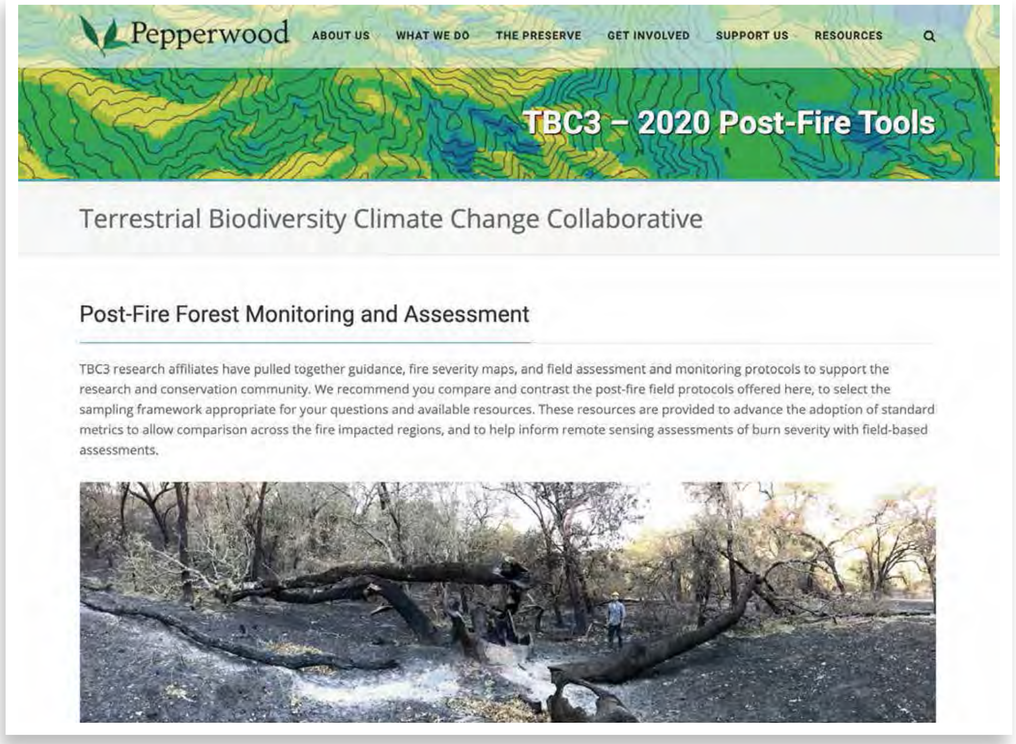
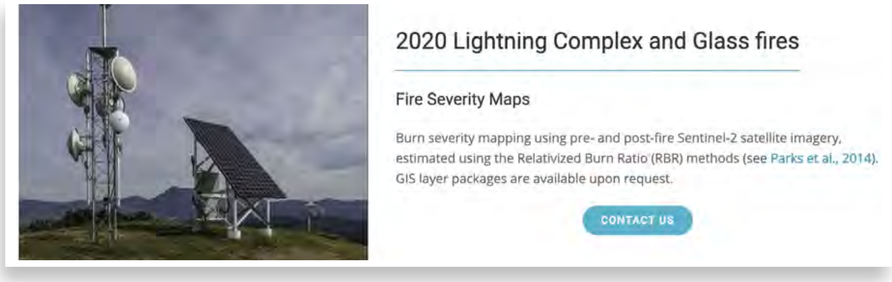
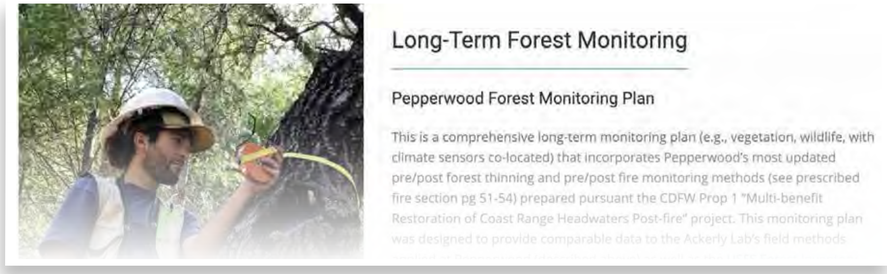
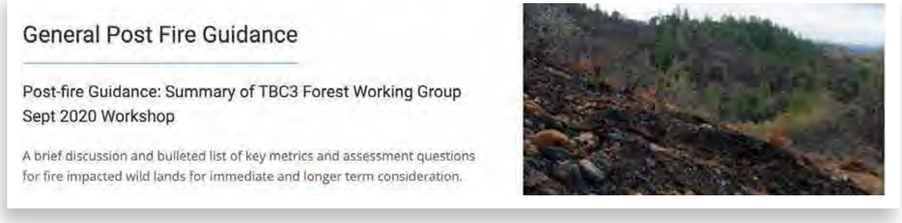
Pepperwood's Post-Fire Tools

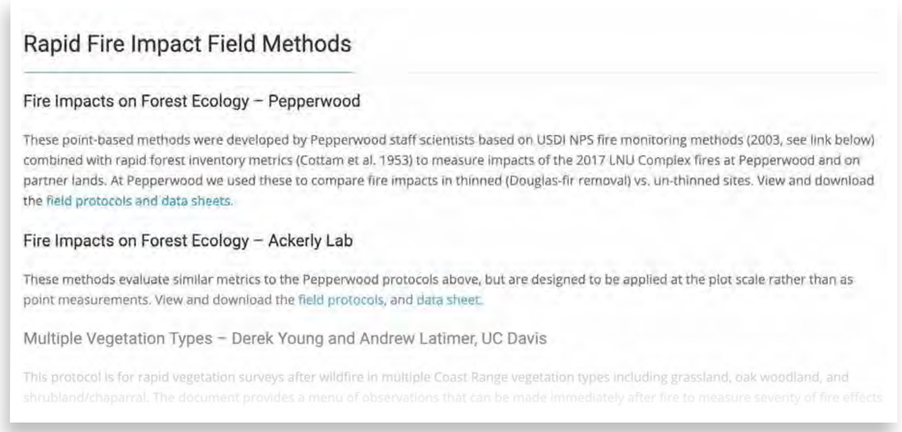
www.pepperwoodpreserve.org/tbc3/2020-post-fire-tools











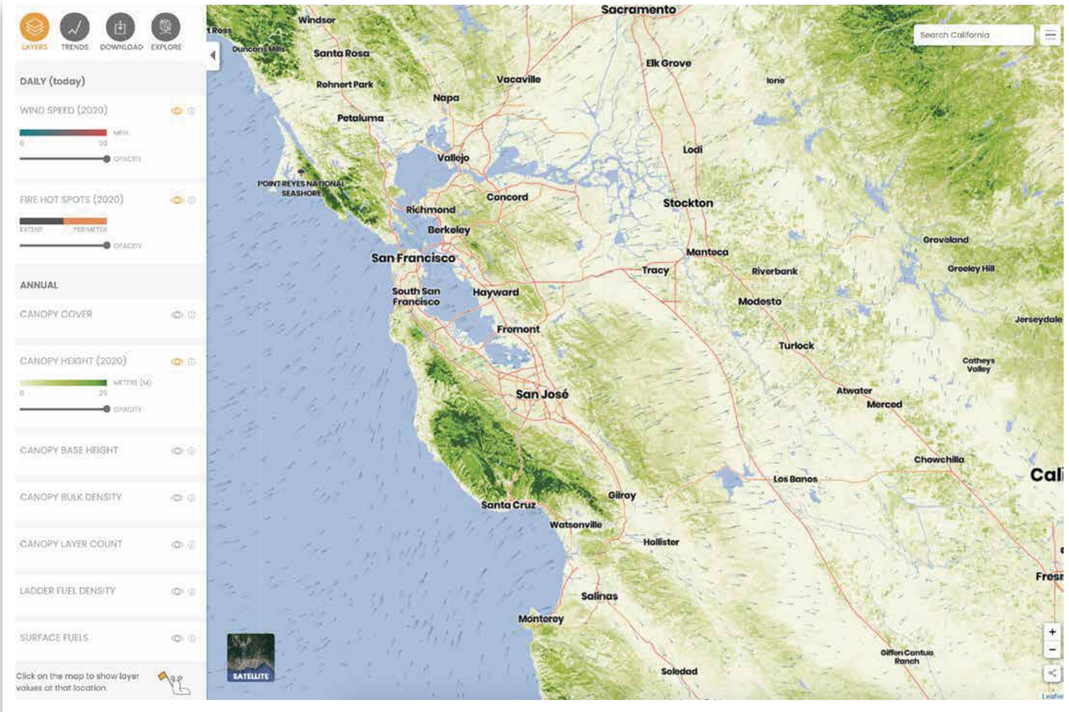
Pepperwood

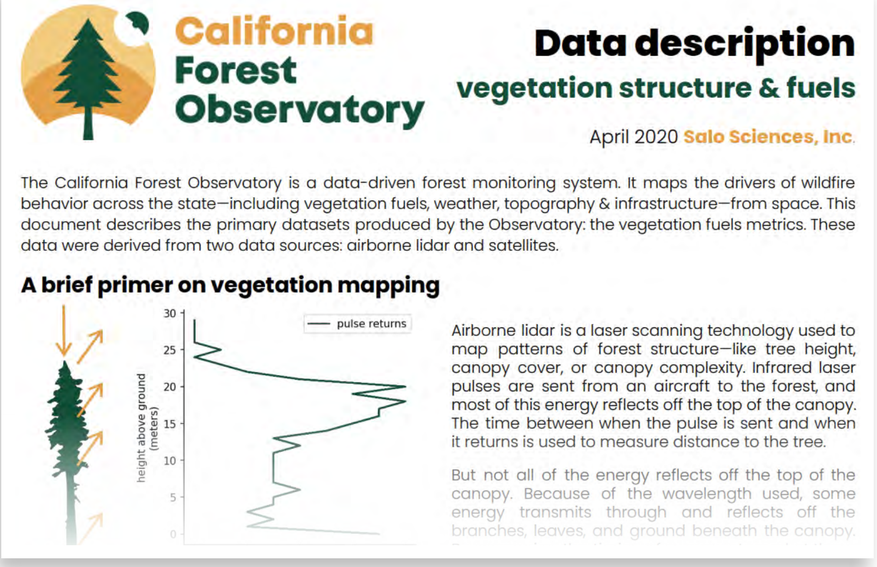
Salo's California Forest Observatory

https://salo.ai/projects/california-forest-observatory

California Forest Observatory

A dynamic, data-driven platform to inform wildfire risk, emergency operations, and forest management decisions





Tree Mortality Mapping

Sustainable harvesting practices and reduction in wildfire hazards through better mapping techniques and monitoring

Forest Restoration Monitoring

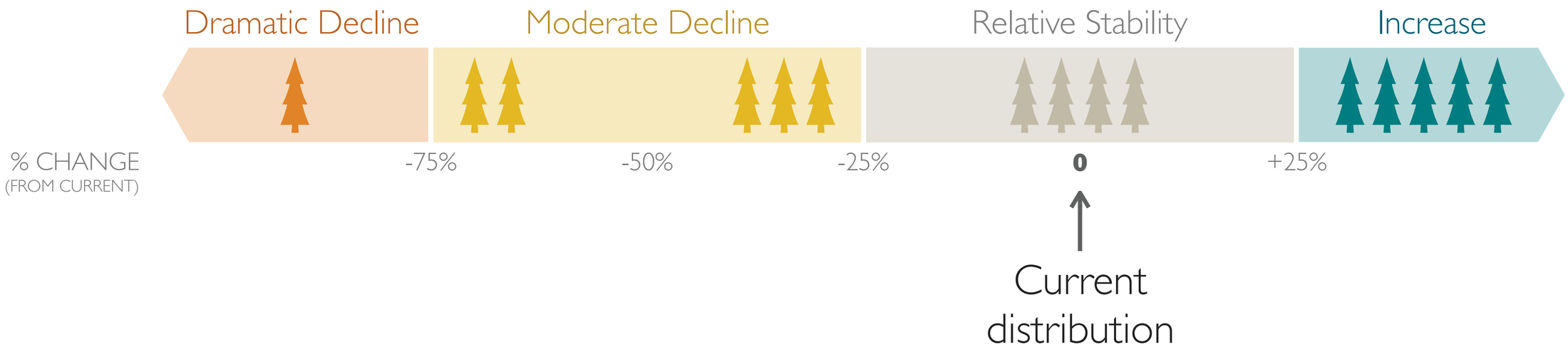
Tracking progress and providing feedback for forest thinning and prescribed burn projects

Pepperwood

Visualizing vegetation vulnerability

Pepperwood

How is the climate suitability for specific vegetation types expected to shift in response to climate change?



Pepperwood

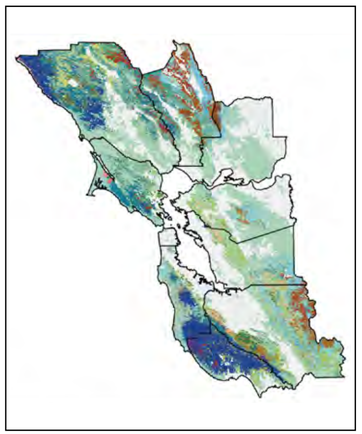
The Probabilistic Vegetation Model (PVM)

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

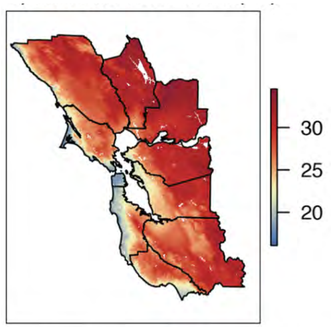
- Project biotic responses to future climate change
- Evaluate responses of individual species along with the overall responses of communities and ecosystems

22 Vegetation Types

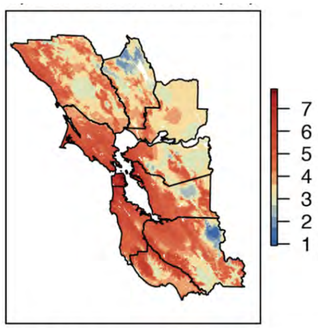


Climatic Variables (1951-1980 historic norms)

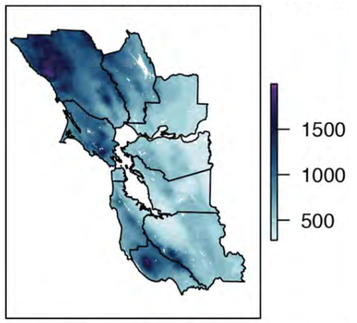
Summer maximum temperature (°C)



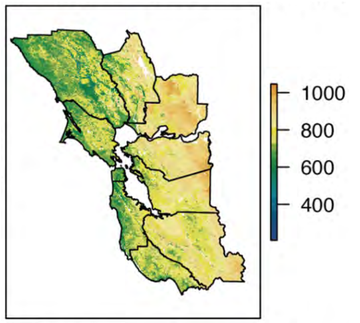
Winter minimum temperature (°C)



Annual precipitation (mm)



Climatic water deficit (mm)



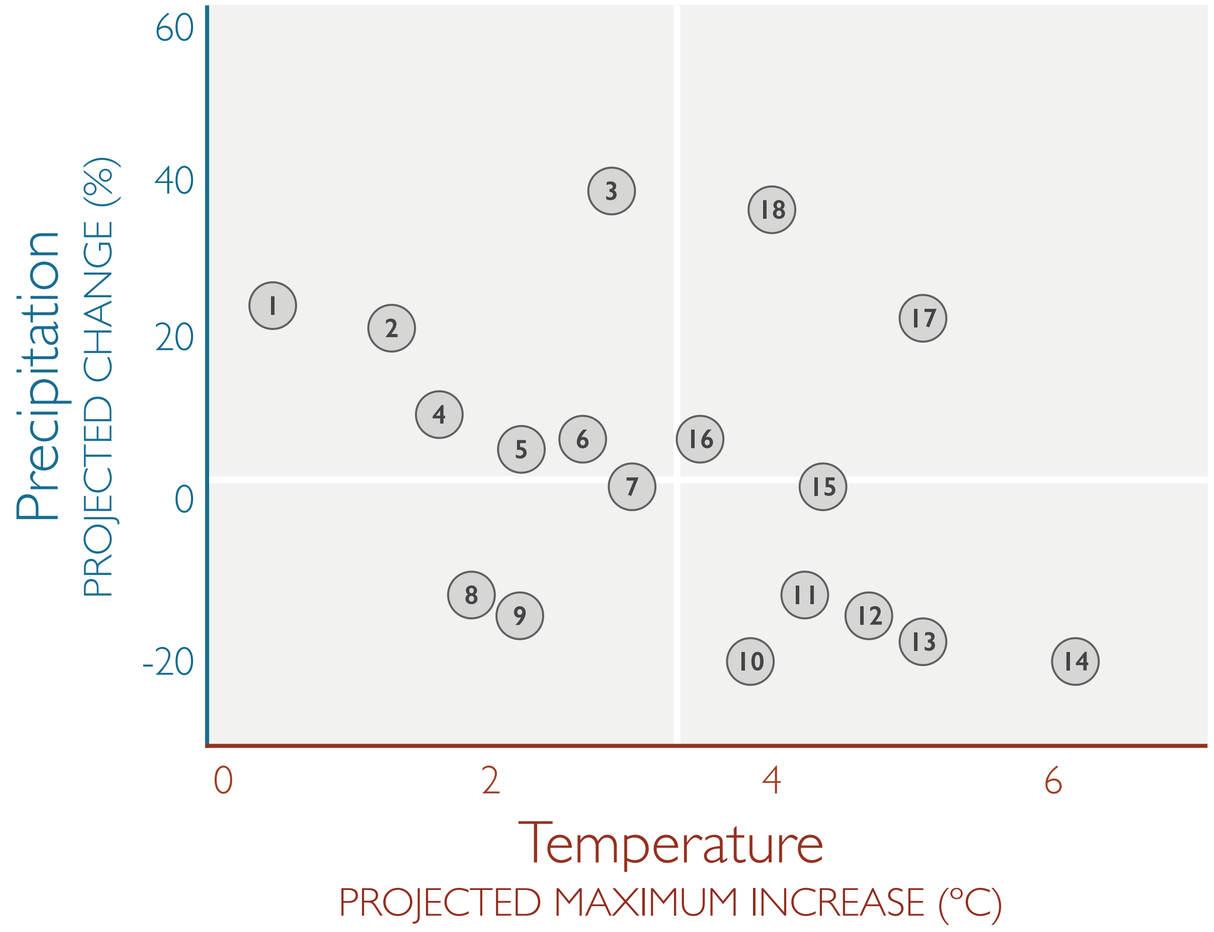
Ackerly DD, Cromwell WK, Weiss SB, Flint LE, Flint AL. 2015.
A Geographic Mosaic of Climate Change Impacts on Terrestrial Vegetation: Which Areas Are Most at Risk? PLoS ONE 10(6)

Pepperwood

18 climate change projections

Climate Ready North Bay: 2070-2099 relative to 1951-1980

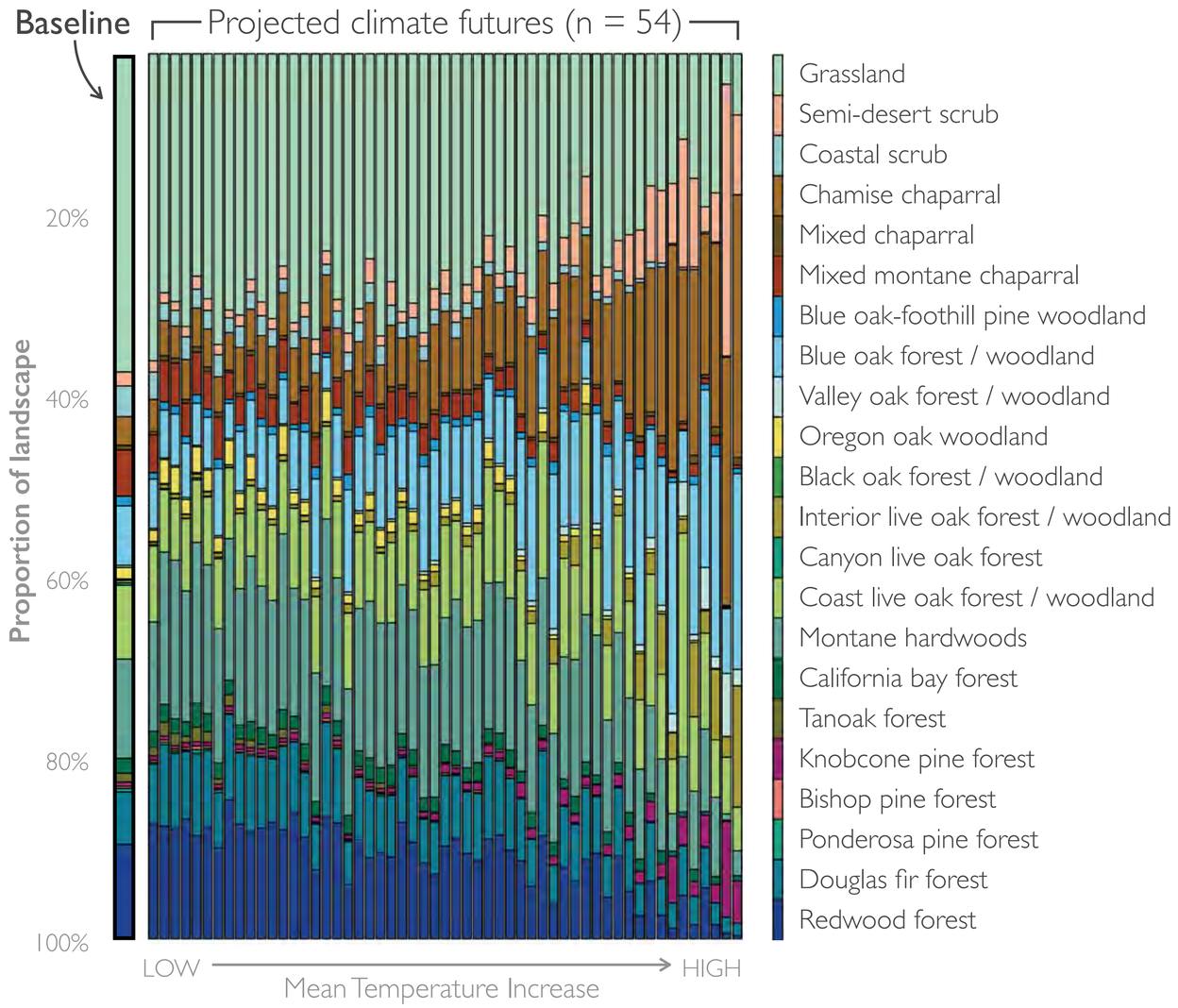
Projected change in **precipitation** and **temperature**



ID	Climate Scenario
1	GISS-E2 rcp2.6
2	MRI-cgm3 rcp2.6
3	CSIRO-mk3.5 A1B
4	PCM B1
5	PCM A2
6	MPI-em rcp4.5
7	GISS-apm A1B
8	MIROC-5 rcp 2.6
9	GFDL B1
10	GFDL A2
11	MIROC-esm rcp4.5
12	MIROC-esm rcp6.0
13	MIROC-2-medres A2
14	MIROC-esm rcp8.5
15	FGOALS-G2 rcp8.5
16	CCSM-4 rcp8.5
17	IPSL-cm5a-In rcp8.5
18	CNRM-cm5 rcp8.5

Pepperwood

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 x **3 time periods** = 54 scenarios

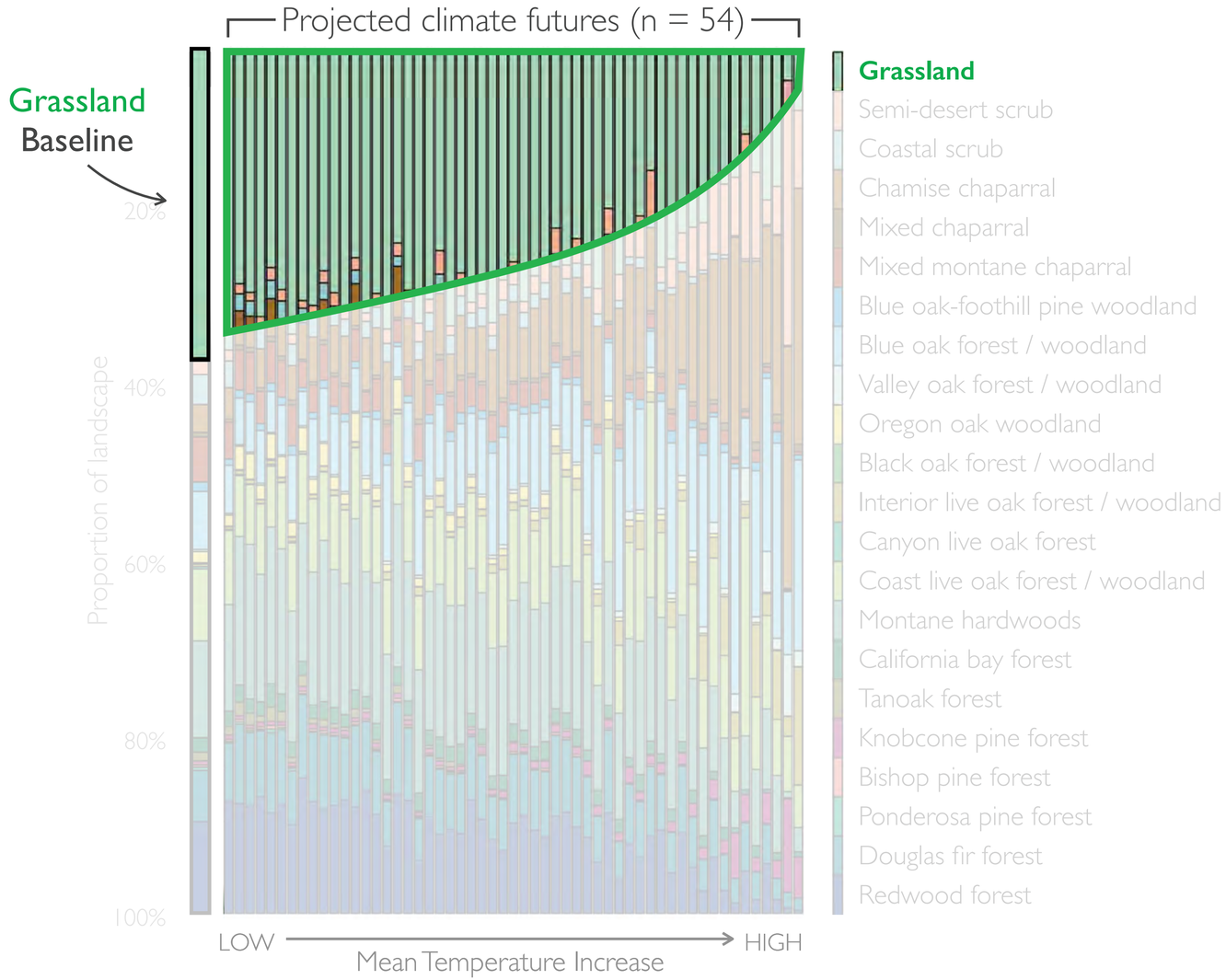
2010 – 2039 **2040 – 2069** **2070 – 2099**

This figure shows the relative frequency of 22 vegetation types, parameterized for the historical baseline period and then projected for 54 possible futures

Ackerly et al. 2015

Pepperwood

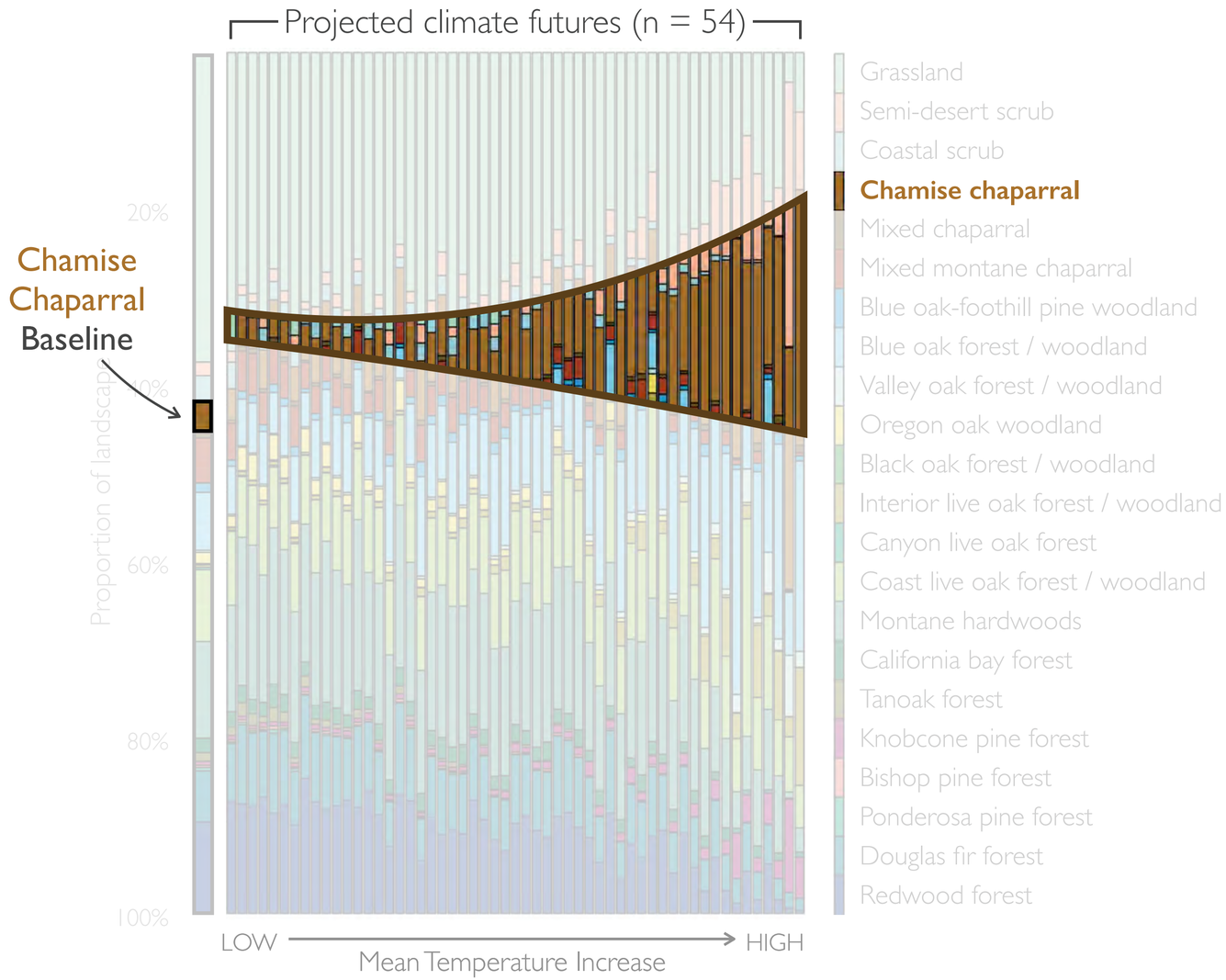
General trend: Decrease in relative distribution of **grassland**



Ackerly et al. 2015

Pepperwood

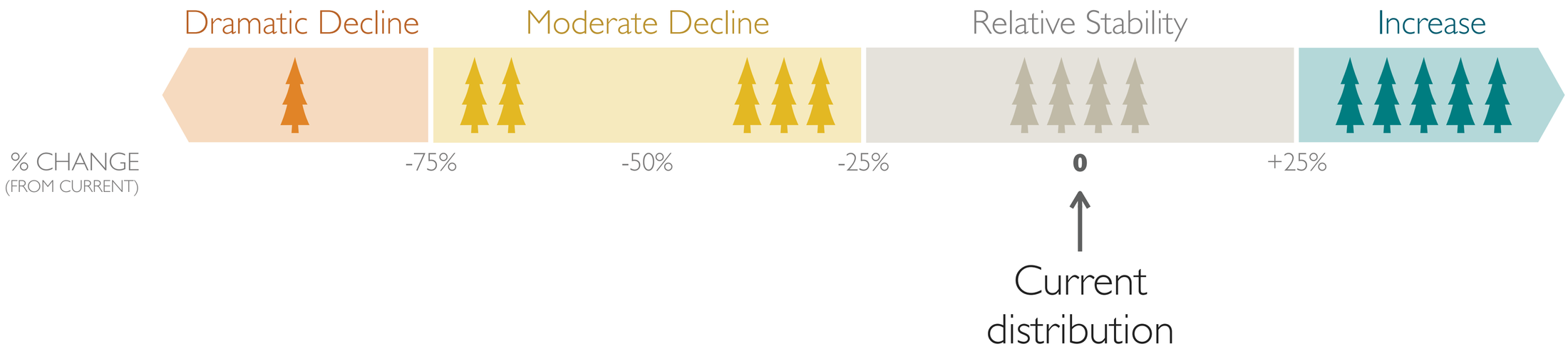
General trend: Increase in relative distribution of **chamise chaparral**



Ackerly et al. 2015

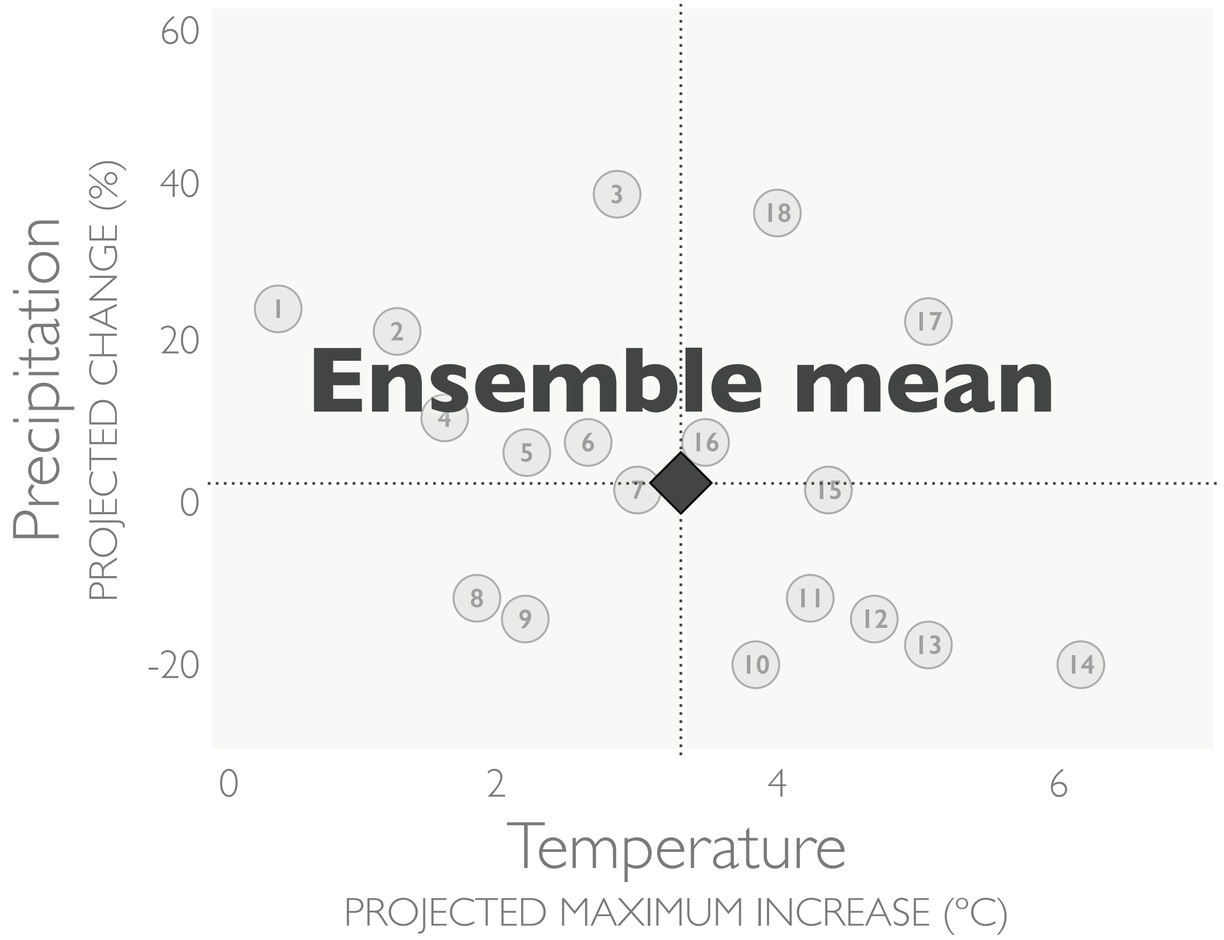
Pepperwood

We use a simplified approach based on the Probabilistic Vegetation Model to project vegetation responses to future climate change



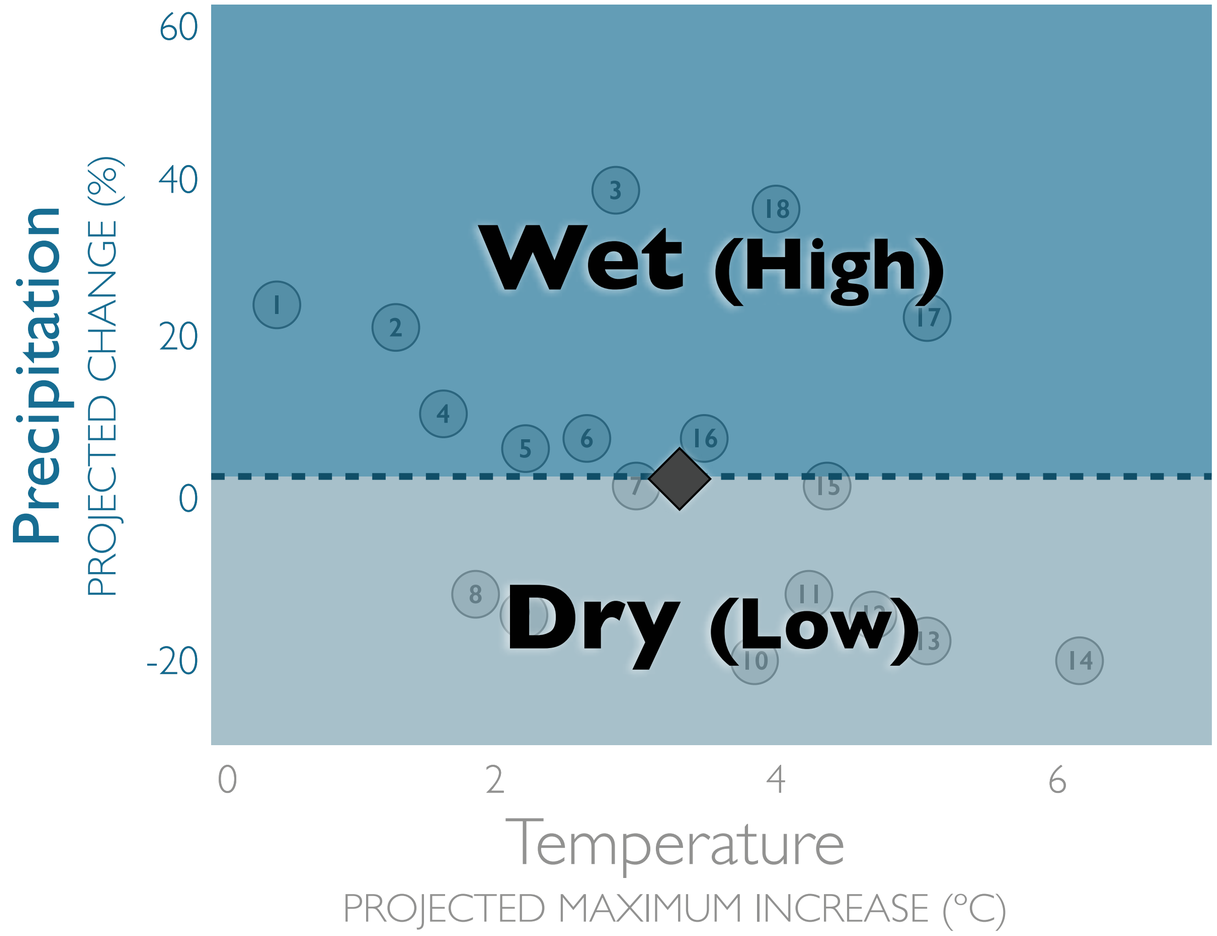
Pepperwood

The ensemble mean for the 18 models was used as a threshold to categorize the climate projections



Pepperwood

Values for each metric were assigned to a low or high category based on the ensemble mean

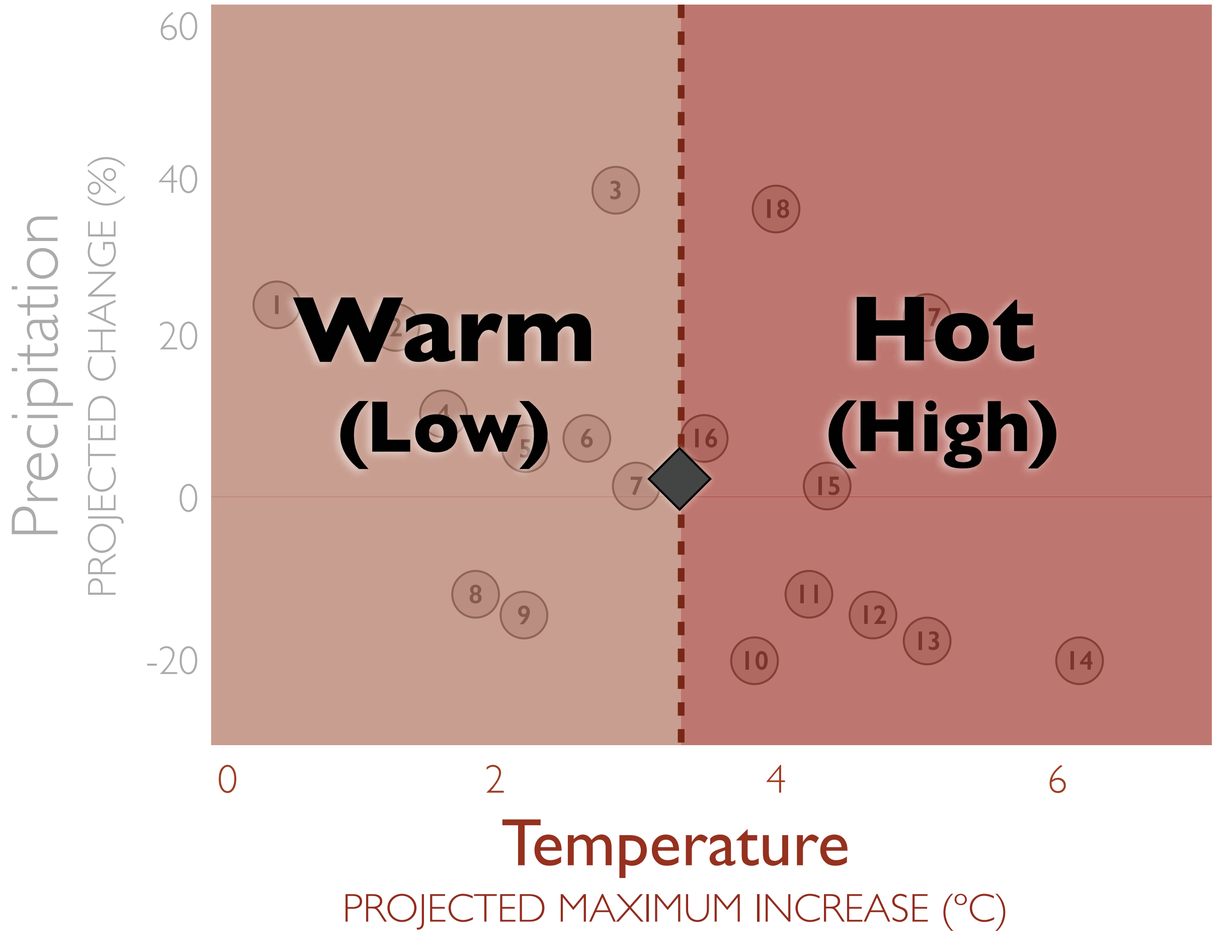


Projected change in precipitation

Category	Descriptor	Values
Low	**Dry**	**< 3%**
High	**Wet**	**> 3%**

Pepperwood

Values for each metric were assigned to a low or high category based on the ensemble mean

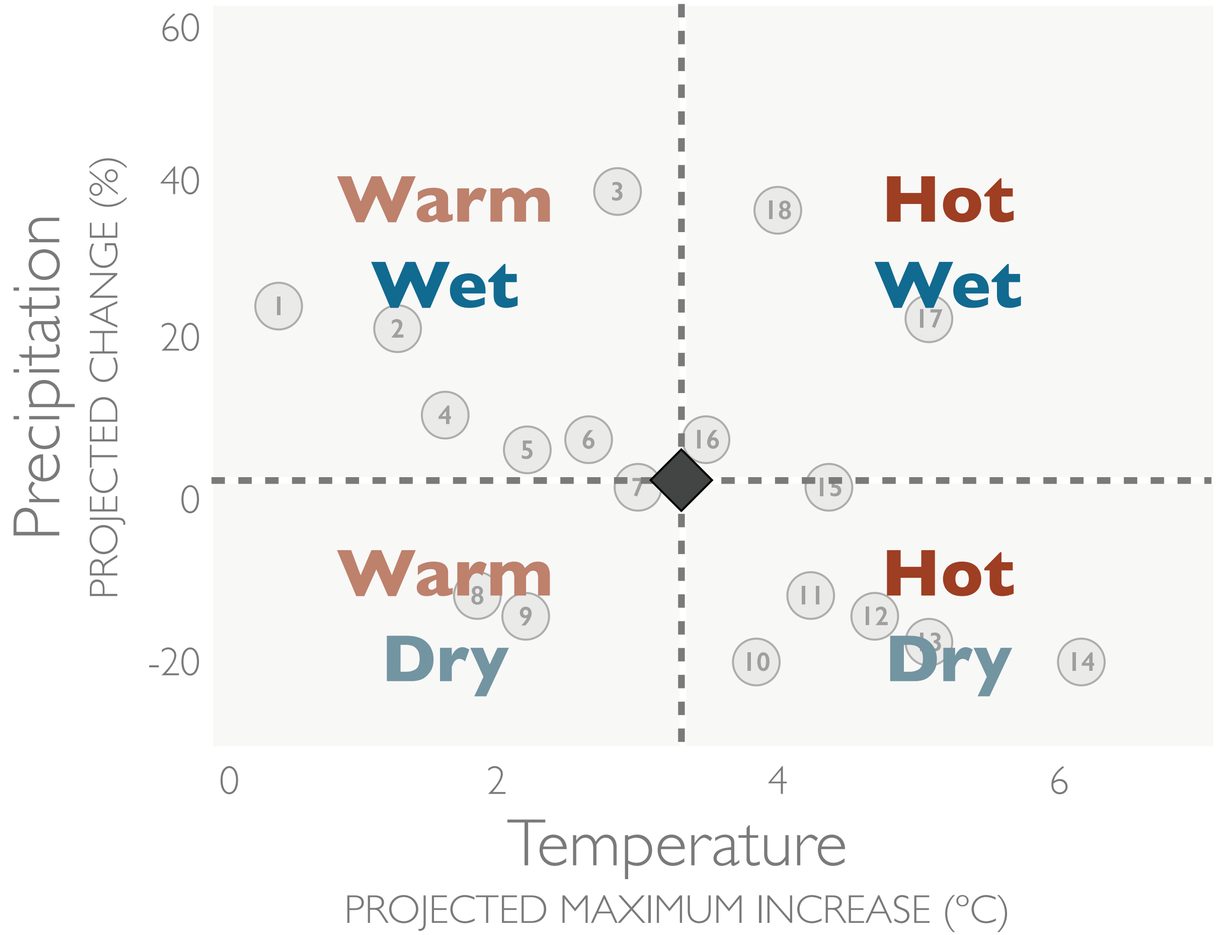


Projected change in temperature

Category	Descriptor	Values
Low	**Warm**	**< 3.3 °C**
High	**Hot**	**> 3.3 °C**

Pepperwood

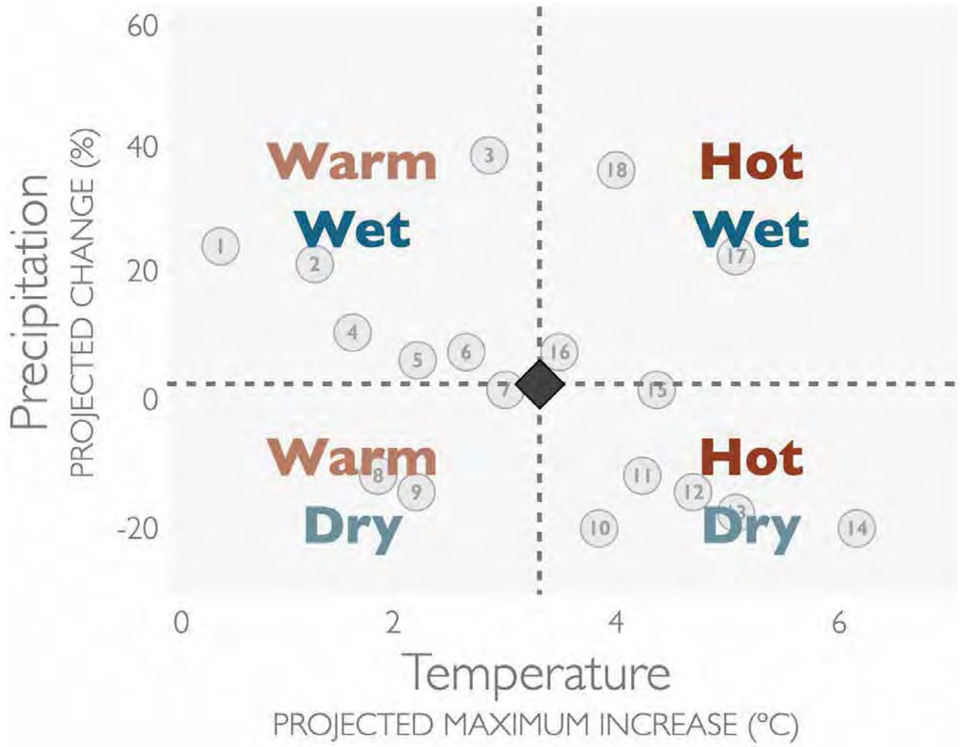
The four pairwise categories capture high and low projected precipitation and temperature values



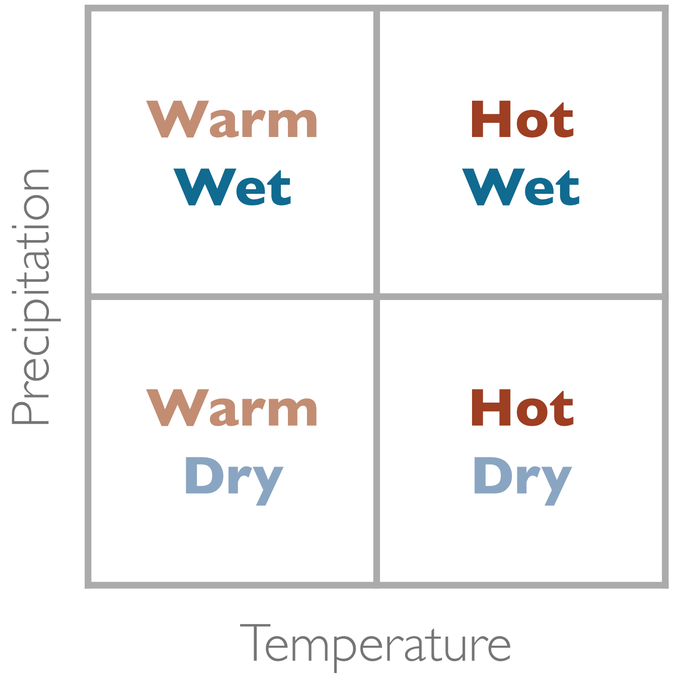
Pepperwood

The four climate categories are summarized as a **four square**, and represent key rainfall and temperature combinations

Climate projections

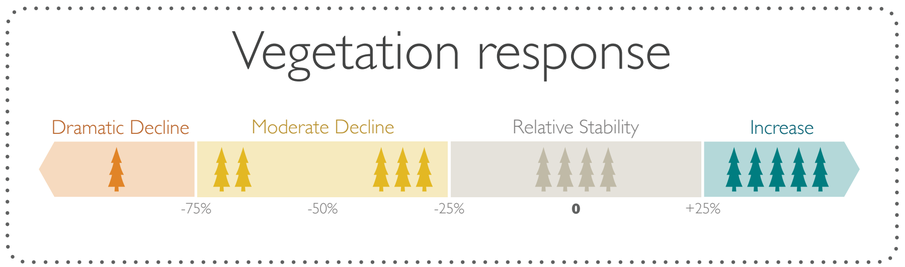


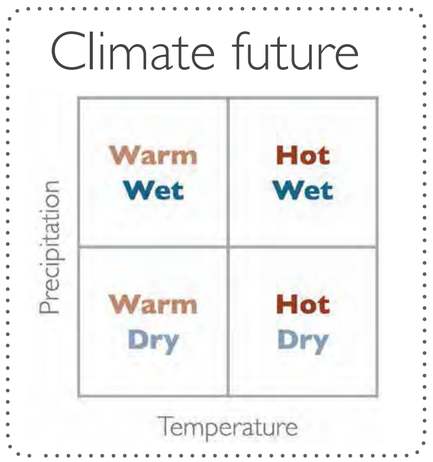
Four square



Pepperwood

We used four squares to assess species-specific potential responses to changing climate





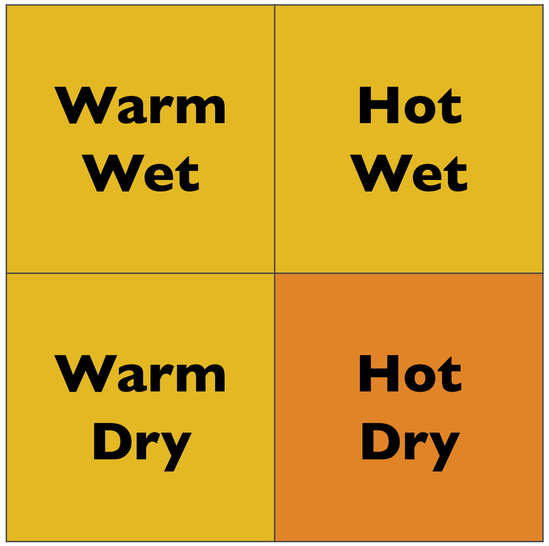
Struggling oaks

Thriving bushes

Pepperwood

The percent change was predicted for each vegetation type across the four future climate categories

This vegetation type is predicted to show **moderate** or **dramatic** decreases in abundance by mid-century



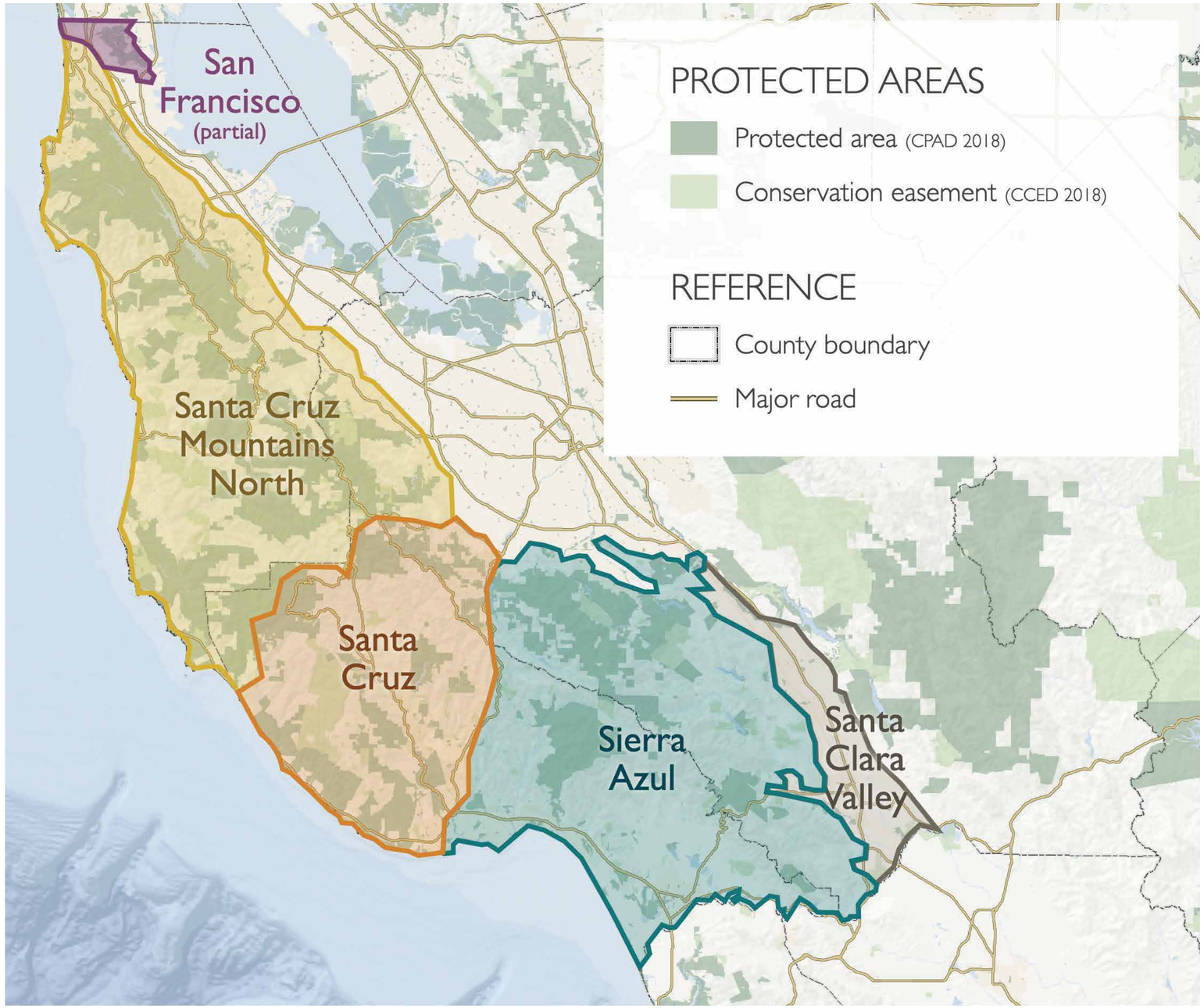
This vegetation type is predicted to be **relatively stable** or **increase** in abundance by mid-century

Pepperwood

Vegetation types used in this assessment were cross-walked to PVM types

Santa Cruz Mountains	Probabilistic Vegetation Model (Ackerly et al. 2015)	
Ecosystem	Vegetation Type	Dominant Taxa
Chaparral	Chamise chaparral	*Adenostoma fasciculatum*
	Mixed montane chaparral	*Various species*
	Mixed chaparral	*Various species*
Coastal Redwood Trees	Redwood forest	*Sequoiadendron sempervirens*
Coastal Scrub	Coastal scrub	*Various species*
Mixed Evergreen / Montane Hardwood	California bay forest	*Umbellularia californica*
	Douglas fir forest	*Pseudostuga menziesii*
	Tanoak forest	*Notholithocarpus densiflorus*
	Montane hardwoods	*Various species*
Mixed Grasslands	Grassland	*Various species*
Oak Woodlands	Black oak forest / woodland	*Quercus kelloggii*
	Blue oak forest / woodland	*Quercus douglasii*
	Blue oak-foothill pine woodland	*Quercus douglasii / Pinus sabiniana*
	Canyon live oak forest	*Quercus chrysopelis*
	Coast live oak forest / woodland	*Quercus agrifolia*
	Interior live oak forest / woodland	*Quercus wislezini*
	Oregon oak woodland	*Quercus garryana*
	Valley oak forest / woodland	*Quercus lobata*

Pepperwood



Landscape Units

Conservation Lands Network (CLN)

Landscape Units are geographic divisions based on physiographic* features, and inform the vegetation vulnerability model.

Five Landscape Units in this region are:

- Santa Cruz Mountains North
- Santa Cruz
- Sierra Azul
- Santa Clara Valley
- San Francisco (partial)

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

Pepperwood

Summary of results across all Landscape Units

▲ Increase

Chamise chaparral

Valley oak forest / woodland

Interior live oak forest / woodland

Blue oak forest / woodland

▼ Moderate Decline

Redwood forest

Grassland

Mixed chaparral

Mixed montane chaparral

Oregon oak woodland

Tanoak forest

Coastal scrub

▼▼ Dramatic Decline

Black oak forest / woodland

Canyon live oak forest

○ Mixed Response

Douglas fir forest

Coast live oak forest / woodland

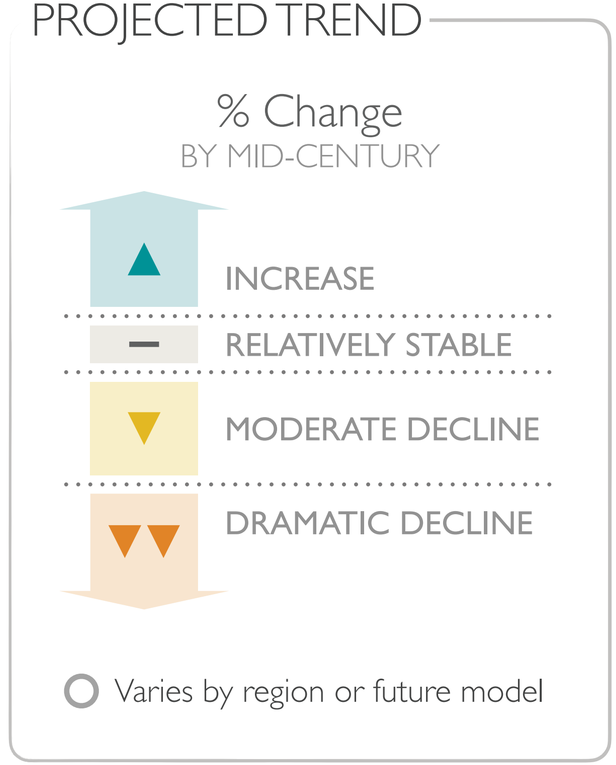
Blue oak-foothill pine woodland

Montane hardwoods

California bay forest

Pepperwood

Vegetation Type	Vegetation Type
Chamise chaparral	▲
Valley oak forest / woodland	▲
Interior live oak forest / woodland	▲
Blue oak forest / woodland	▲
Douglas fir forest	○
Coast live oak forest / woodland	○
Blue oak-foothill pine woodland	○
Montane hardwoods	○
California bay forest	○
Redwood forest	▼
Grassland	▼
Mixed chaparral	▼
Mixed montane chaparral	▼
Oregon oak woodland	▼
Tanoak forest	▼
Coastal scrub	▼
Black oak forest / woodland	▼▼
Canyon live oak forest	▼▼
All Vegetation Types	▼



Pepperwood

Vegetation vulnerability by Landscape Unit

Pepperwood

Vegetation Type	San Francisco	Santa Clara Valley	Santa Cruz Mtns. North	Santa Cruz	Sierra Azul
Chamise chaparral	▲	▲	▲	▲	▲
Valley oak forest / woodland	▲	▲	▲	▲	▲
Interior live oak forest / woodland	–	▲	▲	–	▲
Blue oak forest / woodland	▲	▲	▲	–	▲
Douglas fir forest	▲	–	▲	–	–
Coast live oak forest / woodland	▽	▽	▲	▲	▽
Blue oak-foothill pine woodland	▲	–	▽	▽	–
Montane hardwoods	▽	▲	▽	–	▽
Redwood forest	–	–	▽	▽	▽
California bay forest	▽▽	▲	▽	▽	▽
Grassland	▽	▽	▽	▽	▽
Mixed chaparral	▽	▲	▽	▽	▽
Mixed montane chaparral	–	▽	▽	▽	▽
Oregon oak woodland	–	▽	▽▽	–	▽
Tanoak forest	▽	–	–	▽▽	▽▽
Coastal scrub	▽	▽▽	▽	▽	▽
Black oak forest / woodland	▽▽	▽▽	▽▽	▽▽	▽▽
Canyon live oak forest	▽▽	▽▽	▽▽	▽▽	▽▽
All Vegetation Types	▽	▽	▽	▽	▽

PROJECTED TREND

% Change
BY MID-CENTURY

▲ Increase

– Relatively stable

▽ Moderate decline

▽▽ Dramatic decline

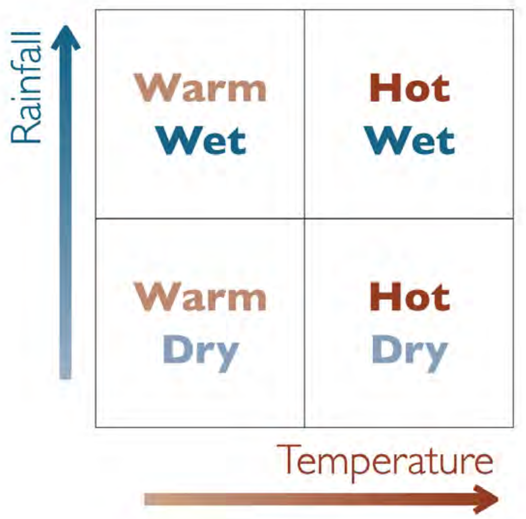
Pepperwood

Santa Cruz Mountains North

Response	Vegetation Type
Increase	Chamise chaparral
	Valley oak forest / woodland
	Douglas fir forest
	Interior live oak forest / woodland
	Blue oak forest / woodland
	Coast live oak forest / woodland
Moderate Decline	Mixed montane chaparral
	Montane hardwoods
	Grassland
	Blue oak-foothill pine woodland
	Mixed chaparral
	Redwood forest
	California bay forest
	Coastal scrub
Mixed	Tanoak forest
Dramatic Decline	Oregon oak woodland
	Black oak forest / woodland
	Canyon live oak forest

Area of suitable climate is projected to **increase** by mid-century

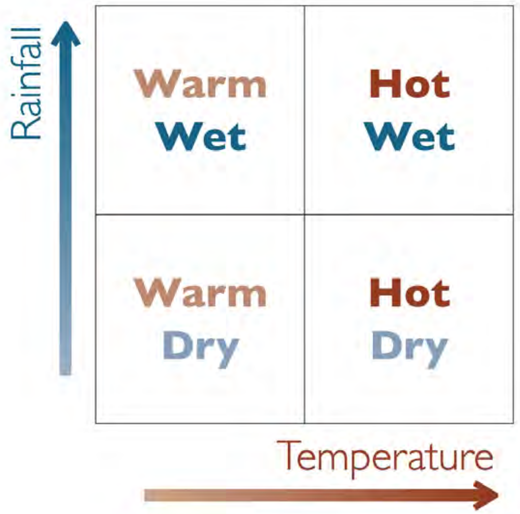
Four Square	Vegetation Type
	Chamise chaparral Valley oak forest / woodland
	Douglas fir forest
	Interior live oak forest/woodland
	Blue oak forest / woodland
	Coast live oak forest / wodland



Pepperwood

Area of suitable climate is predicted to **dramatically decline** by mid-century

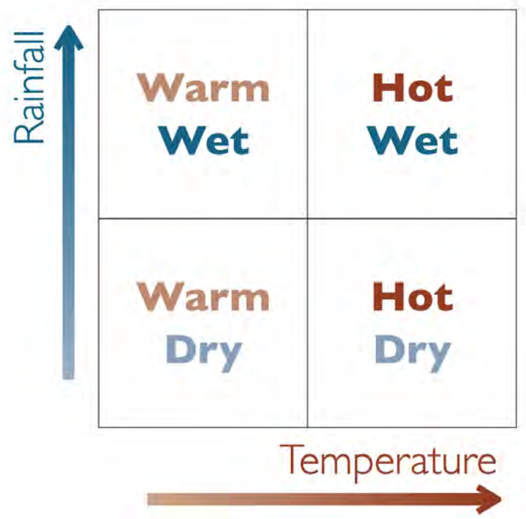
Four Square	Vegetation Type
	Oregon oak woodland
	Black oak forest / woodland
	Canyon live oak forest



Pepperwood

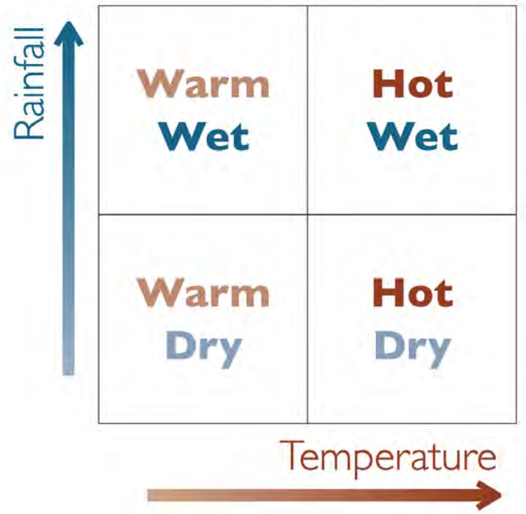
Area of suitable climate is predicted to **moderately decline** by mid-century

Four Square	Vegetation Type
	Mixed montane chaparral Montane hardwoods Grasslands
	Blue oak-foothill pine woodland
	Mixed chaparral
	Redwood forest
	California bay forest
	Coastal scrub

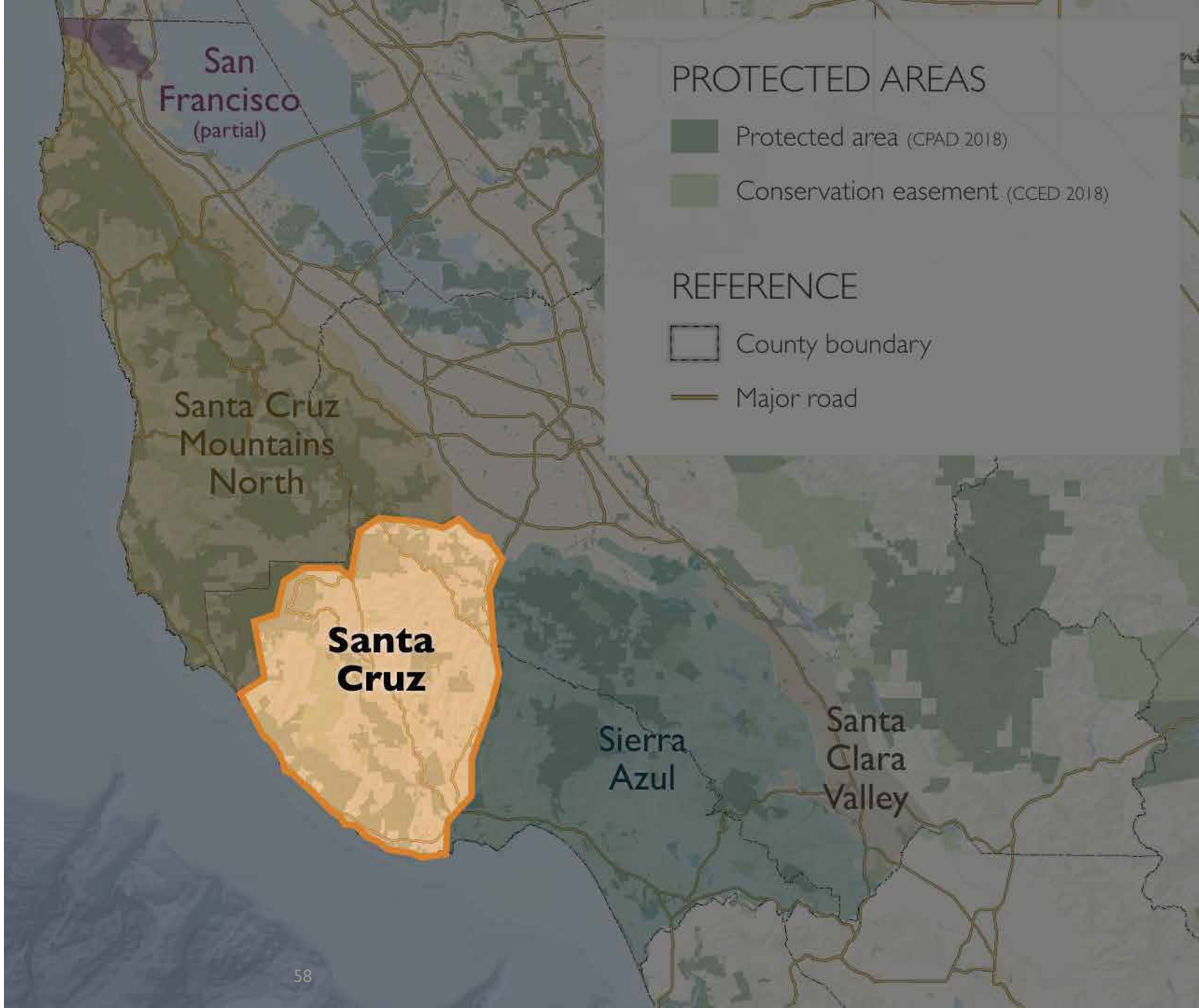


Area of suitable climate is predicted to have a **mixed response** by mid-century

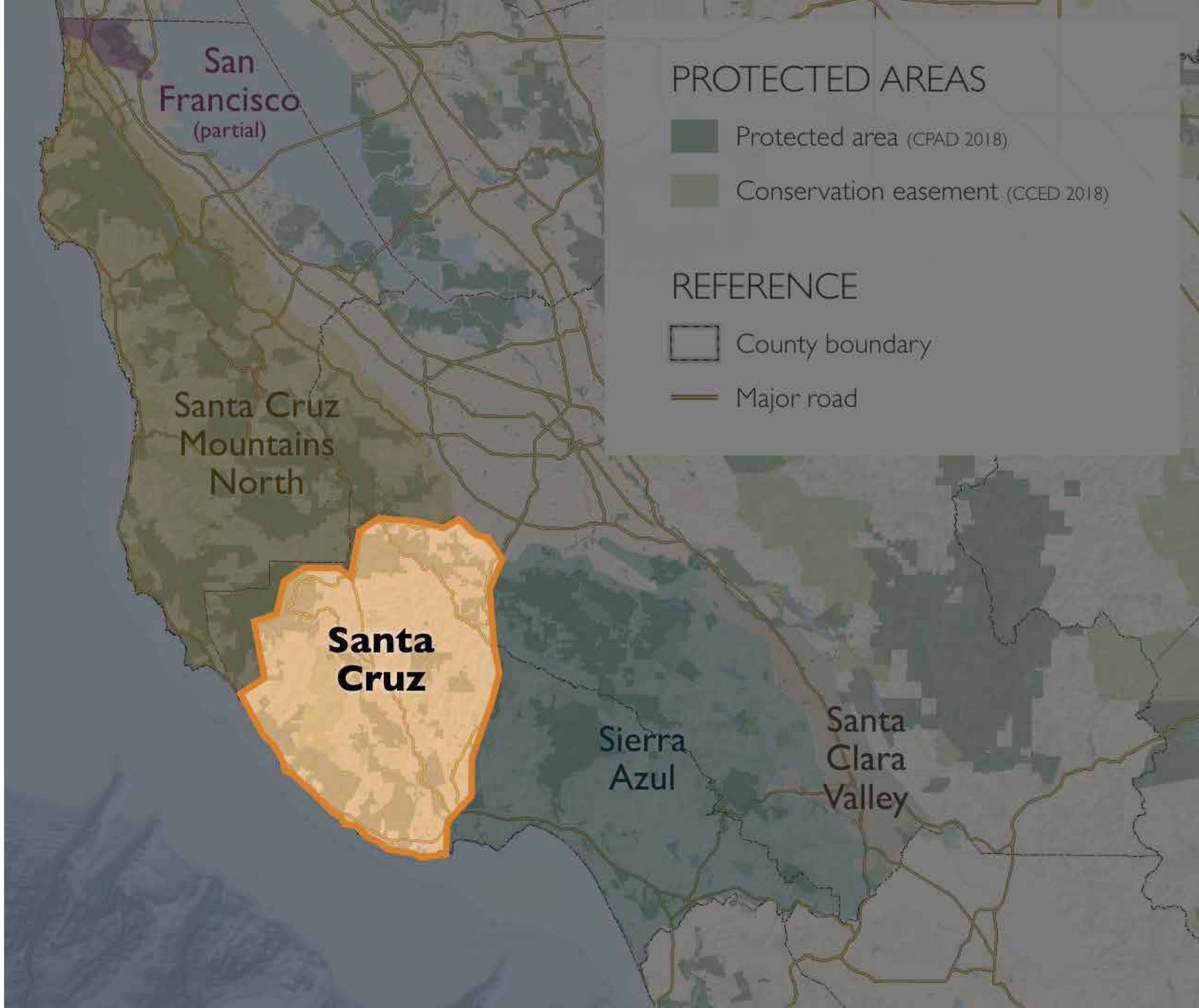
Four Square	Vegetation Type
	Tanoak forest



Santa Cruz

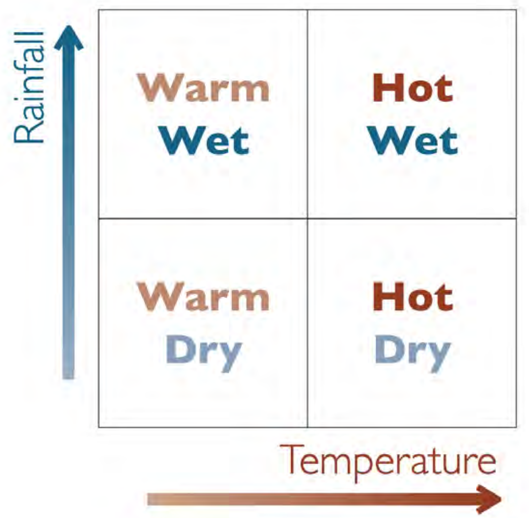

San Francisco (partial)
Santa Cruz Mountains North
Santa Cruz
Sierra Azul
Santa Clara Valley
PROTECTED AREAS
Protected area (CPAD 2018)
Conservation easement (CCED 2018)
REFERENCE
County boundary
Major road

Response	Vegetation Type
Increase	Chamise chaparral
	Coast live oak forest / woodland
	Valley oak forest / woodland
Mixed Response	Douglas fir forest
	Montane hardwoods
	Blue oak forest / woodland
	Interior live oak forest / woodland
	Oregon oak woodland
Moderate Decline	Grassland
	California bay forest
	Redwood forest
	Blue oak-foothill pine woodland
	Coastal scrub
	Mixed chaparral
	Mixed montane chaparral
Dramatic Decline	Tanoak forest
	Black oak forest / woodland
	Canyon live oak forest



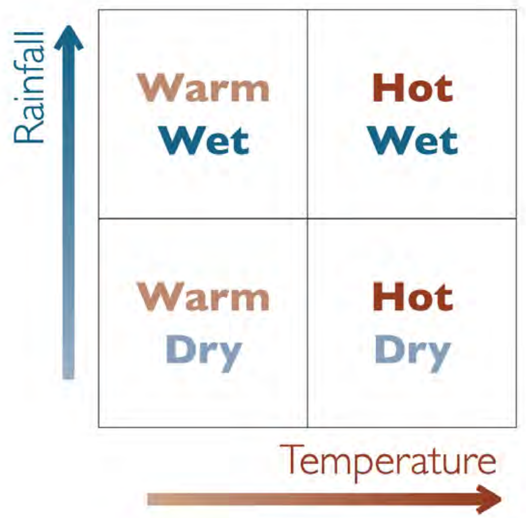
Area of suitable climate is projected to **increase** by mid-century

Four Square	Vegetation Type
	Valley Oak Forest / Woodland
	Chamise Chaparral
	Coast Live Oak Forest / Woodland



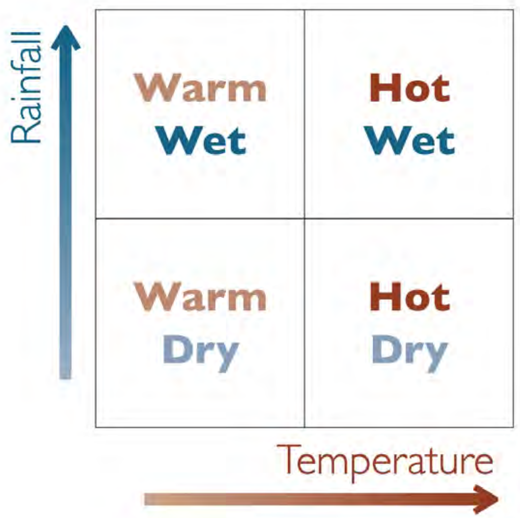
Area of suitable climate is predicted to **dramatically decline** by mid-century

Four Square	Vegetation Type
	Tanoak Forest
	Black Oak Forest / Woodland
	Canyon Live Oak Forest



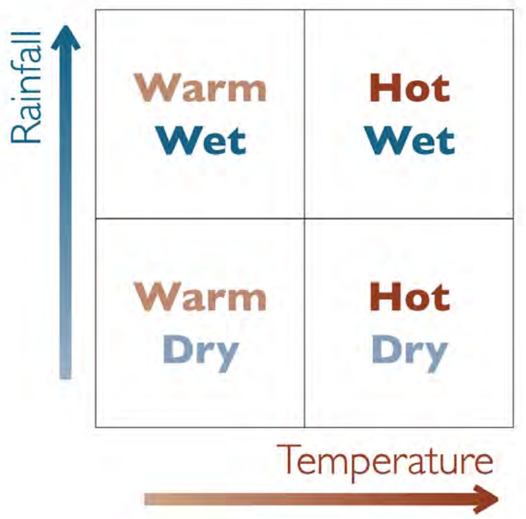
Area of suitable climate is predicted to **moderately decline** by mid-century

Four Square	Vegetation Type
	Mixed Grasslands
	Redwood Forest
	California Bay Forest
	Blue Oak / Foothill Pine Woodland
	Mixed Chaparral
	Mixed Montane Chaparral
	Coastal Scrub



Area of suitable climate is predicted to have a **mixed response** by mid-century

Four Square	Vegetation Type
	Montane Hardwood
	Douglas Fir Forest
	Oregon Oak Woodland
	Blue Oak Forest / Woodland Interior Live Oak Forest / Woodland



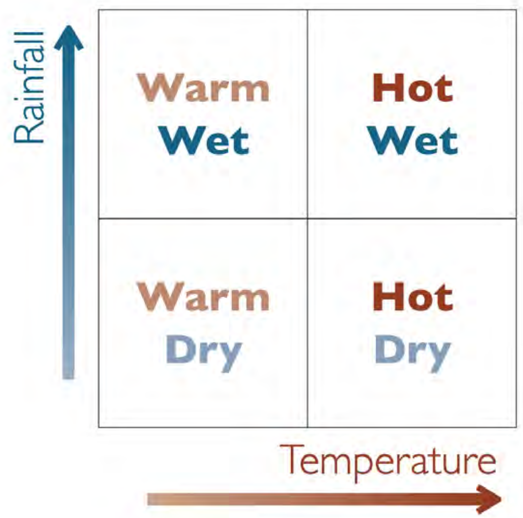
Sierra Azul


San Francisco (partial)
Santa Cruz Mountains North
Santa Cruz
Sierra Azul
Santa Clara Valley
PROTECTED AREAS
Protected area (CPAD 2018)
Conservation easement (CCED 2018)
REFERENCE
County boundary
Major road

Response	Vegetation Type
Increase	Blue oak forest / woodland
	Interior live oak forest / woodland
	Chamise chaparral
	Valley oak forest / woodland
Mixed Response	Douglas fir forest
	Blue oak-foothill pine woodland
Moderate Decline	Coast live oak forest / woodland
	Montane hardwoods
	California bay forest
	Grassland
	Mixed chaparral
	Redwood forest
	Oregon oak woodland
	Mixed montane chaparral
	Coastal scrub
Dramatic Decline	Black oak forest / woodland
	Canyon live oak forest
	Tanoak forest

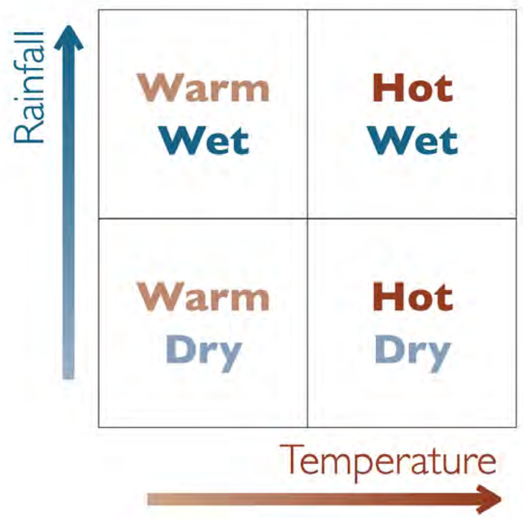
Area of suitable climate is projected to **increase** by mid-century

Four Square	Vegetation Type
	Blue oak forest / woodland
	Interior live oak forest / woodland
	Chamise chaparral
	Valley oak forest / woodland



Area of suitable climate is predicted to **dramatically decline** by mid-century

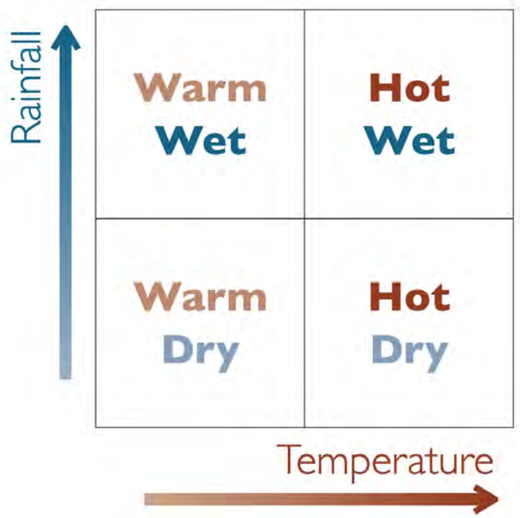
Four Square	Vegetation Type
	Canyon live oak forest
	Black oak forest / woodland
	Tanoak forest



Pepperwood

Area of suitable climate is predicted to **moderately decline** by mid-century

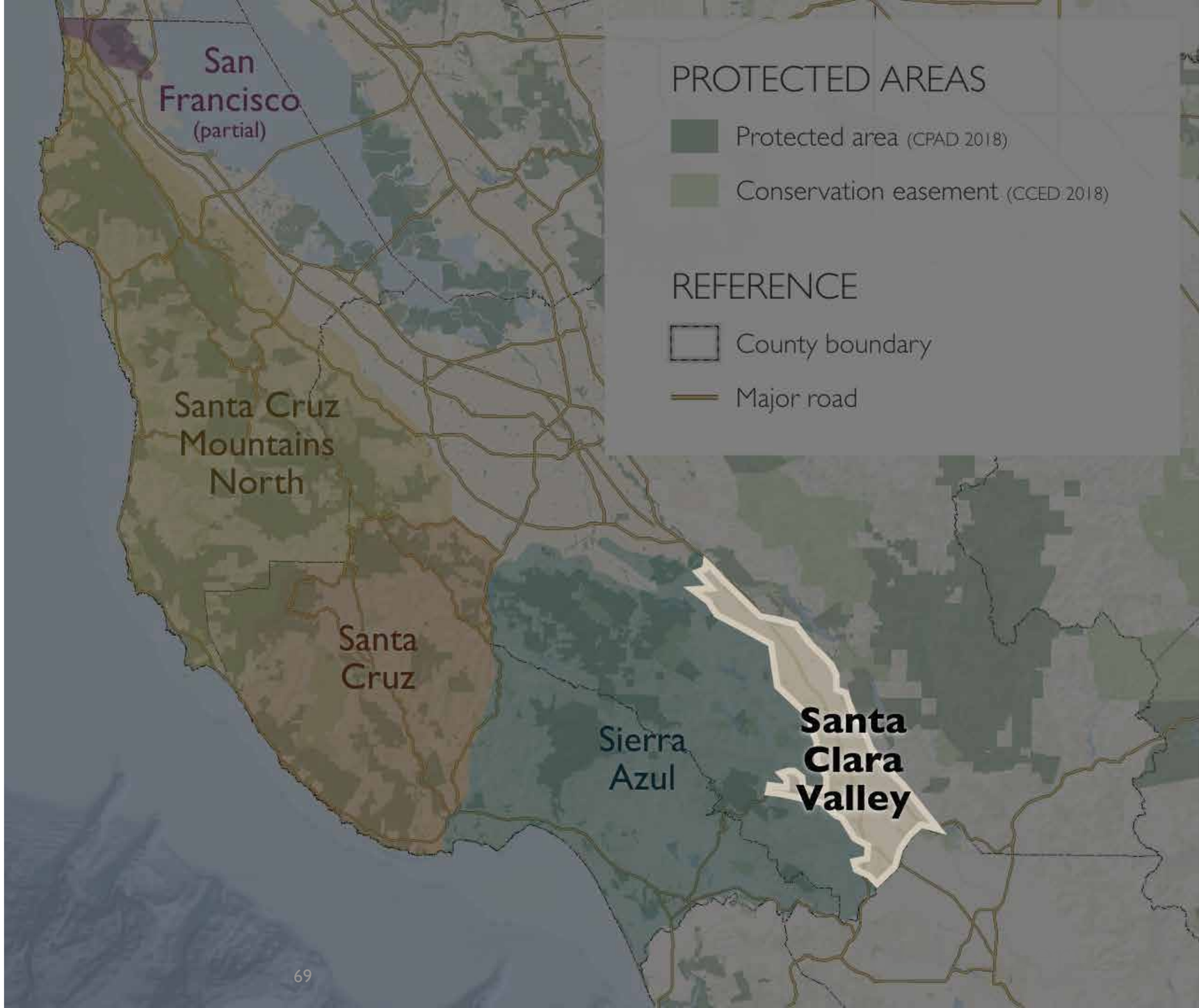
Four Square	Vegetation Type
	Coast live oak forest / woodland
	Montane hardwoods
	Mixed chaparral
	Grassland
	California bay forest
	Redwood forest
	Oregon oak woodland
	Mixed montane chaparral
	Coastal scrub



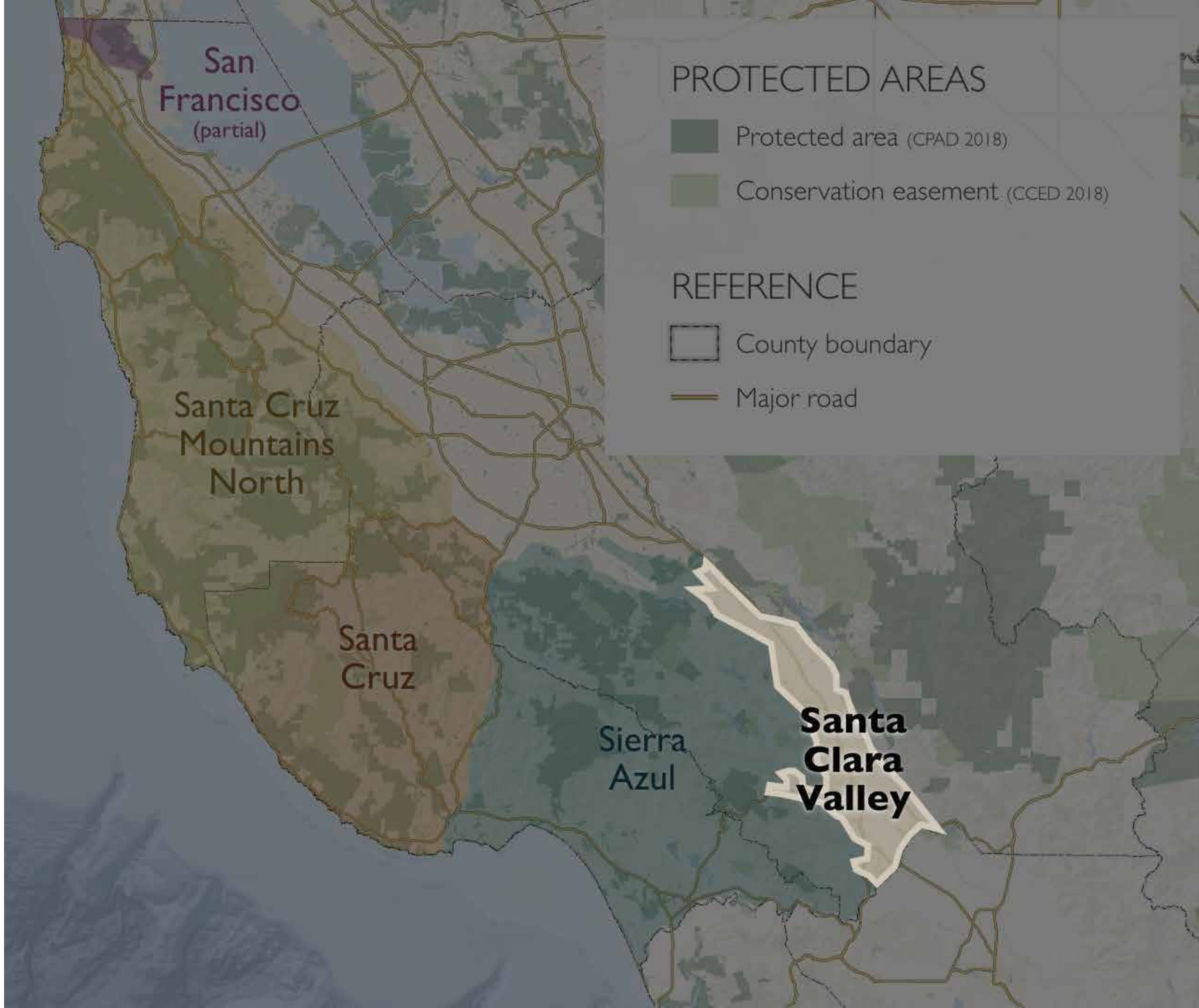
Sierra Azul

Pepperwood

Santa Clara Valley

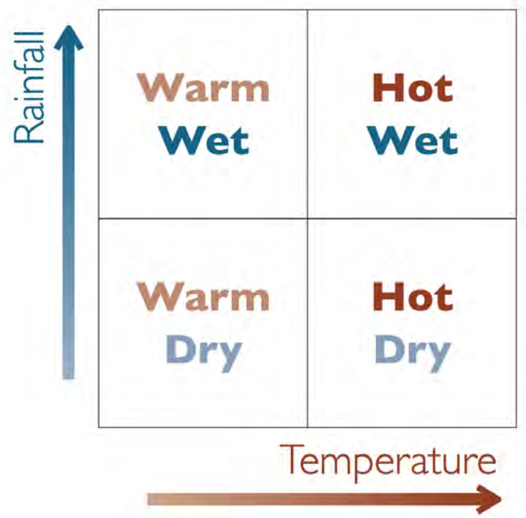


Response	Vegetation Type
Increase	Blue oak forest / woodland
	Chamise chaparral
	Interior live oak forest / woodland
	Mixed chaparral
	California bay forest
	Montane hardwoods
	Valley oak forest / woodland
Mixed Response	Douglas fir forest
	Blue oak-foothill pine woodland
	Tanoak forest
	Redwood forest
Moderate Decline	Grassland
	Mixed montane chaparral
	Coast live oak forest / woodland
	Oregon oak woodland
Dramatic Decline	Black oak forest / woodland
	Coastal scrub
	Canyon live oak forest



Area of suitable climate is projected to **increase** by mid-century

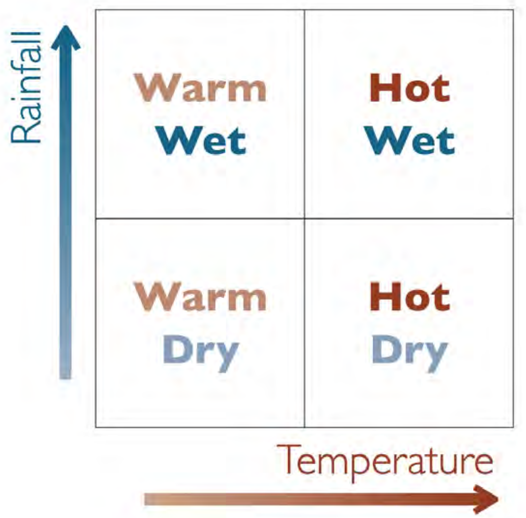
Four Square	Vegetation Type
	Blue oak forest / woodland Chamise chaparral Interior live oak forest / woodland Mixed chaparral
	California bay forest Montane hardwoods
	Valley oak forest / woodland



Pepperwood

Area of suitable climate is predicted to **dramatically decline** by mid-century

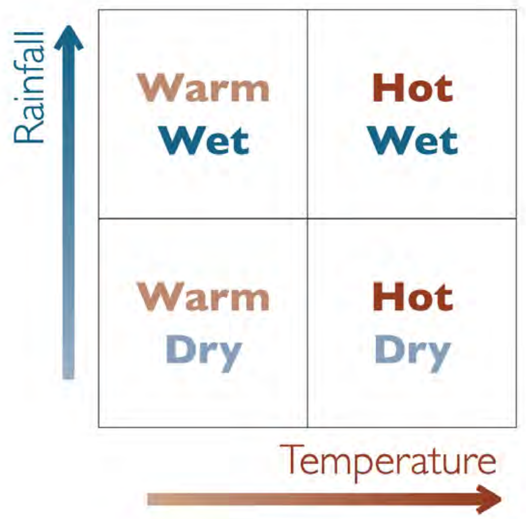
Four Square	Vegetation Type
	Black oak forest / woodland
	Coastal scrub
	Canyon live oak forest



Pepperwood

Area of suitable climate is predicted to **moderately decline** by mid-century

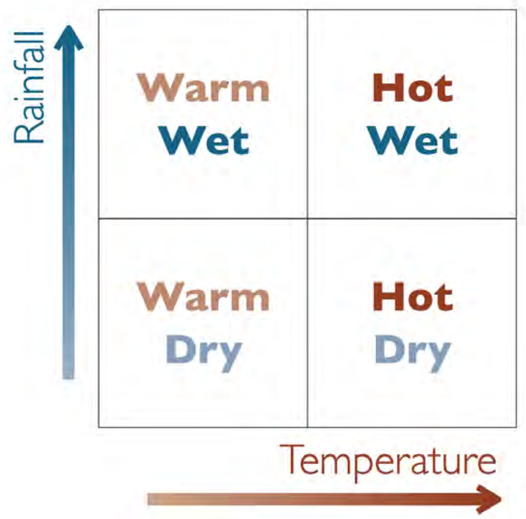
Four Square	Vegetation Type
	Grassland
	Mixed montane chaparral
	Coast live oak forest / woodland
	Oregon oak woodland



Pepperwood

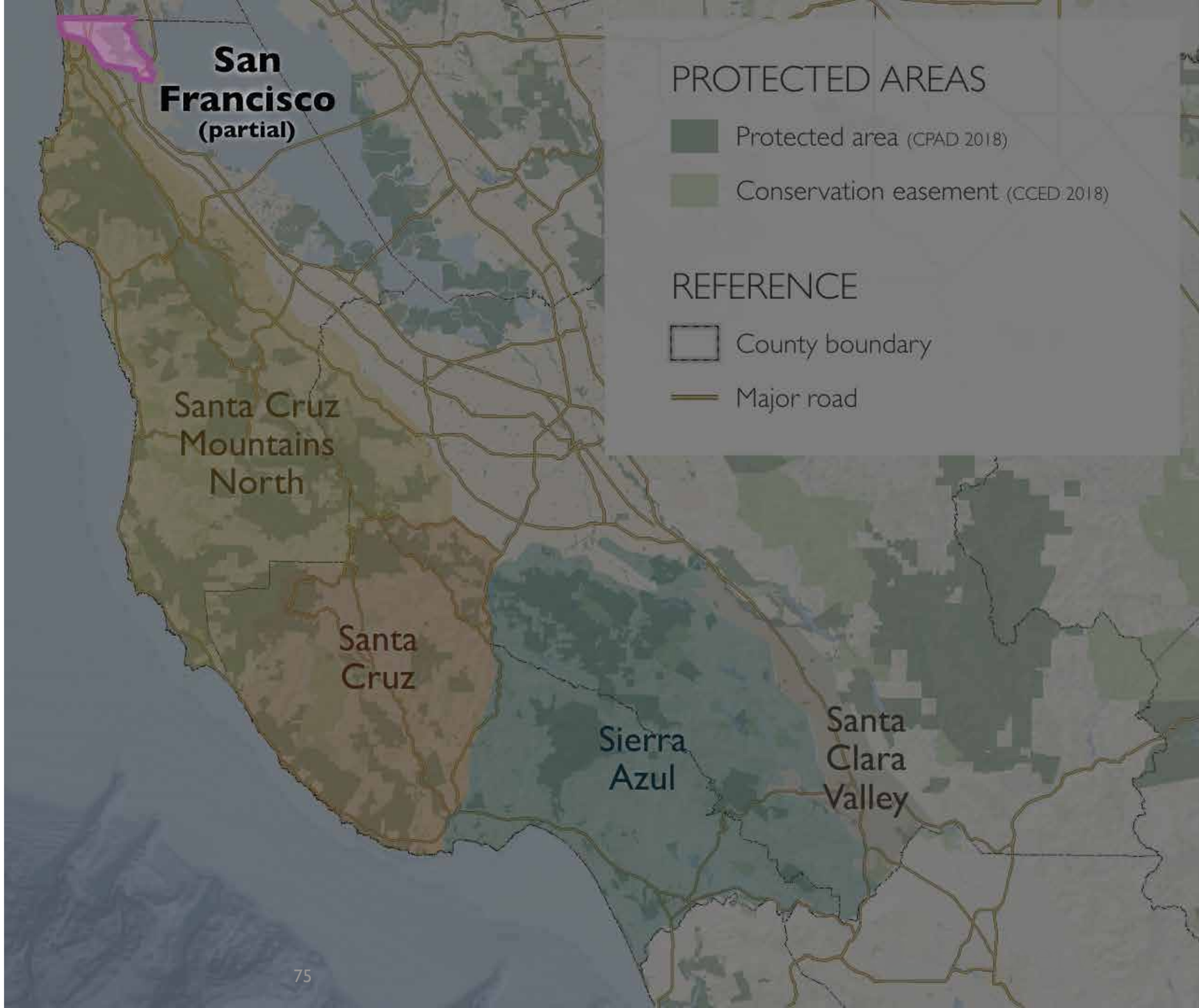
Area of suitable climate is predicted to have a **mixed response** by mid-century

Four Square	Vegetation Type
	Douglas fir forest
	Blue oak-foothill pine woodland
	Tanoak forest
	Redwood forest

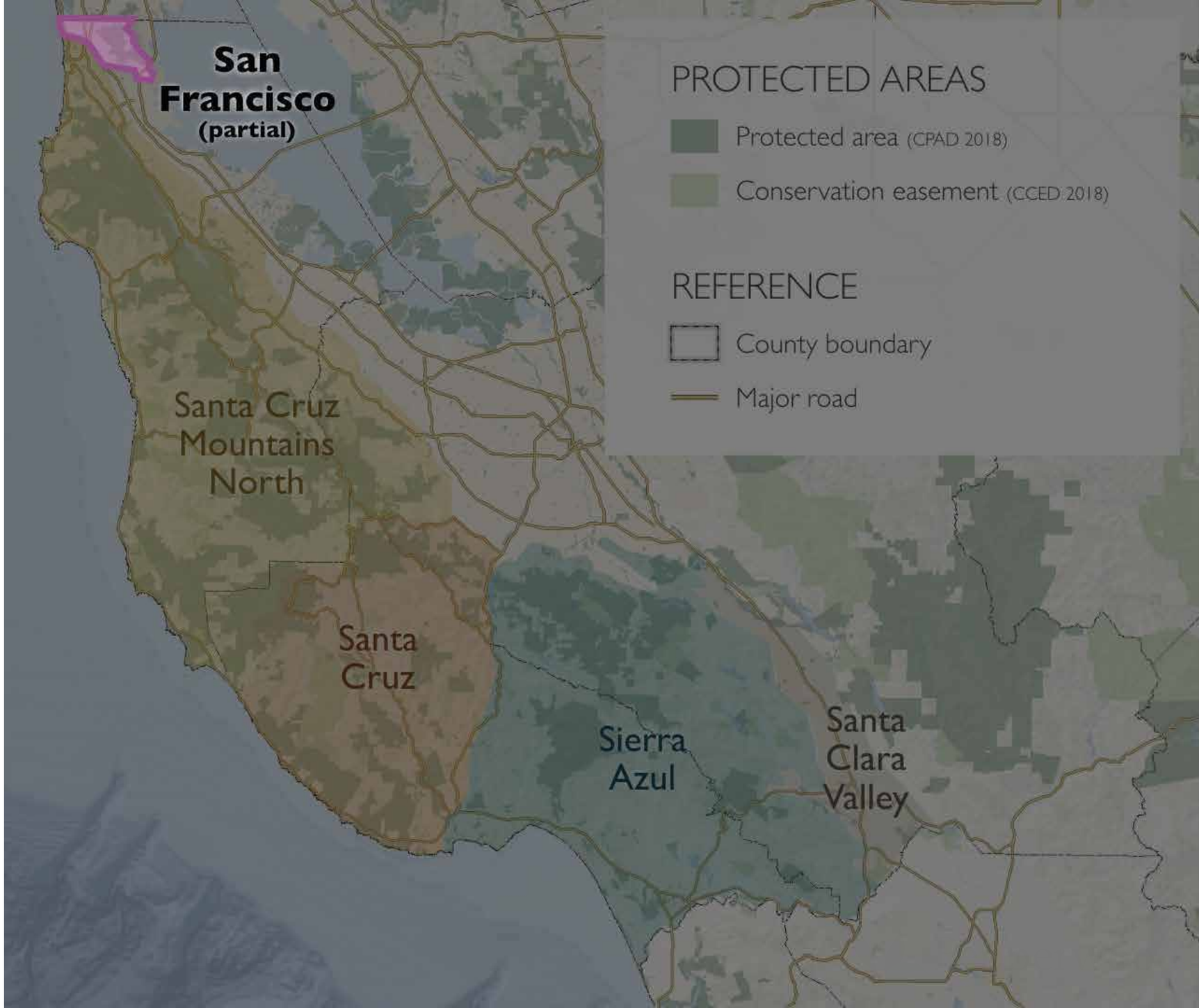


Pepperwood

San Francisco
(partial)

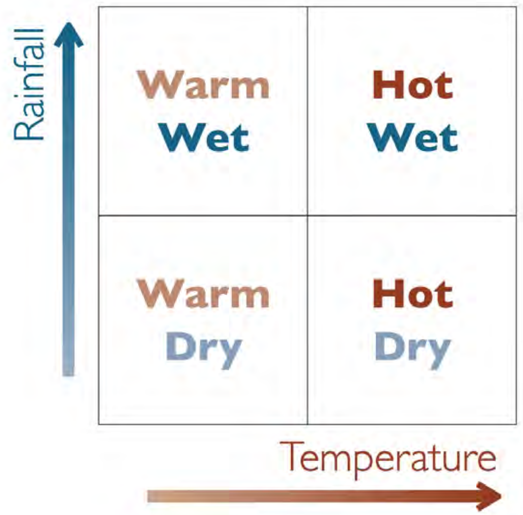


Response	Vegetation Type
Increase	Blue oak forest / woodland
	Chamise chaparral
	Blue oak-foothill pine woodland
	Douglas fir forest
	Valley oak forest / woodland
Mixed Response	Interior live oak forest / woodland
	Mixed montane chaparral
	Redwood forest
	Oregon oak woodland
Moderate Decline	Coast live oak forest / woodland
	Grassland
	Coastal scrub
	Montane hardwoods
	Tanoak forest
Dramatic Decline	Mixed chaparral
	Black oak forest / woodland
	California bay forest
	Canyon live oak forest



Area of suitable climate is projected to **increase** by mid-century

Four Square	Vegetation Type
	Blue oak forest / woodland Chamise chaparral
	Douglas fir forest
	Blue oak - foothill pine woodland
	Valley oak forest / woodland

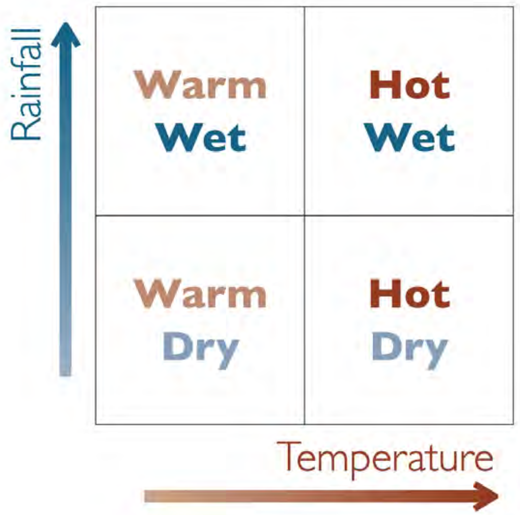


San Francisco (partial)

Pepperwood

Area of suitable climate is predicted to **dramatically decline** by mid-century

Four Square	Vegetation Type
	Black oak forest / woodland
	Canyon live oak forest
	California bay forest
	Tanoak forest

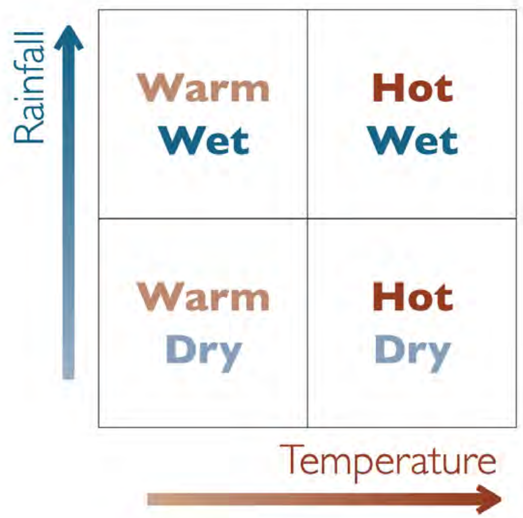


San Francisco (partial)

Pepperwood

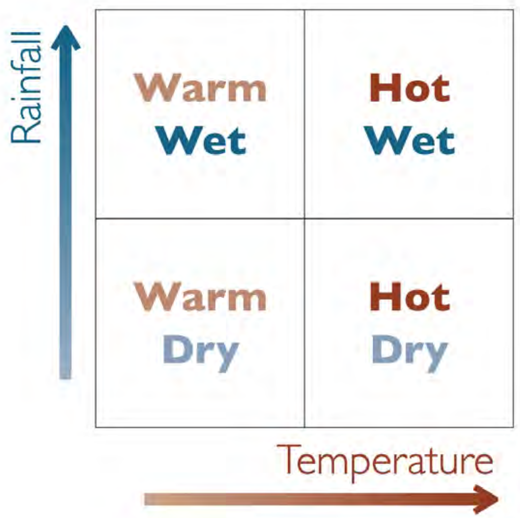
Area of suitable climate is predicted to **moderately decline** by mid-century

Four Square	Vegetation Type
	Grassland
	Coast live oak forest / woodland
	Coastal scrub
	Montane hardwoods
	Mixed chaparral



Area of suitable climate is predicted to have a **mixed response** by mid-century

Four Square	Vegetation Type
	Interior live oak forest / woodland
	Mixed montane chaparral
	Redwood forest
	Oregon oak woodland



San Francisco (partial)

Pepperwood