Water at Risk

Land Use and Climate Change Threats to Rangelands

Lorrie Flint and Alan Flint
USGS
California Water Science Center

HOME PAGE | TODAY'S PAPER | VIDEO | MOST POPULAR | TIMES TOPICS

The New York Times

Environment

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

ENVIRONMENT SPACE & COSMOS

SMUD Solar Smart HOMES
• Save up to 60% on your electricity bill
• Tax Incentives
Learn more at savewithsmud.org

TEMPERATURE RISING

A Warming Planet Struggles to Feed Itself

Josh Haner/The New York Times

Victor Valenzuela selects wheat plants for breeding at the International Maize and Wheat Improvement Center in Mexico.
More Photos »

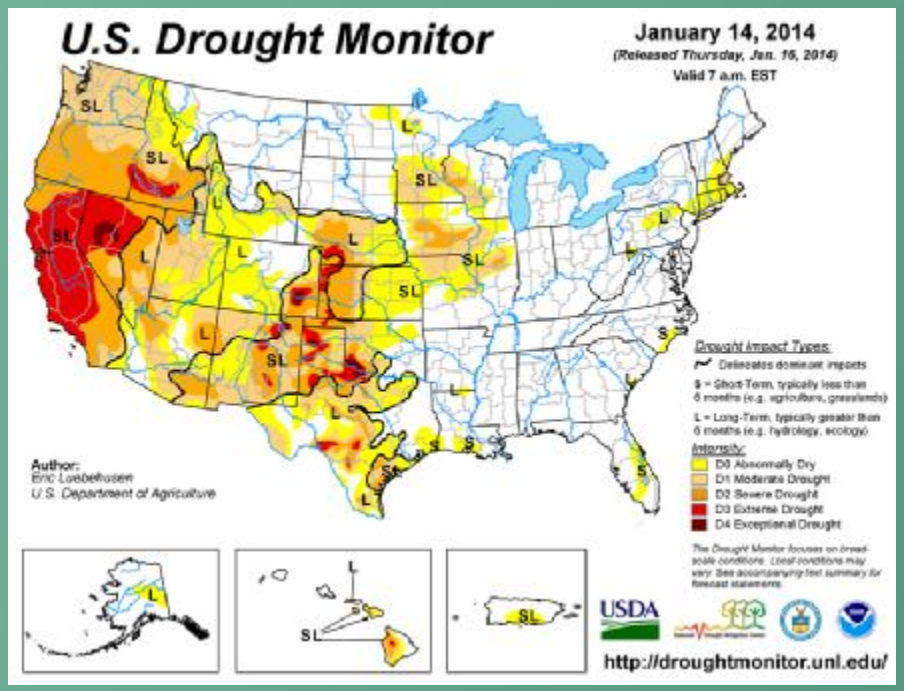
By JUSTIN GILLIS
Published: June 4, 2011

CIUDAD OBREGÓN, Mexico — The dun wheat field spreading out at Ravi P. Singh's feet offered a possible clue to human destiny. Baked by a desert sun and deliberately starved of water, the plants were parched and nearly dead.

RECOMMEND
TWITTER
SIGN IN TO E-MAIL

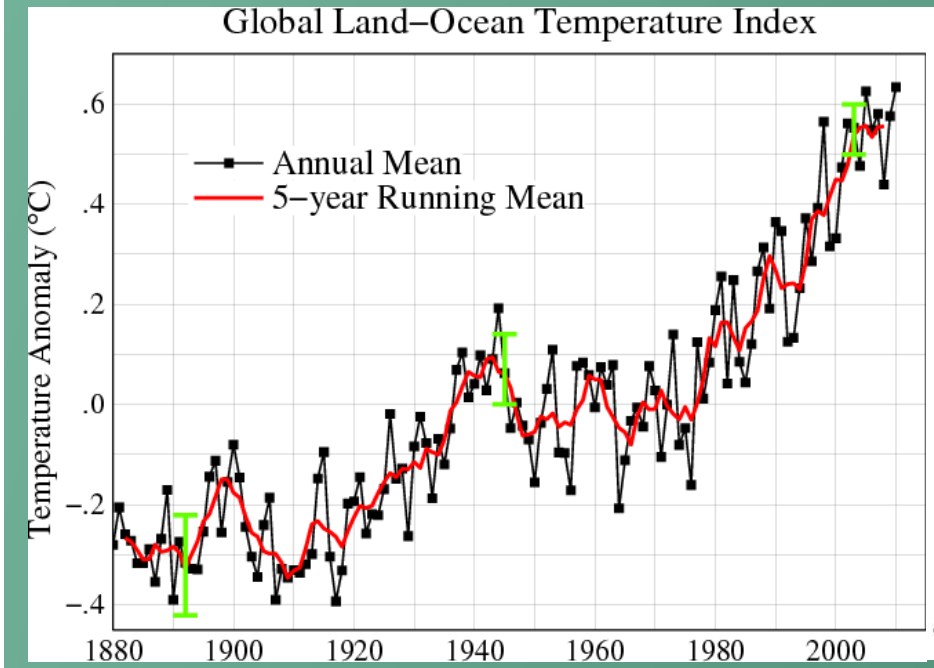
Changing climate impacts agriculture in many ways

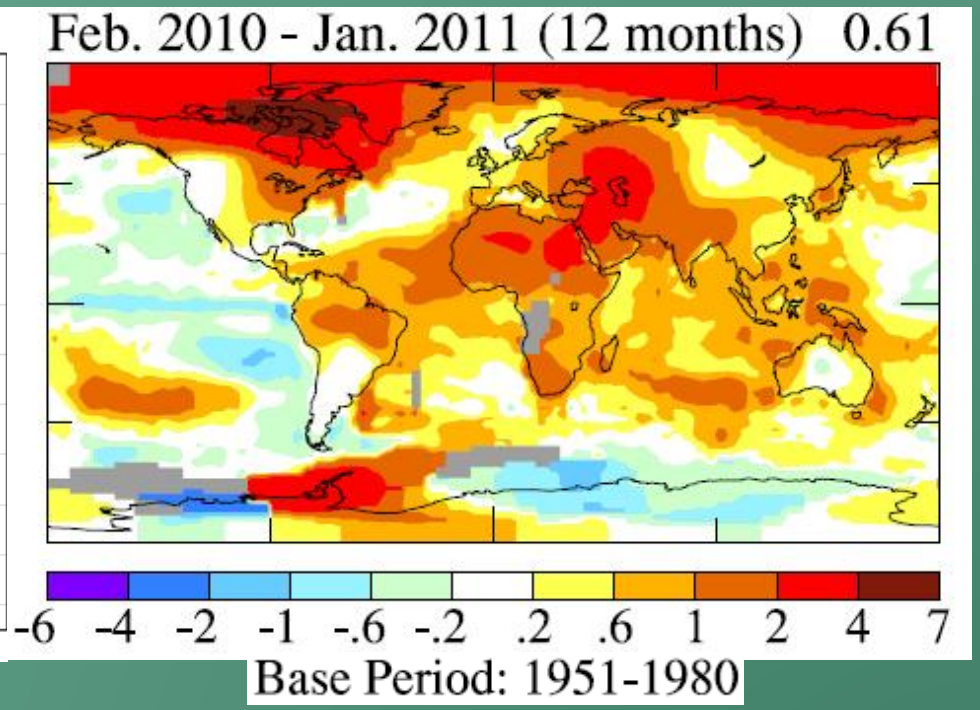
Climate Change and Extremes



USGS
science for a changing world

Global warming and the spatial variability of a changing climate

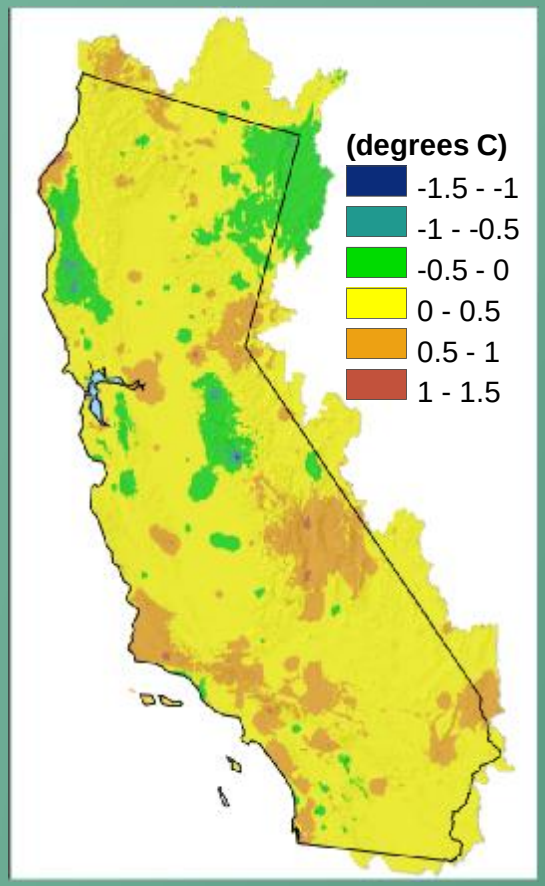




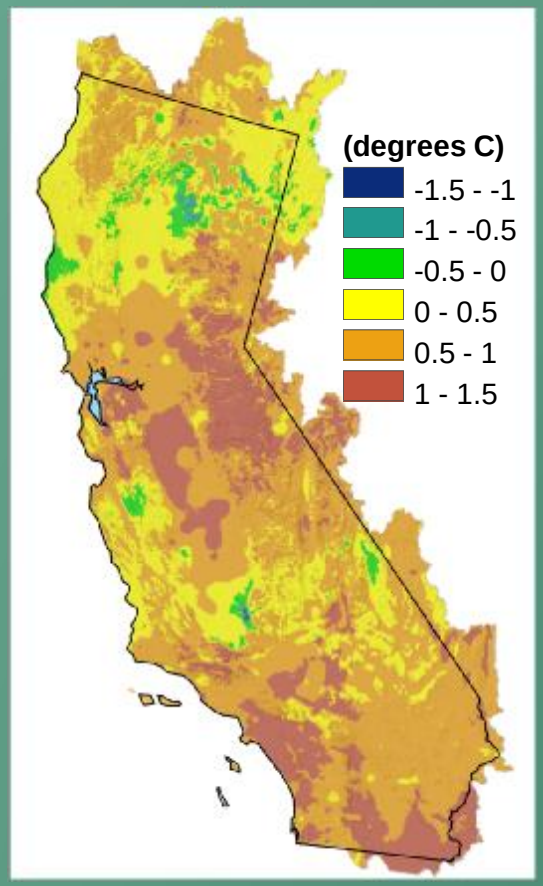
From Jim Hansen, NASA

Change in Climate from (1951-1980) to (1981-2010)

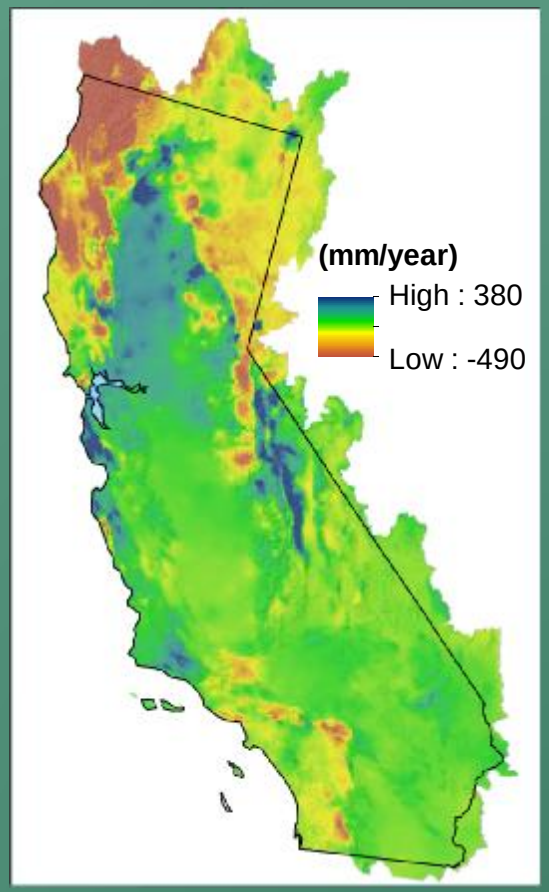
Minimum Air Temperature



Maximum Air Temperature

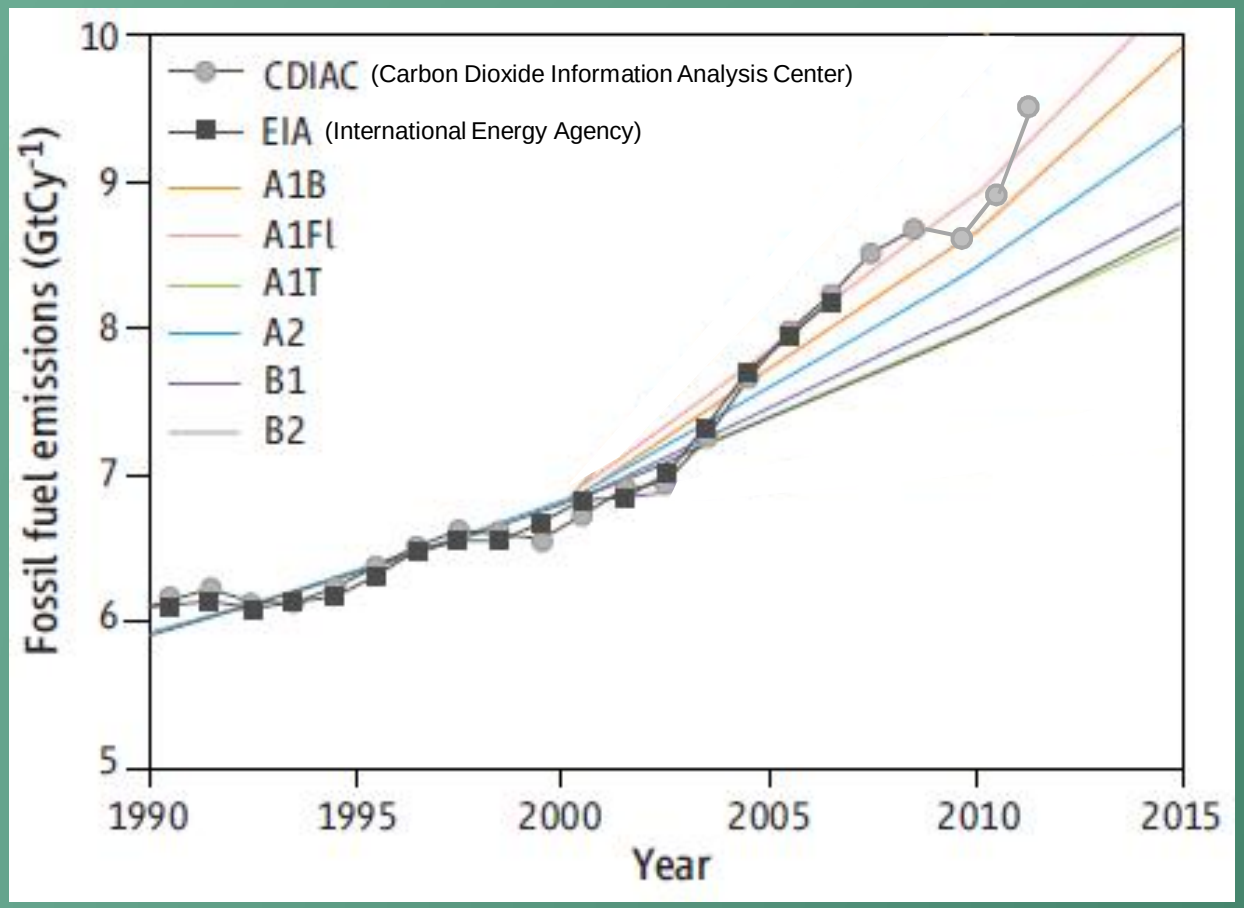


Precipitation

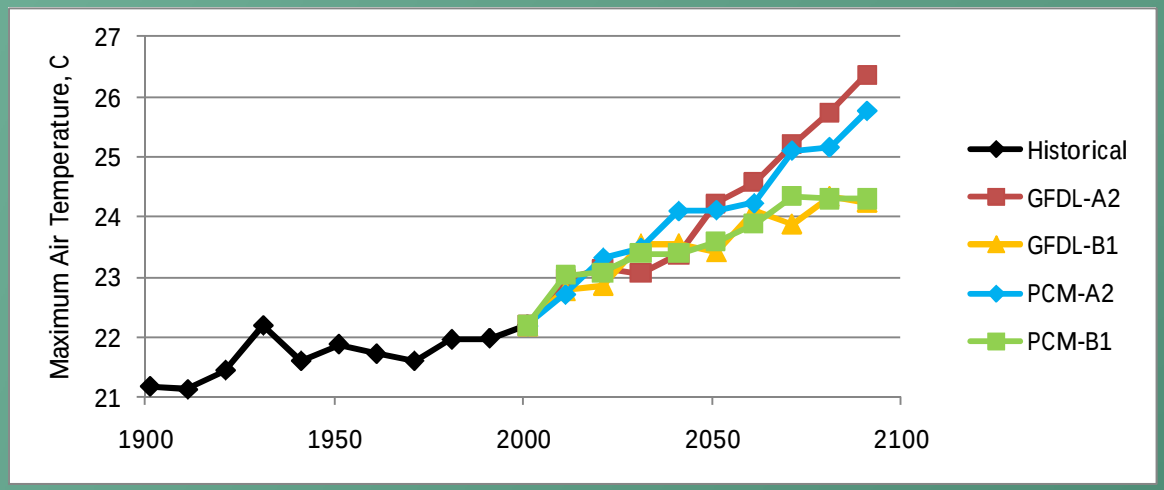


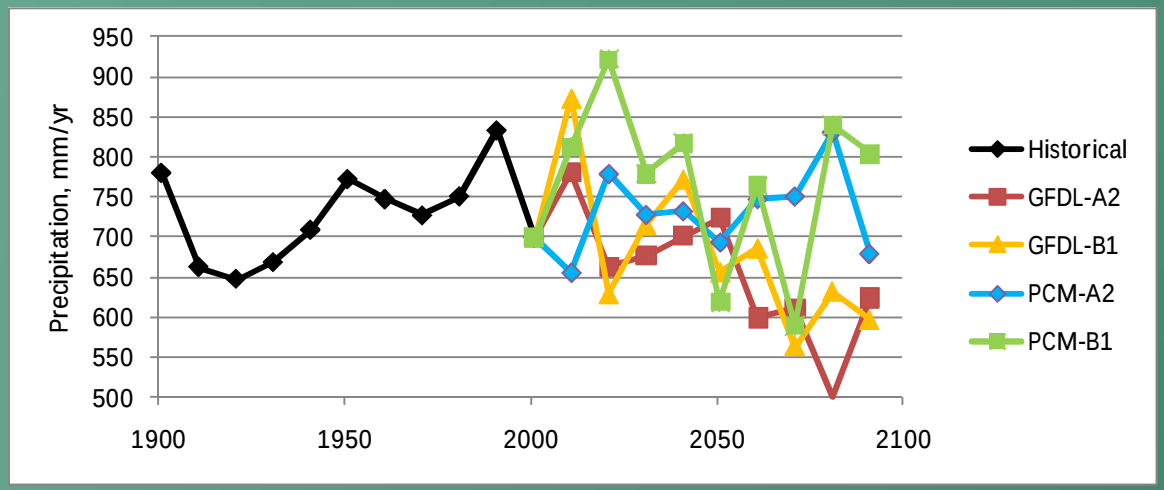
Climate Change Scenarios

IPCC Special Report on Emission Scenarios (SRES; 4th Assessment Report, 2007) has developed scenarios corresponding to potential future global and regional economic and land use strategies



Climate for California:
current and future conditions – a range of scenarios

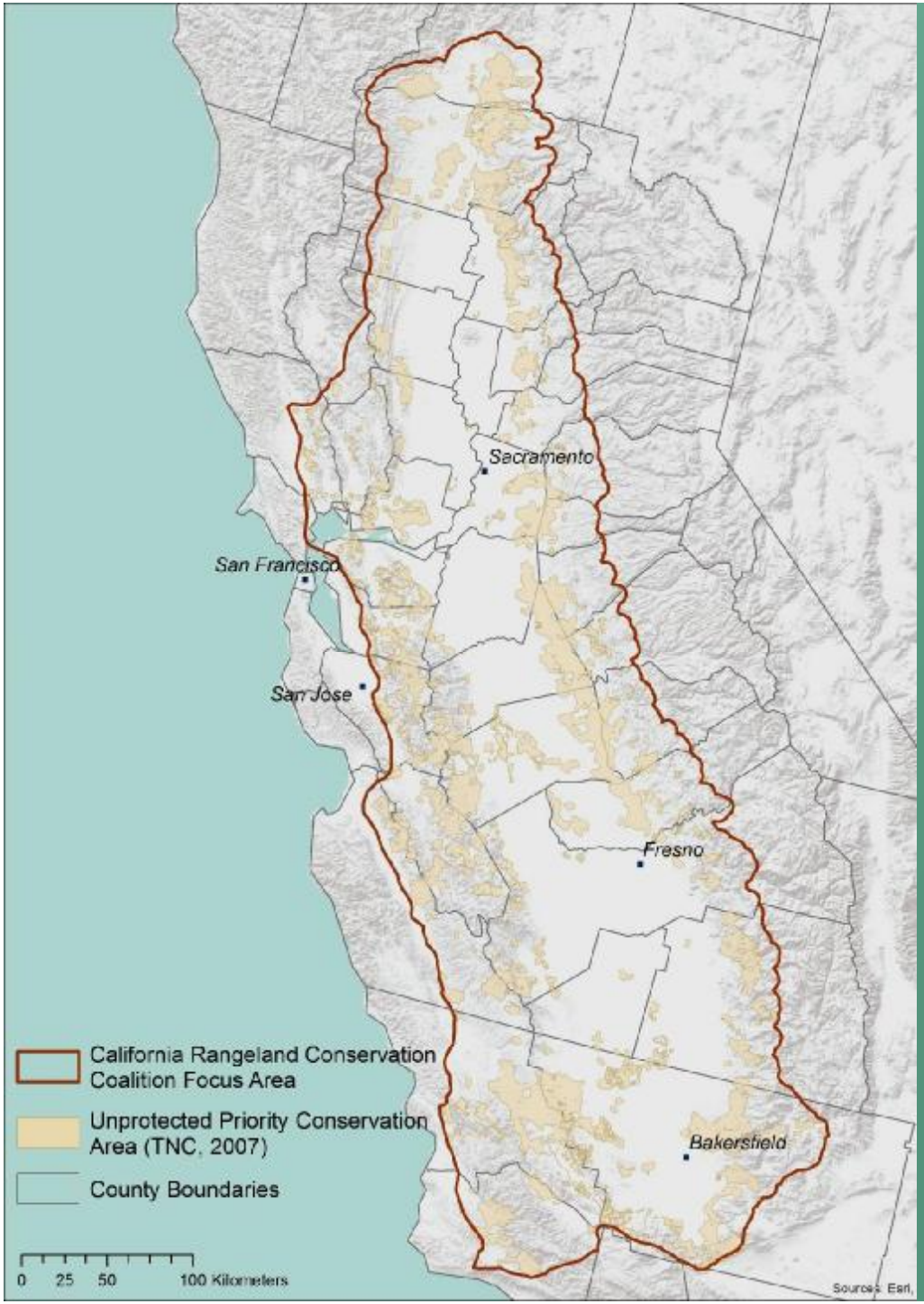




Integrated Threats to Rangelands: Land use and climate change

- In California 20,000 acres of rangelands are lost every year
- Cattle ranching: low profits
- Low levels of protection

Land conversion and climate change lead to loss of grazing land, water availability, altered species distribution, reduction in ecosystem services



California Rangeland Conservation Coalition Focus Area

- 18 million acres of rangeland
- Mainly privately owned
- Managed for livestock production

USGS
science for a changing world

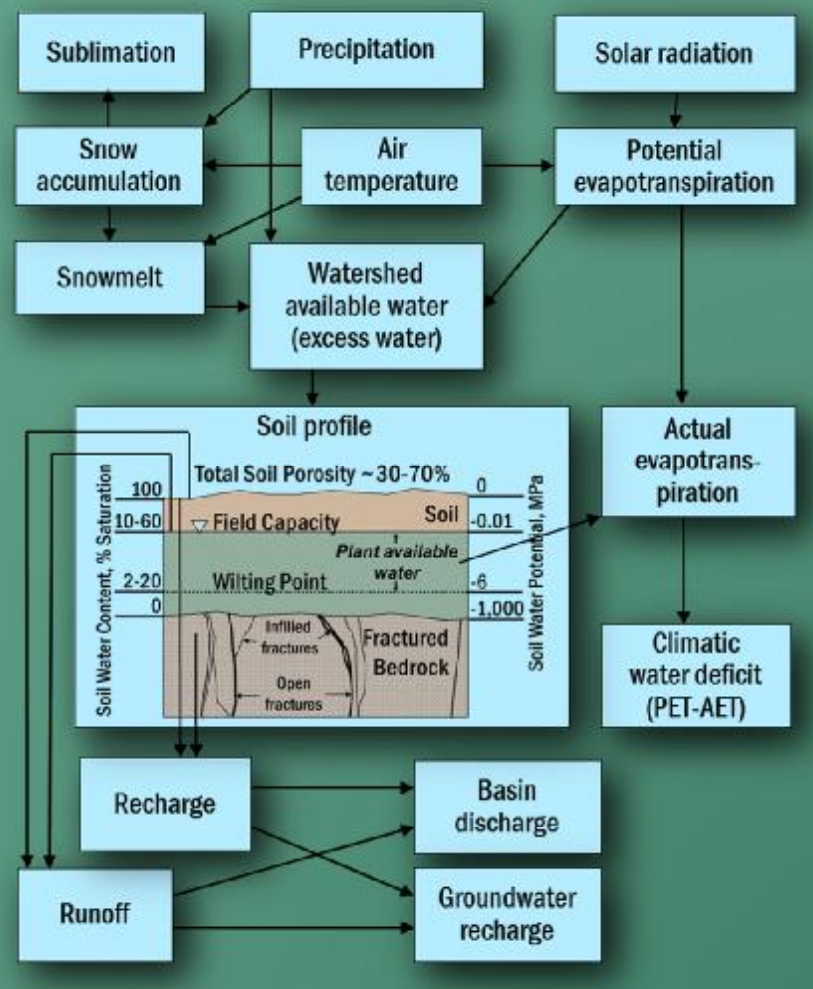
Objective

- What are the effects of urbanization and climate change on water availability?
  - Recharge
  - Runoff
  - Streamflow
- 6 case study watersheds
- Impacts of agriculture
- Vegetation on the landscape
- Adaptation and mitigation measures

Basin Characterization Model (BCM)

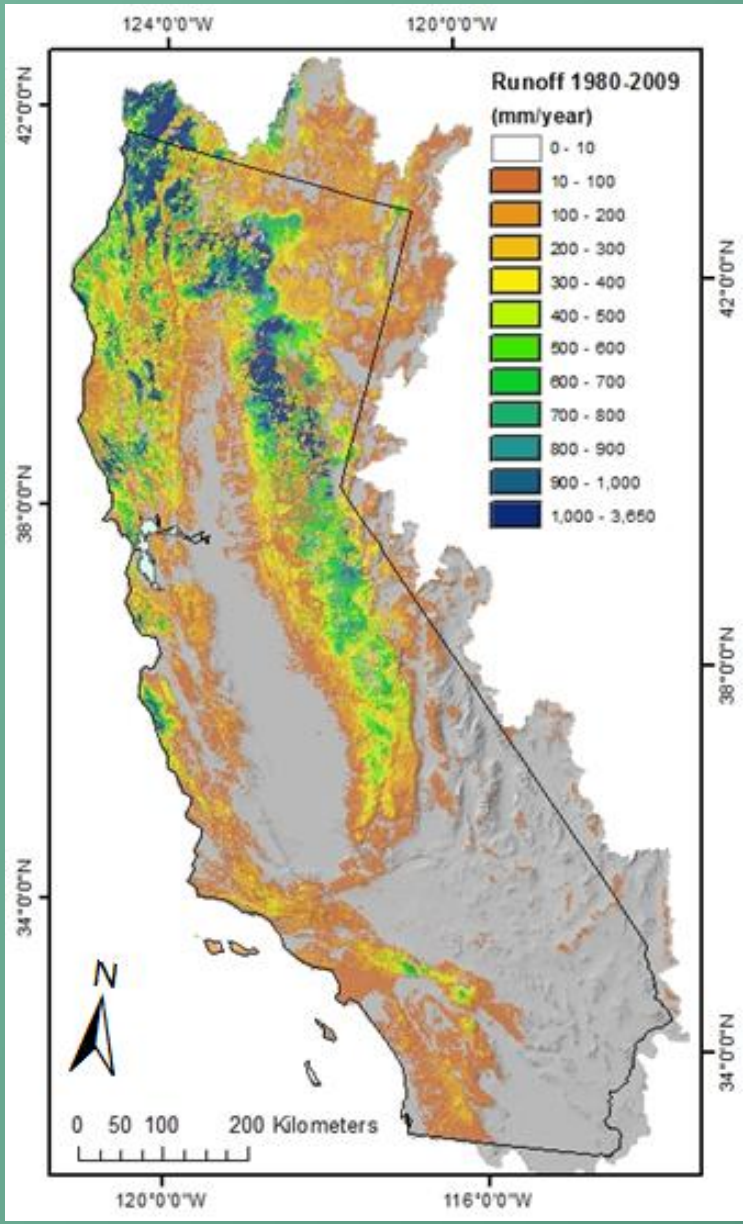
Downscaled GCM data:
Monthly Precipitation
Max, Min Air
Temperature

Land use change data:
Urbanization

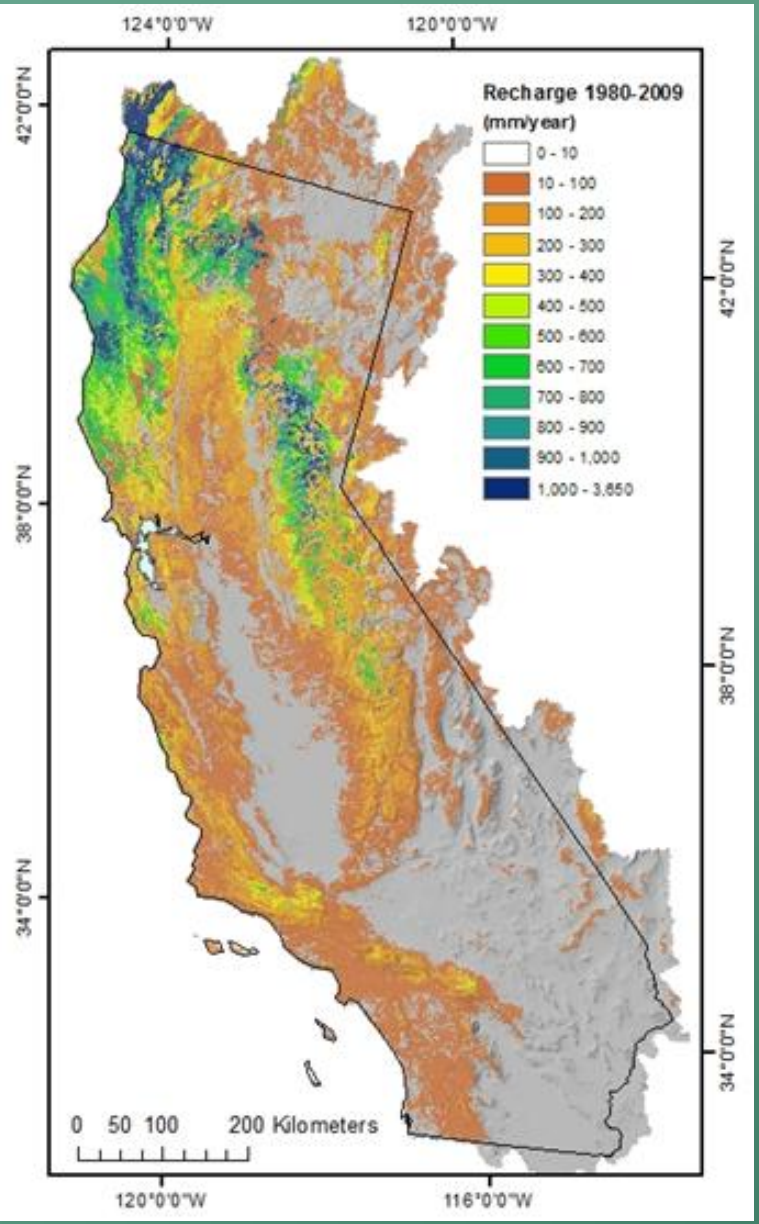


Flint et al. 2013, Ecological Processes; Flint and Flint 2012, Ecological Processes; Thorne et al. 2012, California Energy Commission.

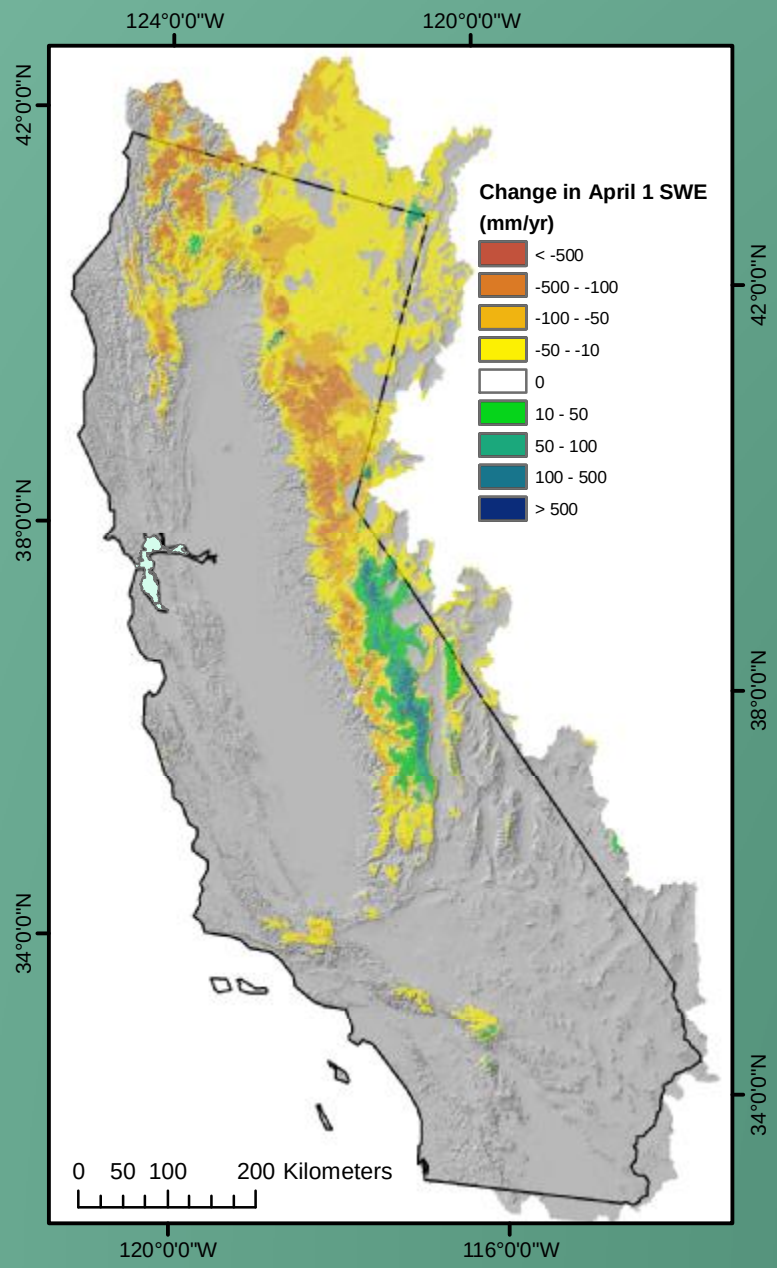
Runoff



Recharge



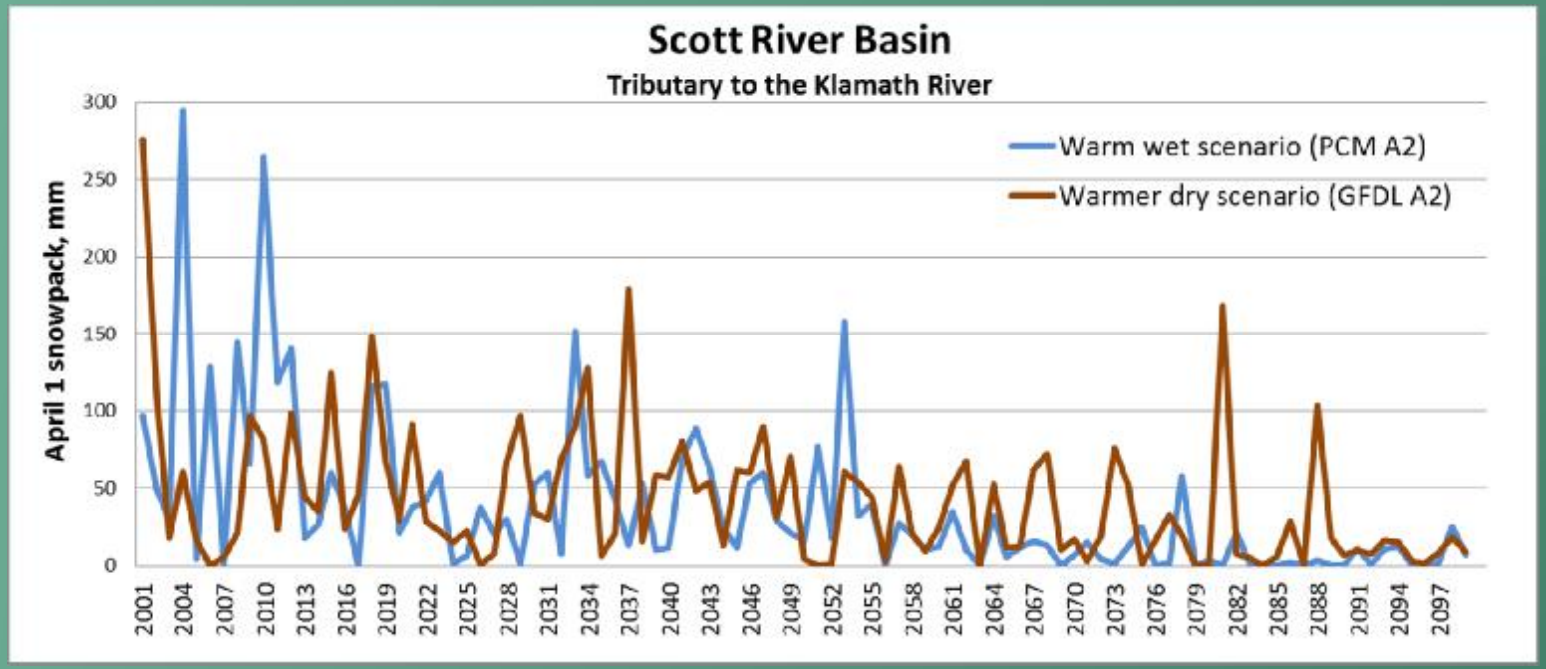
Changes in April 1st snowpack (SWE)



- Change from baseline (1951-1980) to current (1981-2010)
- Decreases due to warming at all but the highest elevations

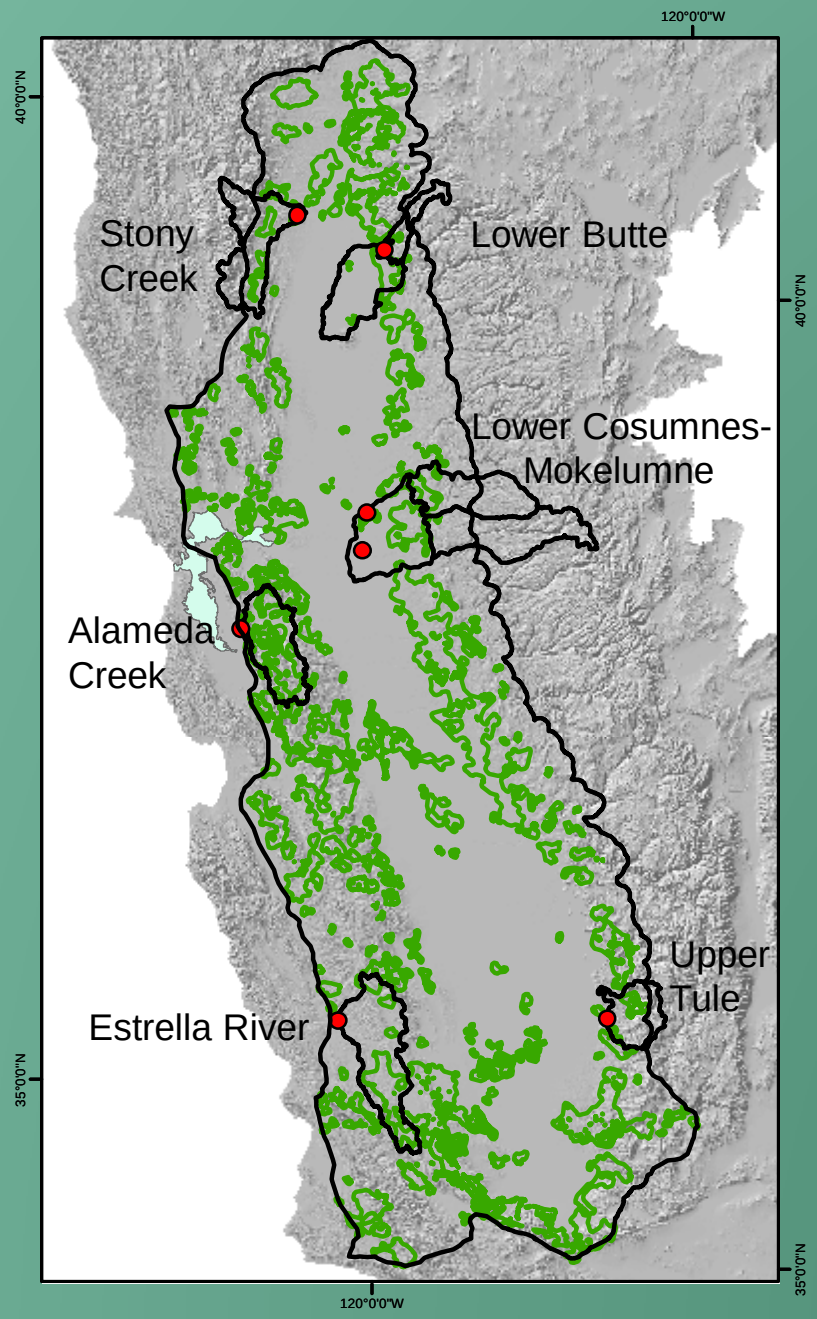
Changes in Snow and Impacts to Surface Water Supply

The timing of springtime snowmelt is controlled by air temperature and has been earlier in recent years. Regardless of the amount of precipitation, less is likely to fall as snow and snowpack will not maintain the water supply as long into the dry season.



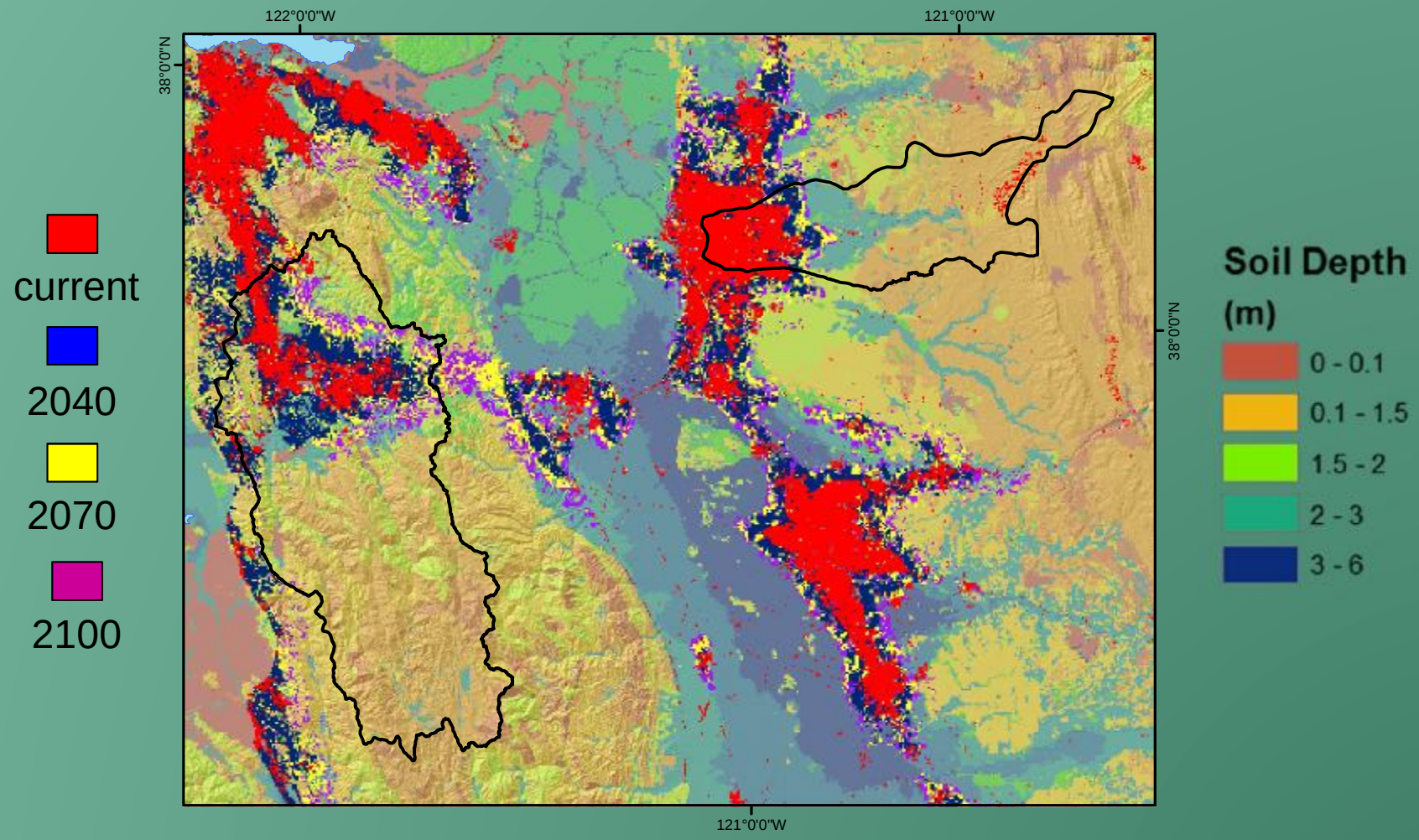
Approach

- Test impacts of increasing urbanization on 6 basins with varying degrees of projected change to evaluate differences in recharge and runoff
- Approach: reduce soil storage in locations projected to become urbanized
- Apply to BCM water balance model for 6 future scenarios for 21st century
- Basins selected span east and west sides of valley and the entire length



Projections	
Scenarios	Models
A2	GFDL, PCM
A1B	CSIRO, MIROC
B1	GFDL, PCM

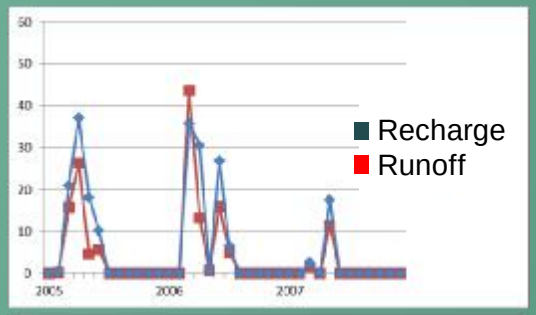
Urbanization Projections

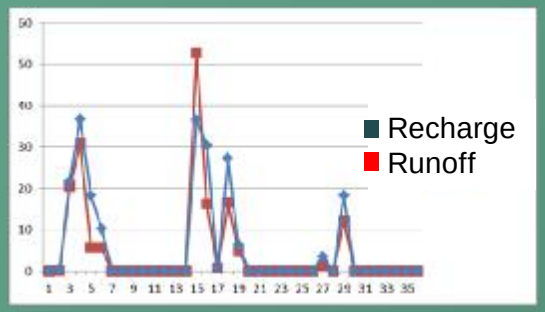


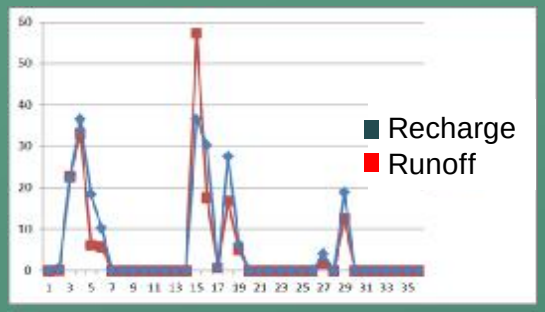
Sensitivity Analysis

Current | **2040 GFDL A2** | **2070 GFDL A2**

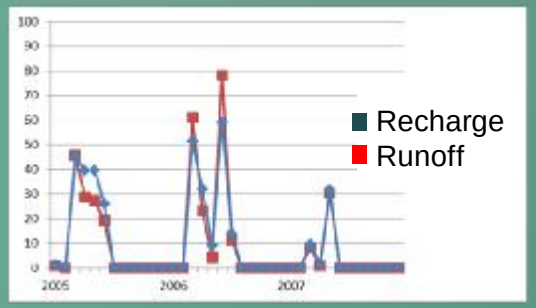
Alameda Creek

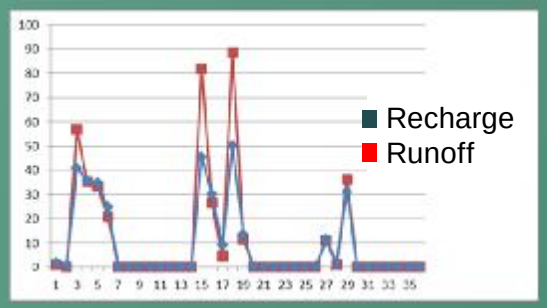


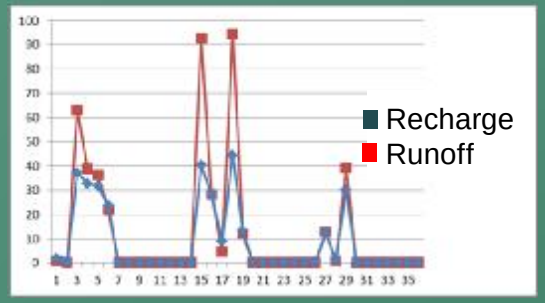




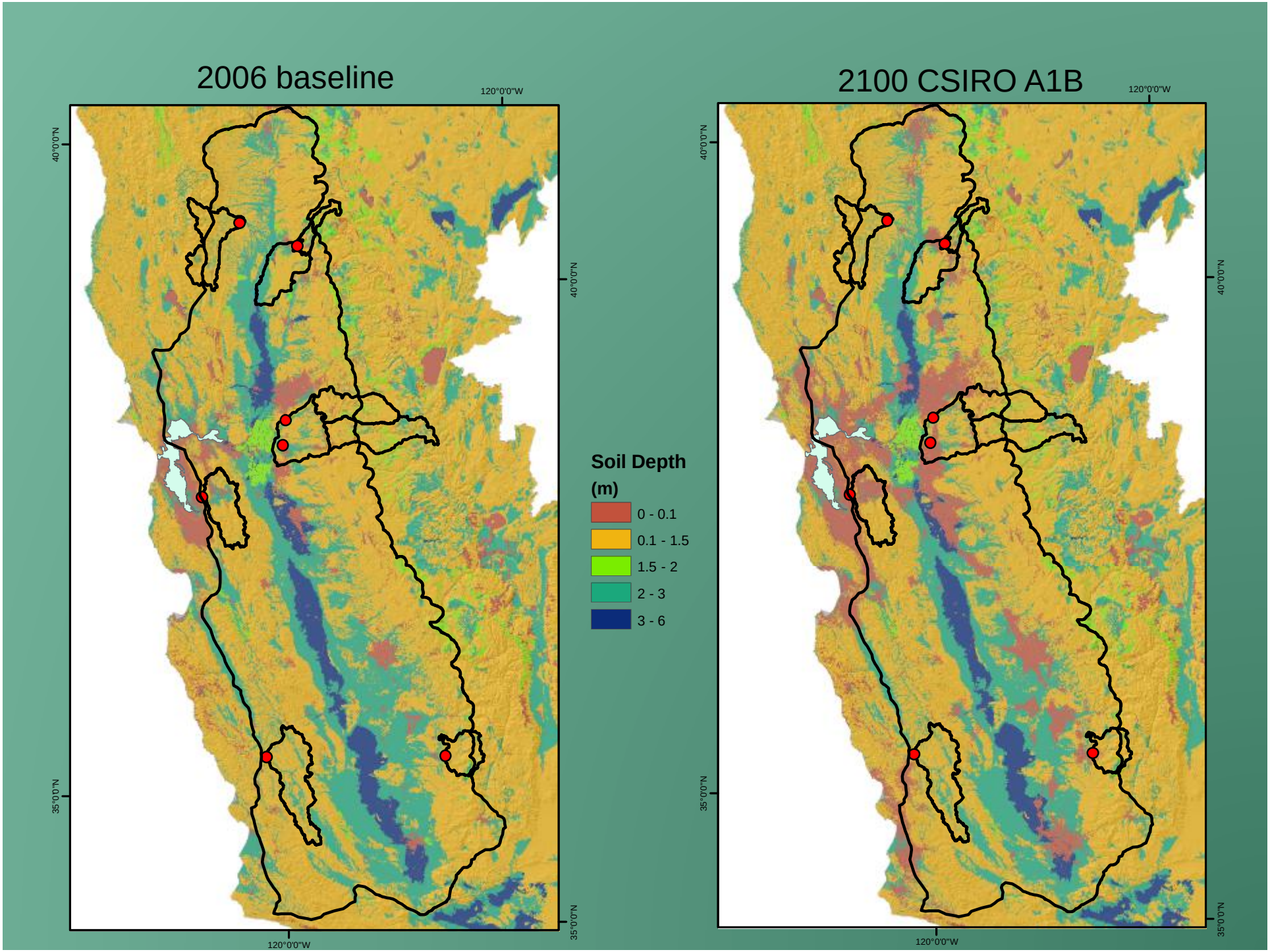
Calaveras River

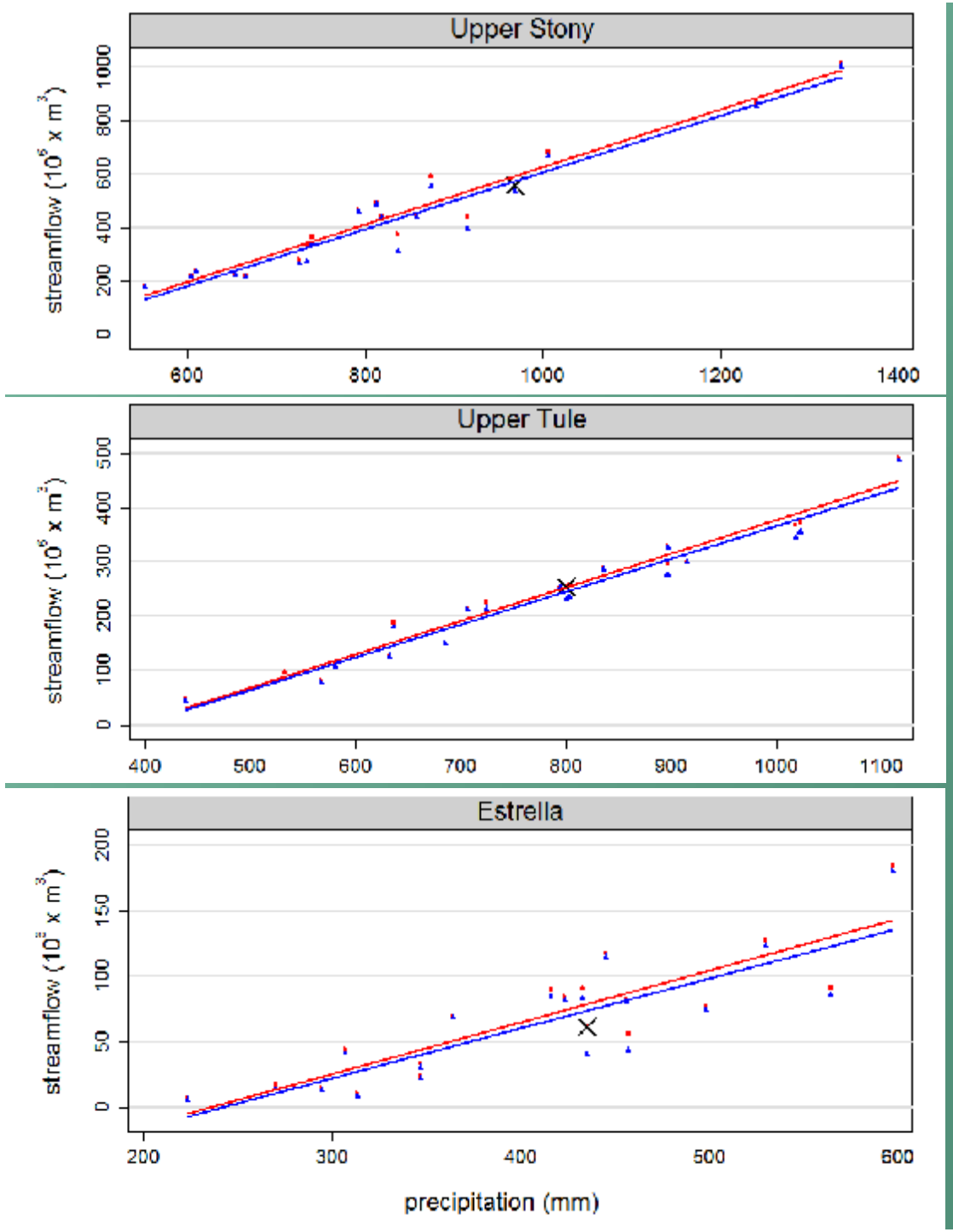






GFDL A2 land use scenario

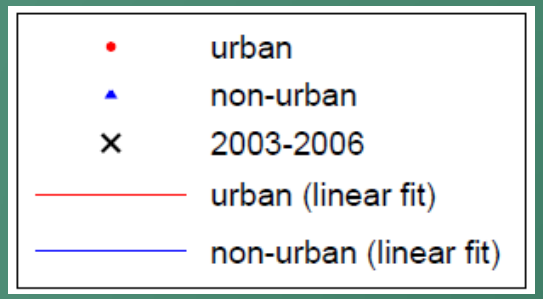

2006 baseline
2100 CSIRO A1B
120°0'0"W
40°0'0"N
35°0'0"N
Soil Depth (m)
0 - 0.1
0.1 - 1.5
1.5 - 2
2 - 3
3 - 6

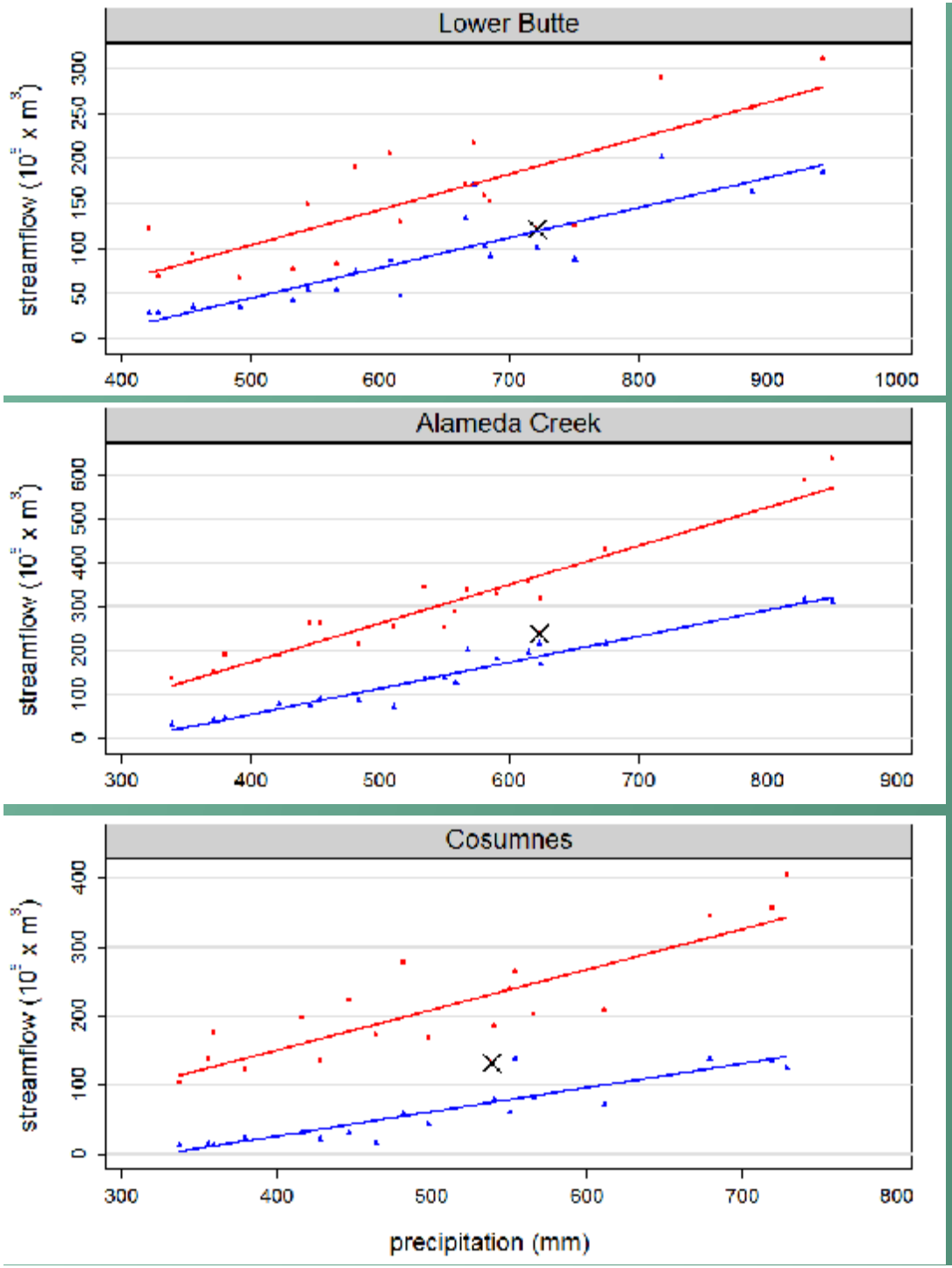


Streamflow vs. Precipitation

(**NON-URBAN** watersheds)

Using a range of precipitation years over the next century



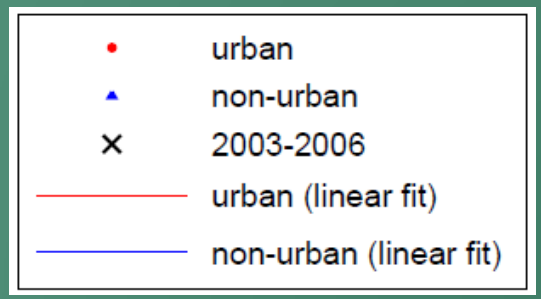


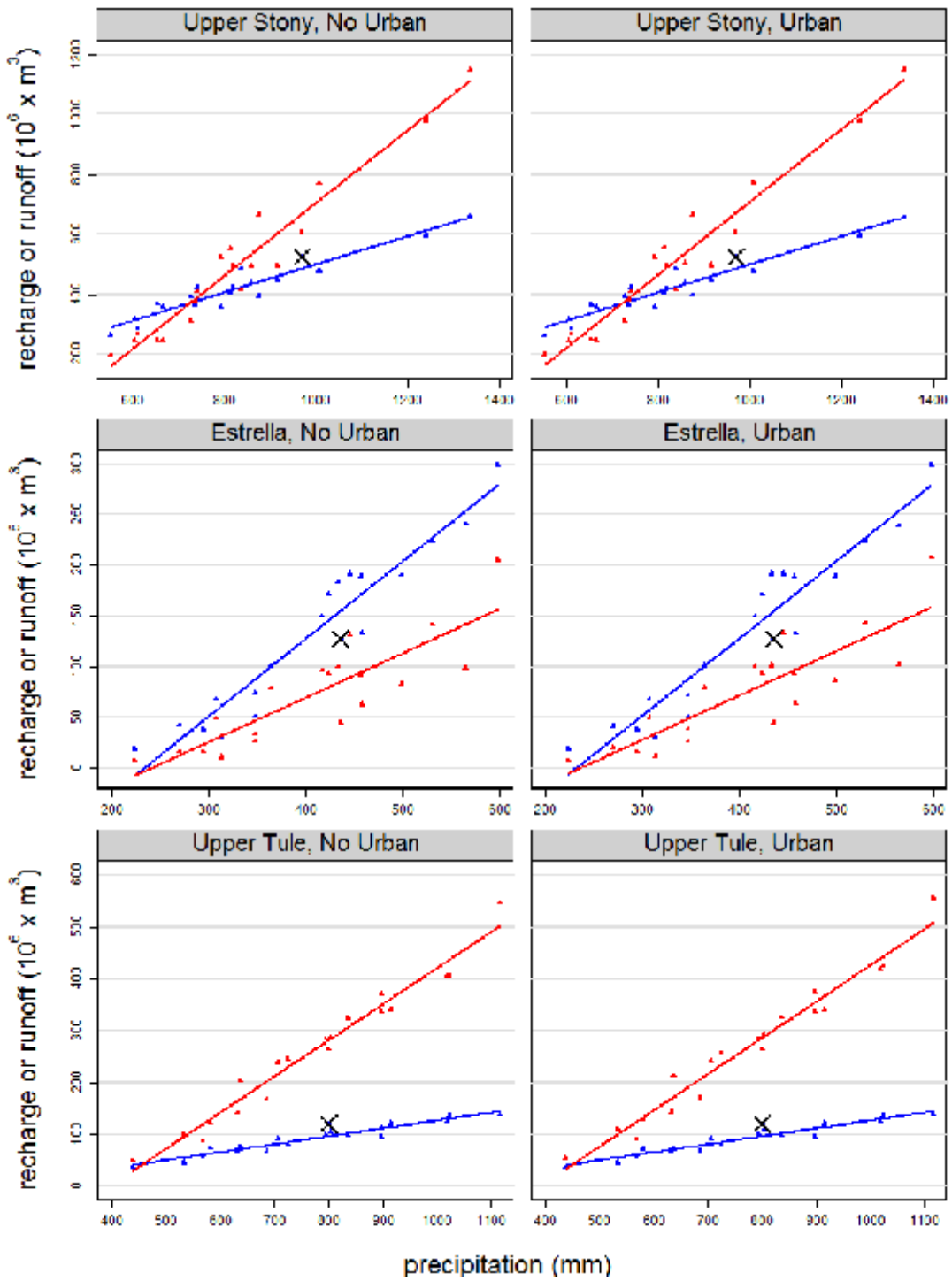
Streamflow vs. Precipitation

(**URBAN** watersheds)

ANCOVA results:
urban vs. non-urban regression

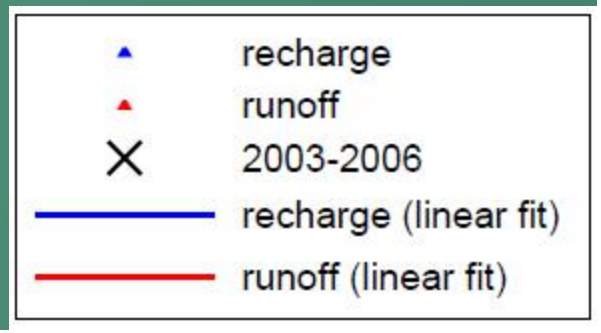
Streamflow			
Lower Butte	Slope	($F_{1,34}$ = 0.54	P = 0.467)
	Intercept	**($F_{1,35}$ = 31.28**	**P = 0.000)**
Alameda Creek	Slope	**($F_{1,34}$ = 10.63**	**P = 0.003)**
	Intercept	N/A	
Cosumnes	Slope	**($F_{1,34}$ = 4.74**	**P = 0.037)**
	Intercept	N/A	

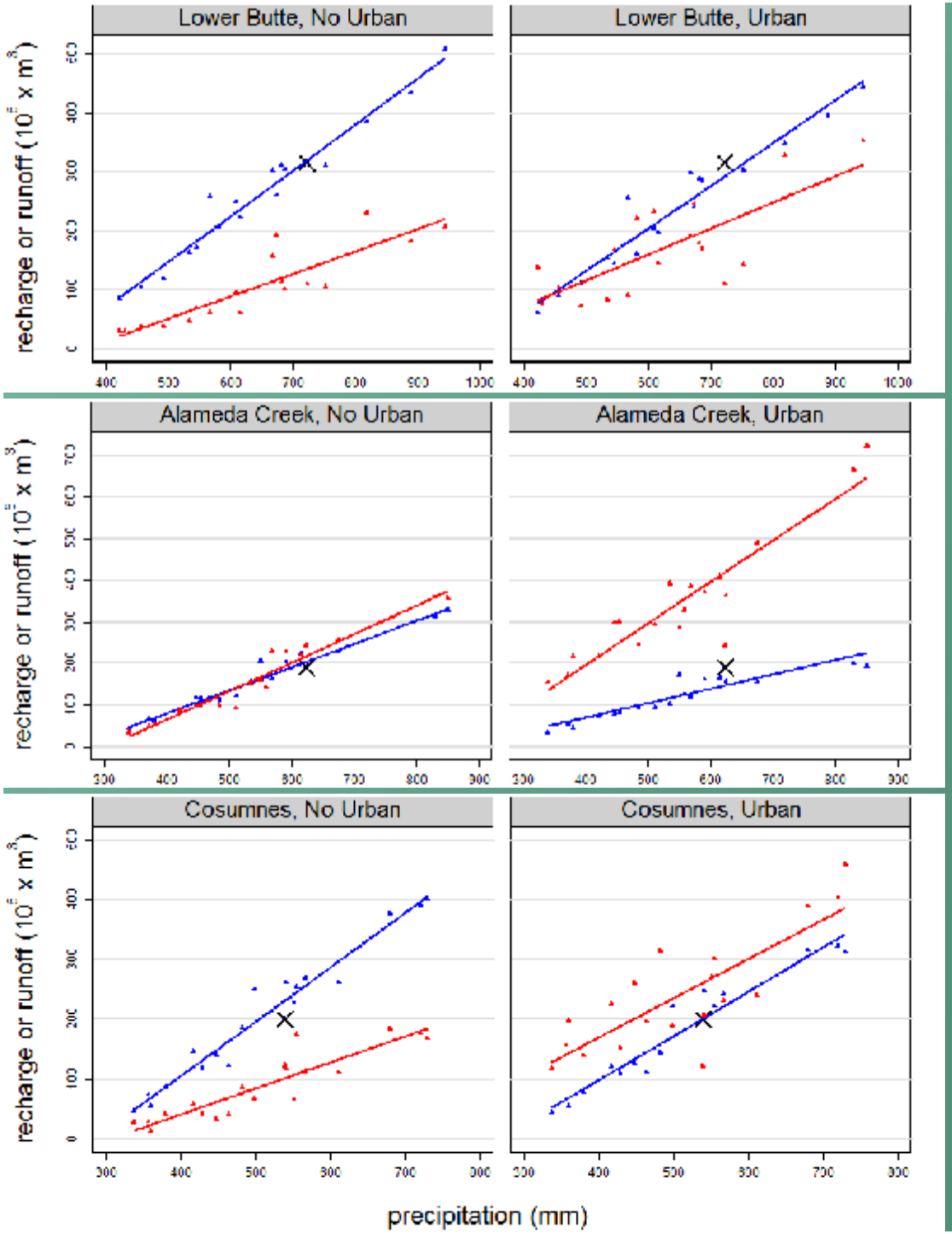




Recharge and Runoff vs. Precipitation

(**NON-URBAN** watersheds)





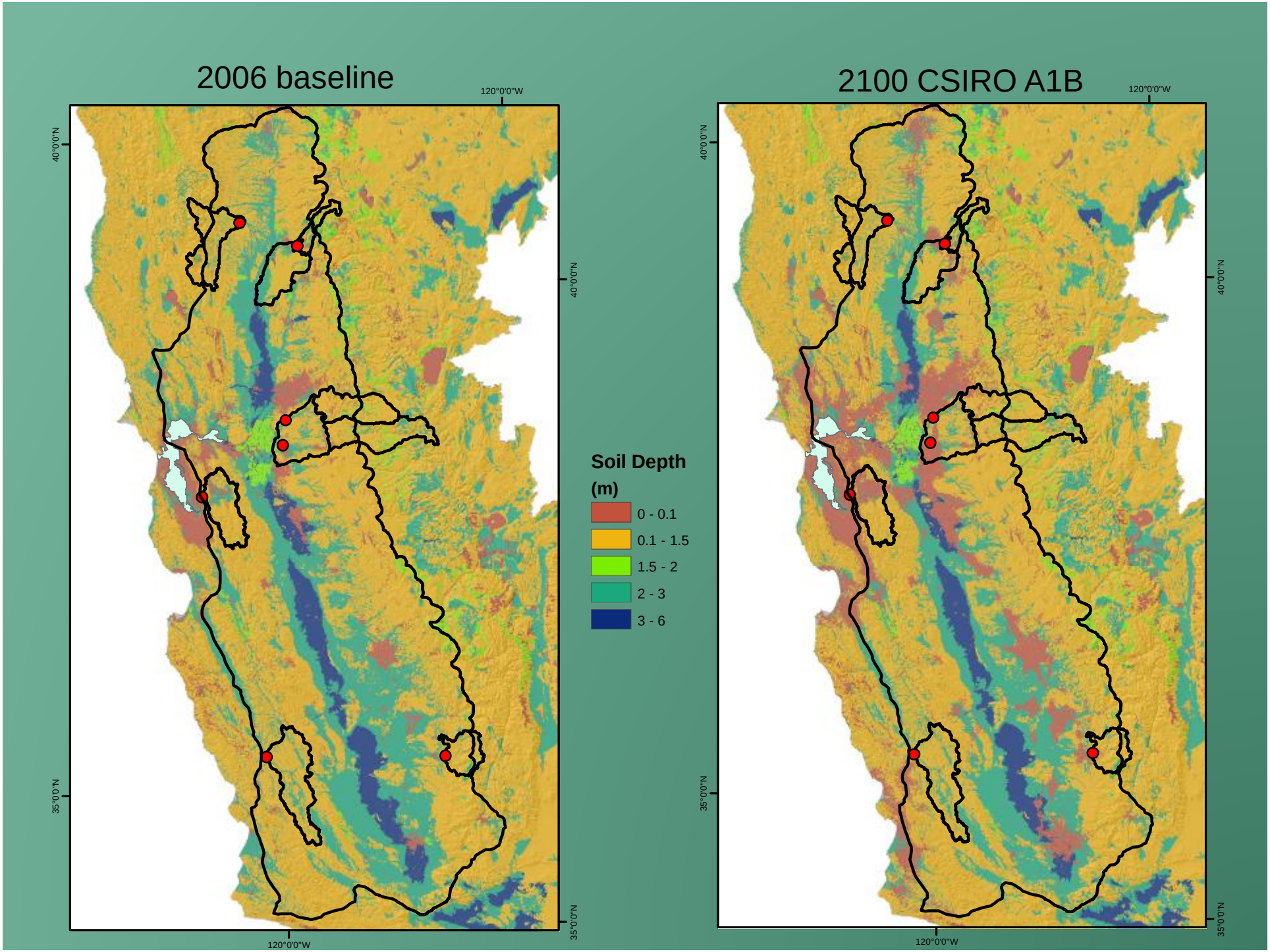
Recharge and Runoff vs. PPT

(**URBAN** watersheds)

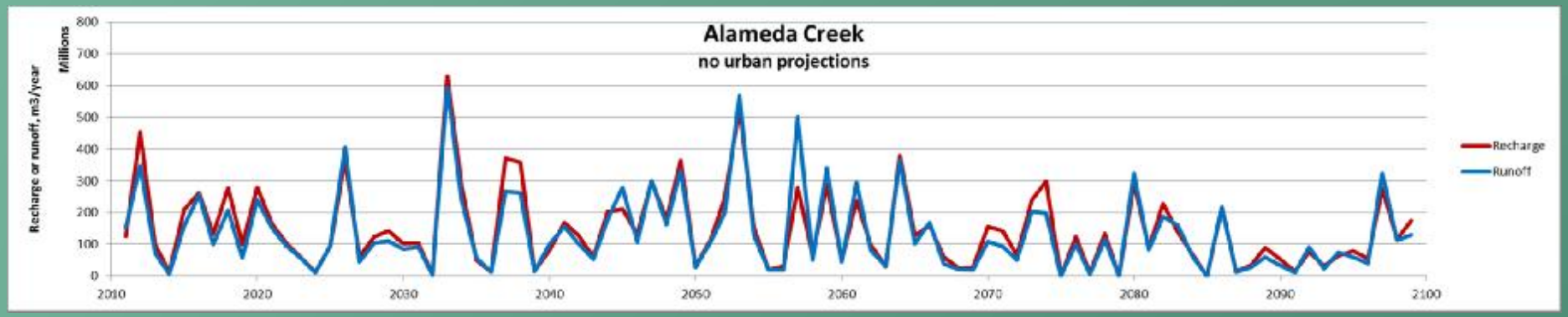
- recharge
- runoff
- 2003-2006
- recharge (linear fit)
- runoff (linear fit)

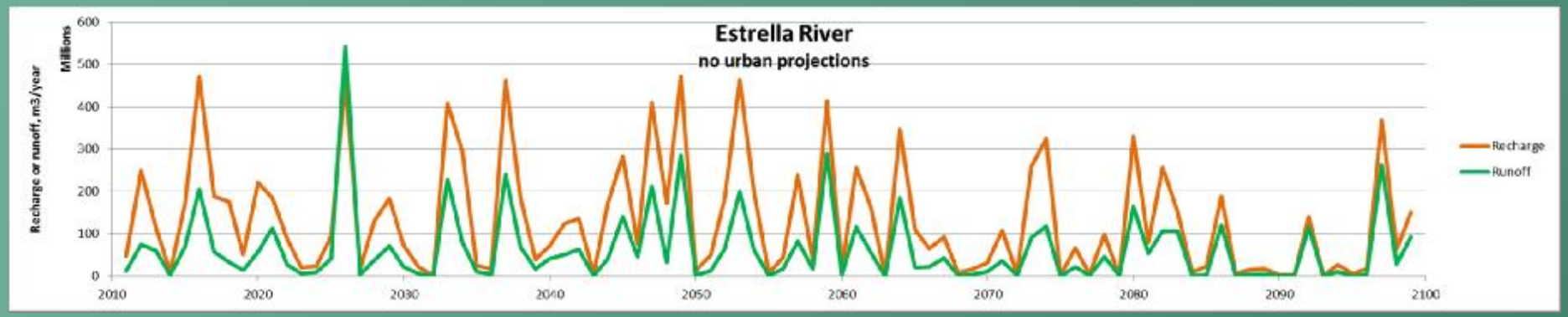
ANCOVA results:

Recharge			
Lower Butte	Slope	($F_{1,34}$ = 1.01	P = 0.32)
	Intercept	**($F_{1,35}$ = 7.84**	**P = 0.008)**
Alameda Creek	Slope	**($F_{1,34}$ = 20.41**	**P = 0.000)**
	Intercept	N/A	
Cosumnes	Slope	**($F_{1,34}$ = 6.48**	**P = 0.016)**
	Intercept	N/A	
Runoff			
Lower Butte	Slope	($F_{1,34}$ = 0.42	P = 0.52)
	Intercept	**($F_{1,35}$ = 26.67**	**P = 0.000)**
Alameda Creek	Slope	**($F_{1,34}$ = 8.65**	**P = 0.006)**
	Intercept	N/A	
Cosumnes	Slope	**($F_{1,34}$ = 3.13**	**P = 0.086)**
	Intercept	**($F_{1,35}$ = 102.5**	**P = 0.000)**


2006 baseline
2100 CSIRO A1B
120°0'0"W
40°0'0"N
35°0'0"N
Soil Depth (m)
0 - 0.1
0.1 - 1.5
1.5 - 2
2 - 3
3 - 6

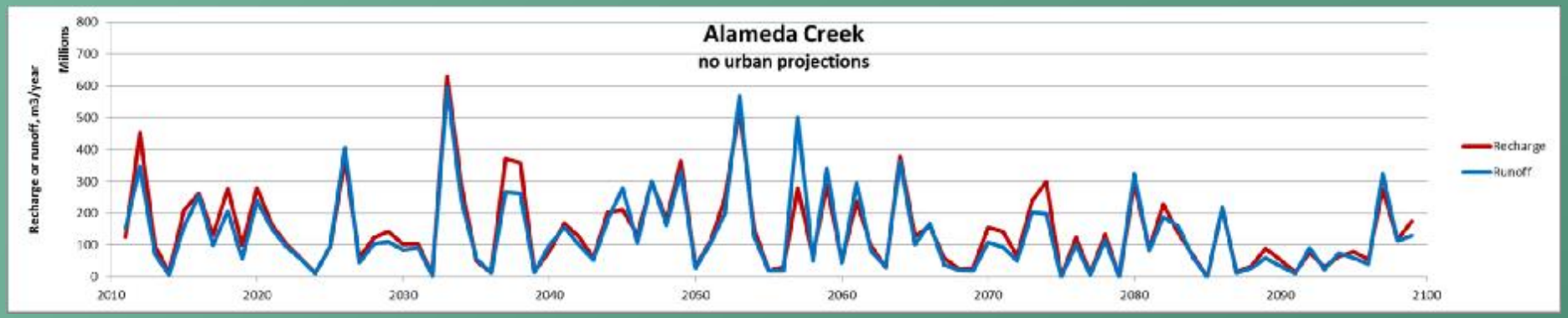
Non-urbanized scenario

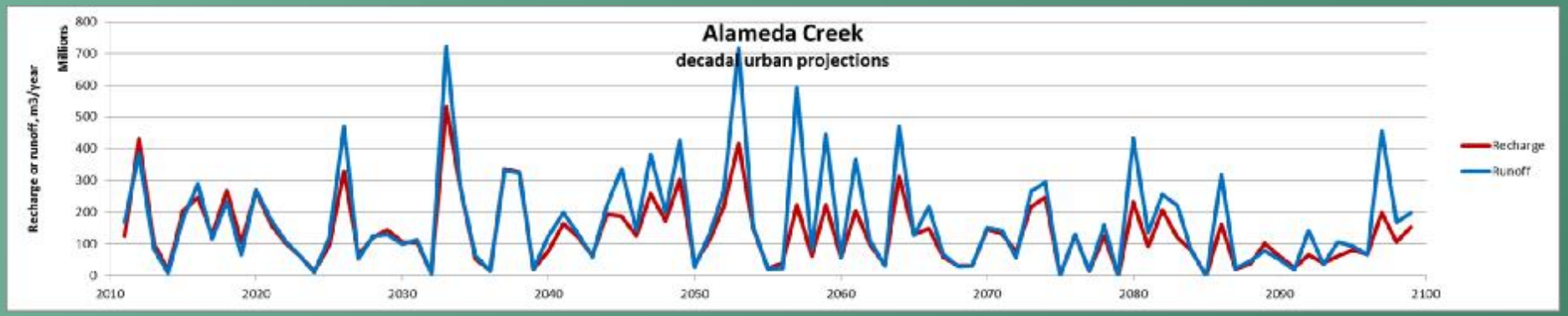




GFDL A2 climate scenario

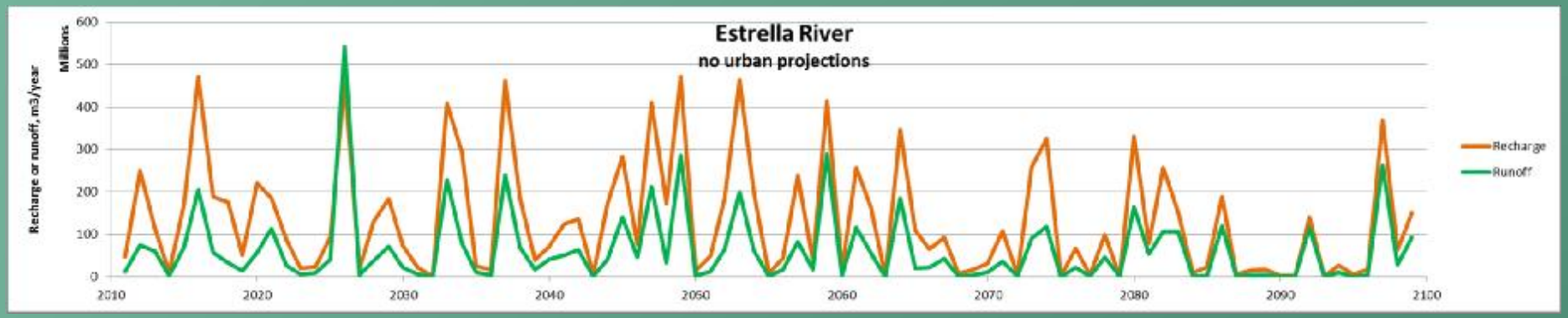
Both non-urban and urban scenarios

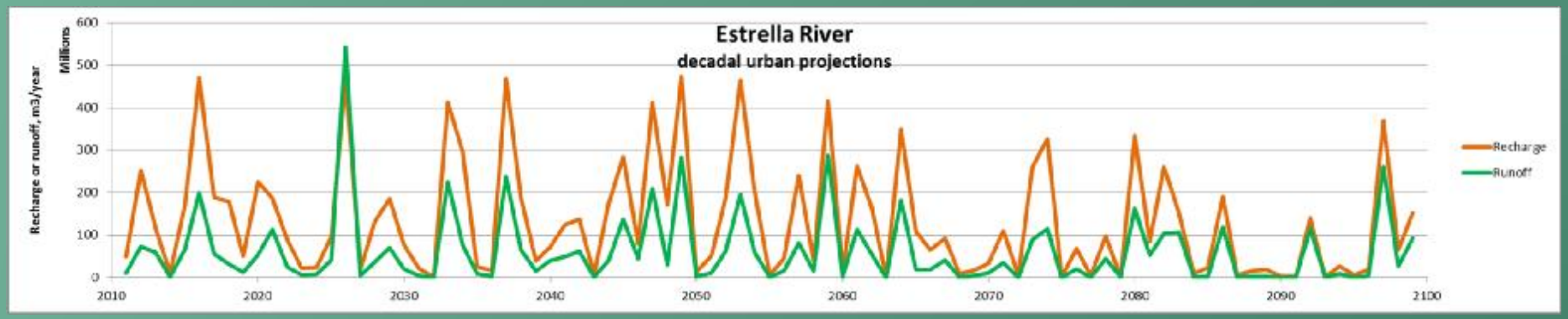




GFDL A2 climate and land use scenario

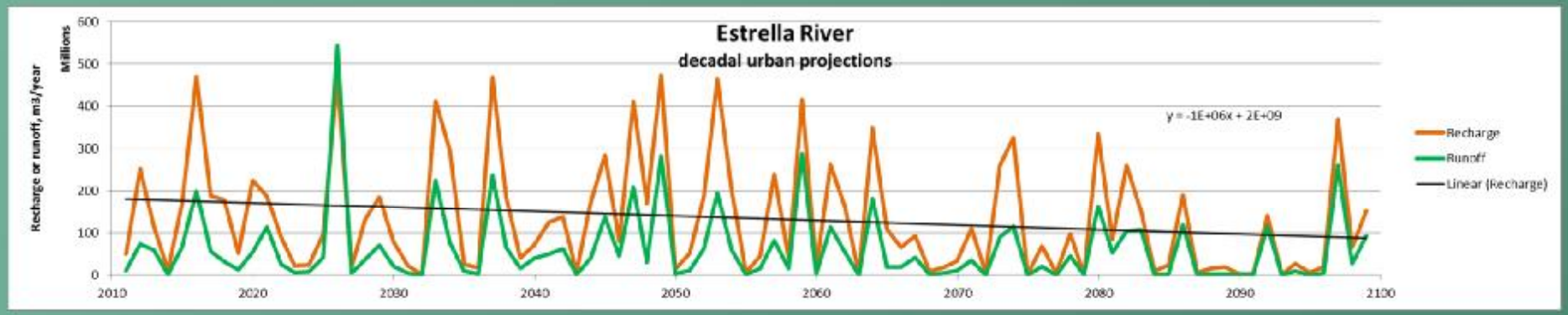
Both non-urban and urban scenarios





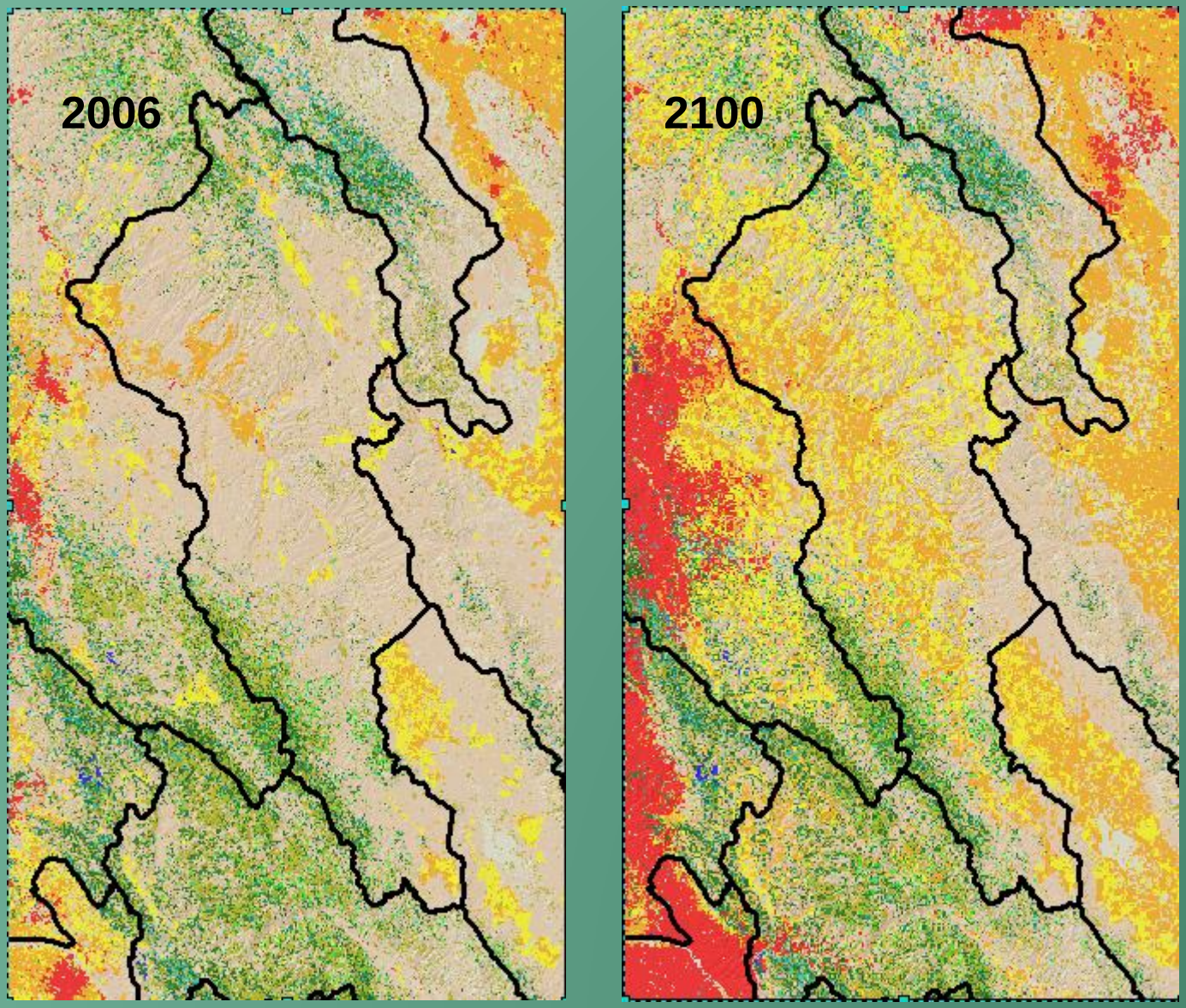
GFDL A2 climate and land use scenario

Projected decline in recharge



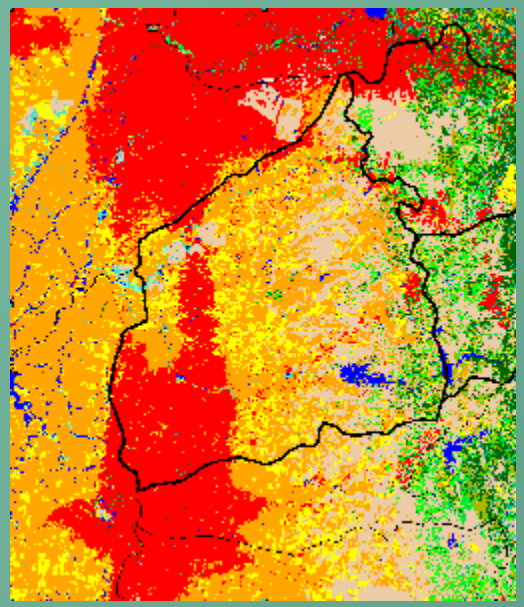
GFDL A2 climate and land use scenario

Agriculture and Rangelands: Estrella River



- Water
- Developed
- Mech Disturbed NF
- Mech Disturbed OP
- Mech Disturbed PVT
- Mining
- Barren
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Grassland
- Shrubland
- Agriculture
- Hay/Pasture
- Herbaceous Wetland
- Woody Wetland

A1B scenario



Economic impacts of decreased groundwater recharge

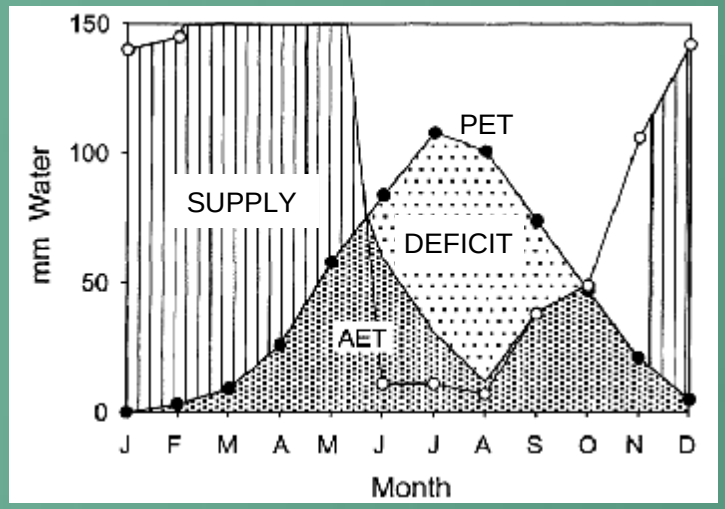
- Cosumnes watershed: Groundwater overdraft leads to extended periods of zero flow
- Impacted ecosystem services include: uncertain forest water supply, marshes dependent on return flows from irrigation, and delay or preclusion of Fall Chinook migration
- Higher costs potentially related to reduced wildlife viewing and recreation, less wetland filtration of sediment and nutrients, more costly gray infrastructure, reduced salmon fisheries
- Strategies for lower recharge: reservoir re-operation, water transfers, conveyance improvements, managed groundwater recharge, and recharge area protection. Each has different cost structures and potential secondary benefits

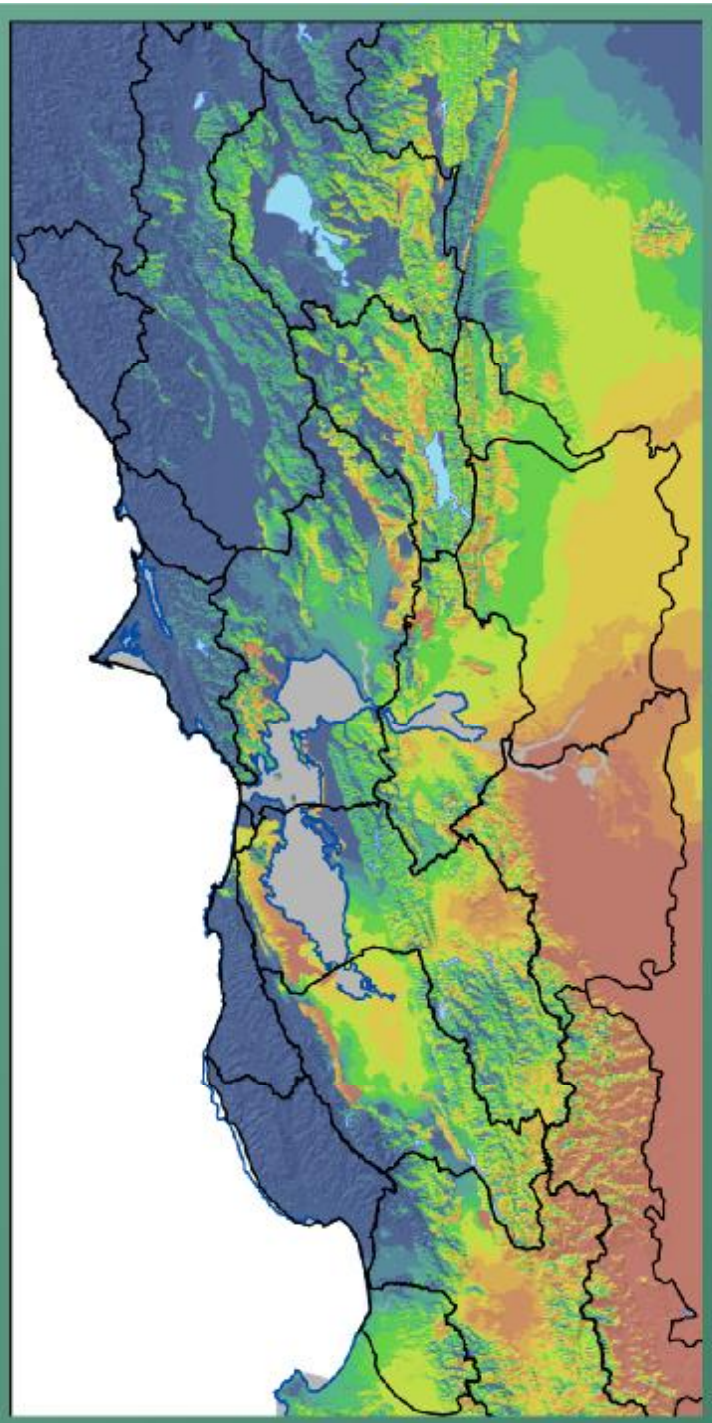
Climatic Water Deficit

Annual evaporative demand that exceeds available water

Potential – Actual Evapotranspiration

- Integrates climate, energy loading, drainage, and available soil moisture storage
- Address irrigation demand
- Generally increases with all future climate scenarios
- Defines level of stress on landscape



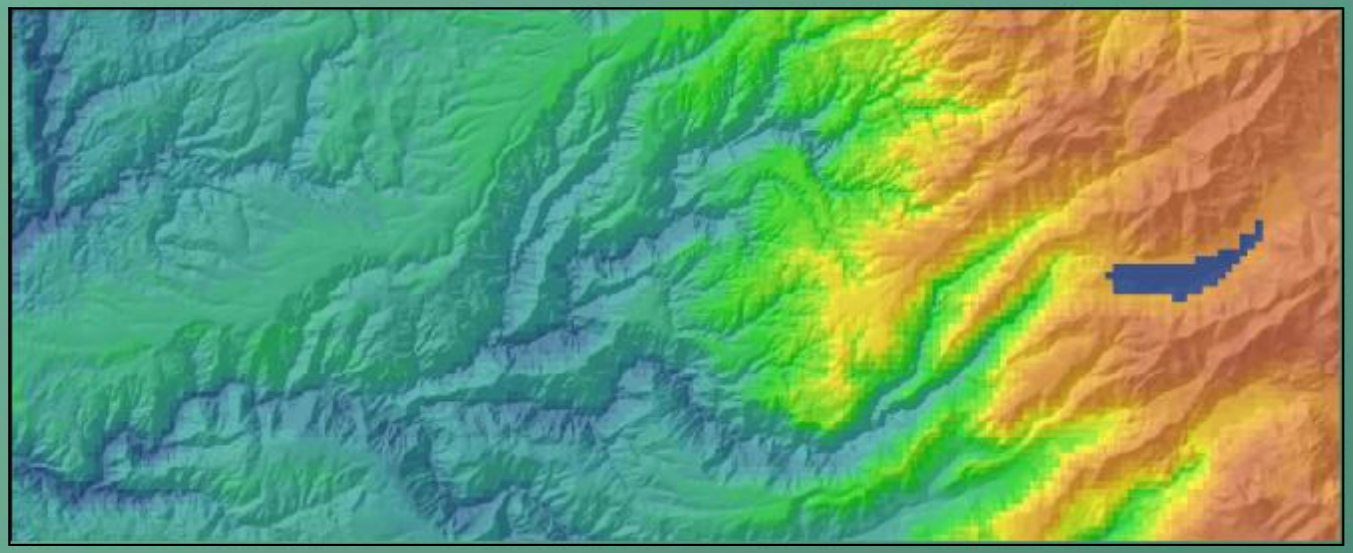


2001
mm/yr

- <775
- 775 - 800
- 800 - 825
- 825 - 850
- 850 - 875
- 875 - 900
- 900 - 925
- 925 - 950
- 950 - 975
- 975 - 1000

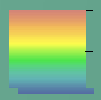
USGS
science for a changing world

Local to watershed application characterizes landscape resilience



Change in climatic water deficit (1981-2010) relative to (2070-2099)

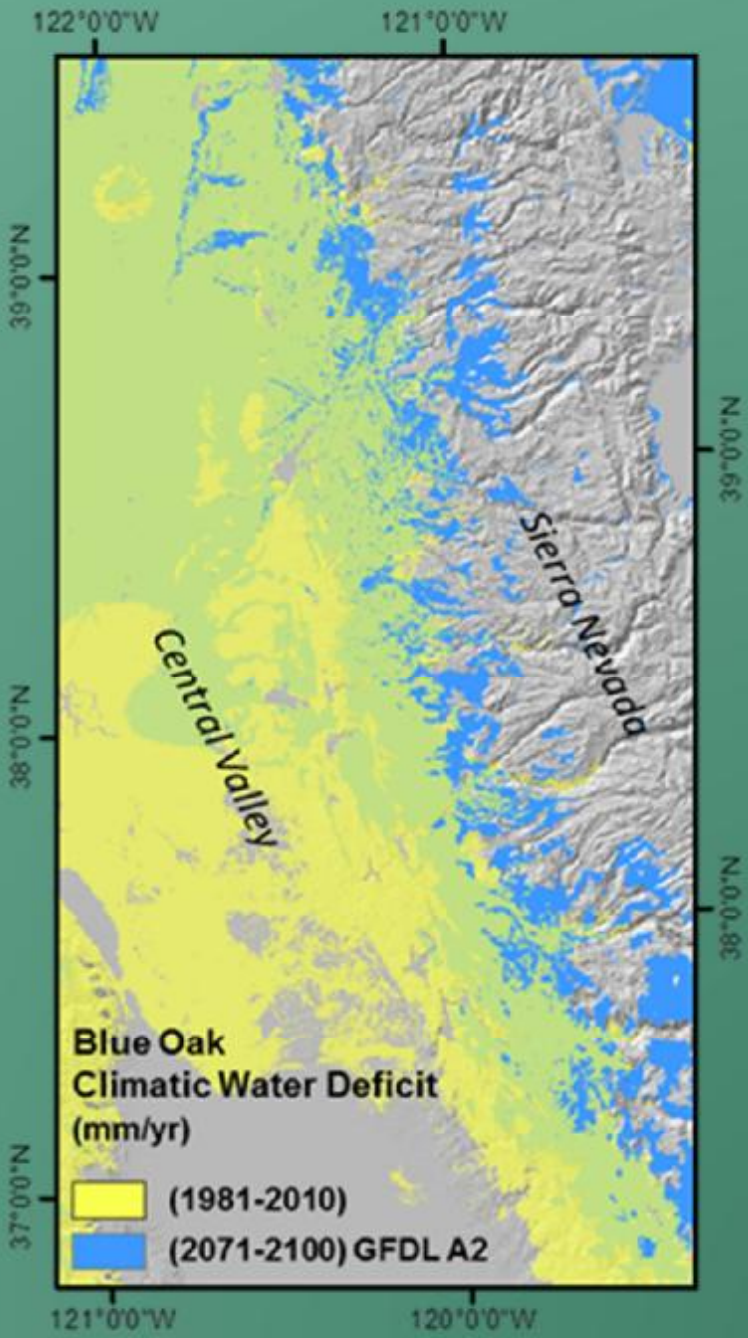
(mm/year)



High : 500

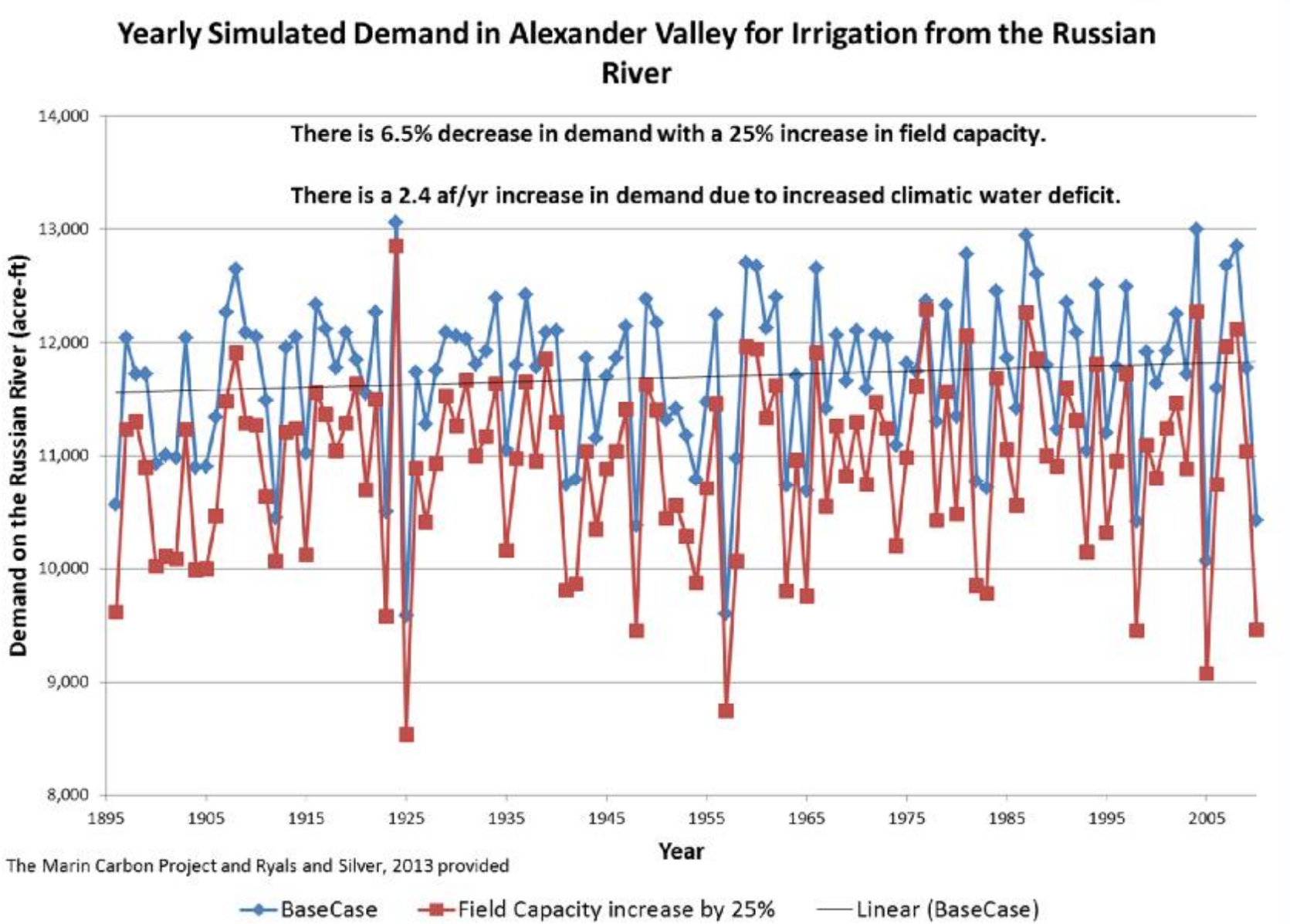
Low : 120

GFDL A2 climate scenario


122°0'0"W
121°0'0"W
39°0'0"N
38°0'0"N
37°0'0"N
121°0'0"W
120°0'0"W
39°0'0"N
38°0'0"N
Sierra Nevada
Central Valley
Blue Oak
Climatic Water Deficit
(mm/yr)
(1981-2010)
(2071-2100) GFDL A2

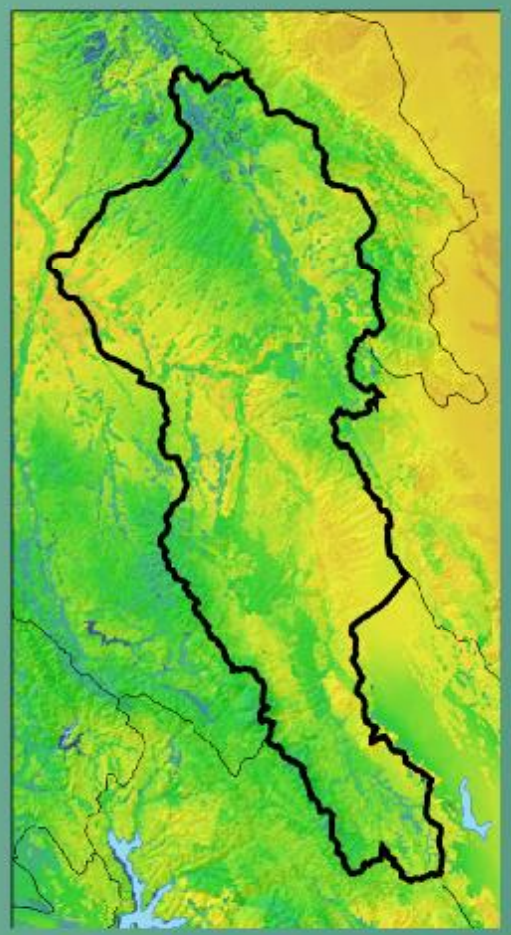
The Marin Carbon Project and Ryals and Silver, 2013, showed that increasing organic matter in soils could also increase field capacity and therefore soil water holding capacity. It also increases net primary productivity and forage quality.

That information was added to our hydrology model.


Yearly Simulated Demand in Alexander Valley for Irrigation from the Russian River
There is 6.5% decrease in demand with a 25% increase in field capacity.
There is a 2.4 af/yr increase in demand due to increased climatic water deficit.
Demand on the Russian River (acre-ft)
14,000
13,000
12,000
11,000
10,000
9,000
8,000
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
1995
2005
Year
The Marin Carbon Project and Ryals and Silver, 2013 provided
BaseCase
Field Capacity increase by 25%
Linear (BaseCase)

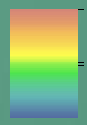
Implications of Strategic Soil Management
Estrella River

WY1998
No soil amendments



Climatic Water Deficit WY1998

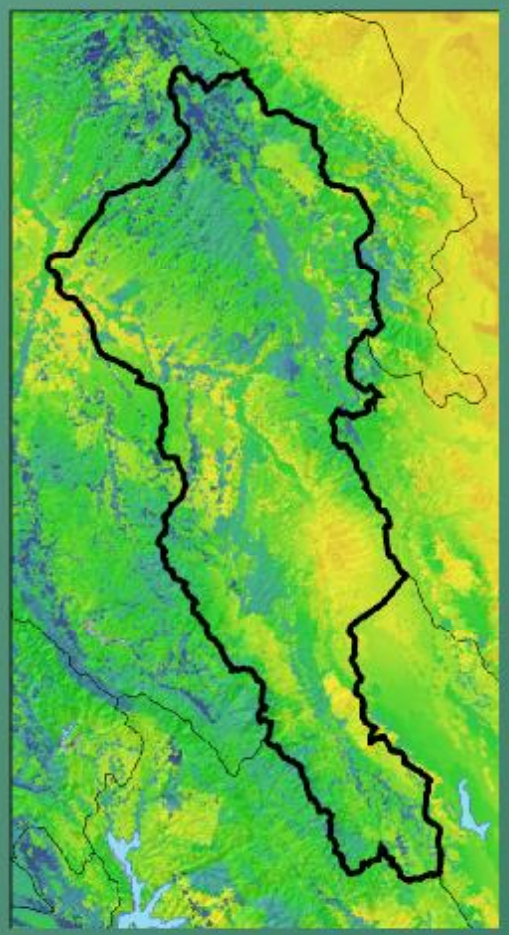
(mm/year)



High : 1,200

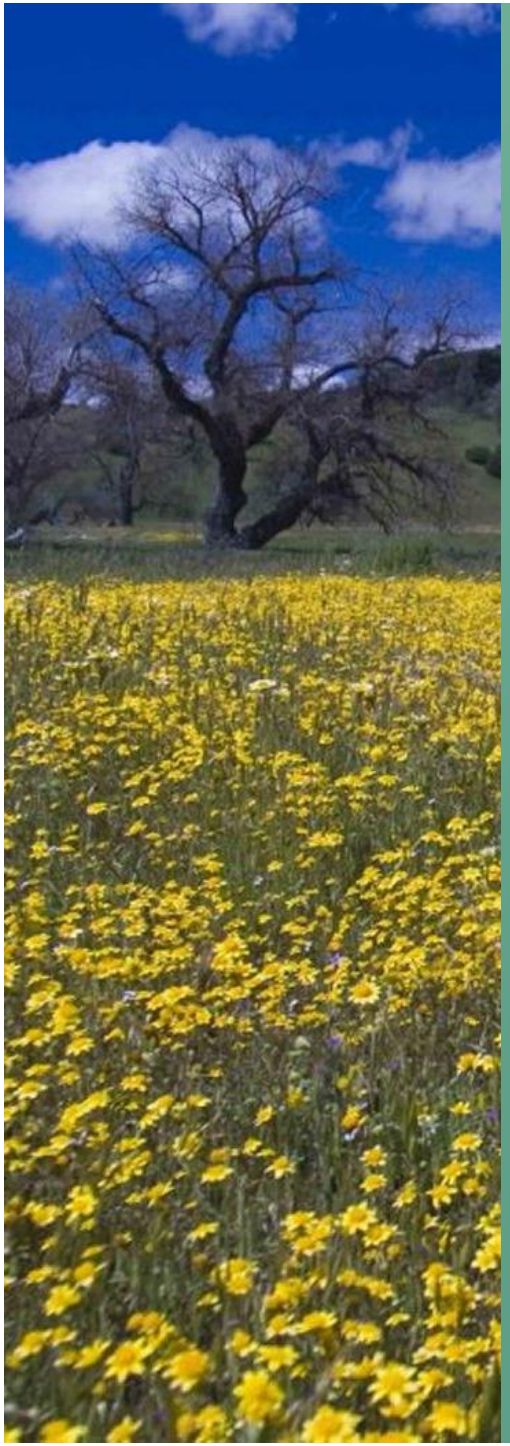
Low : 400

WY1998
Soil amendments to increase WHC 25%



Summary

- Highly variable future climate – long dry seasons, longer droughts, and larger precipitation events
- Rates of recharge, runoff, and streamflow will change with urbanization, across a wide precipitation gradient
- Urbanization greatly reduces opportunity for recharge potential under changing climate
- The rate of change in water storage and streamflow depends on current soil storage capacity
- While the projections of recharge and runoff are variable throughout California, recharge is projected to decline in many rangelands that are currently dependent on groundwater
- Climatic water deficit can be
  - used to characterize the resilience of a landscape to climate change
  - used as part of a soil management plan for increased productivity and soil water storage



Managing for Climate Change

- Management implication: most scenarios project the dry season will be extended, storage will be necessary, either above or below ground
- Understand how your watersheds respond to climate
  - Where do the trees live on the landscape? What parts of your watershed are the least resilient to change? What are the soil properties?
  - Monitor: climate, soil moisture, streamflow -> look for trends
- Optimize storage, enhance recharge, preserve recharge zones, maintain a permeable watershed
  - Soils can be managed to improve productivity and maintain water in the watershed
  - Surface depressions
  - Channel, floodplain, and habitat restoration

Future Work

- With the goal of conserving ranching landscapes that hold great potential for biodiversity conservation and ecosystem services, tools and information developed as part of this project are being disseminated via workshops with RCDs and other local land managers throughout California
- The goal is to
  - Quantify benefits of rangeland conservation (wildlife habitat, water supply, and carbon sequestration)
  - Provide guidance on how to make decisions regarding rangeland management in a changing climate
- Webpage has been developed to describe results and provide downloadable maps

- Contact: Kristin Byrd (kbyrd@usgs.gov), Pelayo Alvarez (palvarez@defenders.org), Lorrie Flint (lflint@usgs.gov)