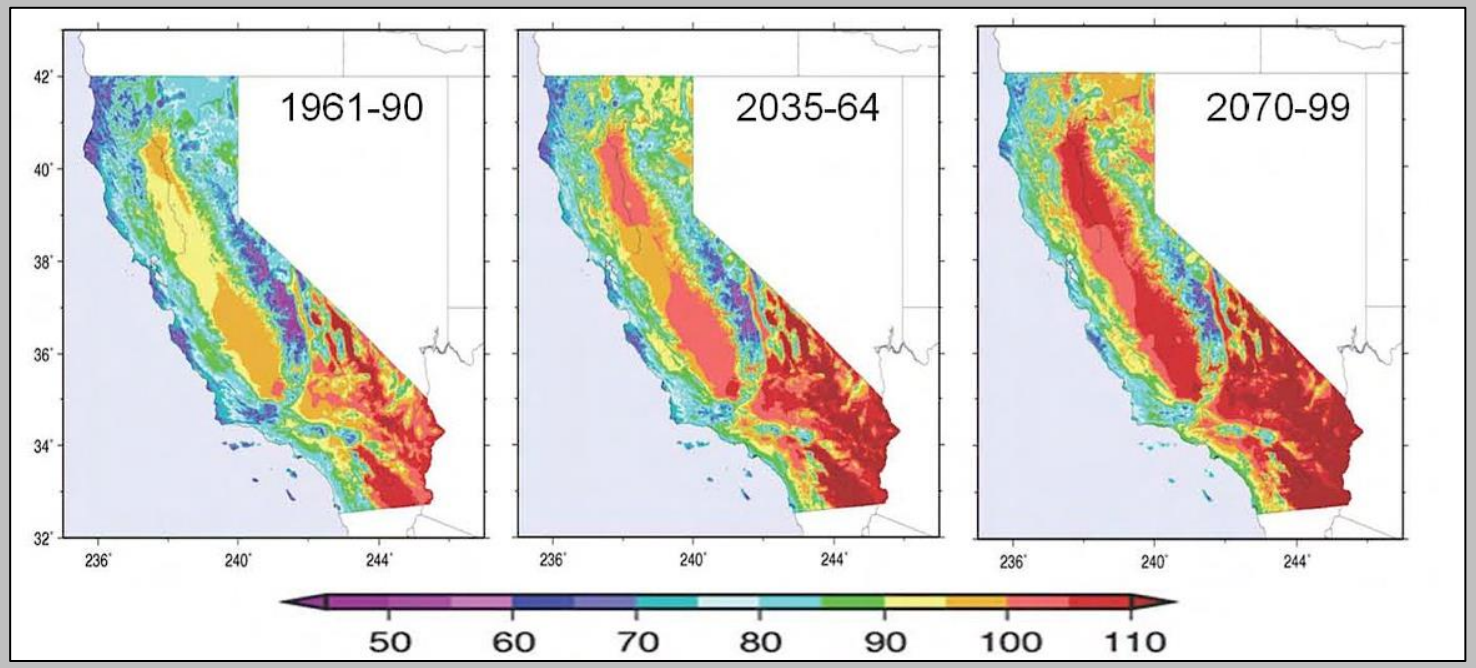
The Impact of Climate Change on Street Trees in California



EBMUD | Landscape Advisory Committee
Sustainable Landscape Speaker Series
LAC

Joe R. McBride and Igor Lacan
Departments of Landscape Architecture and Environmental Planning
and Environmental Science, Policy and Management
and
University of California Cooperative Extension
University of California

Objective

1. Report on climate change in California
2. Identify impacts to trees due to climate change
3. Report on my research concerning the impact of climate change on street trees in California

San Francisco Chronicle

SFCHRONICLE.COM | Saturday, September 2, 2017 | PRINTED ON RECYCLED PAPER | $1.50 ★★★★★•

Bay swelters in record heat

S.F. all-time mark melts: 'It's horrible out there'

By Steve Rubenstein, Nanette Asimov and Jenna Lyons

Friday's scorching 106-degree heat in San Francisco broke the all-time record dating to 1874 for the hottest day in the usually foggy city by the bay.

And that record may get broken by Saturday's similarly hot temperature.

"It's horrible out there," Fritz Waldron said Friday as he stood in line to buy strawberry ice cream at the Haagen-Dazs shop at Westfield San Francisco Centre downtown. "Just horrible. It's like Phoenix. I can't wait for it to end."

106°
Friday's high in San Francisco, an all-time record

103°
Previous record, achieved June 14, 2000

70°
Normal high for Sept. 1 in San Francisco

Before Friday, the hottest day ever recorded by the National Weather Service for San Francisco was 103 degrees on June 14, 2000. And the hottest Sept. 1 was a mere 90, a record set in 1952.

The National Weather Service attributed San Francisco's blazing heat and other falling records around the Bay Area to a "massive area of high pressure" hovering above Northern California and no onshore wind, which usually brings cooling sea air into the city

Weather continues on A10

Russell Yip / The Chronicle

Adonis Lejao (left) and Elma Lejao, who are both from the Philippines, try to keep cool in line to ride a cable car.

Heat's rising on hot planet

In '16, climate disruptions, temperatures set records

2015 Far Eclipsed 2014 As World's Hottest Year, Climate Scientists Say

Global Warming Blamed for System That Is 'Warming Up, Relentlessly'

San Francisco Chronicle

SFCHRONICLE.COM | Wednesday, August 9, 2017 | PRINTED ON RECYCLED PAPER | $1.50 ★★★★★★••

'Alarming' climate report

Extreme weather conditions in state likely to accelerate, federal assessment warns

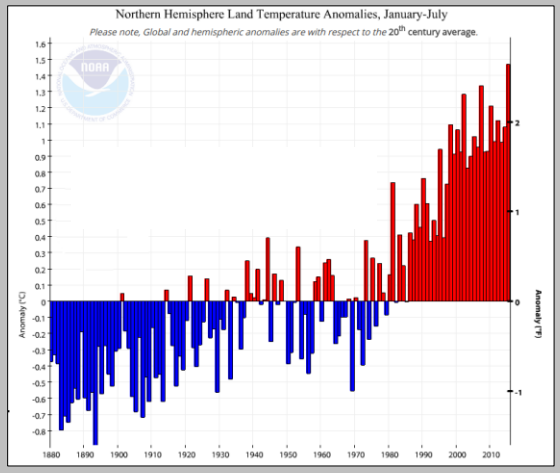
By Carolyn Lochhead

The changes to California's climate since 1980 — higher temperatures, with more extreme swings between droughts and floods — are caused directly by human activity and will accelerate rapidly unless greenhouse gas emissions are cut sharply, according to a new federal climate report that is awaiting action by the Trump administration.

The fourth National Climate Assessment, a federal synthesis of climate science required every four years by law, says temperatures have risen rapidly since the last report was published in 2014. After setting a record that year, global temperatures shot to a new record by a wide margin in 2015, the report says, followed by another record last year.

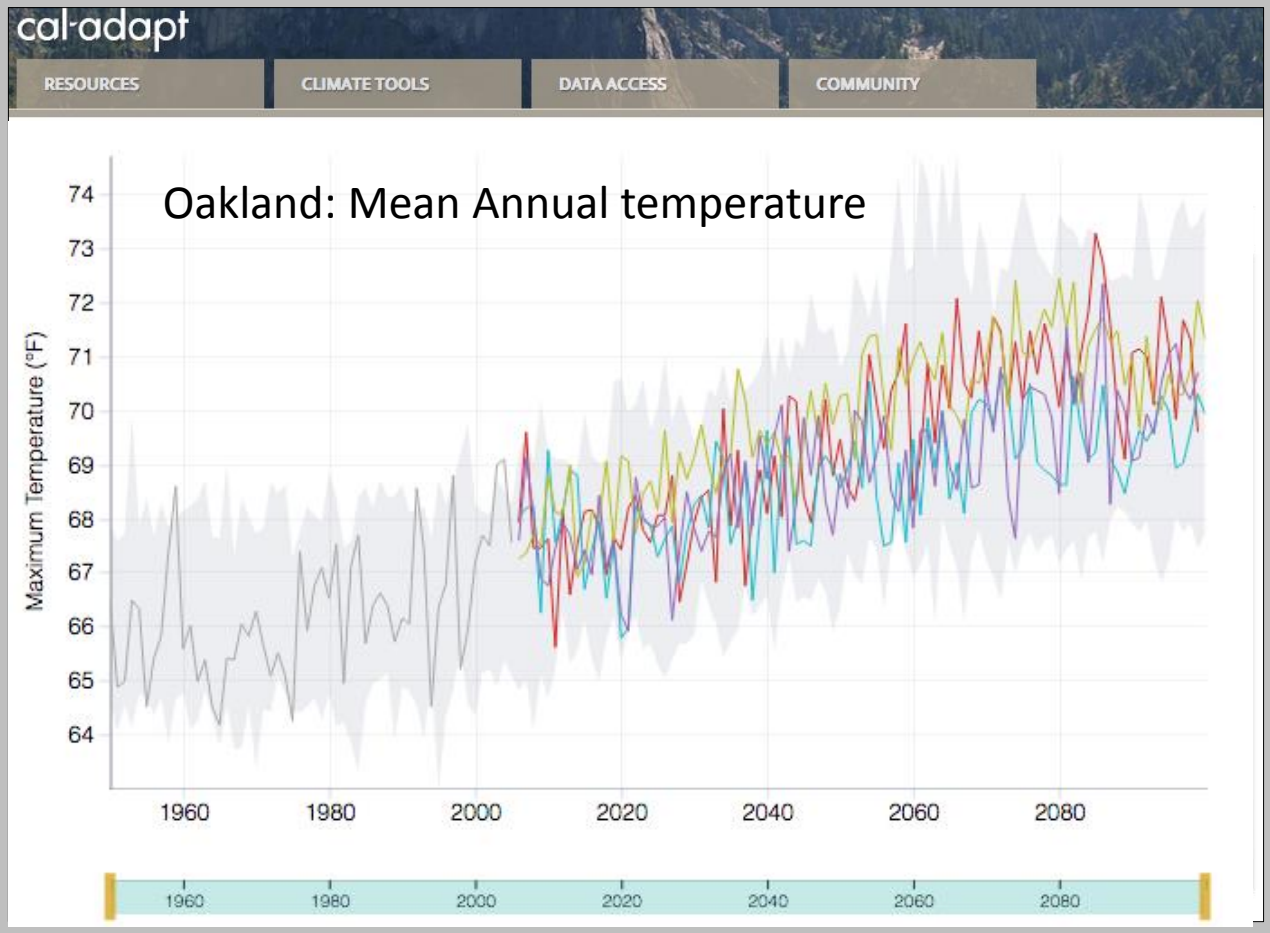
The report, produced by 13 federal agencies and approved by the National Academy of Sciences, is unequivocal in ascribing the warming to human activity, a finding that the Trump administration and

Climate continues on A5



Climatic Problem Facing California's Urban Forests

Increasing Temperatures



Mean Annual Temperature (°F)

1961-1990	2070-2100
65.9°	70.4 °

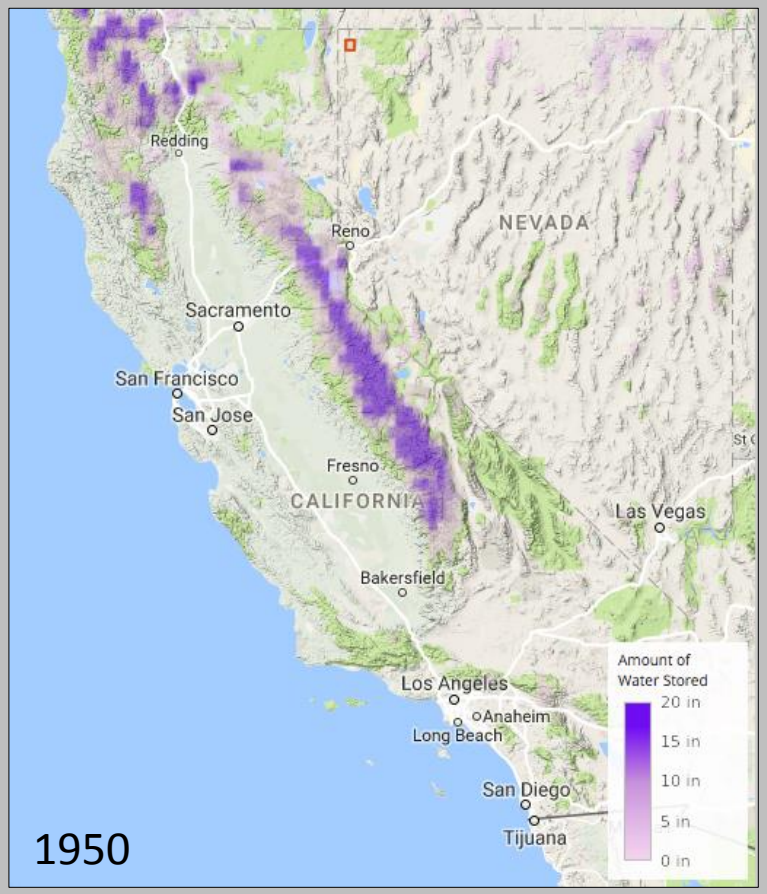
Change in Precipitation

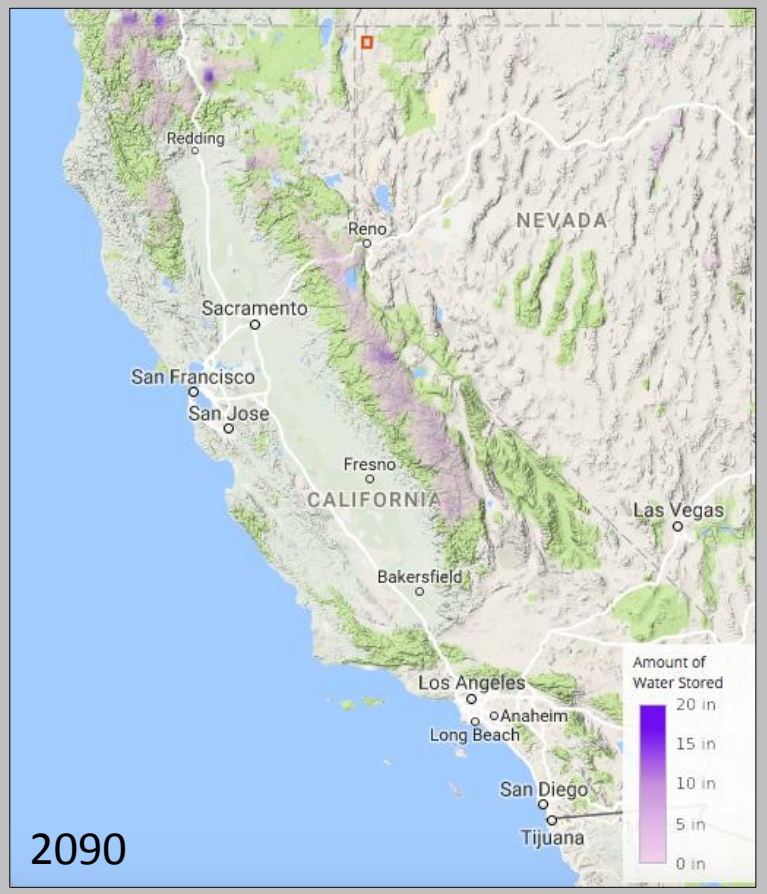
San Francisco, CA

Average Annual Precipitation

Long-term Average	2100
23.6”	18.3”

Change in Snowpack



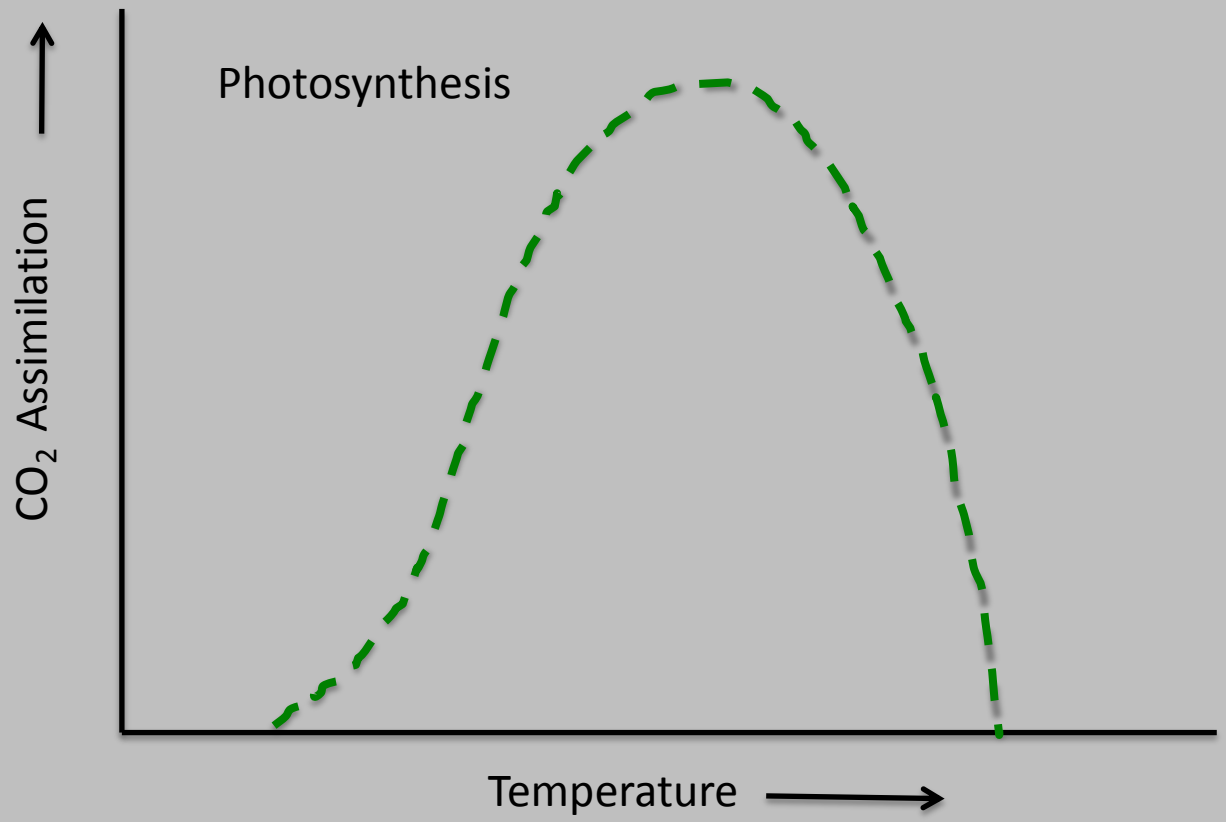


"By the end of this century, the Sierra snowpack is projected to experience a 48-65 percent loss from the historical April 1st average. This loss of snowpack means less water will be available for Californians to use."

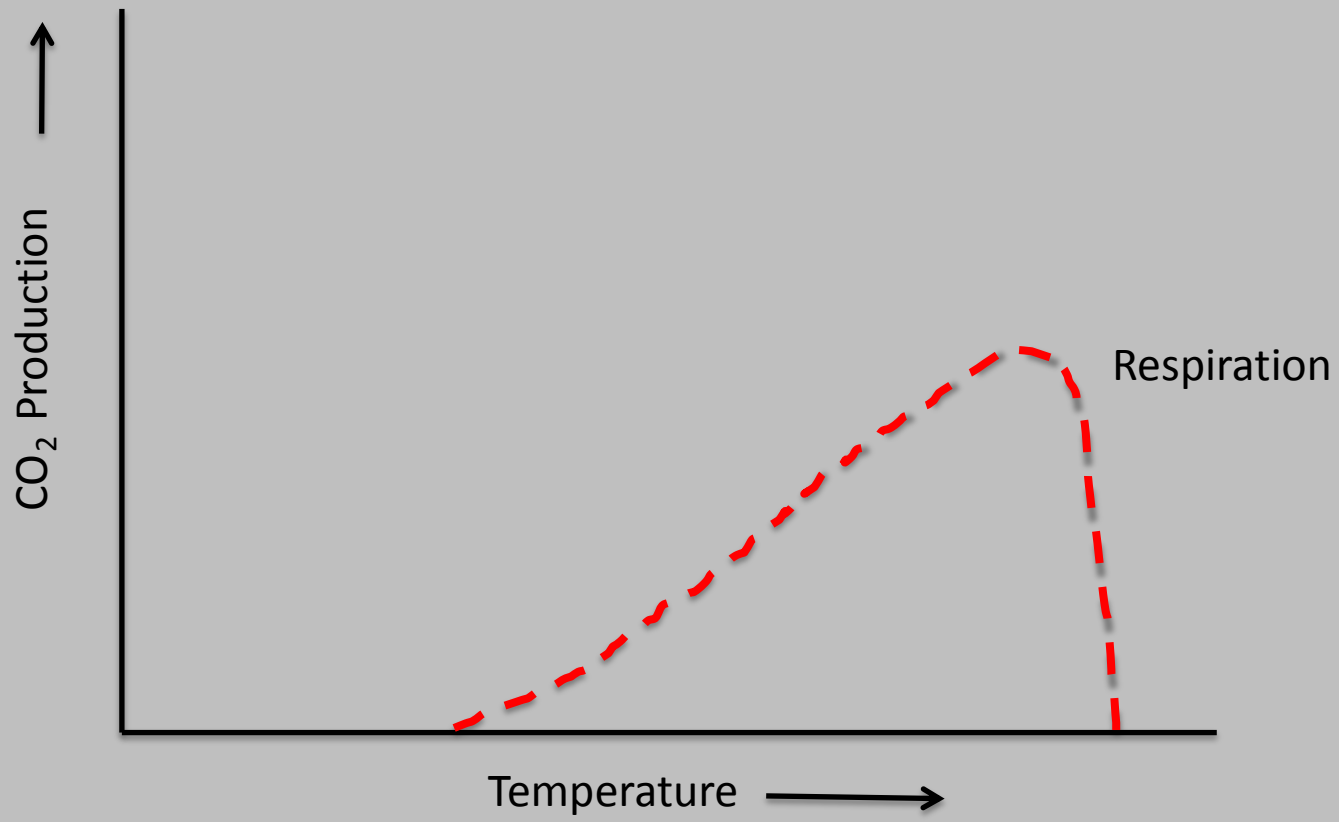
California Department of Water Resources (2015)

Impacts of Climate Change

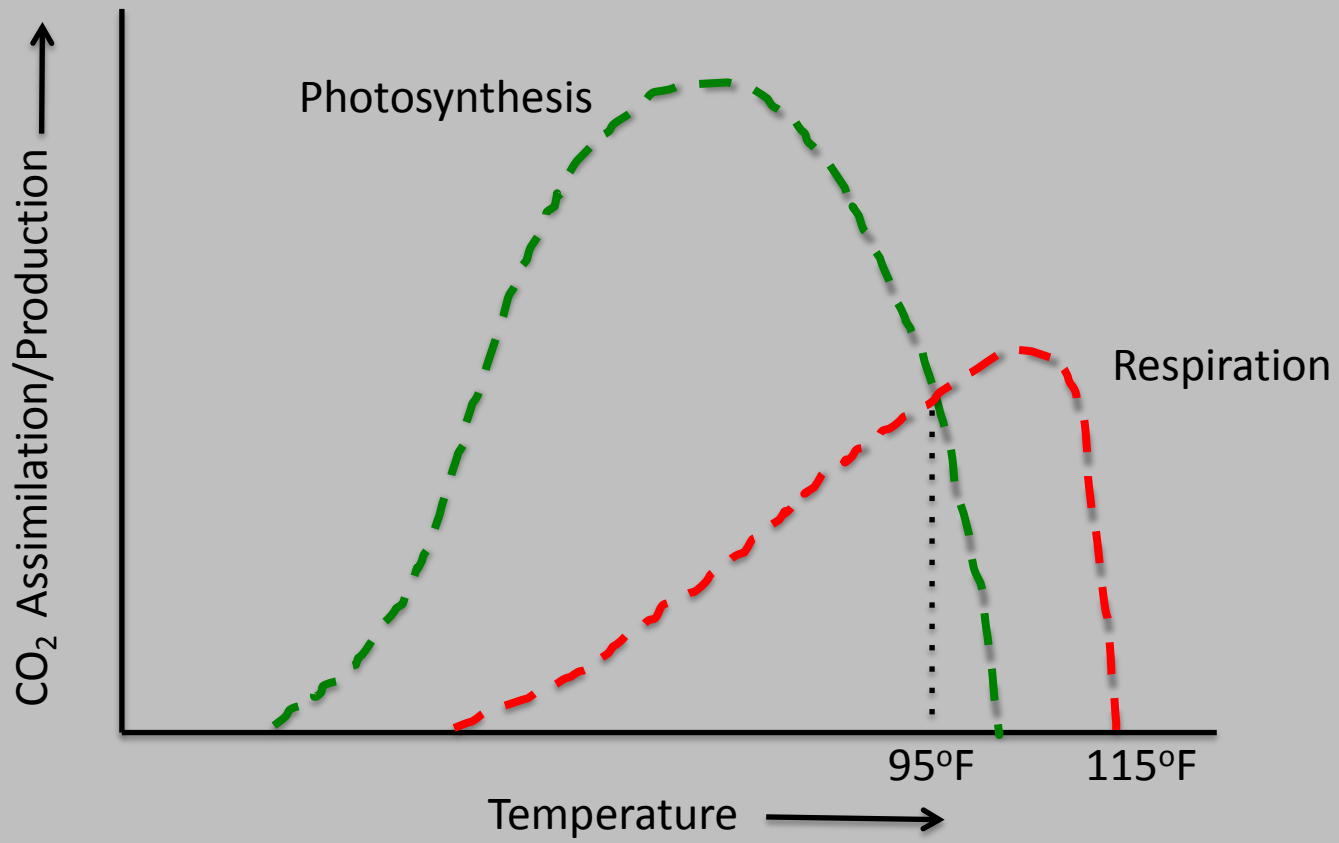
Photosynthesis and Temperature



Respiration and Temperature



Photosynthesis, Respiration, and Temperature



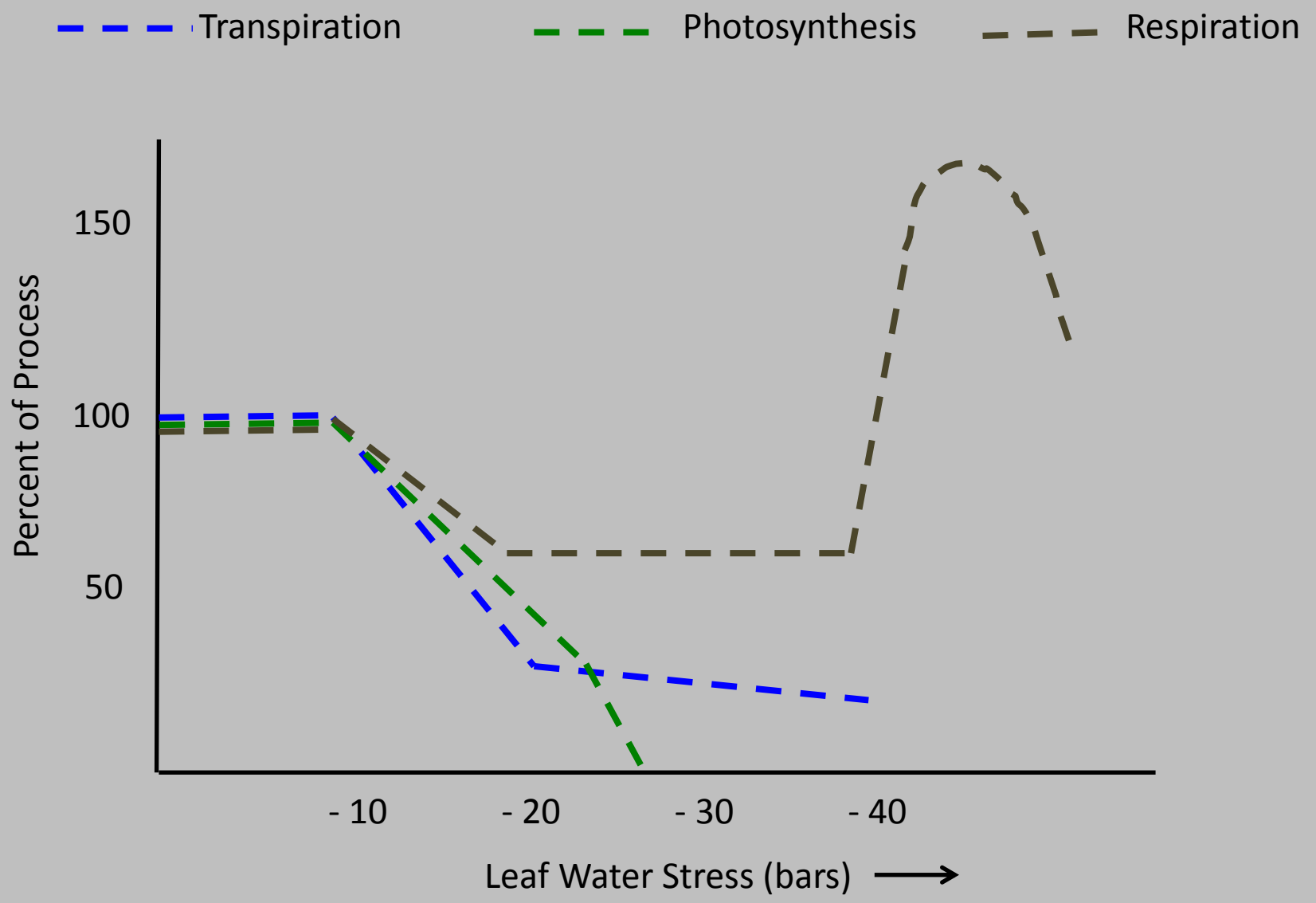
Heat Injury

Oak

Maple

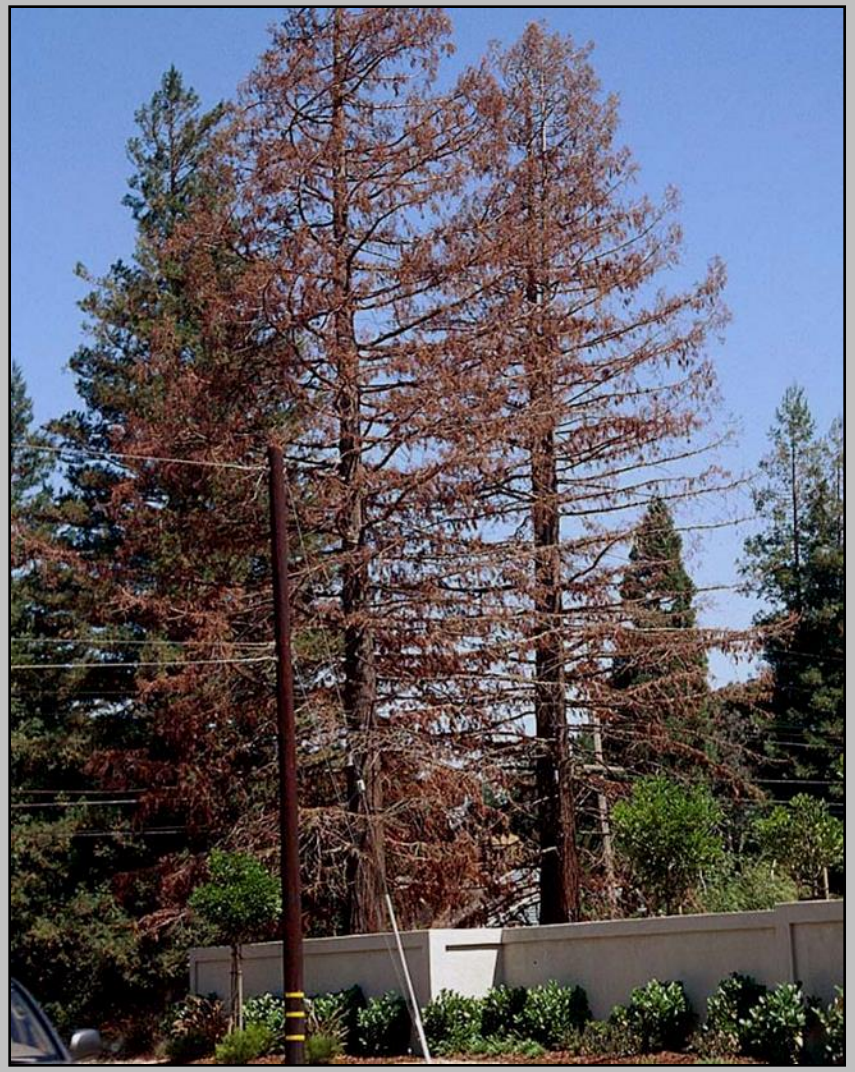
from: Michigan State University Extension (msue.anr.msu.edu)

Impact of Water Stress on Physiological Processes



Water Deficit Injury

Dogwood



Redwood

Loss of Tree Canopy

London Plane Trees – Berkeley

Tree Performance - Shading

drought stressed

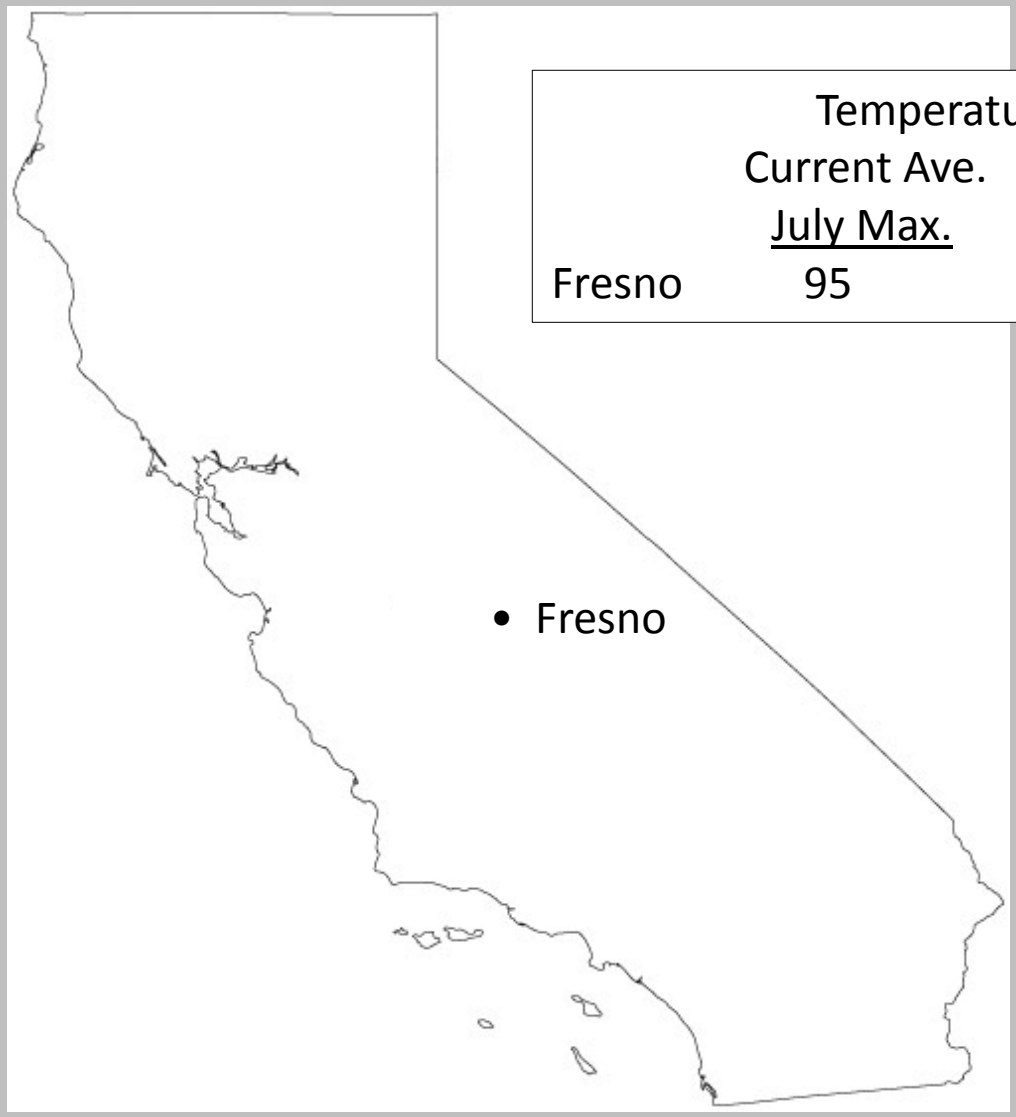
not drought stressed

Impacts of climate change on street trees in California

Conceptual Method

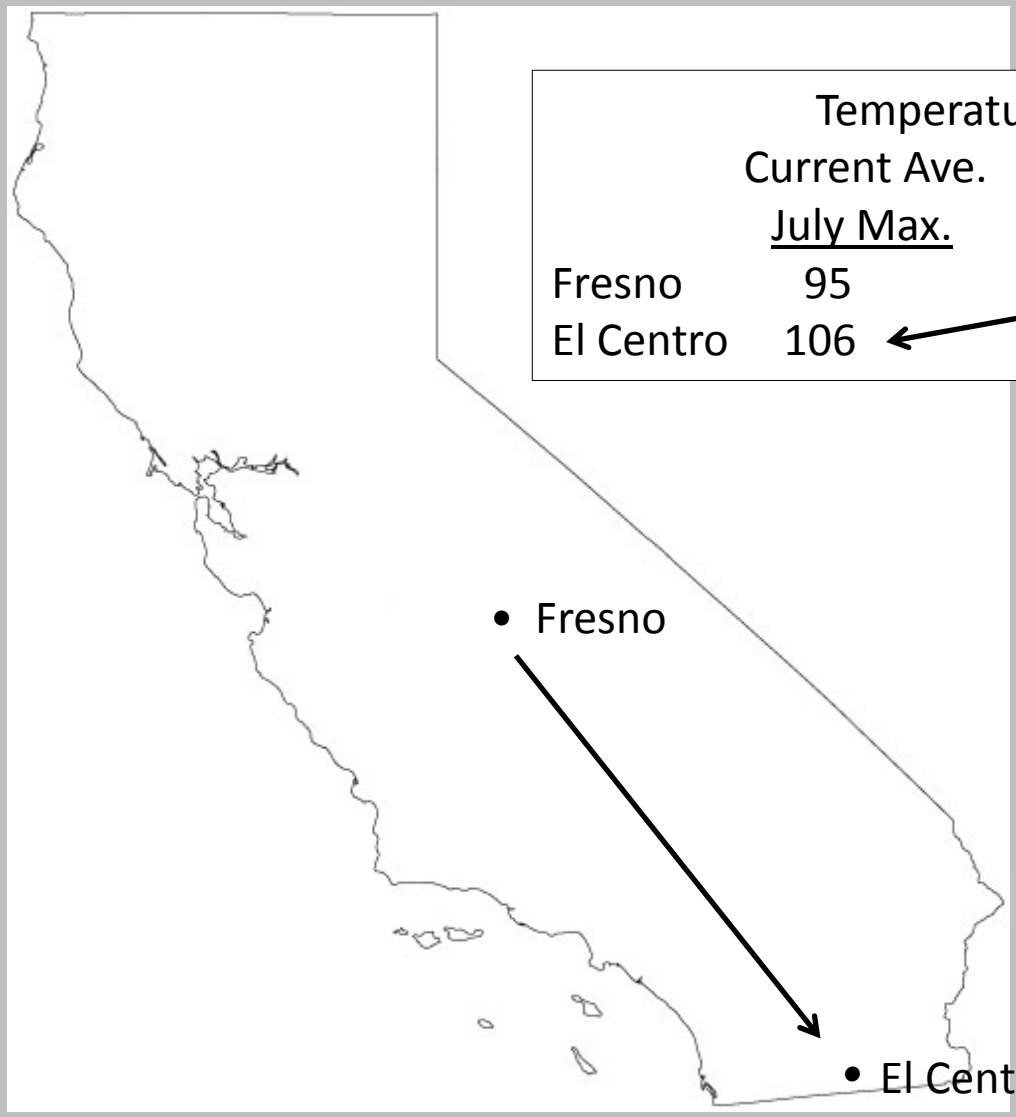
"substitution of space for time"

"substitution of space for time"



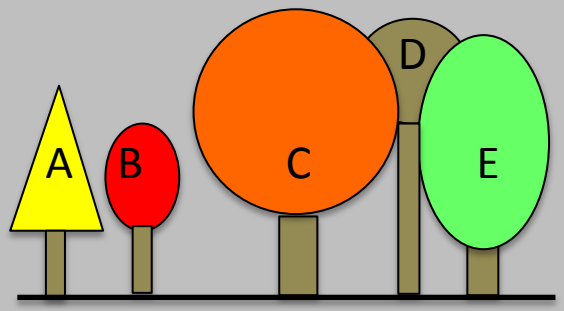
	Temperature ^{o}F	
	Current Ave. July Max.	Predicted Ave. July Max.
Fresno	95	108

"substitution of space for time"

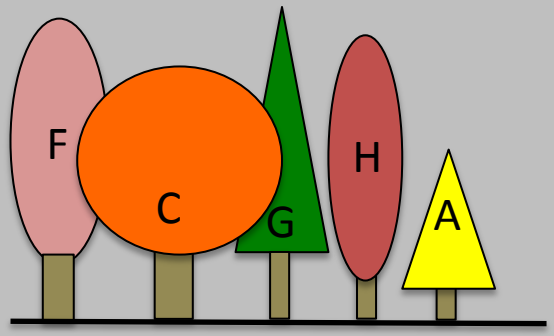


Urban Forest Composition

Fresno



El Centro

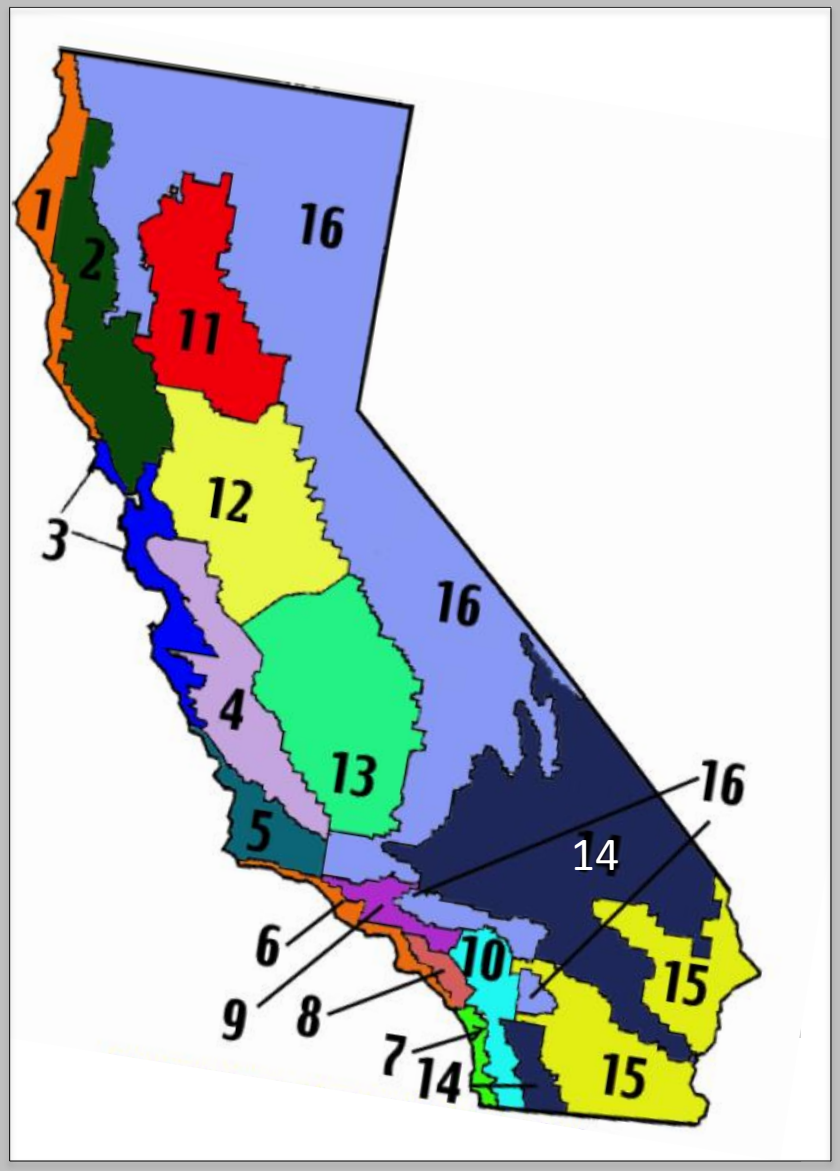


Conclusion: Three of the common street trees in Fresno (B, D, E) will be not survive or not be expected to perform well in Fresno when the temperature becomes as warm as the temperature in El Centro.

Steps in applying the *"substitution of space for time"*

1. Select an example cities
2. Select a comparison city
3. Compare the tree species

Climate Zones



Cities and Towns

Selection Criteria for Example Cities within each Climate Zone

1. Temperature

   near average for cities in climate zone

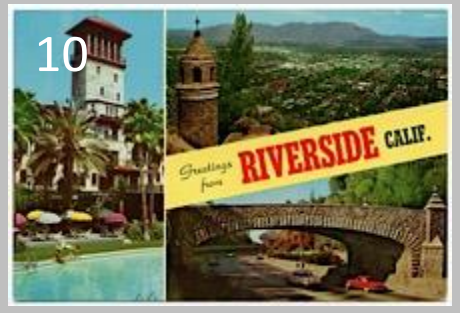
2. Size of City

   large enough to have 'ample' street tree population

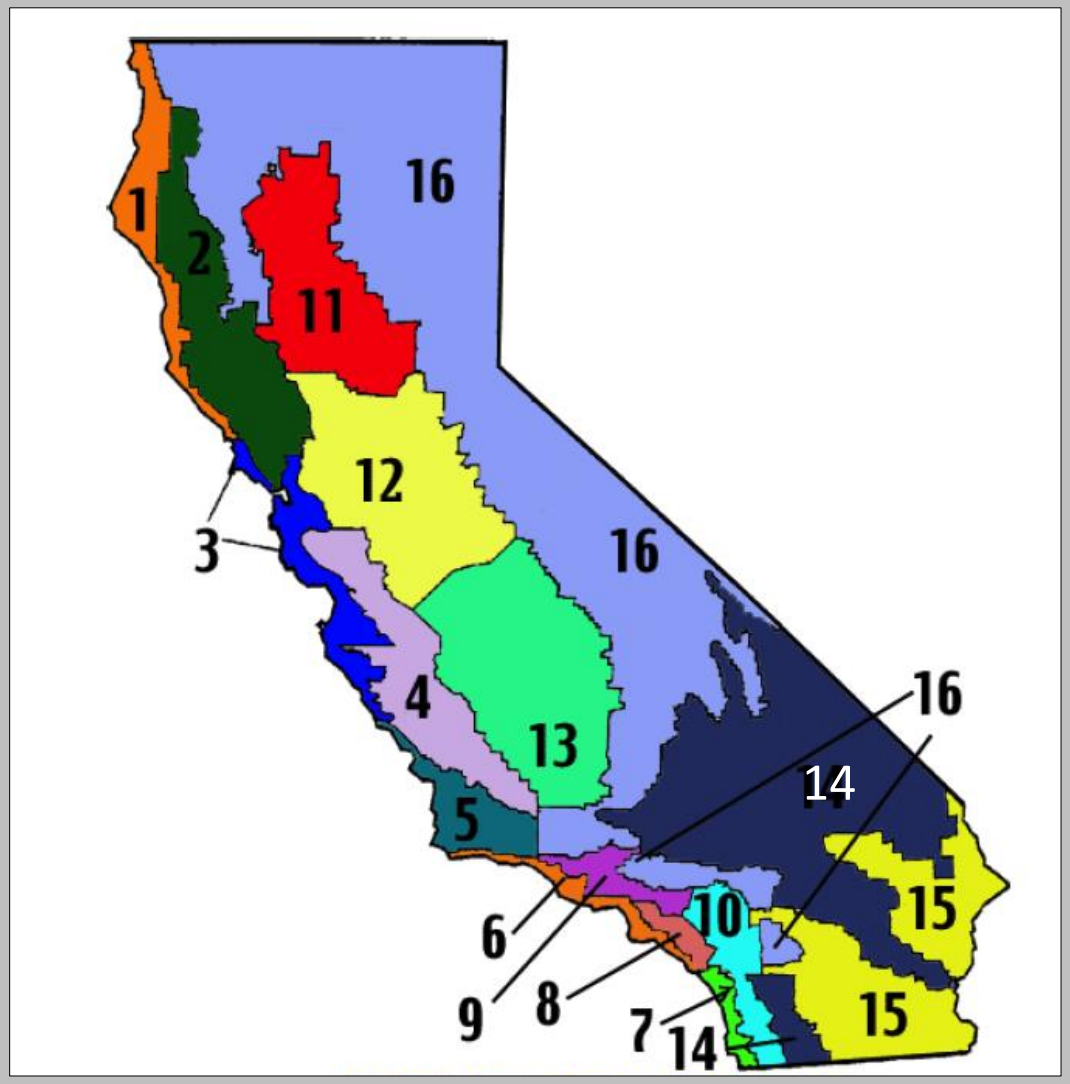
3. Geographic Location

   typical of the climatic zone

Example Cities for the 16 California Climate Zones



Cities Selected as Example Cities



Climate Zone	Example City
1	Eureka
2	Ukiah
3	Berkeley
4	King City
5	Santa Maria
6	Santa Monica
7	San Diego
8	Santa Ana
9	Burbank
10	Riverside
11	Yuba City
12	Stockton
13	Fresno
14	Barstow
15	El Centro
16	Susanville

Steps in Applying the *"substitution of space for time"* Method

1. Select an example cities
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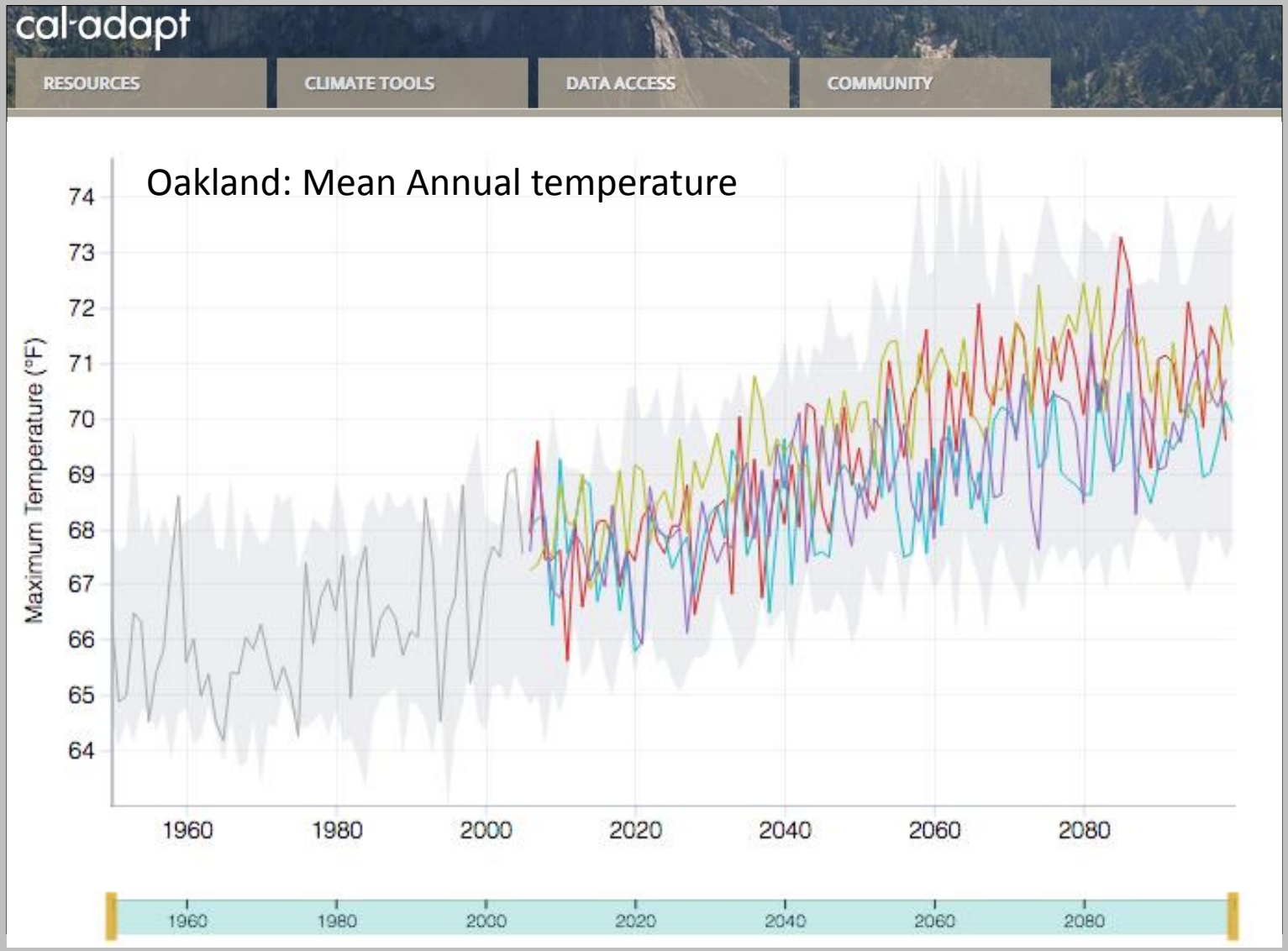
3. Compare the tree species

Historic July Average Maximum Temperatures

Climate Zone	Example City	Historic July Ave. Maximum Temp. (°F)
1	Eureka	61.9
2	Ukiah	89.7
3	Berkeley	70.3
4	King City	85.7
5	Santa Maria	76.3
6	Santa Monica	70.5
7	San Diego	74.0
8	Santa Ana	82.3
9	Burbank	86.2
10	Riverside	91.9
11	Yuba City	93.5
12	Stockton	90.4
13	Fresno	95.4
14	Barstow	99.5
15	El Centro	106.0
16	Susanville	88.7

from: Western Regional Climate Center

Predicted Weather Data



Predicted July Average Maximum Temperatures

Climate Zone	Example City	Predicted July Ave. Maximum Temp. (°F)
1	Eureka	68.9
2	Ukiah	96.2
3	Berkeley	80.4
4	King City	93.7
5	Santa Maria	80.4
6	Santa Monica	82.0
7	San Diego	83.8
8	Santa Ana	86.9
9	Burbank	95.2
10	Riverside	100.8
11	Yuba City	106.7
12	Stockton	101.7
13	Fresno	107.9
14	Barstow	112.5
15	El Centro	115.6
16	Susanville	97.7

from: http://cal-adapt.org/temperature/annual/

Historic and Predicted July Average Maximum Temperatures

Climate Zone	Example City	Historic July Ave. Maximum Temp. (°F)	Predicted July Ave. Maximum Temp. (°F)
1	Eureka	61.9	68.9
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4	King City	85.7	93.7
5	Santa Maria	76.3	80.4
6	Santa Monica	70.5	82.0
7	San Diego	74.0	83.8
8	Santa Ana	82.3	86.9
9	Burbank	86.2	95.2
10	Riverside	91.9	100.8
11	Yuba City	93.5	106.7
12	Stockton	90.4	101.7
13	Fresno	95.4	107.9
14	Barstow	99.5	112.5
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Selection of Comparison Cities

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6	Santa Monica	70.5	82.0
7	San Diego	74.0	83.8
8	Santa Ana	82.3	86.9
9	Burbank	86.2	95.2
10	Riverside	91.9	100.8
11	Yuba City	93.5	106.7
12	Stockton	90.4	101.7
13	Fresno	95.4	107.9
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7	San Diego	74.0	83.8
8	Santa Ana	82.3	86.9
9	Burbank	86.2	95.2
10	Riverside	91.9	100.8
11	Yuba City	93.5	106.7
12	Stockton	90.4	101.7
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7	San Diego	74.0	83.8
8	Santa Ana	82.3	86.9
9	Burbank	86.2	95.2
10	Riverside	91.9	100.8
11	Yuba City	93.5	106.7
12	Stockton	90.4	101.7
13	Fresno	95.4	107.9
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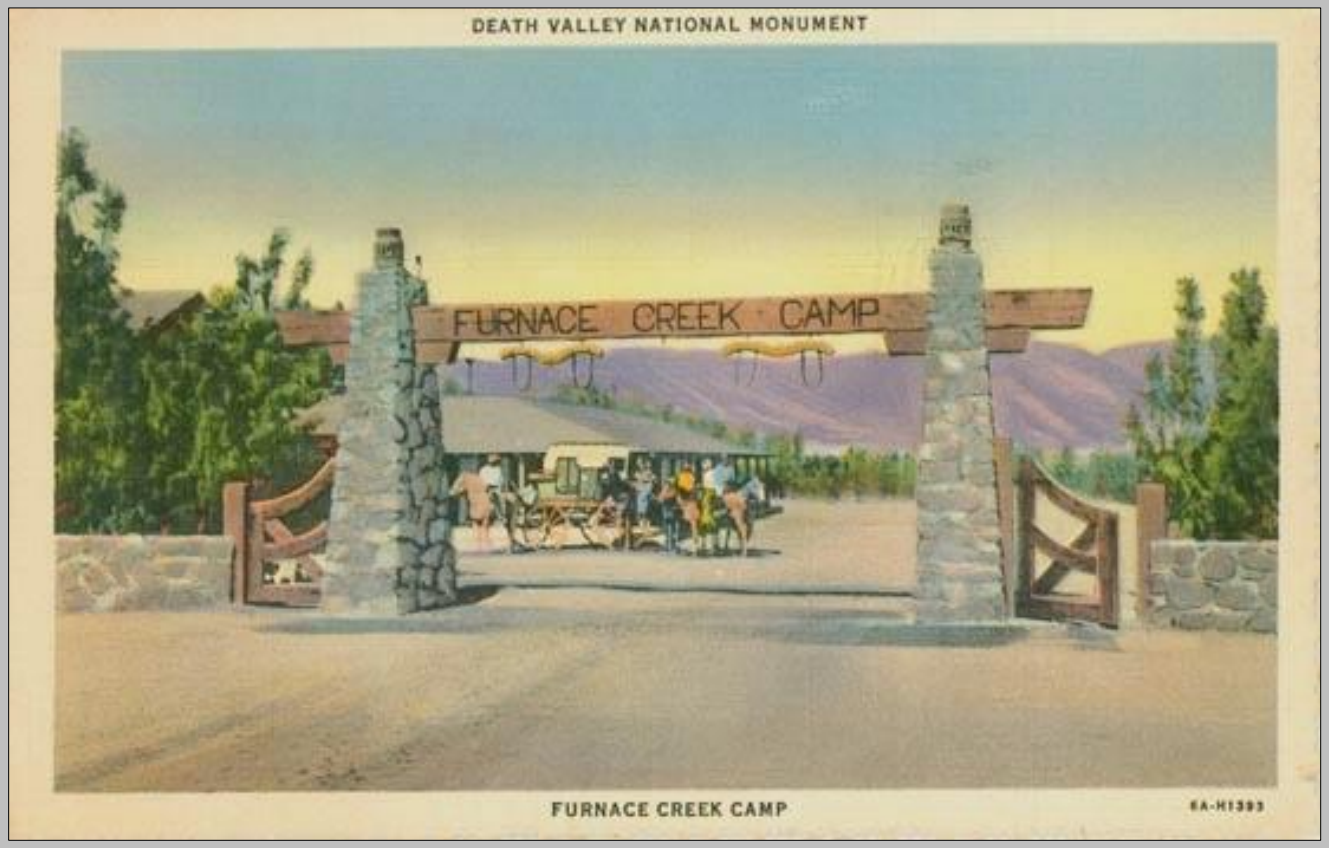
15	El Centro	106.0	115.6
16	Susanville	88.7	97.7

?

from: http://cal-adapt.org/temperature/annual/

Furnace Creek



Average July Maximum Temperature = 116^{o}F

Example Cities and Comparison Cities

Climate Zone	Example City	"Warm" City
1	Eureka	Berkeley
2	Ukiah	Fresno
3	Berkeley	Santa Ana
4	King City	Stockton
5	Santa Maria	Santa Ana
6	Santa Monica	King City
7	San Diego	Santa Ana
8	Santa Ana	Burbank
9	Burbank	Fresno
10	Riverside	Barstow
11	Yuba City	El Centro
12	Stockton	Barstow
13	Fresno	El Centro
14	Barstow	El Centro
15	El Centro	Furnace Creek
16	Susanville	Barstow

Steps in Applying the *"substitution of space for time"* Method

1. Select an example cities
2. Select a comparison city
3. Compare the tree species

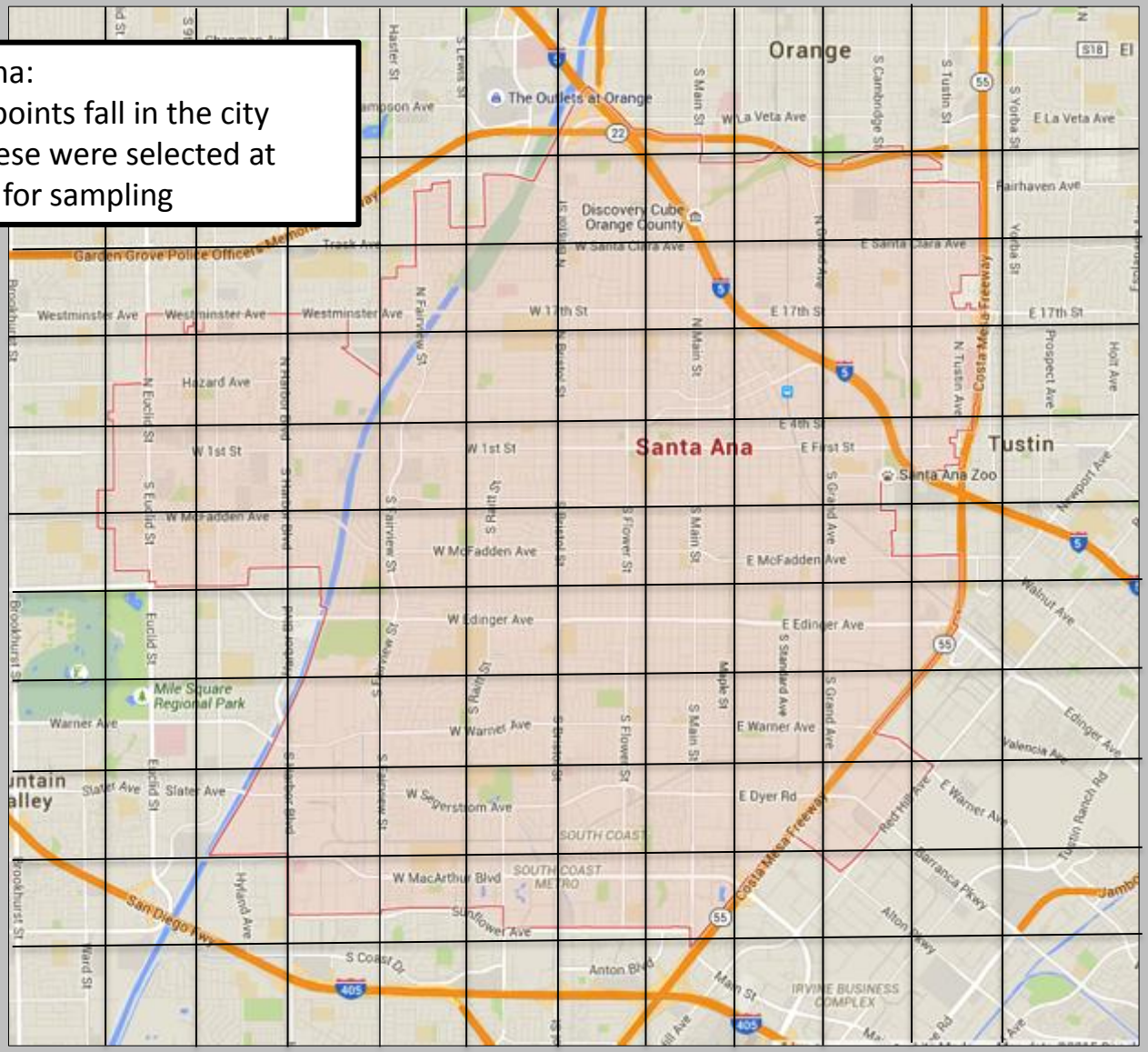
Street Tree Survey

From: C. M. Highsmith

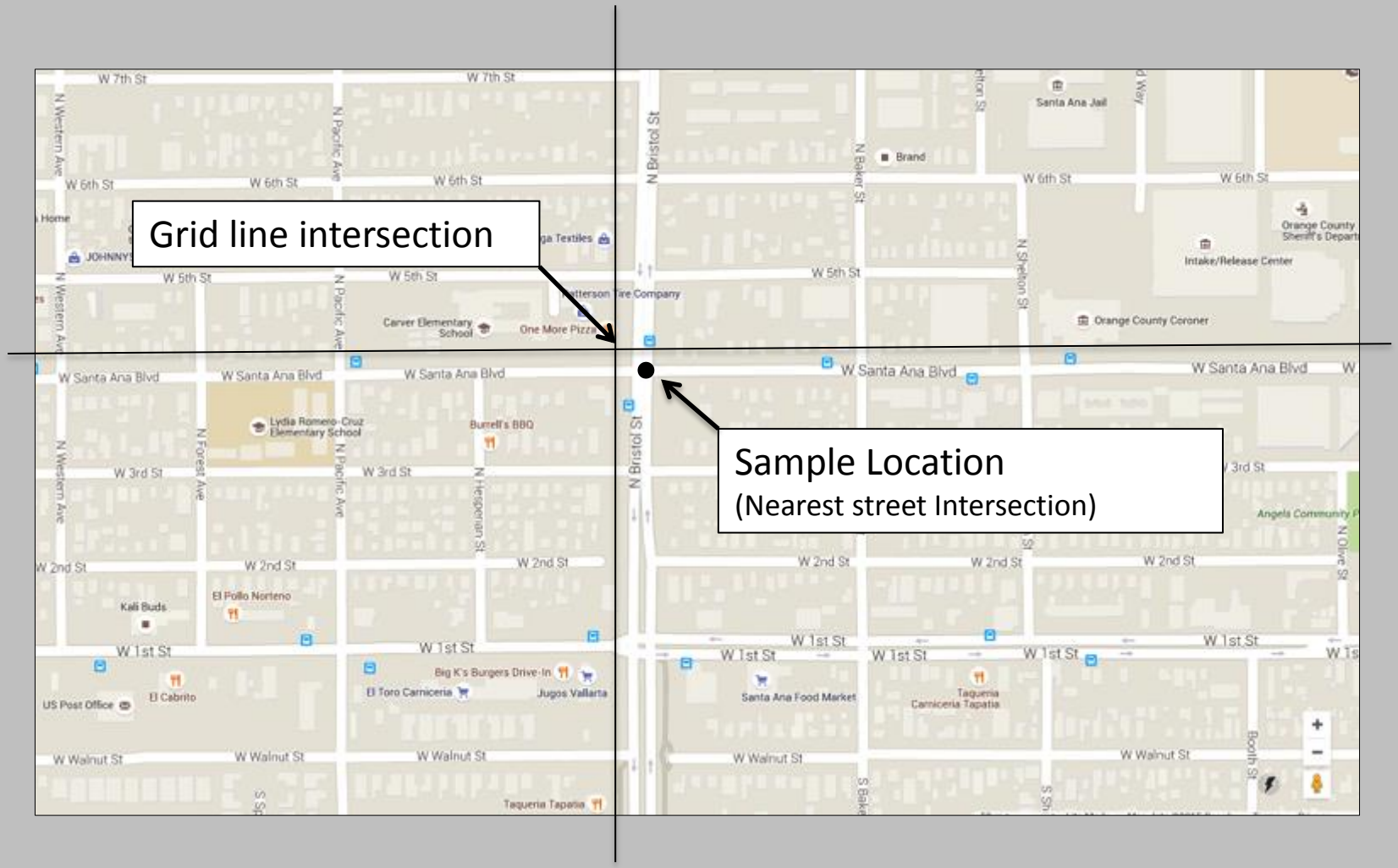
Street Tree Survey – Santa Ana

Locations of Sample Plots (10 x 10 grid)

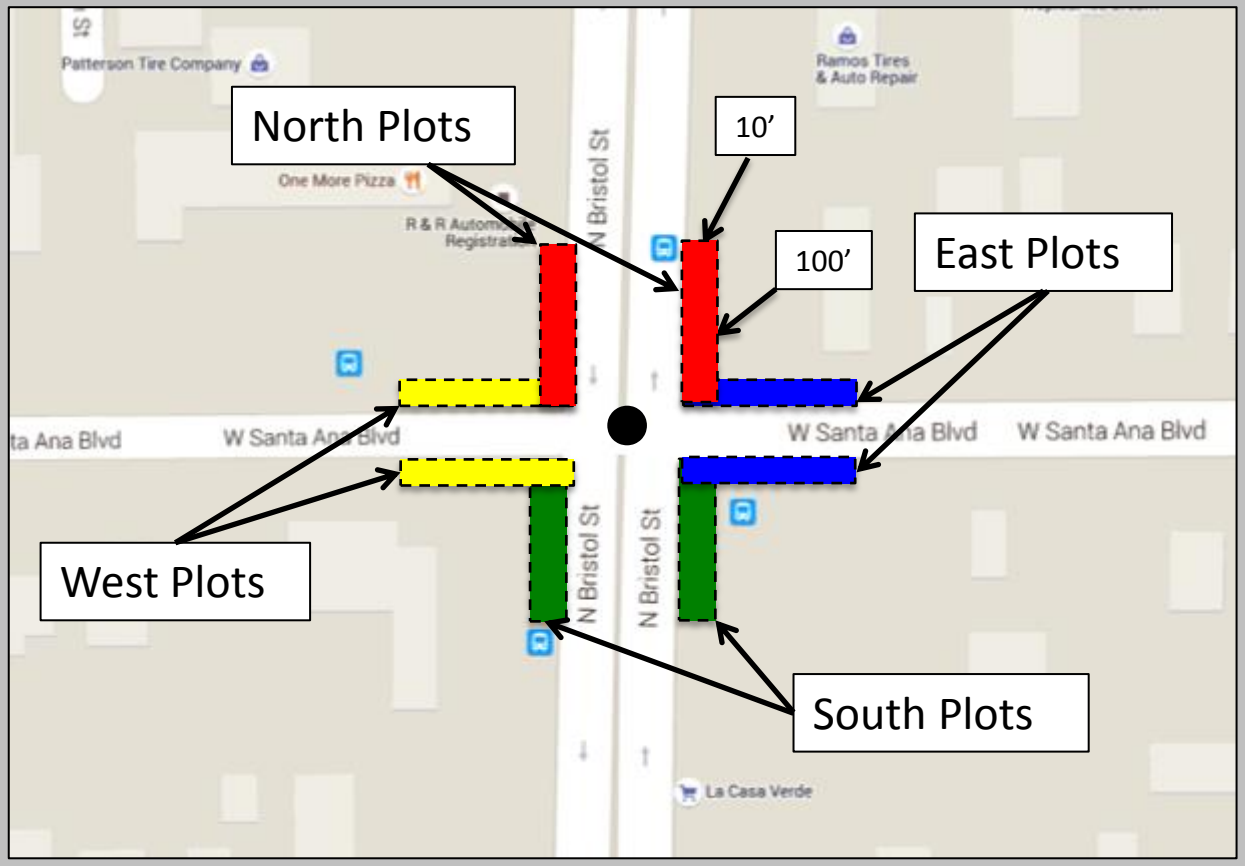
Santa Ana:
59 grid points fall in the city
50 of these were selected at random for sampling

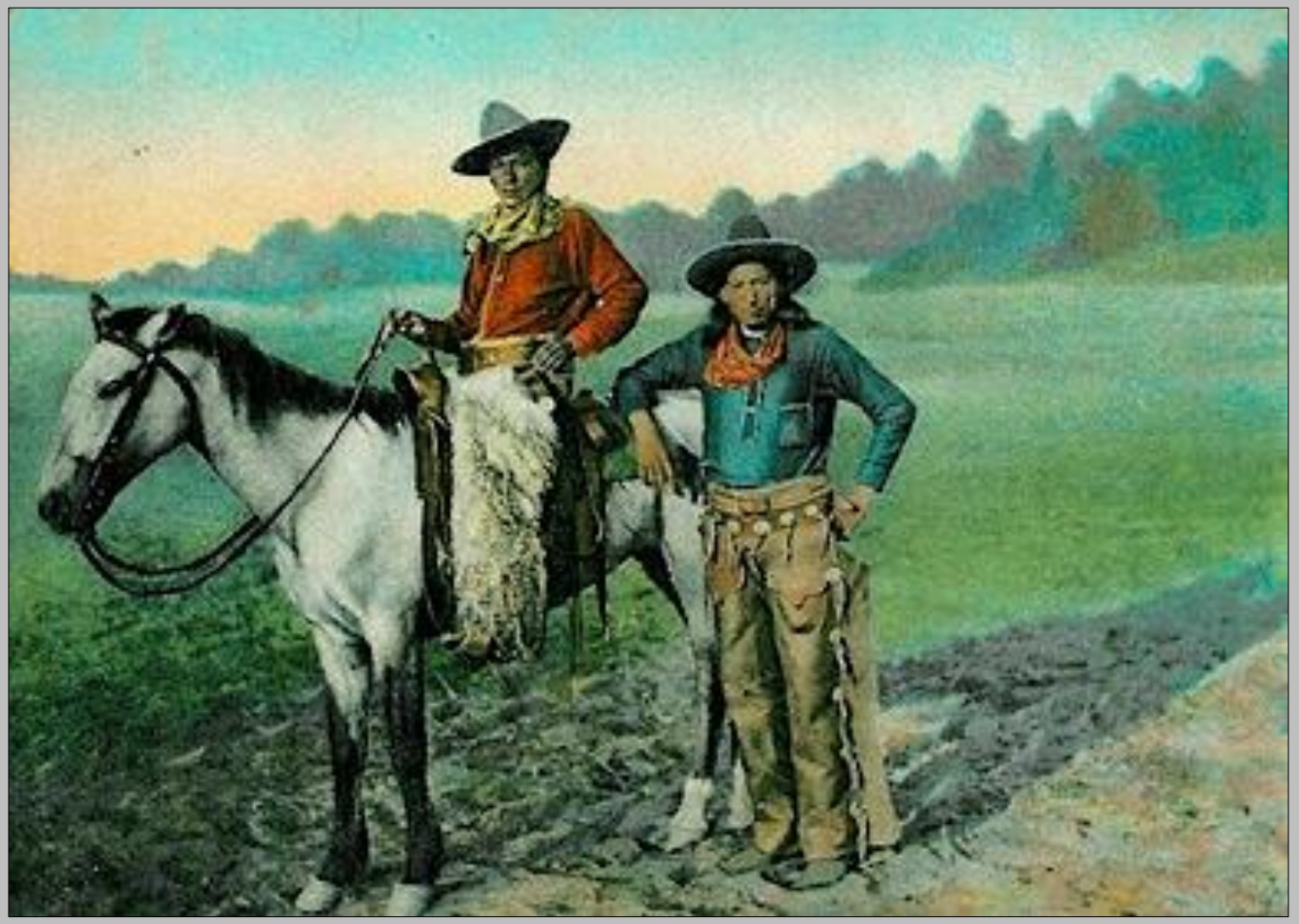


Sample Location



Arrangement of Sample Plots





McBride and Lacan off to survey the street trees of California

Number of Tree Species

Climate Zone	Example City	Number of Species
1	Eureka	56
2	Ukiah	85
3	Berkeley	71
4	King City	55
5	Santa Maria	49
6	Santa Monica	68
7	San Diego	63
8	Santa Ana	42
9	Burbank	47
10	Riverside	62
11	Yuba City	79
12	Stockton	65
13	Fresno	57
14	Barstow	31
15	El Centro	28
16	Susanville	57

Most Common Species in each Example City

Purple Leaf Plum
(Eureka)

London Plane Tree
(Ukiah)

Sweetgum
(Berkeley)

London Plane Tree
(King City)

Southern Magnolia
(Santa Maria)

Moreton Bay Fig
(Santa Monica)

Mexican Fan Palm
(San Diego)

London Plane Tree
(Santa Ana)

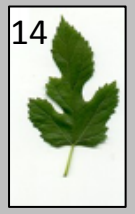
Crape Myrtle
(Burbank)

Mexican Fan Palm
(Riverside)

Redwood
(Yuba City)

London Plane Tree
(Stockton)

Crape Myrtle
(Fresno)



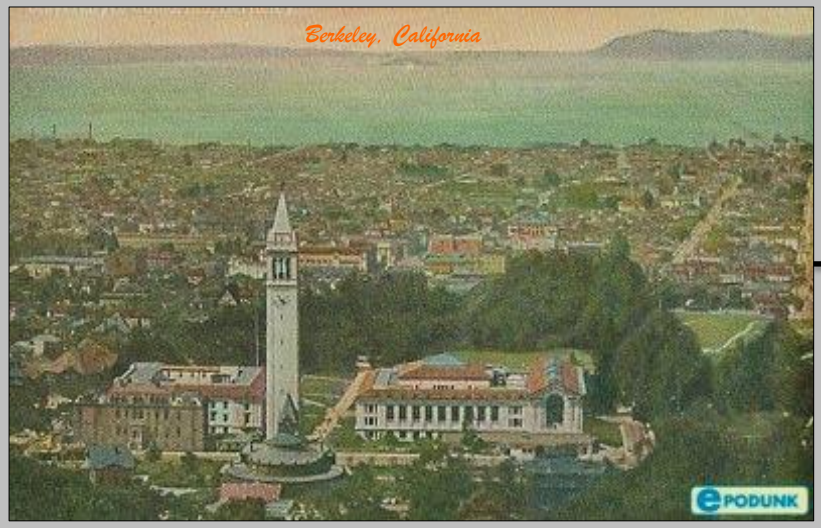
White Mulberry
(Barstow)

Silver Wattle
(El Centro)

Siberian Elm
(Susanville)

Climate Zone 3

Example City = Berkeley



Comparison City = Santa Ana

City	July Average Max. Temp (°F) Historic	Predicted
Berkeley	70.3	80.4
Santa Ana	82.3	86.9

Common Berkeley street trees and their occurrence in Santa Ana

Common Name	Example City Zone #3	Warm City
	Berkeley	Santa Ana
Black locust	+	-
Bradford pear	+	+
Callery pear	+	+
Camphor tree	+	+
Chinese elm	+	-
Chinese pistache	+	-
Evergreen ash	+	+
London plane tree	+	+
Purple leaf plum	+	-
Southern magnolia	+	+
Sweetgum	+	+
Trident maple	+	-

Common Berkeley street trees and their occurrence in Santa Ana and warmer cities

Common Name	Example City Zone #3	Warm City	Warmer Cities
	Berkeley	Santa Ana	
Black locust	+	-	+ (Yuba City, Stockton, Fresno, Susanville)
Bradford pear	+	+	+ (Burbank, Riverside, Yuba City, Stockton, Fresno)
Callery pear	+	+	+ (King City, Burbank, Riverside, Yuba City, Fresno)
Camphor tree	+	+	+ (King City, Burbank, Riverside, Yuba City, Stockton, Fresno)
Chinese elm	+	-	+ (King City, Burbank, Riverside, Yuba City, Stockton, Fresno, Barstow)
Chinese pistache	+	-	+ (King City, Riverside, Yuba City, Fresno, Barstow)
Evergreen ash	+	+	+ (King City, Burbank, Riverside, Yuba City, Stockton, Barstow, Susanville)
London plane tree	+	+	+ (King City, Burbank, Riverside, Yuba City, Stockton, Fresno, Susanville)
Purple leaf plum	+	-	+ (King City, Burbank, Yuba City, Stockton, Fresno, Barstow, Susanville)
Southern magnolia	+	+	+ (King City, Burbank, Riverside, Yuba City, Stockton, Fresno)
Sweetgum	+	+	+ (King City, Burbank, Riverside, Yuba city, Stockton, Fresno)
Trident maple	+	-	+ (Yuba City)

Conclusion

The common street trees in Berkeley will survive and can be expected to perform well as the climate becomes warmer

Sweetgum

Evergreen Ash

London Plane Tree

Purple Leaf Plum

Chinese Pistache

Camphor Tree

Black Locust

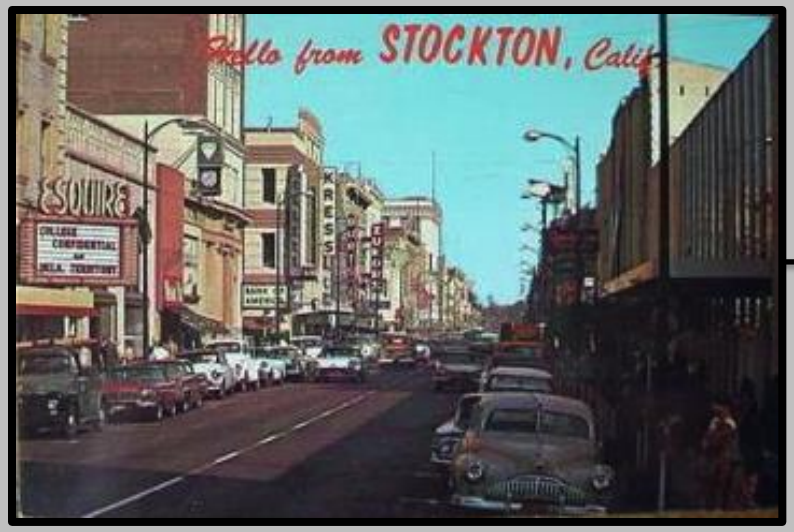
Bradford Pear

Southern Magnolia

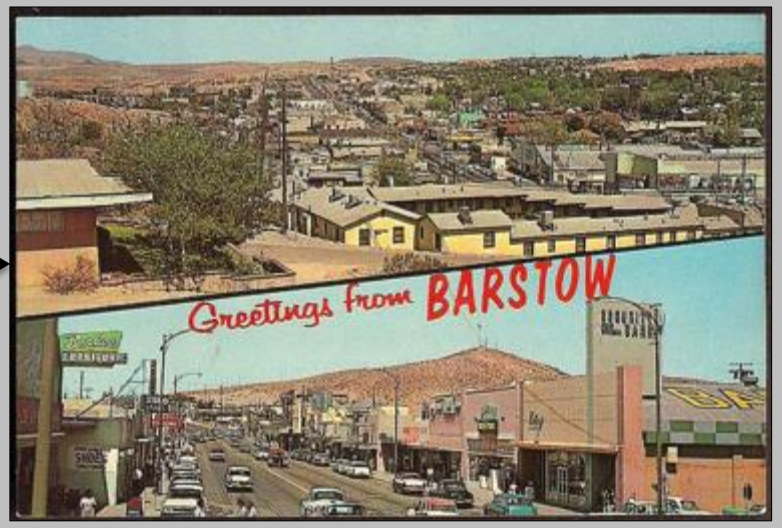
Chinese elm

Climate Zone 12

Example City = Stockton



Comparison City = Barstow



	July Average Max. Temp (°F)	
City	Historic	Predicted
Stockton	90.4	101.7
Barstow	99.5	112.5

Common Stockton street trees and their occurrence in Barstow

Common Name	Example City Zone #12	Warm City
	Stockton	Barstow
Bradford pear	+	-
Chinese elm	+	+
Chinese pistache	+	+
Common Hackberry	+	-
Crape myrtle	+	+
Evergreen ash	+	+
London plane tree	+	-
Modesto ash	+	+
Purple leaf plum	+	+
Sweetgum	+	-

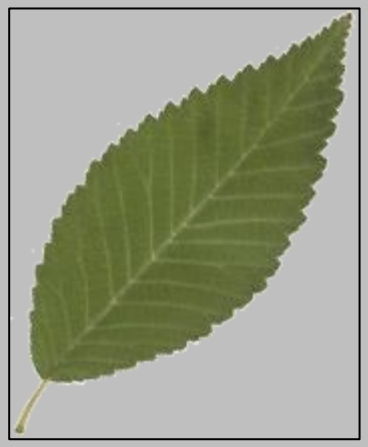
Common Stockton street trees and their occurrence in Barstow and warmer cities

Common Name	Example City Zone #12	Warm City	Warmer Cities	
	Stockton	Barstow	El Centro	Furnace Creek
Bradford pear	+	-	-	-
Chinese elm	+	+	-	-
Chinese pistache	+	+	-	-
Common Hackberry	+	-	-	-
Crape myrtle	+	+	-	-
Evergreen ash	+	+	-	-
London plane tree	+	-	-	-
Modesto ash	+	+	+	-
Purple leaf plum	+	+	-	-
Sweetgum	+	-	-	-

Conclusion

Four of the common street trees in Stockton will not survive or not perform well as the climate becomes warmer

Bradford Pear



Chinese Elm

Chinese Pistache

Common Hackberry

Crape Myrtle

Evergreen Ash

London Plane Tree

Modesto Ash

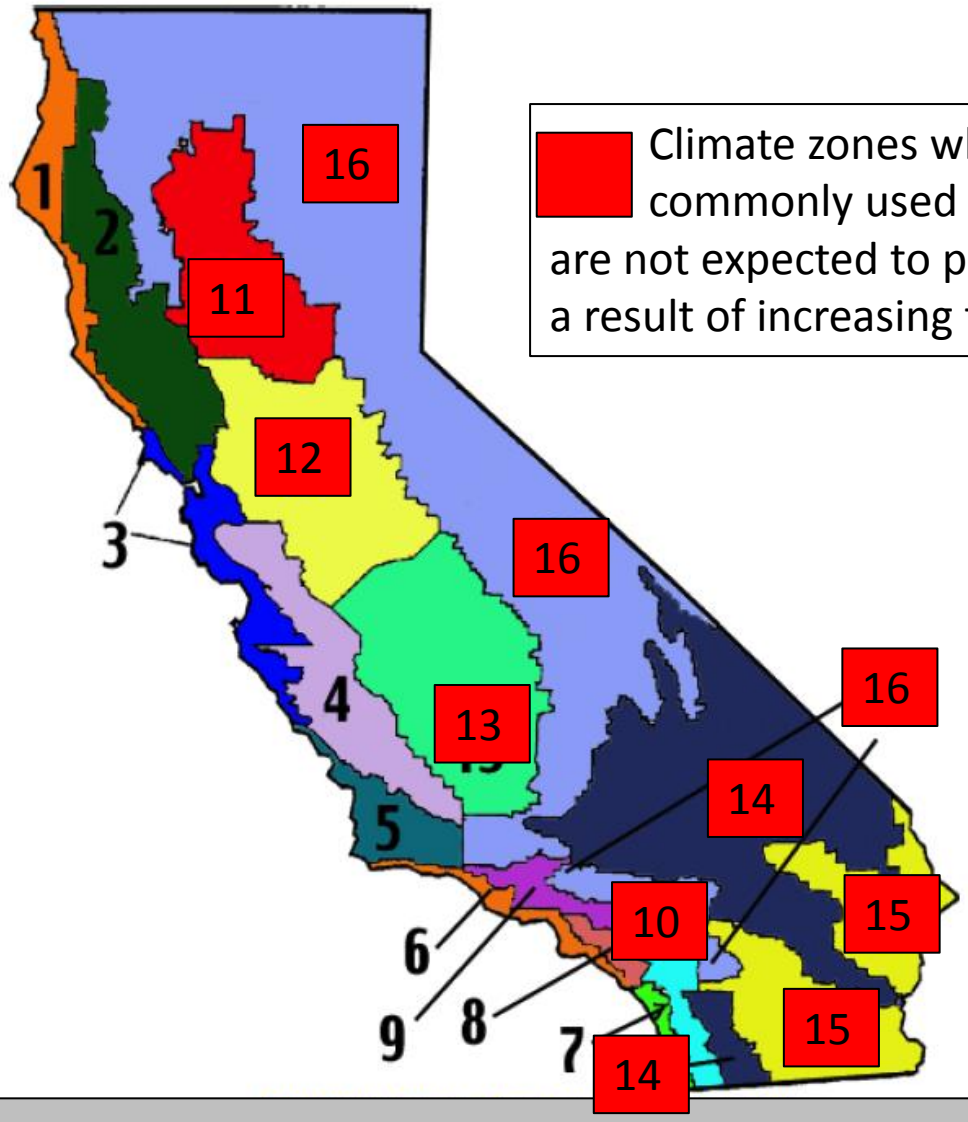
Purple leaf plum

Sweetgum

Results for the Climate Zones

Climate Zone	Example City	Comparison City	Common Species not in Comparison City or "Warmer cities"	
			(#)	(%)
1	Eureka	Berkeley	0	0
2	Ukiah	Fresno	0	0
3	Berkeley	Santa Ana	0	0
4	King City	Stockton	0	0
5	Santa Maria	Santa Ana	0	0
6	Santa Monica	King City	0	0
7	San Diego	Santa Ana	0	0
8	Santa Ana	Burbank	0	0
9	Burbank	Fresno	0	0
10	Riverside	Barstow	8	61.5
11	Yuba City	El Centro	9	90
12	Stockton	Barstow	4	40
13	Fresno	El Centro	12	80
14	Barstow	El Centro	4	40
15	El Centro	Furnace Creek	7	70
16	Susanville	Barstow	4	40

California Climate Zones



Climate zones where some commonly used street trees are not expected to perform well as a result of increasing temperature

Climate Zone	Example City
1	Eureka
2	Ukiah
3	Berkeley
4	King City
5	Santa Maria
6	Santa Monica
7	San Diego
8	Santa Ana
9	Burbank
10	Riverside
11	Yuba City
12	Stockton
13	Fresno
14	Barstow
15	El Centro
16	Susanville

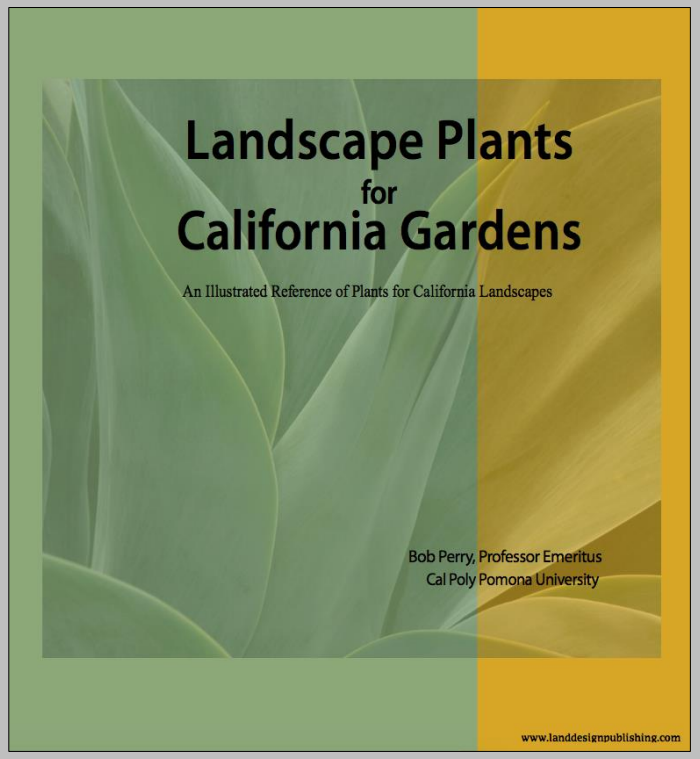
Questions regarding the absence of tree species in comparison cities

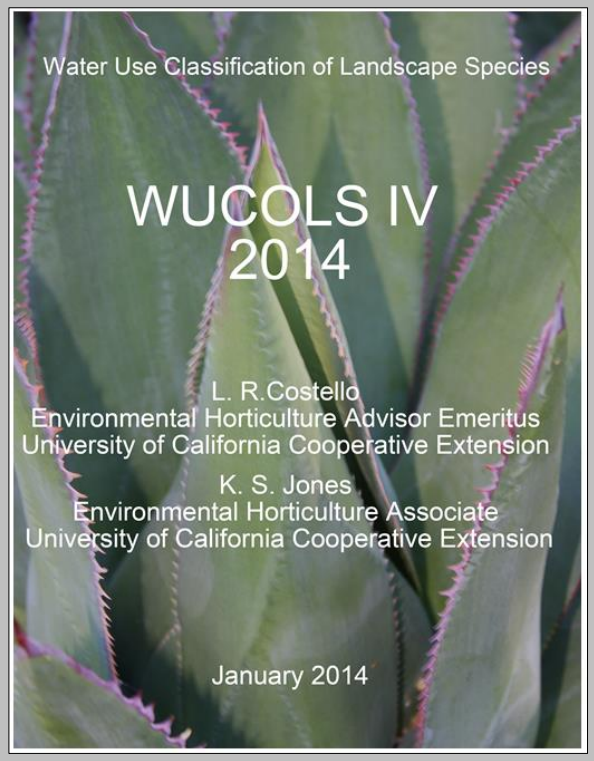
1. Could the absence of a species in a comparison city be do to a factor other than temperature?

2. How should decreasing available moisture (decreased rainfall and decreased snowpack) be taken into account?

Answering the Questions

1. Interviews with local experts
2. Checked the suitability of the species to grow in the predicted climatic (Perry)
3. Checked the water needs of the species (WUCOLS)

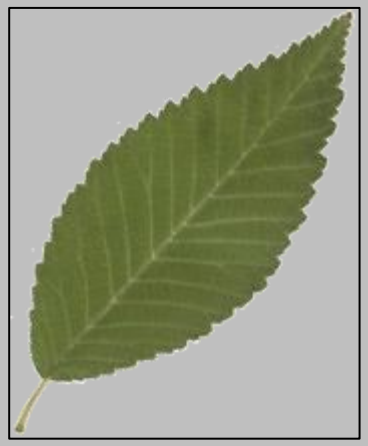




Example - Stockton

Common Street Tree Species in Stockton

Bradford Pear



Chinese Elm

Chinese Pistache

Common Hackberry

Crape Myrtle

Evergreen Ash

London Plane Tree

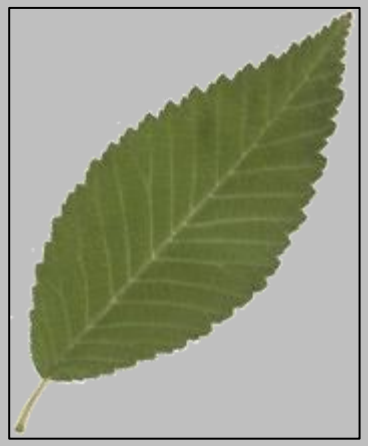
Modesto Ash

Purple-leaf Plum

Sweetgum

Stockton trees not found in comparison city or warmer cities

Bradford Pear



Chinese Elm

Chinese Pistache

Common Hackberry

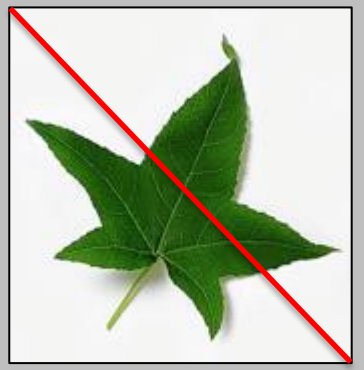
Crape Myrtle

Evergreen Ash

London Plane Tree

Modesto Ash

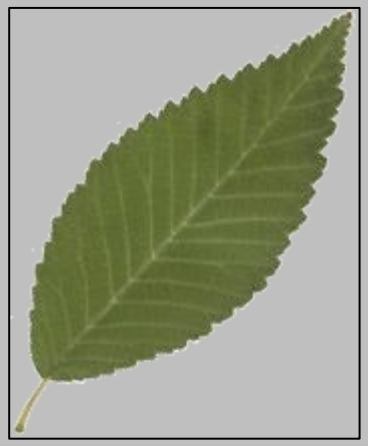
Purple-leaf Plum



Sweetgum

Stockton trees not suitable for the future climate of Stockton according to local experts

Bradford Pear


Chinese Elm


Chinese Pistache


Common Hackberry


Crape Myrtle


Evergreen Ash

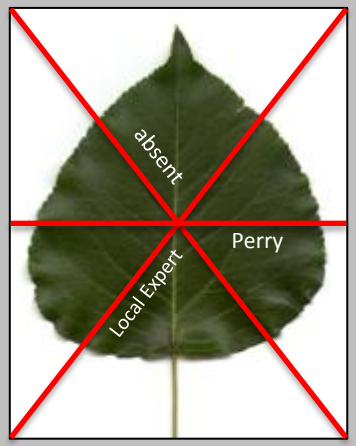

London Plane Tree


Modesto Ash

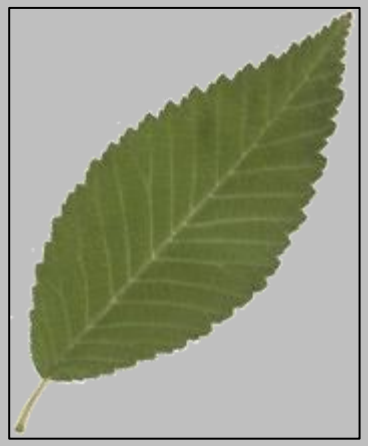

Purple-leaf Plum


Sweetgum

Stockton trees not suitable for the future climate of Stockton according to Perry (2010)



Bradford Pear



Chinese Elm

Chinese Pistache

Common Hackberry
Perry = OK

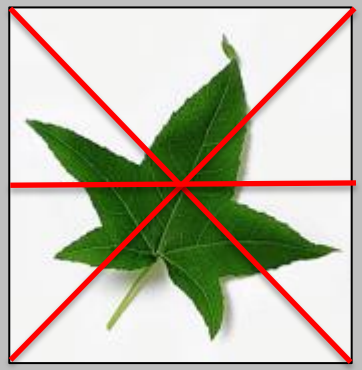
Crape Myrtle

Evergreen Ash
Perry = OK

London Plane Tree

Modesto Ash

Purple-leaf Plum

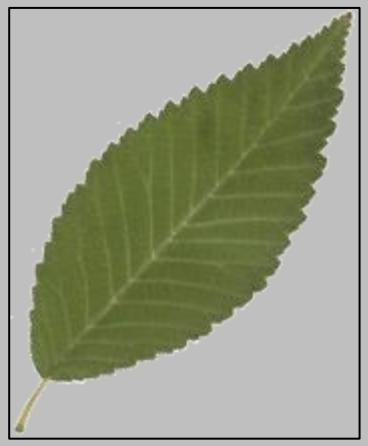


Sweetgum

Irrigation Requirement and Drought Tolerance

Bradford Pear

IR[1]: M



Chinese Elm

M/L

Chinese Pistache

M/L

Common Hackberry

M/L

Crape Myrtle

M/L

Evergreen Ash

IR[1]: M

London Plane Tree

M/H

Modesto Ash

M

Purple-leaf Plum

M

Sweetgum

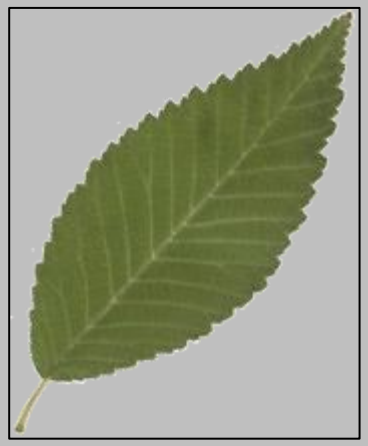
M

[1] Irrigation Requirement: M/H = medium to high, M = medium, M/L = medium to low (from WUCOLS IV, 2014)

Stockton trees not suitable for the future climate of Stockton according to water requirements

Bradford Pear

IR[1]: M



Chinese Elm

M/L

Chinese Pistache

M/L

Common Hackberry

M/L

Crape Myrtle

M/L

Evergreen Ash

IR[1]: M

London Plane Tree

M/H

Modesto Ash

M

Purple-leaf Plum

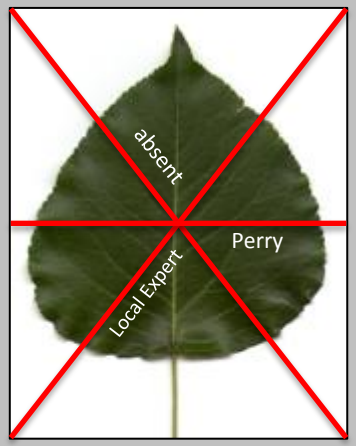
M

Sweetgum

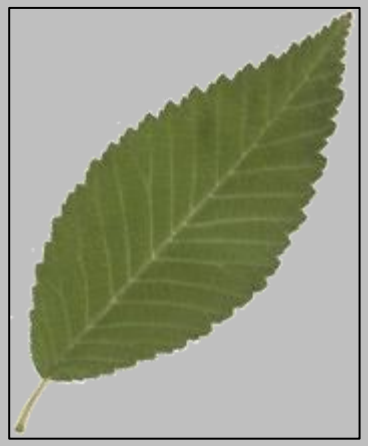
M

[1] Irrigation Requirement: M/H = medium to high, M = medium, M/L = medium to low (from WUCOLS IV, 2014)

Stockton trees not suitable for the future climate



Bradford Pear



Chinese Elm

Chinese Pistache

Common Hackberry

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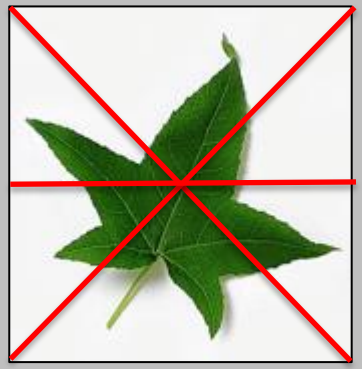
London Plane Tree

Modesto Ash

Purple-leaf Plum



Sweetgum

Incorporation of Information from Local Experts, Perry, and WUCOLS

ClimateZone/ Example City	Number of Trees						
	Common Street Trees[1]	Found in Comparison City[2]	Initial List (trees not expected to perform well	Keep (+) or Remove (-) from Initial List			Final List (trees not expected to perform well)
				Local Experts	Perry	WUCOLS	
1. Eureka	28	28	0	0	0	0	0
2. Ukiah	24	15	9	0	-6	0	0
3. Berkeley	20	18	2	0	-2	0	0
4. King City	25	23	2	0	-1	0	0
5. Santa Monica	14	23	1	0	-1	0	0
6. Santa Maria	17	17	0	0	0	0	0
7. San Diego	25	25	0	0	0	0	0
8. Santa Ana	12	12	0	0	0	0	0
9. Burbank	23	15	8	0	-1	0	0
10. Riverside	16	5	11	-6	-1	+1	6
11. Yuba City	15	0	15	-10	-6	+2	7
12. Stockton	10	6	4	0	-2 *	+1	5
13. Fresno	32	13	19	-8	-1	+1	12
14. Barstow	15	6	9	-5	-6	0	4
15. El Centro	10	3	7	0	-3	0	7
16. Susanville	34	0	34	-30	-5	-5	4

[1] based on the top ten frequencies of occurrence; [2] and warmer cities

* Perry's conclusion disregarded in favor of local experts

Species not expected to perform well

Climate Zone:	10	11	12	13	14	15	16
Species/City	Riverside	Yuba City	Stockton	Fresno	Barstow	El Centro	Susanville
Allepo pine					✖		
Apple							✖
Australian willow						✖	
Black cottonwood							✖
Bradford pear			✖	✖			
Canary Island pine	✖			✖			
Chinaberry					✖		
Chinese elm				✖	✖		
Chinese pistache		✖		✖			
Common hackberry			✖				
Crape myrtle				✖			
Darlington oak				✖			
Deodar cedar				✖			
Evergreen ash			✖				
Fern pine				✖			
Gingko				✖			
Golden chain tree	✖						
Honey locust							✖
Indian laurel fig						✖	
Lemon scented gum						✖	
London plane tree	✖	✖	✖				
Modesto ash						✖	
Norway spruce							✖
Orange	✖						
Purple leaf plum		✖		✖			
Raywood ash	✖			✖			
Redwood		✖					
Siberian elm						✖	
Silver dollar eucalyptus						✖	
Silver wattle						✖	
Southern magnolia	✖	✖					
Sweetgum		✖	✖	✖			
White mulberry		✖			✖		
Total	6	7	5	12	4	7	4

Consequence of Climate Change:

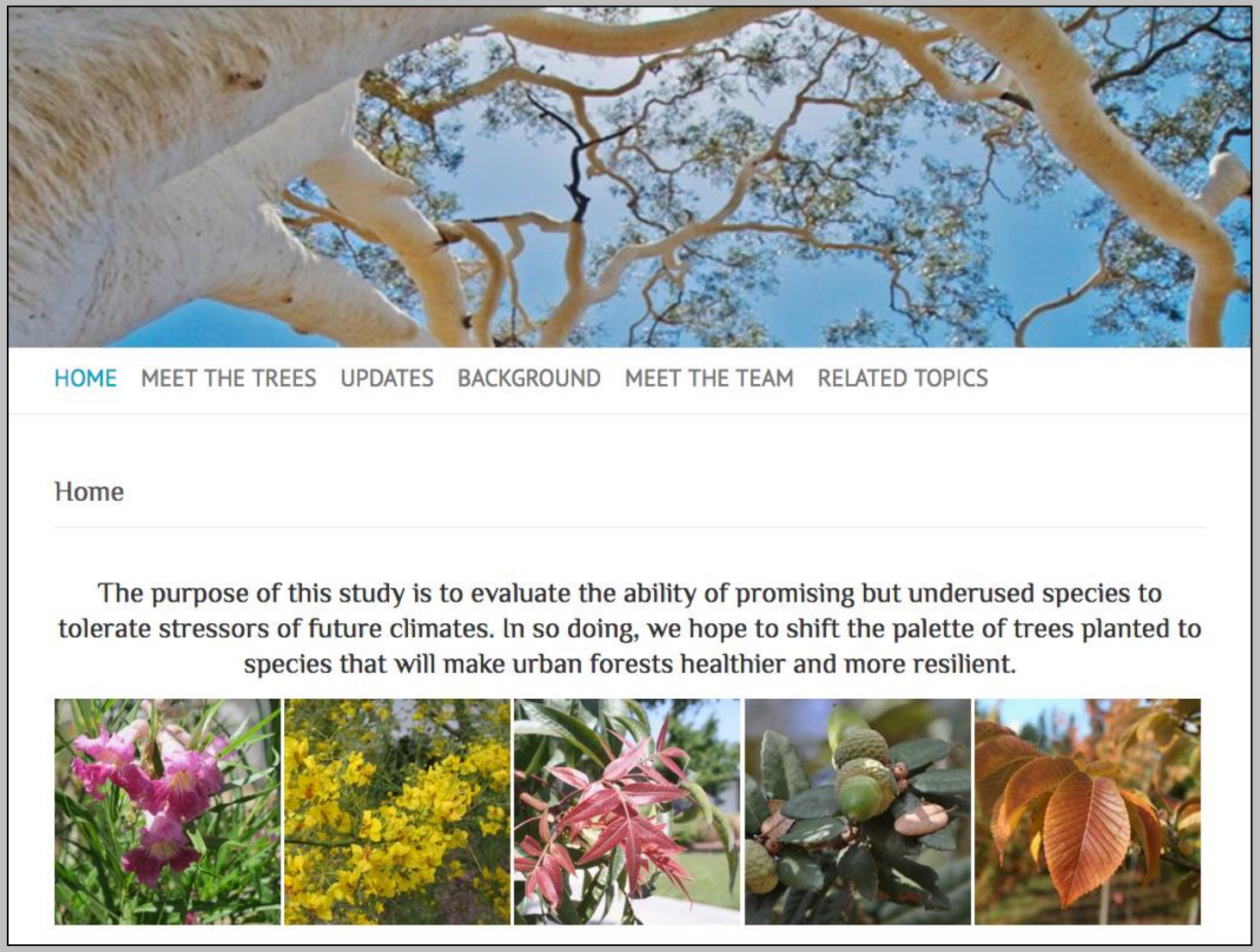
Some currently used trees will not survive or not perform well

Consequence of Climate Change:

We should not be planting trees that will not survive, not perform well, or have high irrigation requirements

Consequence of Climate Change:
Must Identify New Species

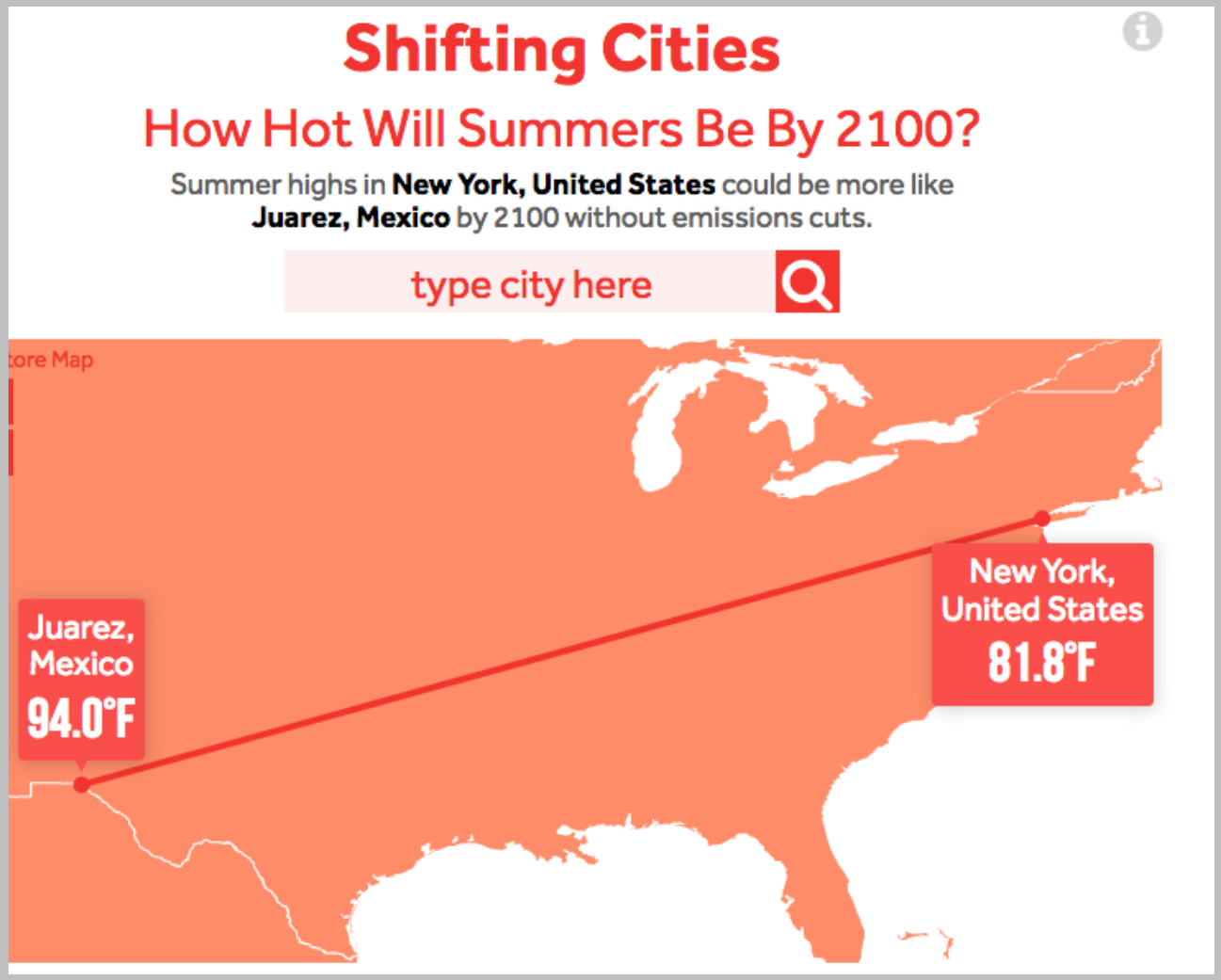
Climate Ready Trees – U.S. Forest Service



Greetings from Climate Change

"substitution of space for time"

CLIMATE CENTRAL



http://www.climatecentral.org/news/global-cities-climate-change-21584