Integrated Scenarios for California Rangeland Ecosystem Services:
Final Results for Habitat, Carbon and Water Supply

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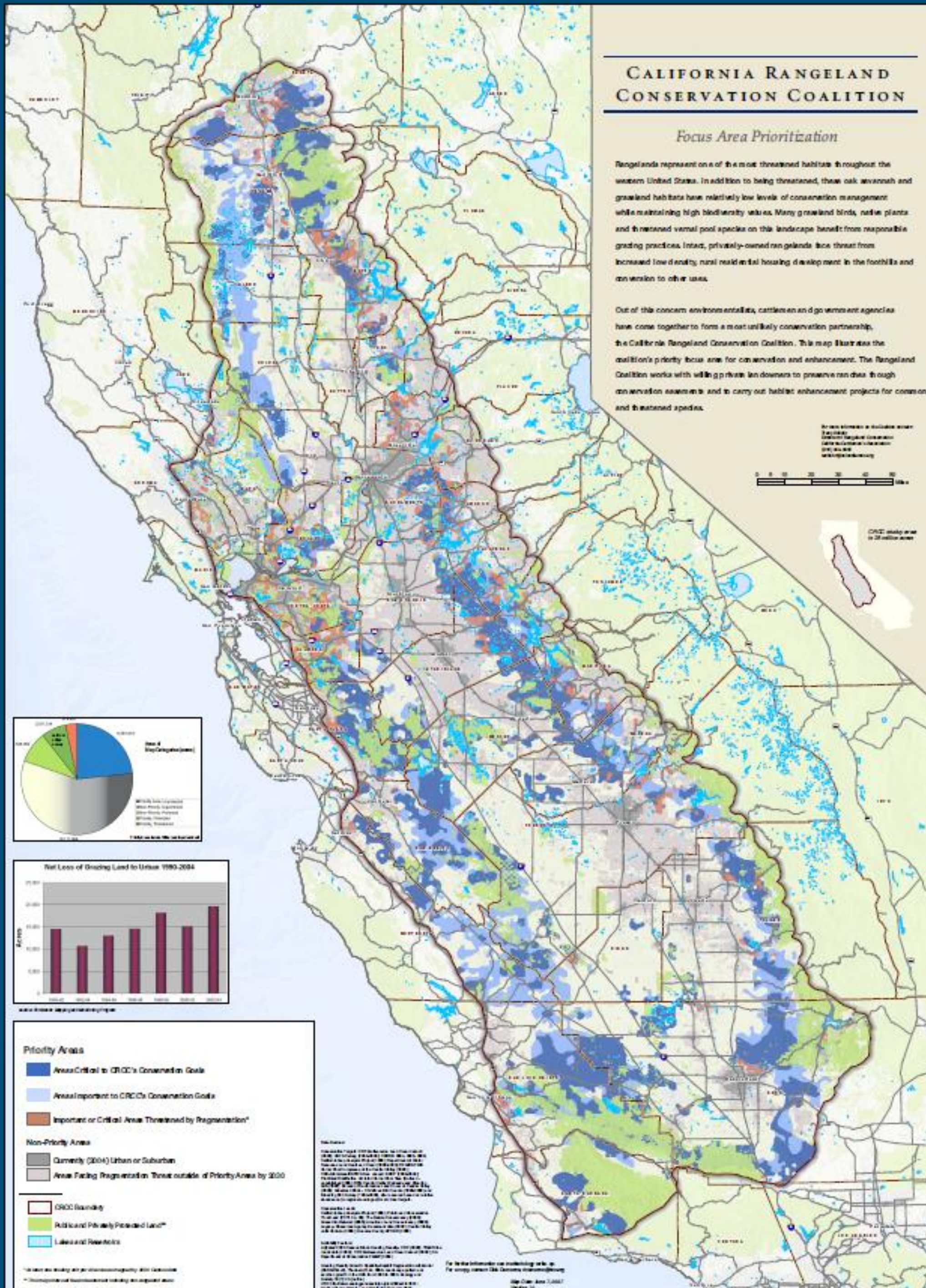

Rangeland Coalition Focus Area Map (TNC, 2007)

http://www.carangeland.org/focusarea.html

Dark blue: Critical Conservation Areas

(Privately-owned rangelands
that have high biodiversity value and require conservation action in the next 2-10 years.)

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Project Goals

- Six spatially-explicit climate change/land use change scenarios from years 2000 – 2100 consistent with three IPCC emission scenarios and two global climate models –

B1 (sustainability)	A1B (wealth and technology)	A2 (population pressures)
1. PCM (warm, wet future)	1. CSIRO Mark 3.5 GCM (warm, wet future)	1. PCM (warm, wet future)
2. GFDL CM 2.1 (hot, dry future)	2. MIROC 3.2 (medres) (hot, dry future)	2. GFDL CM 2.1 (hot, dry future)

- Assess potential threats to rangeland ecosystem services
  1. wildlife habitat
  2. water availability (Lorraine Flint and Alan Flint, USGS)
  3. carbon sequestration

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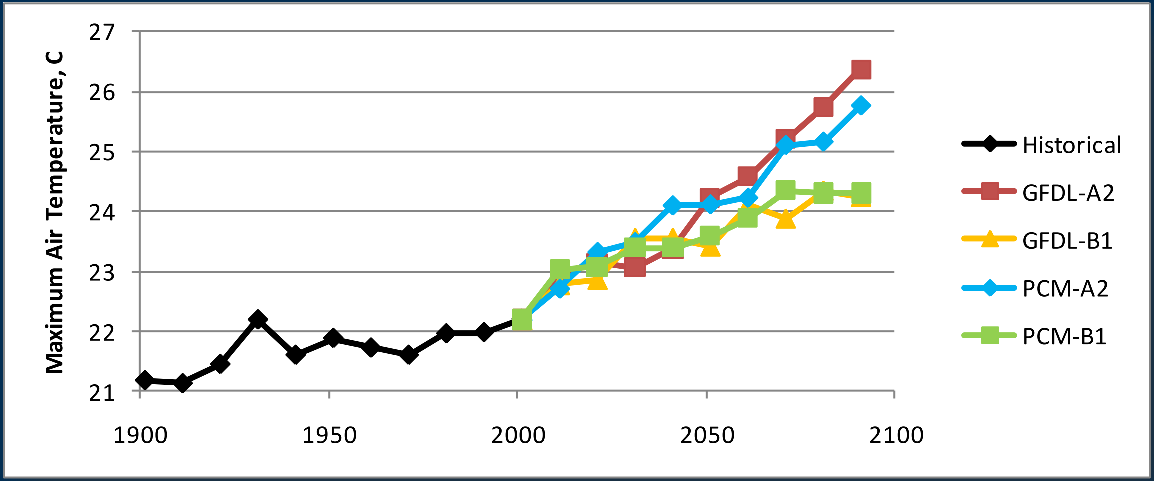
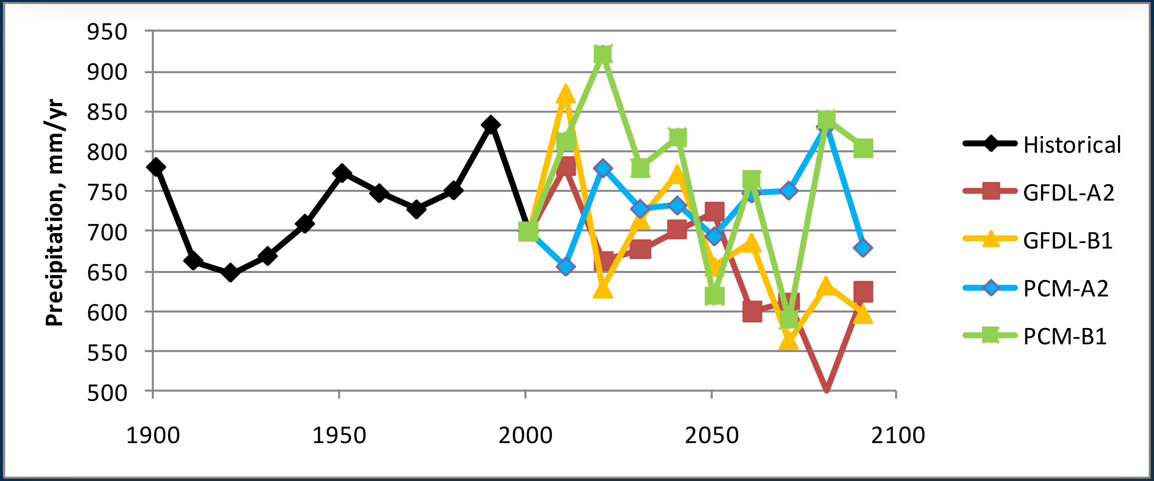
Project Goals, continued

3. An economic analysis of scenarios to quantify economic costs and benefits (Frank Casey, USGS)
4. A web-based visualization tool, and
5. An outreach program that will target the Rangeland Coalition network to communicate how results can be applied to conservation and land management decisions. (Pelayo Alvarez, Defenders of Wildlife)

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





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CA rangeland-adapted SRES land use scenarios

A1B Wealth and Technology

- Development – low density
- Agriculture – high value perennial crops
- Conservation – mixed-use emphasis
- 500,000 acres protected by 2100

A2 Population Pressures

- Development – low density
- Agriculture – intensive, less innovation
- Conservation – low priority
- No active conservation planning

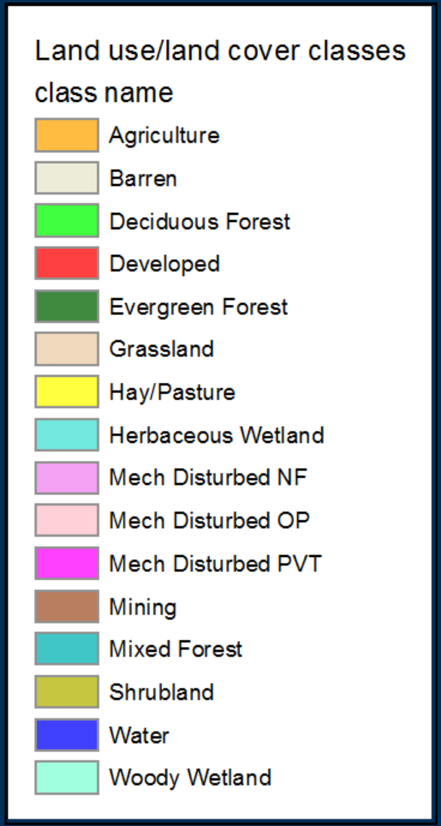
B1 Sustainability

- Development – high density
- Agriculture – moderate
- Conservation – biodiversity high priority
- 1 million acres protected by 2100

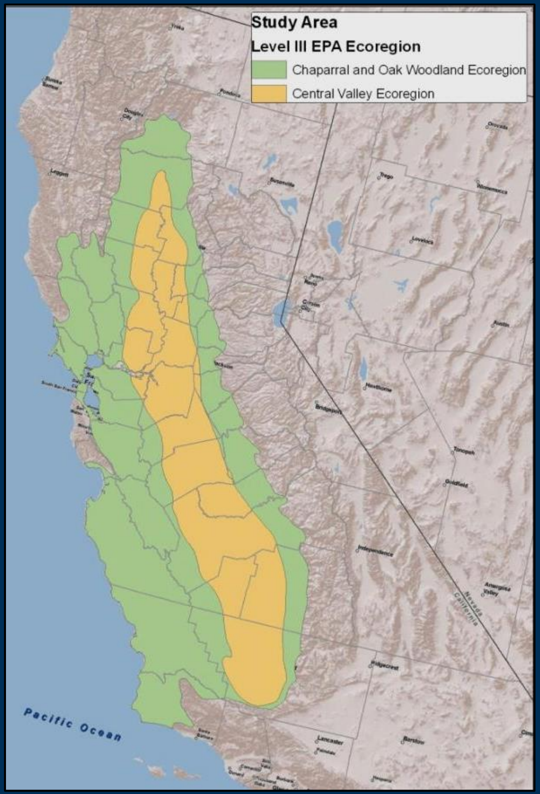
(Sleeter et al. 2012, Global Env. Change)

FOREcasting SCEnarios of future land cover (FORE-SCE)

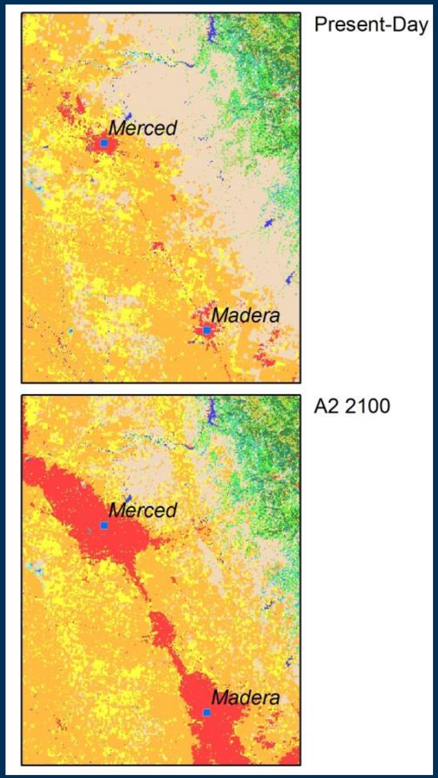
Modified USGS National Land Cover Dataset Classification



Eco-regions: Central Valley and Chaparral and Oak Woodlands

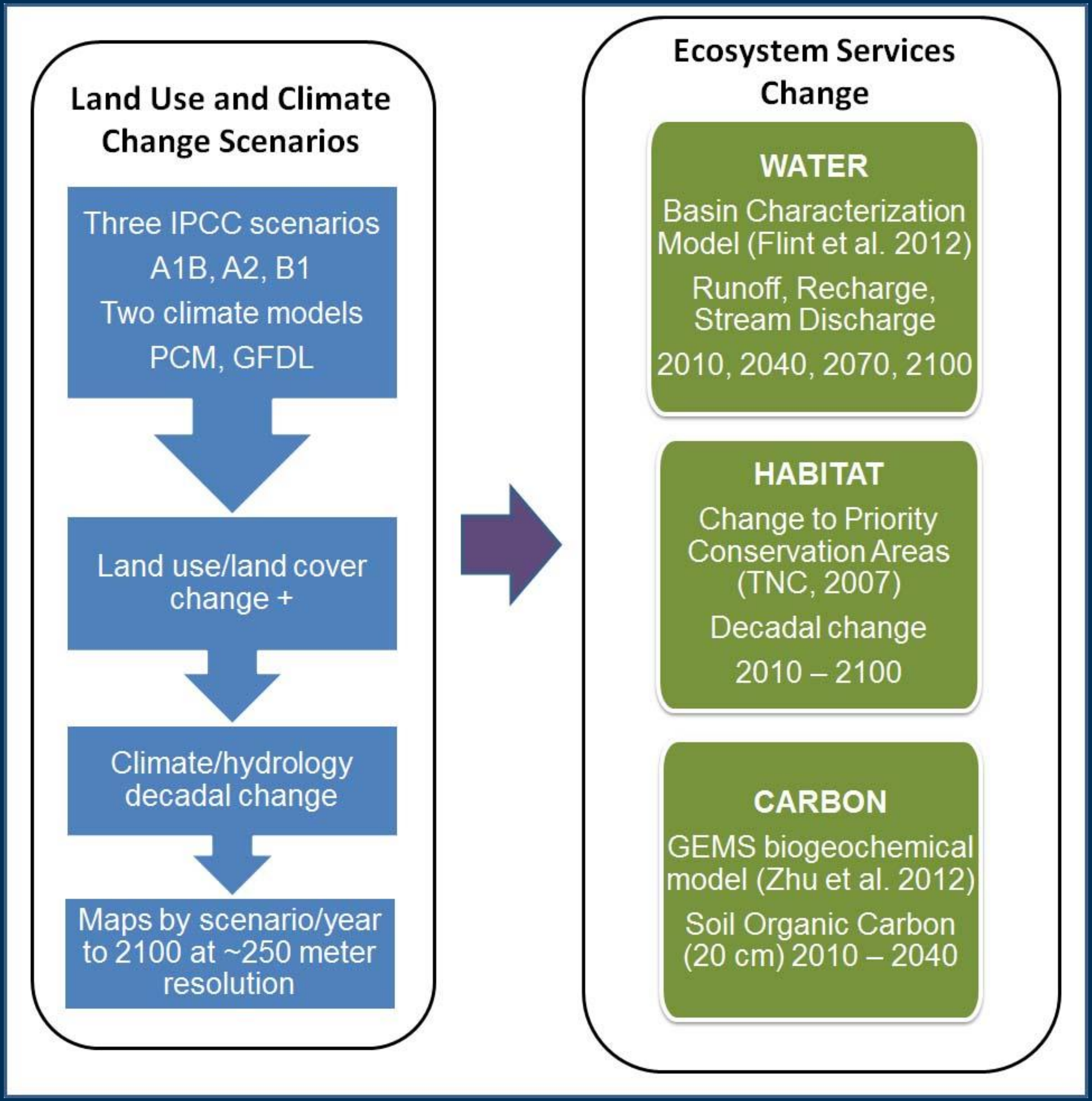


250 m yearly land use/land cover maps



(Sohl and Sayler, 2008, Ecological Modelling)

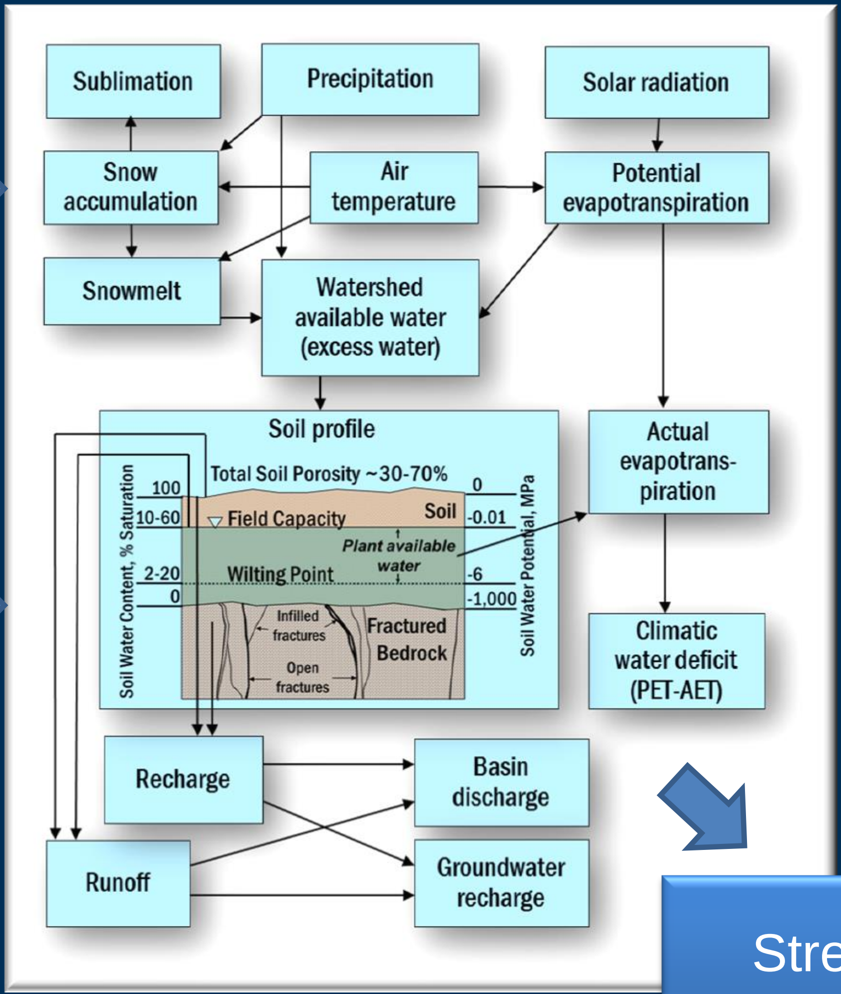
Modeling Changes to Rangeland Ecosystem Services



Basin Characterization Model (BCM)

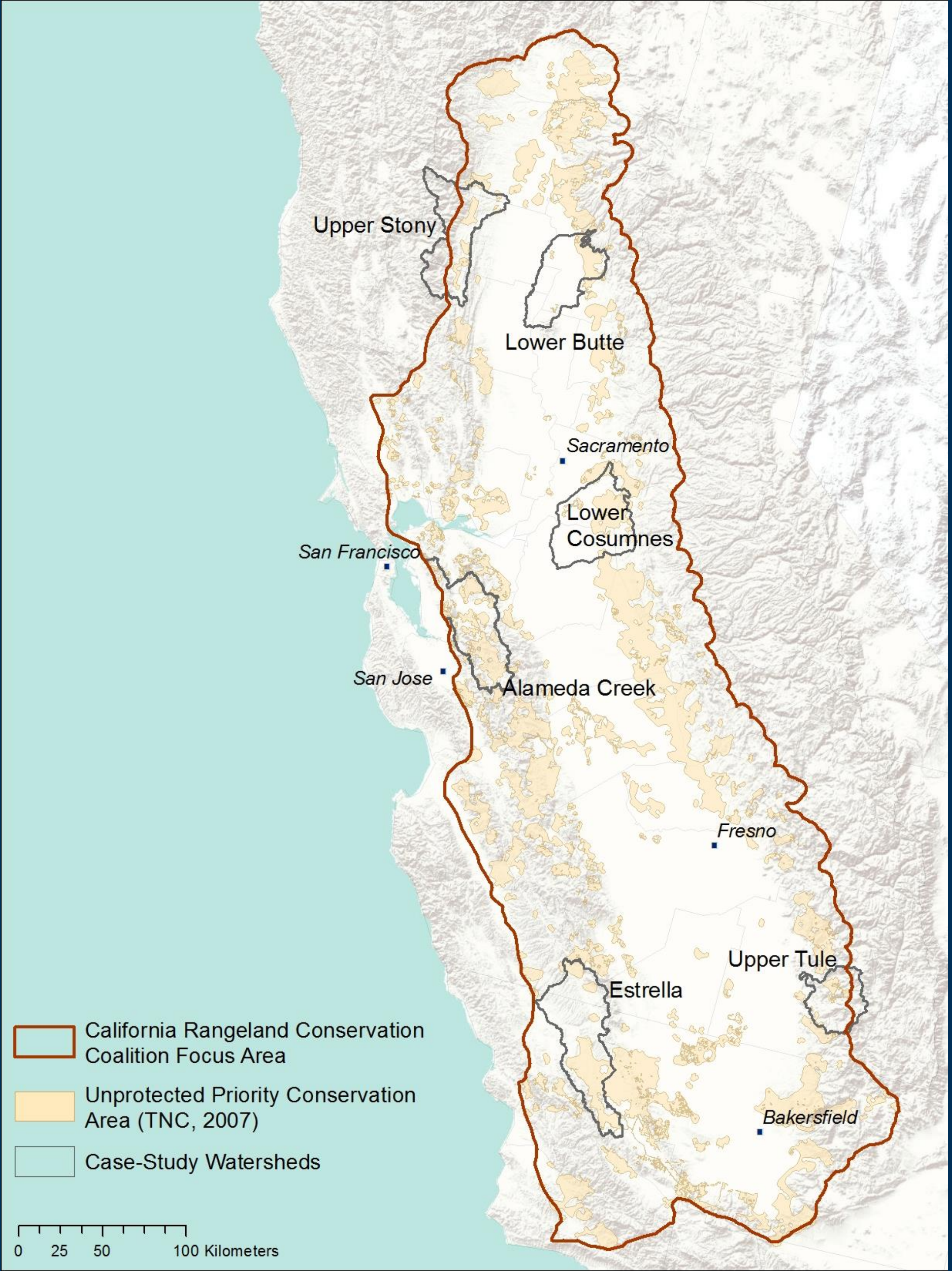
Downscaled GCM data:
Monthly Precipitation
Max, Min Air
Temperature

Land use change data:
Urbanization



Streamflow Model

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



Case Study of Six Watersheds:

North:
Upper Stony
Lower Butte

Central:
Lower Cosumnes
Alameda Creek

South:
Upper Tule
Estrella

Changes in:
- Wildlife habitat
- Carbon
- Runoff, recharge, streamflow

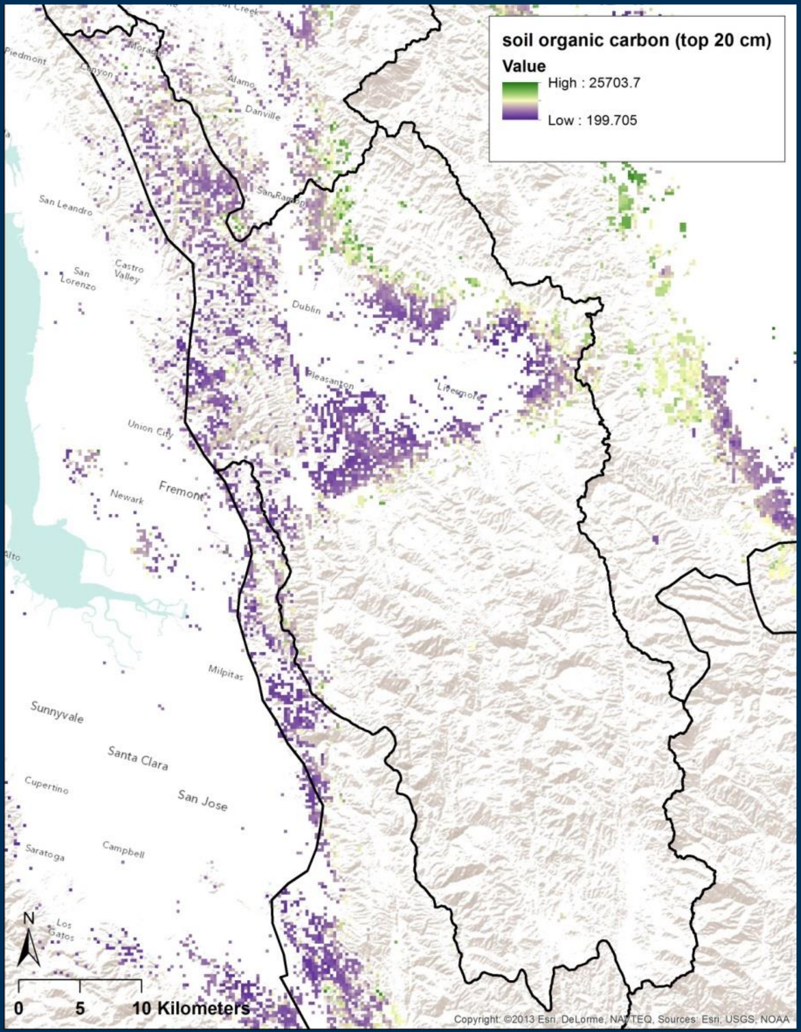
Baseline Ecosystem Services in the Rangeland Coalition Focus Area and Case Study Watersheds

Watershed	Area (10x6 m^2)	Rangeland Habitat (10x6 m^2)	Grassland area 2010 (ha)	Total grassland SOC (Tg, top 20 cm)	Recharge 1981-2010 (10x6 m^3)	Runoff 1981-2010 (10x6 m^3)
Alameda Creek	1,789	1,571	83,231	2.35	214	175
Cosumnes	1,926	990	81,956	2.11	199	75
Estrella	2,464	2,145	170,738	5.76	120	58
Lower Butte	1,552	448	26,869	0.84	244	96
Upper Stony	1,061	1,476	64,700	1.66	149	179
Upper Tule	820	607	17,531	0.46	71	136
Focus Area	113,221	594,002	3,435,400	100.97	9,253	9,814

Soil Carbon

Soil organic carbon (g/m^2, top 20 cm) on grasslands converted to urban land use between 2010 and 2040

Alameda Creek
A1B scenario



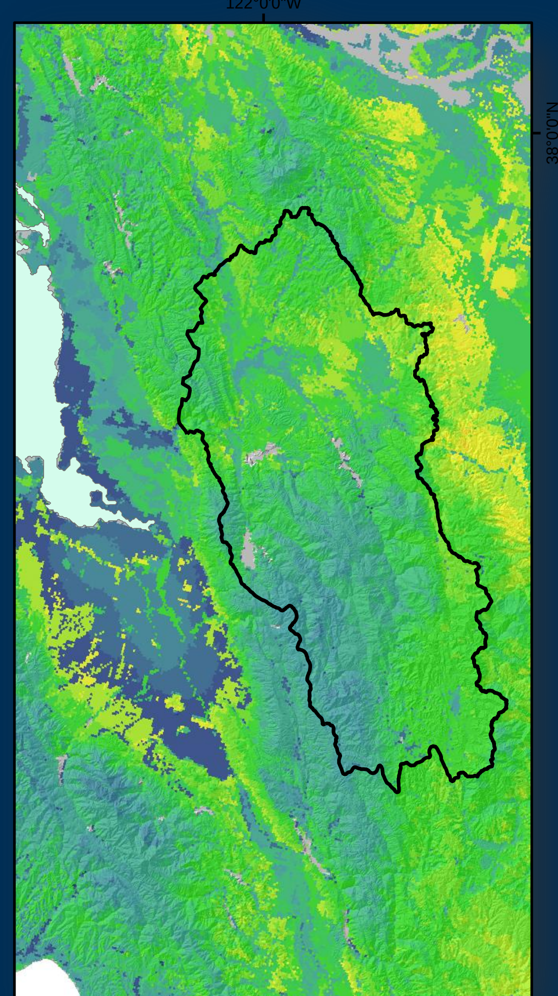
Scenario	Grassland area (ha) 2010	Grassland area (ha) 2040	SOC loss (Mg/ha)	% SOC loss	Total Carbon Lost (Mg) 2040
A1B	81,512.4	58,062.5	12.81	31%	300,455.7
A2	83,287.4	68,587.5	11.13	27%	163,597.5
B1	82,624.9	65,862.5	13.75	34%	230,512.6

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 the BCM hydrology model.

Implications of Strategic Soil Management Alameda Creek

WY1998
No soil amendments



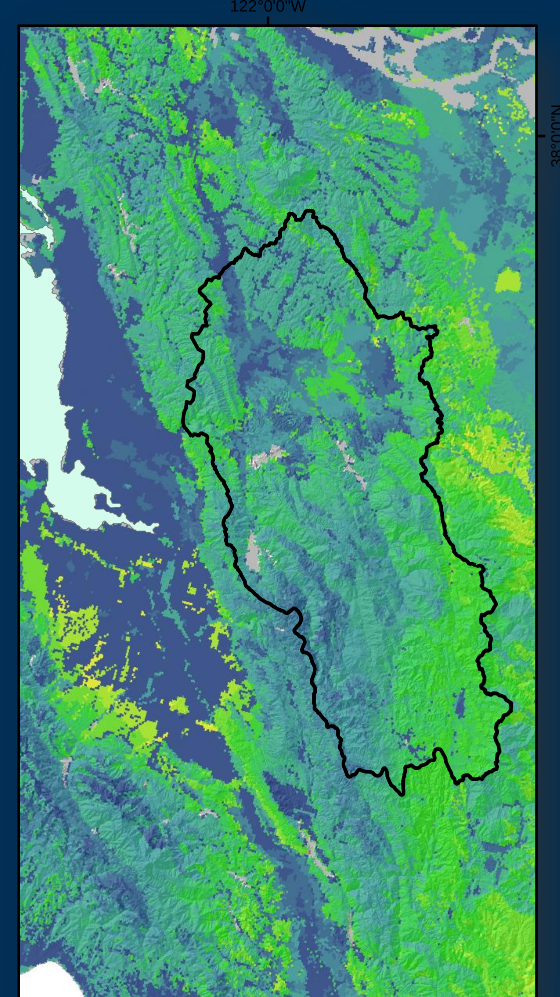
Climatic Water Deficit WY1998

(mm/year)

High : 1,200

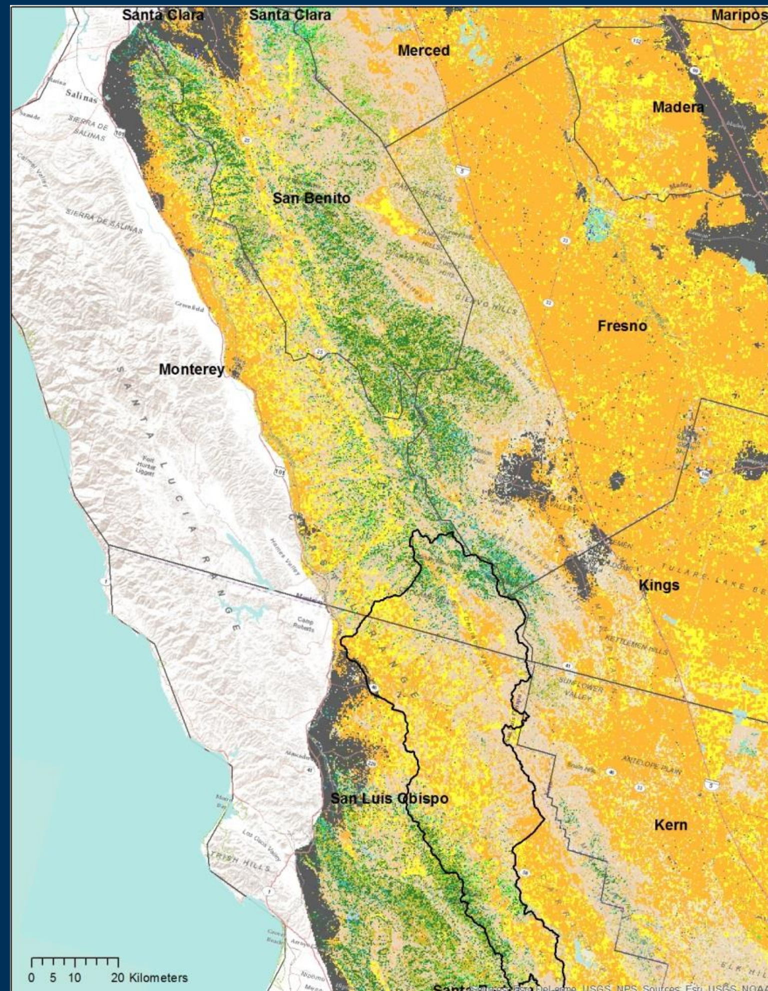
Low : 400

WY1998
Soil amendments to increase WHC 25%



Wildlife Habitat

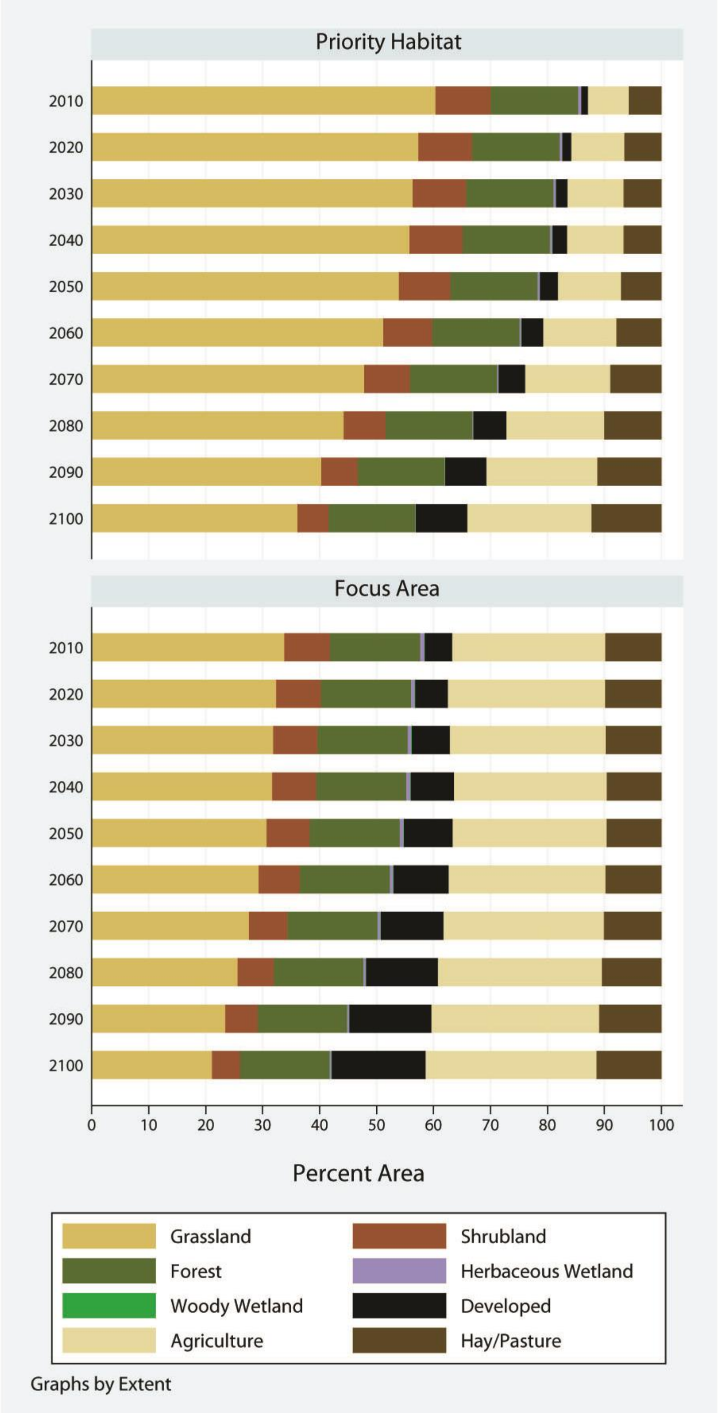
Land use change scenarios – A2, 2010, 2050, 2100



Land use/land cover classes

Class_Name

- Unclassified
- 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



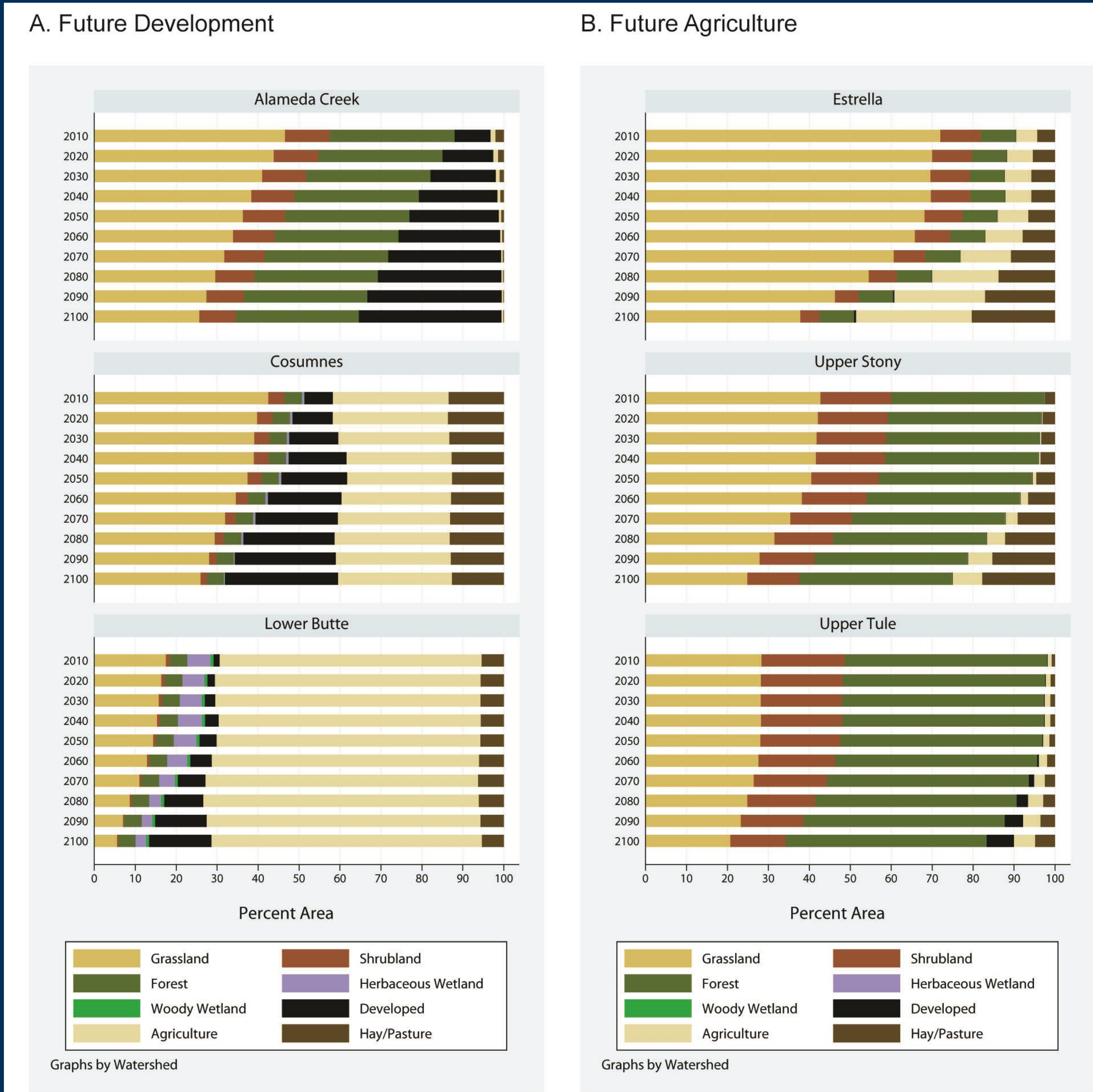
Land use change scenarios – A2 Priority Habitats vs Focus Area

Grassland loses most area in each region

Focus area: A2: 37% loss by 2100
B1: 23% loss by 2100

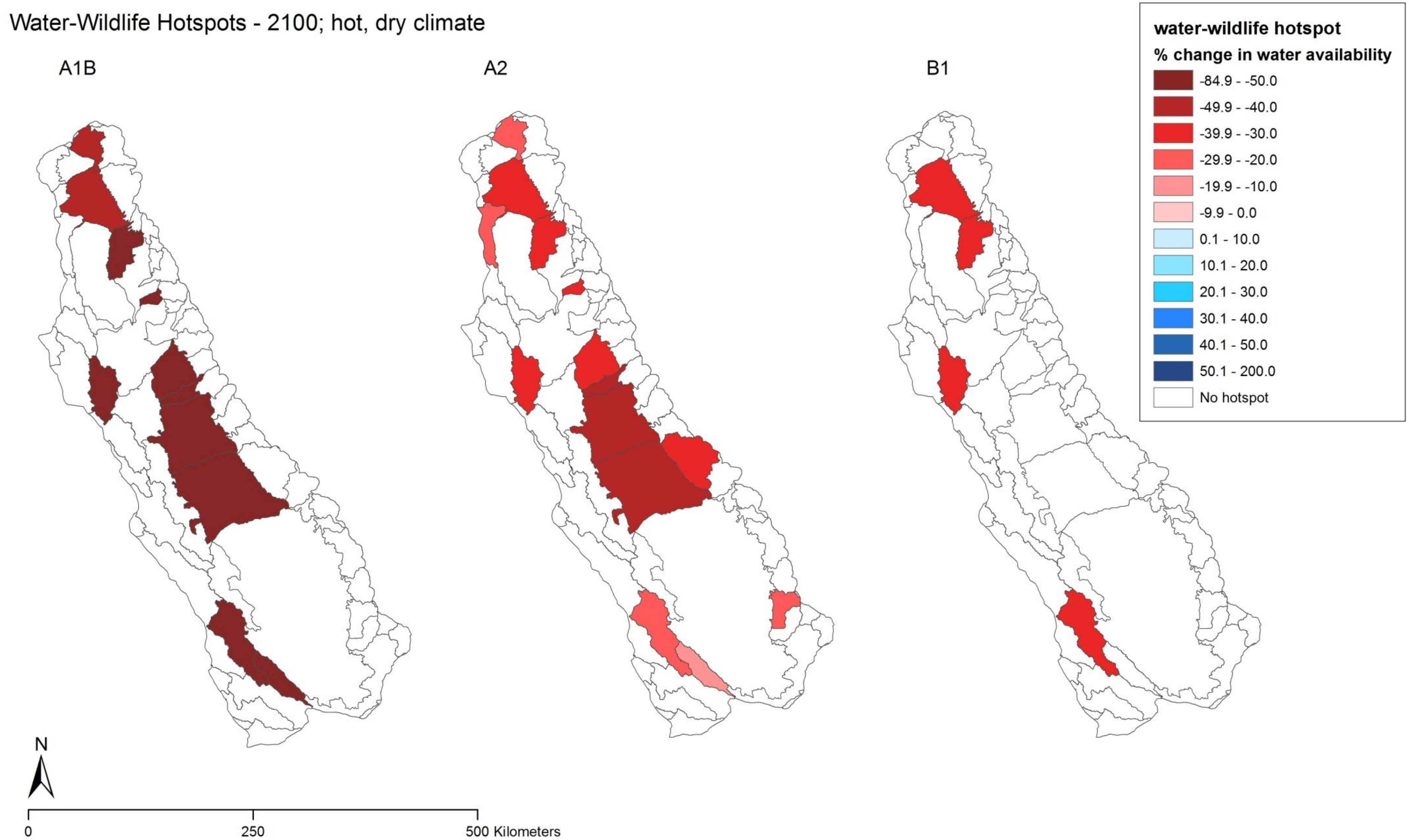
Priority habitat: A2: 40% loss by 2100
B1: 22% loss by 2100

Patterns of grassland loss repeated in case study watersheds



Water-wildlife hotspots: areas where changes in water availability (recharge plus runoff) and loss of critical habitat coincide.

Percent change in water availability (recharge + runoff) relative to the 1981-2010 climate period where 5% or more of watershed area has lost critical habitat



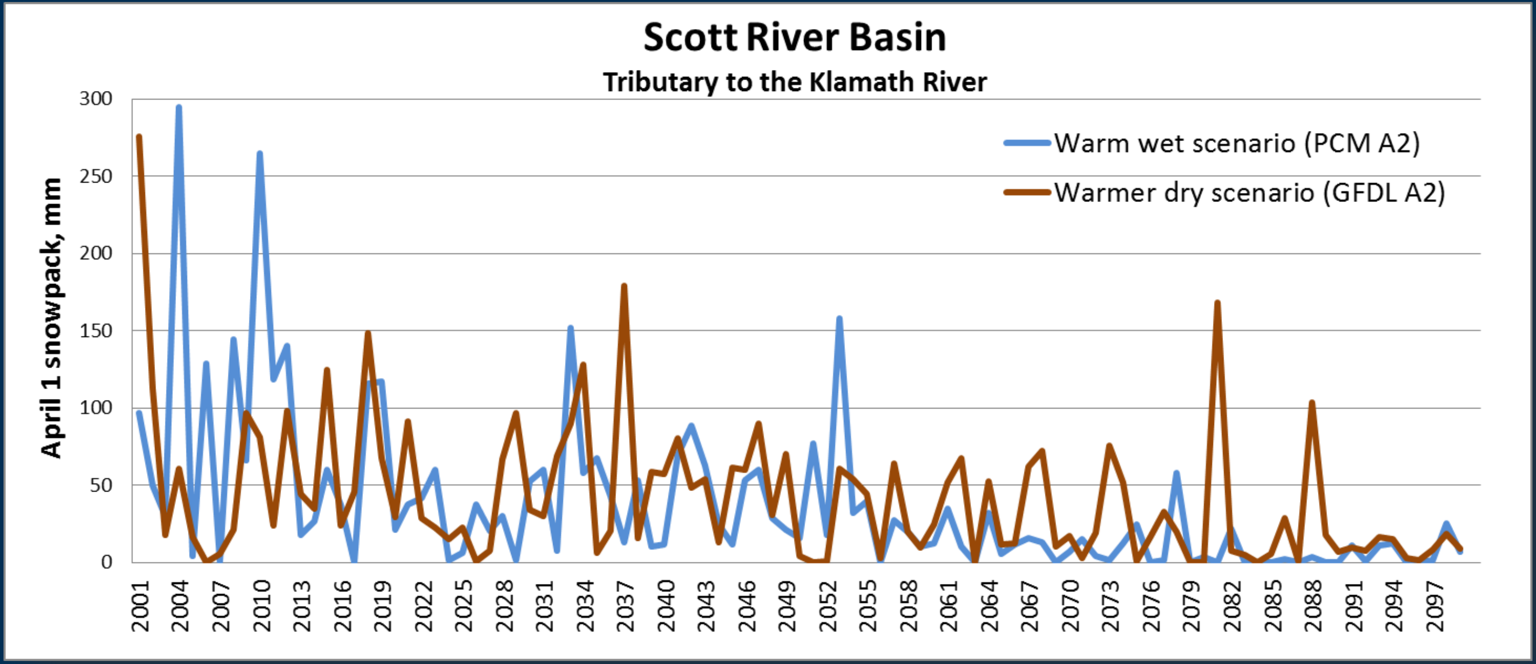
Habitat and Carbon summary

- Projected habitat loss greatest in grasslands at all scales – focus area, priority habitats, watersheds
- Shifts in cropland to foothills: greatest area of grassland conversion in priority habitats
- Most rapid priority habitat loss around Suisun Bay
- Grasslands: significant soil carbon pool (100 Tg in top 20 cm in focus area)
- Little data on soil carbon changes after grassland conversion
- Soil amendments have strong potential to increase carbon sequestration (Marin Carbon Project)

Water Supply

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.

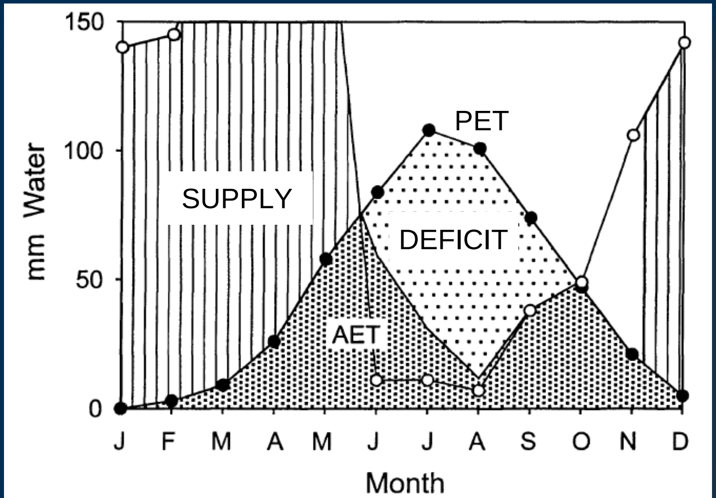


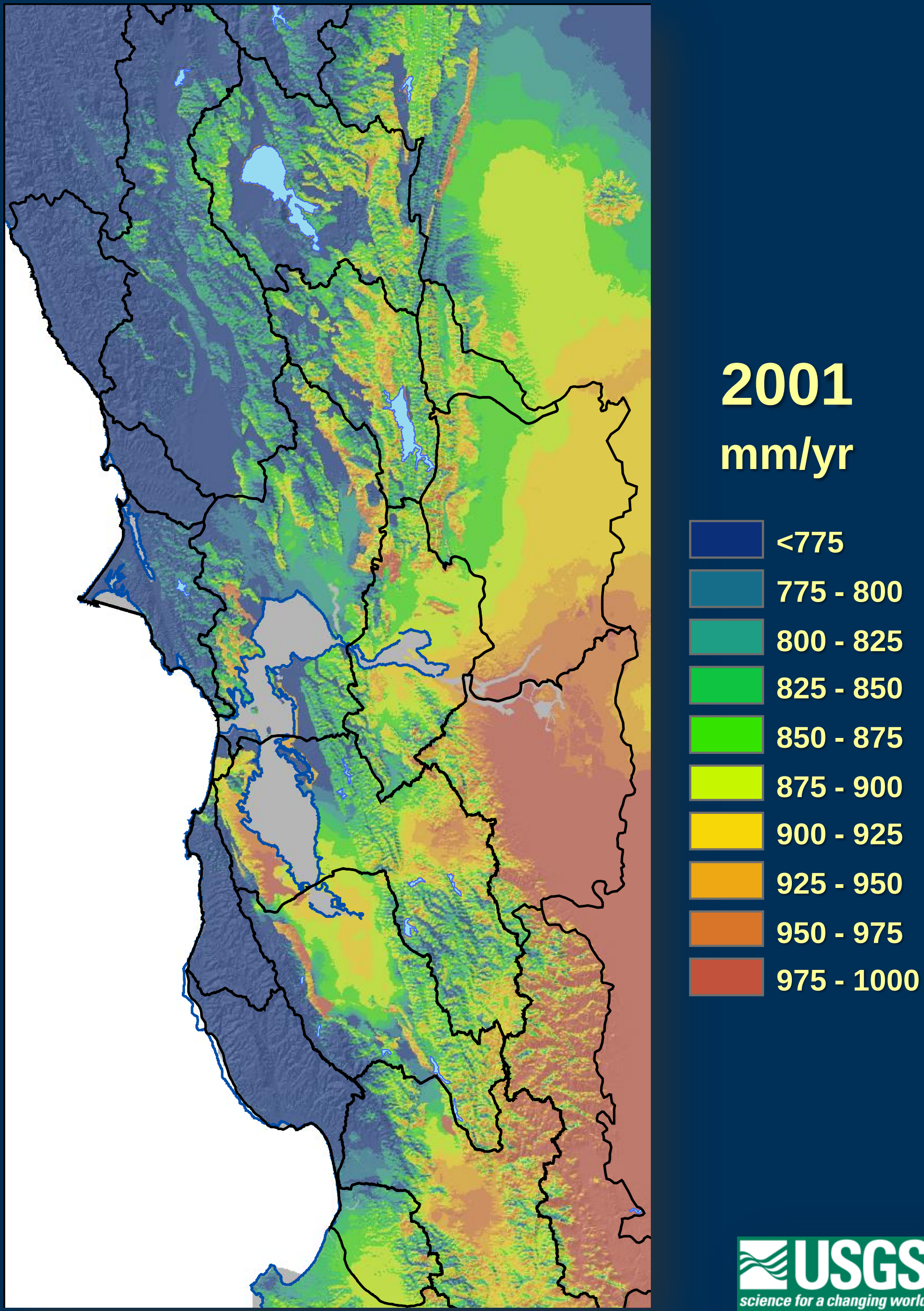
Climatic Water Deficit

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**





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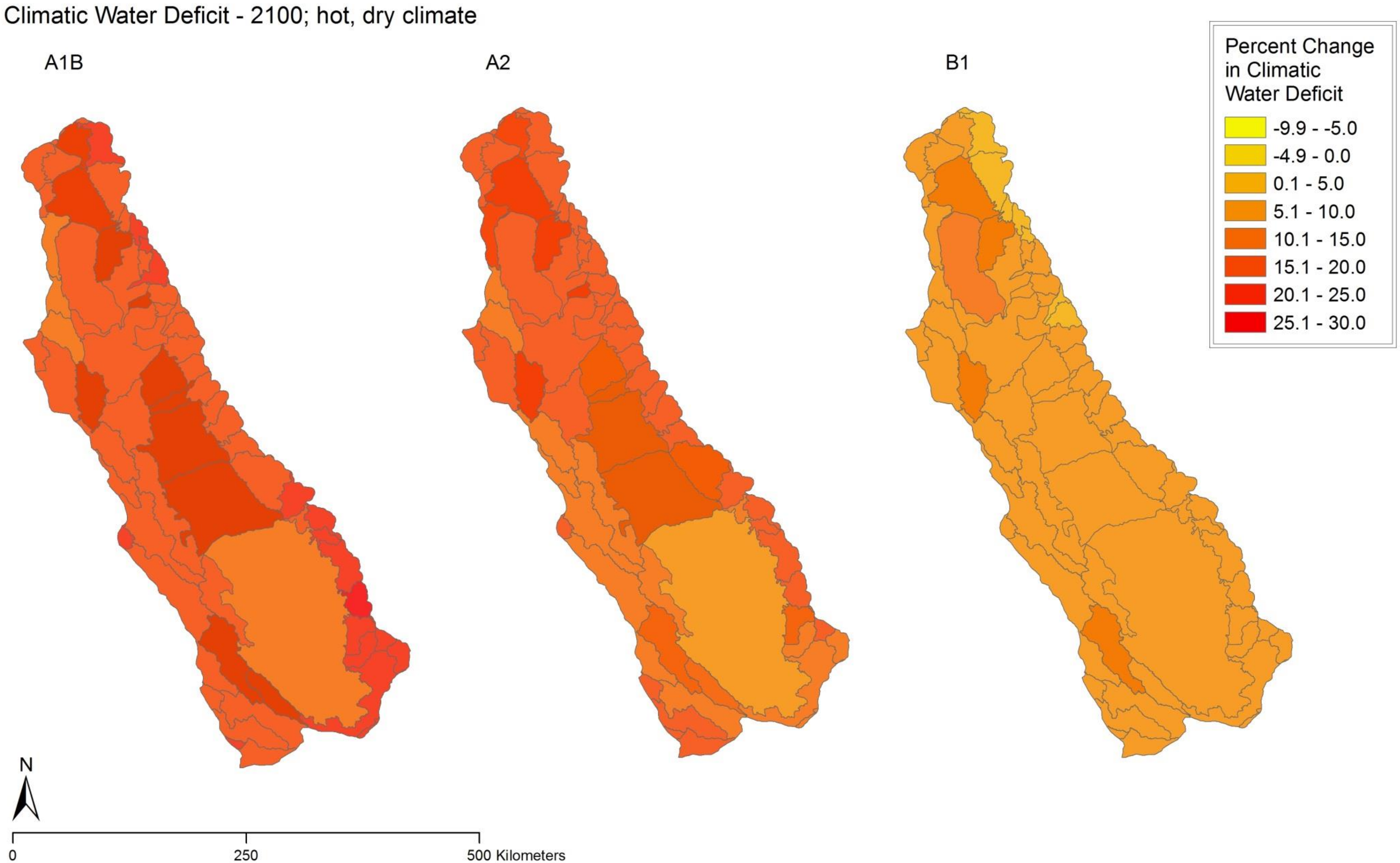
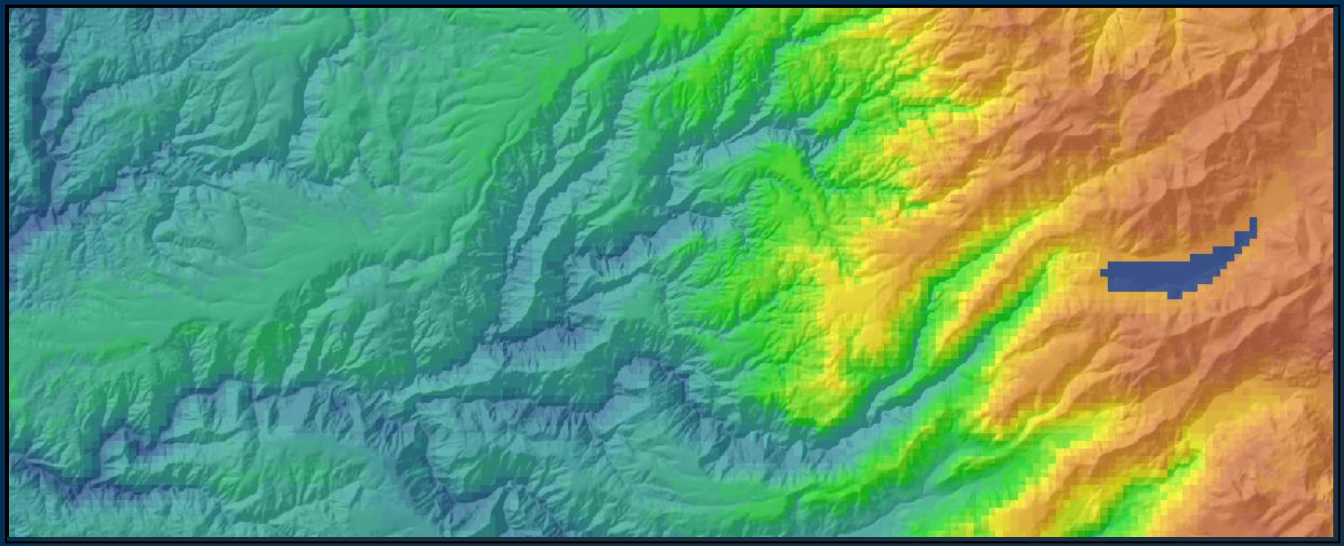
Percent change in climatic water deficit relative to the 1981-2010 climate period

CWD = potential evapotranspiration minus actual evapotranspiration.

This term effectively integrates the combined effects of solar radiation, evapotranspiration, and air temperature on watershed conditions given available soil moisture derived from precipitation.



Local to watershed application characterizes landscape resilience



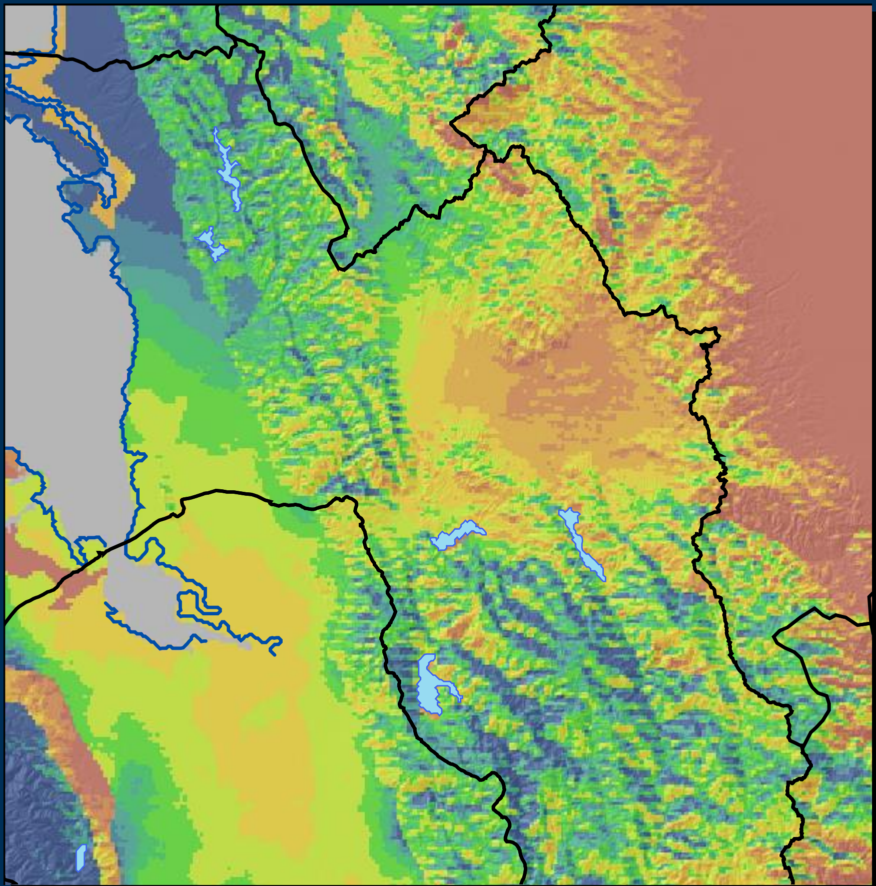
Change in climatic water deficit (1981-2010) relative to (2070-2099)

(mm/year)

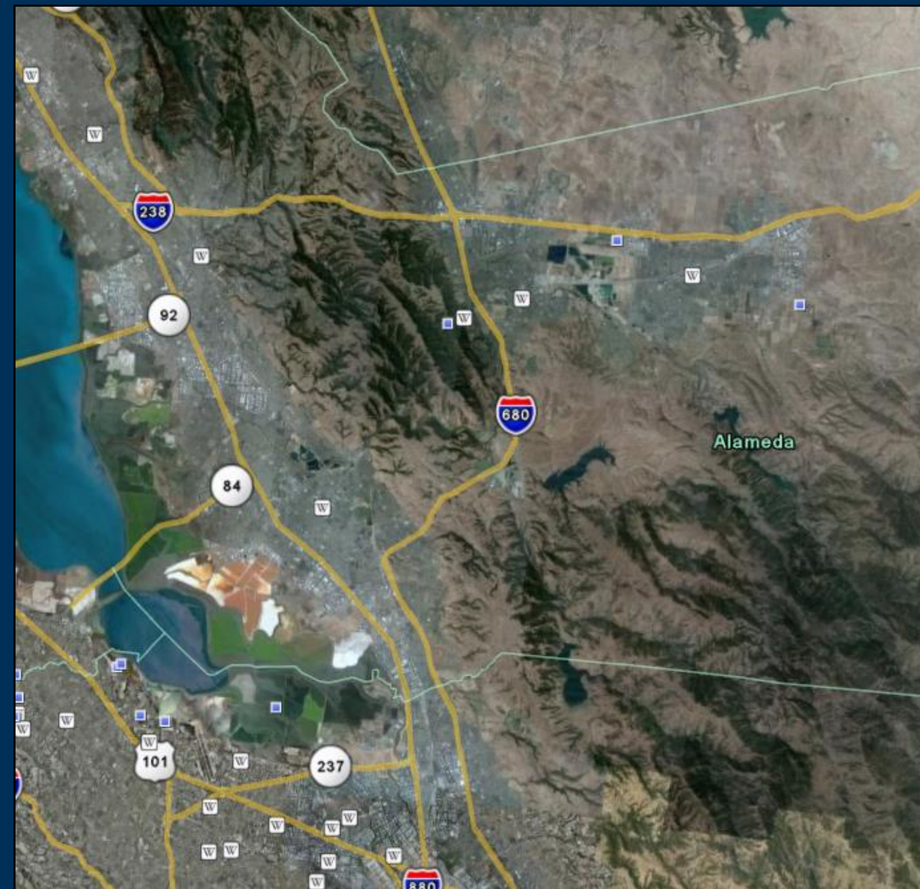
High : 500

Low : 120

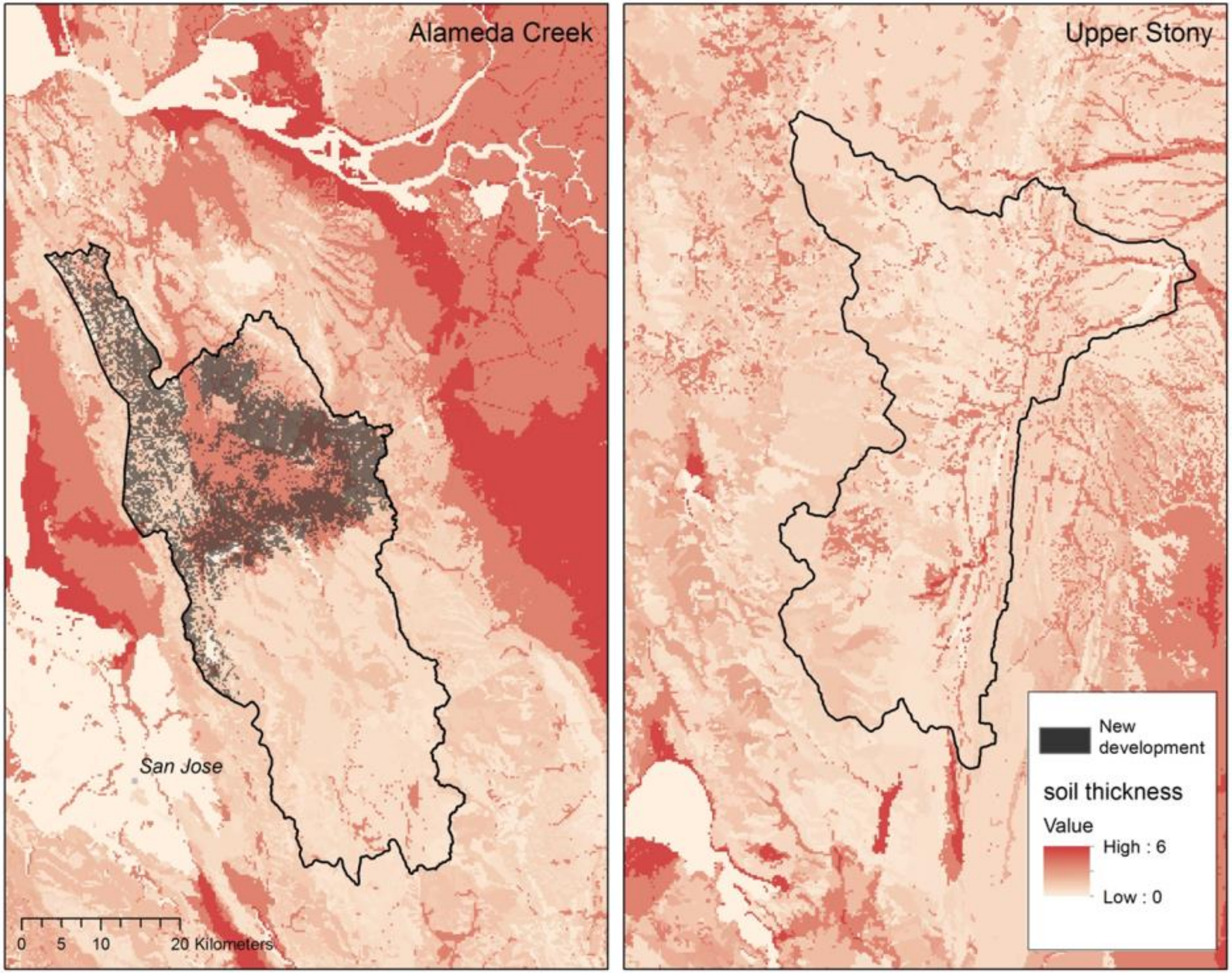
GFDL A2 climate scenario



Climatic Water Deficit in South Bay

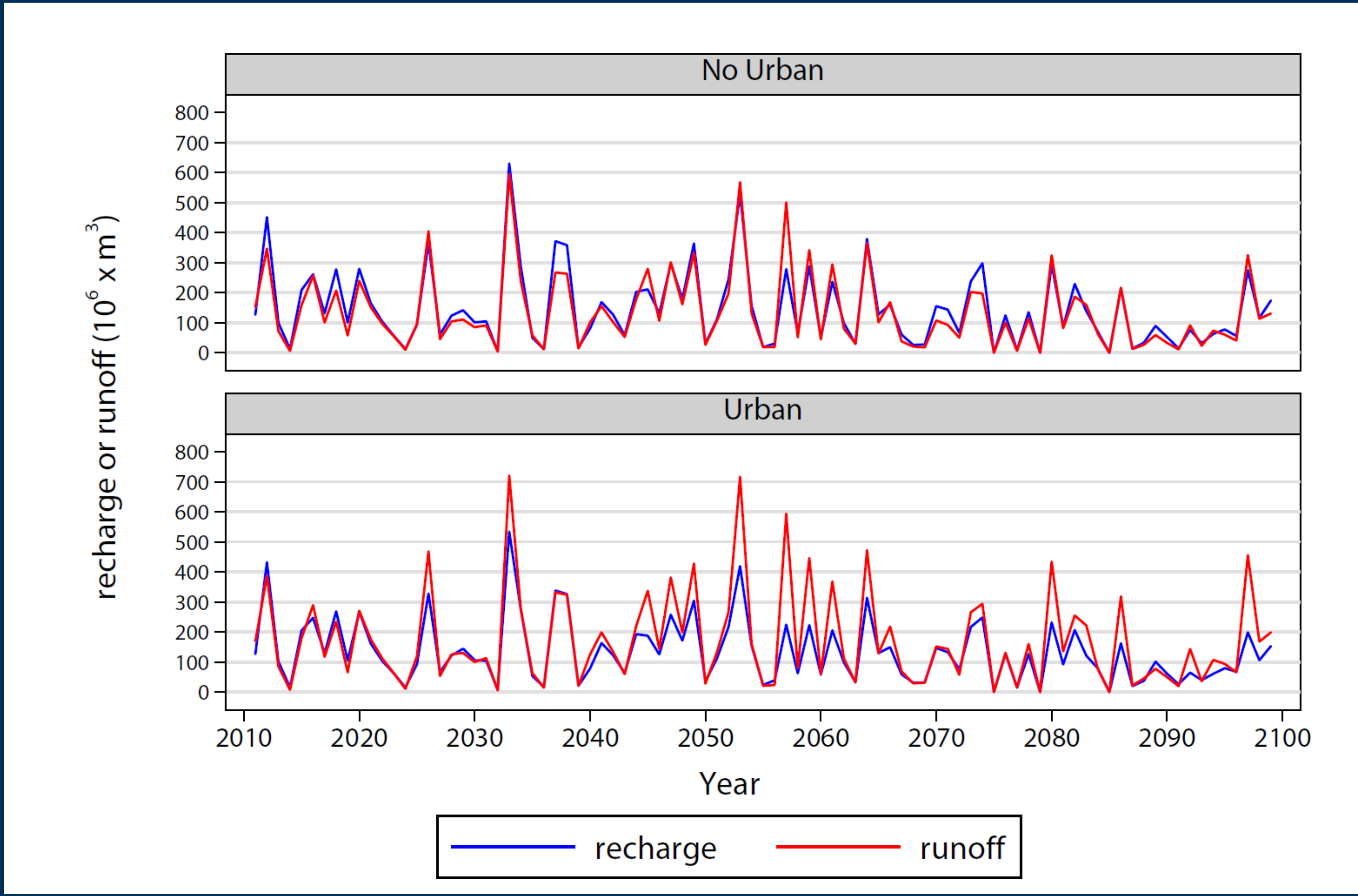


Google Earth Image of South Bay



A2 2100 urbanization scenario, overlaid on new soil thickness dataset – SSURGO county-level soil surveys (Flint et al. 2013).
Soil storage affected by soil porosity and soil depth

GFDL A2 Scenario – Alameda Creek with and without future urbanization



Methods

- Run BCM for 4 time periods, 6 scenarios
- Two cases:
  - With future urbanization
  - Without future urbanization
- Plot change in recharge, runoff, streamflow vs. precipitation for each case
- Use Analysis of Covariance to test for sig. differences between cases

Time period	Scenario
2003-2006	A2 GFDL
2037-2040	A2 PCM
2067-2070	A1B MIROC
2096-2099	A1B CSIRO
	B1 GFDL
	B1 PCM

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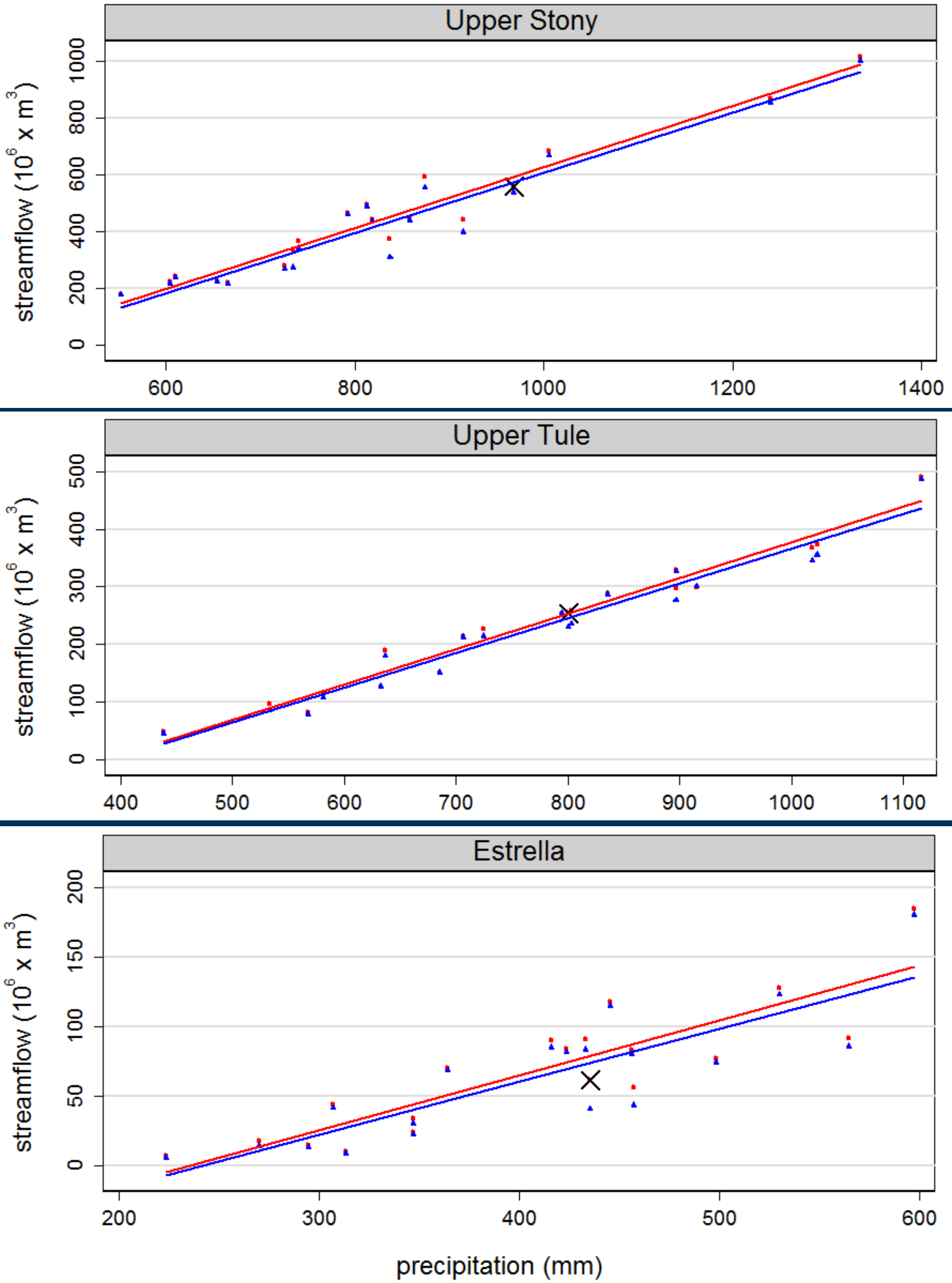
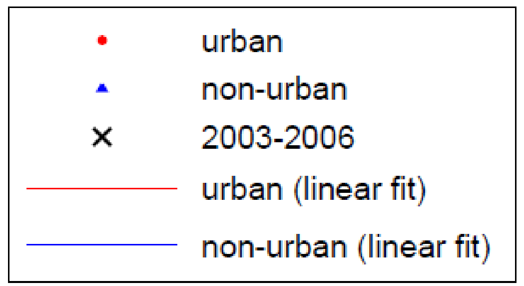
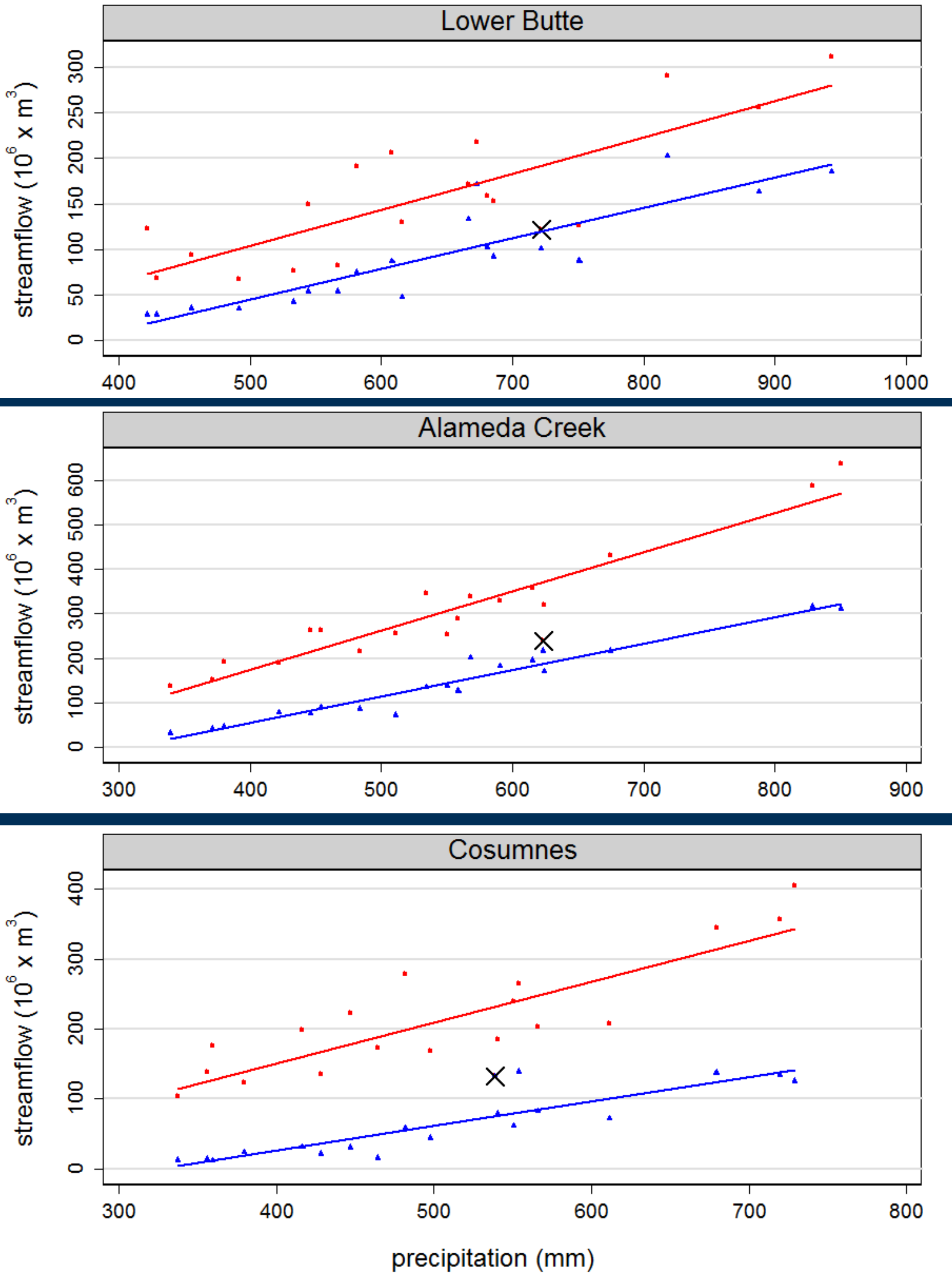
Streamflow vs. Precipitation

(**NON-URBAN** watersheds)





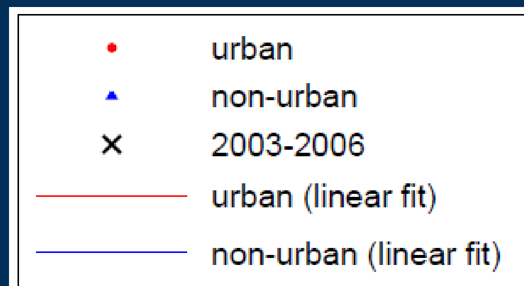


Streamflow vs. Precipitation

(**URBAN** watersheds)

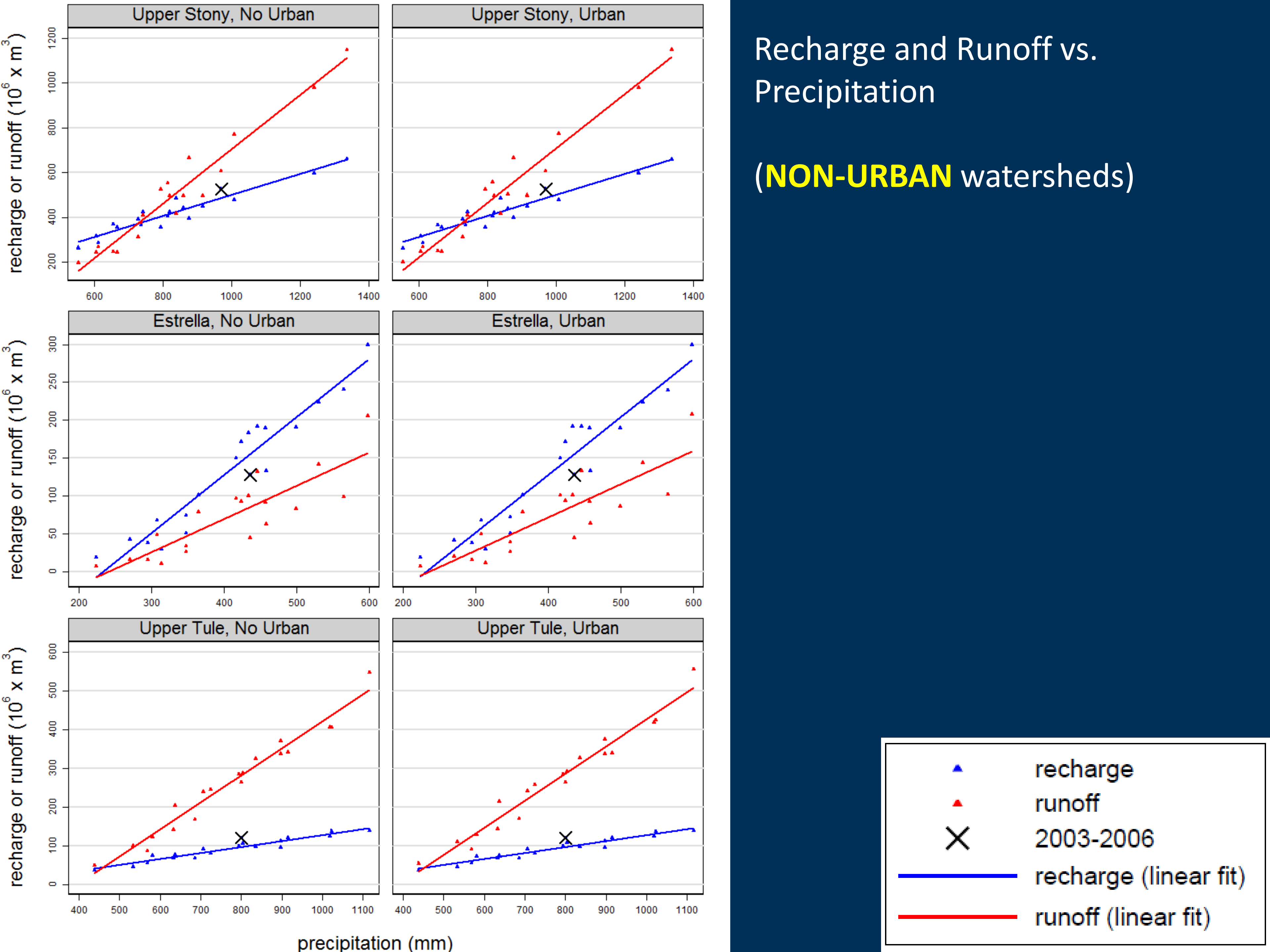
ANCOVA results:
urban vs. non-urban regression

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	

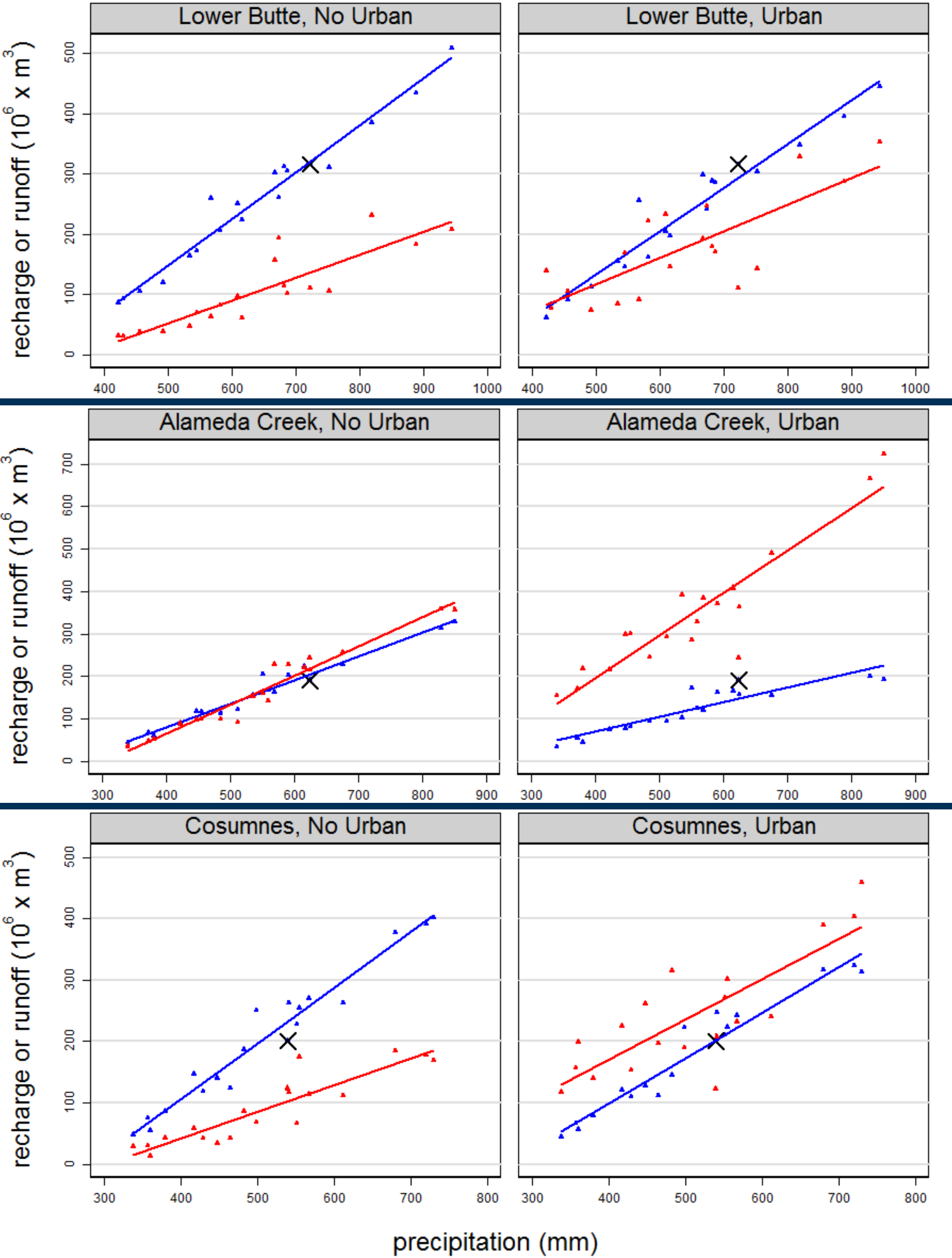


Recharge and Runoff vs. Precipitation

(**NON-URBAN** watersheds)



Recharge and Runoff vs. PPT (**URBAN** watersheds)



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)**

Water Supply Summary

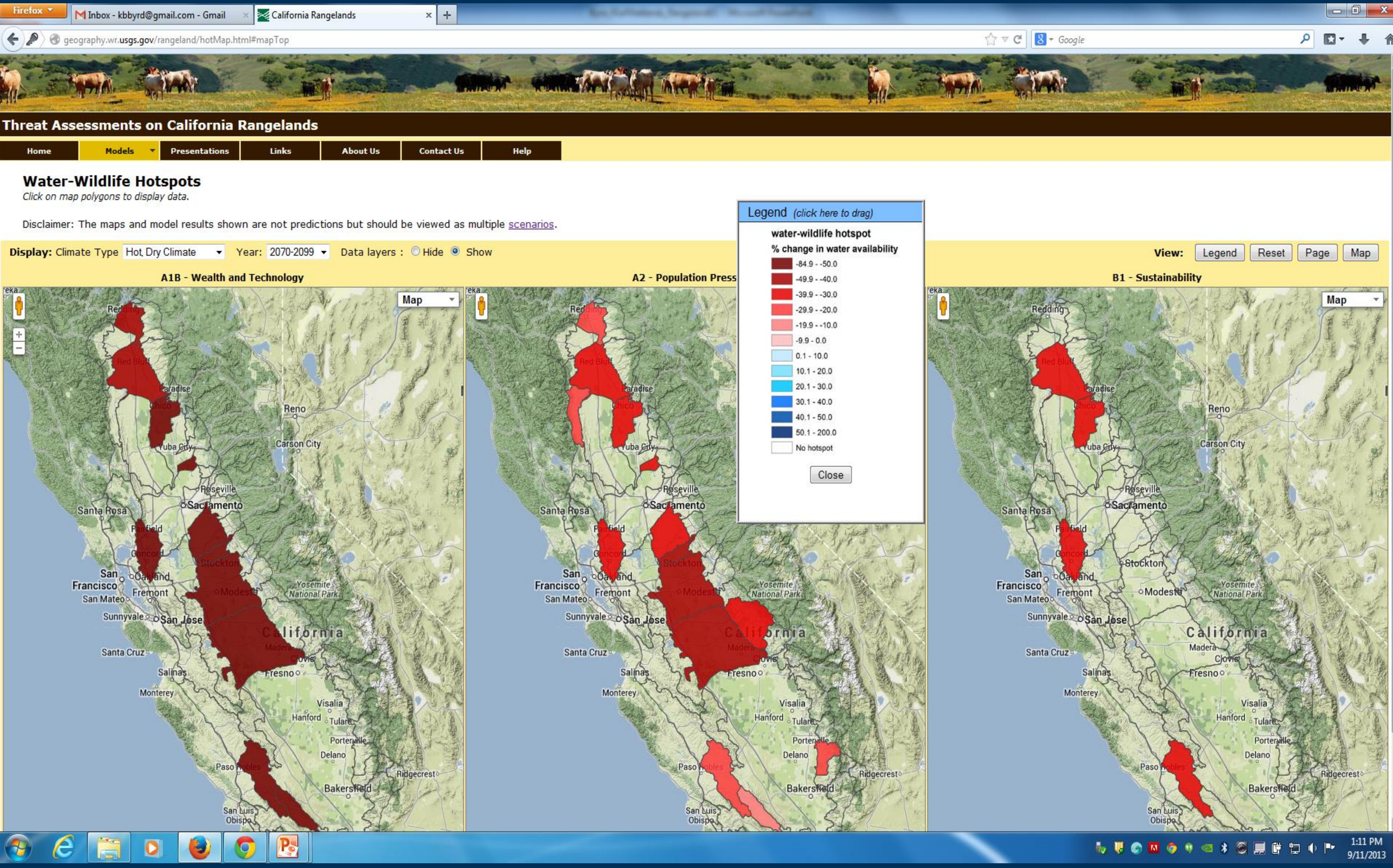
- Highly variable future climate– longer droughts and larger precipitation events
- Climatic water deficit: increases under all scenarios, as much as 30%
- Rates of recharge, runoff, and streamflow will change with urbanization, across a wide precipitation gradient
- In a dryer climate, recharge dominates runoff
- 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 and soil depth

Managing for Climate Change

- Management implication: most scenarios project the dry season will be extended, storage will be necessary, either above or below ground
- Need for **Climate-Smart Land Use Planning**
- Understand how your watersheds respond to climate
  - 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

Web visualization tool:

http://climate.calcommons.org/aux/rangeland/index.html



Web visualization tool:

http://climate.calcommons.org/aux/rangeland/index.html

Maps available:

- Critical Habitat: Change in the percentage of watershed area with critical habitat from 2010 to a future time period
- Percent change in grassland soil carbon sequestration potential
- Percent change in climatic water deficit relative to the 1981-2010 climate period
- Ratio of Recharge to Runoff for each 30-year climate period
- Water-Wildlife Hotspots: areas where changes in water availability (recharge plus runoff) and loss of critical habitat coincide
- Average percent change in multiple ecosystem services from 2010 to 2040

Raster datasets available (250 – 270 m)

- Baseline soil organic carbon
- Soil depth

For three scenarios: A1B (wealth and technology), A2 (population pressures) and B1 (sustainability) and two climate models (hot, dry, and warm, wet), 2010-2100 :

- Land use/land cover change
- Conversion of priority habitat
- Climatic water deficit
- Recharge, runoff, and recharge:runoff ratio
- Water availability (recharge + runoff)

Use of datasets

- Consider limitations of data and appropriate scale at which to use the information
- Evaluate strategic choices regarding land use
- Evaluate relative landscape resiliency to climate change
  - Implications for wildfire, forest health, pests
  - Implications for species distributions and biodiversity, invasives
- Evaluate potential changes in water availability and extremes
  - Flooding, peak flows, erosion
  - Drought, environmental flows, fisheries
  - Recharge zones

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