Potential for Adaptation to Climate Change in an Agricultural Landscape in the Central Valley of California

Scenarios Analysis Project, California Energy Commission

Climate and Agriculture Summit
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Why focus on agricultural adaptation to climate change?

- New emphasis in CA state agencies
- Changes in climate have already begun
  - Awareness→Analysis→Action
- California agriculture is important nationwide
- Without adaptation strategies, land use will likely urbanize
  - Precarious livelihoods for farmers
  - Less open space
  - Higher GHG emissions

Project overview

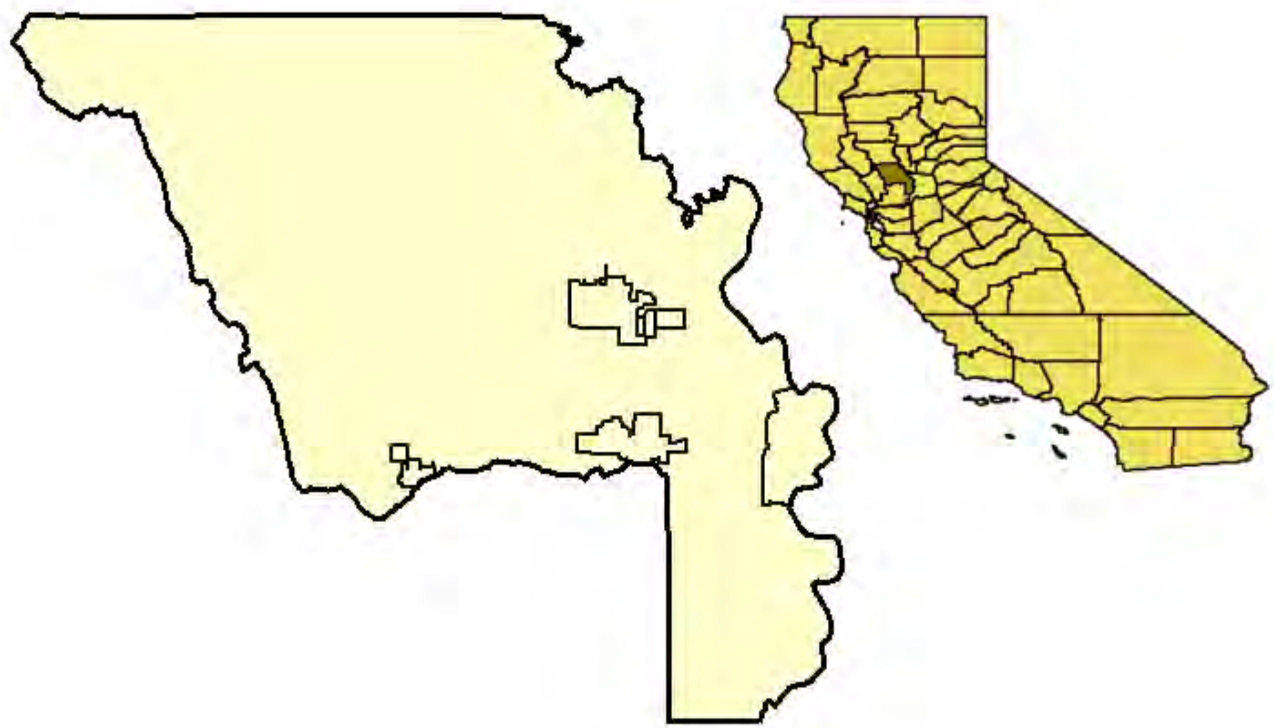
- Purpose
  - Demonstrate climate change responses for a representative agricultural county in California
    - Yolo Co.: strong farmland conservation policies
    - IPCC-A2 (high), IPCC-B1 (low), and AB32-Plus (very low) emissions scenarios
    - 2010-2050
  - Determine the potential role of agriculture in the GHG emissions cap-and-trade system
  - Provide guidance for Yolo Co. agencies and decision-makers on adaptation to climate change
- Outcomes
  - Ground-based analysis cross-cutting biophysical and social sciences
  - Impact on county-wide planning for climate change responses
  - Template for other California counties

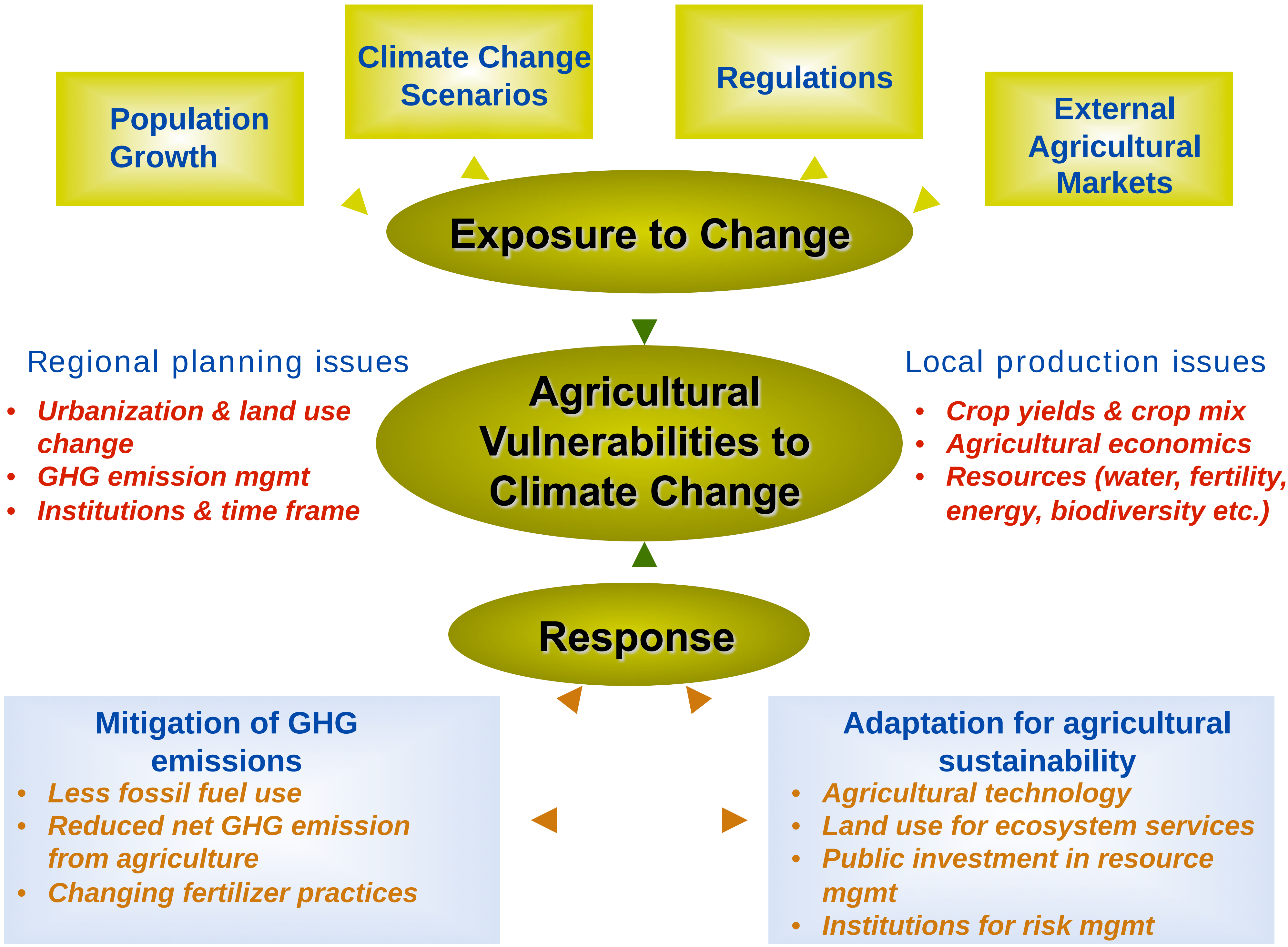
Participants

- UC Davis faculty
  - Agroecology: L.E. Jackson
  - Soils and GIS: A.T. O’Geen, A.D. Hollander
  - Agronomy: J.W. Six
  - Sustainable agriculture: T.P. Tomich
  - Biogeochemistry: W.R. Horwath
  - Economics: R.E. Howitt, D.A. Sumner
  - Anthropology: B.S. Orlove
  - Land use planning: S.M. Wheeler
- Steering committee (local and statewide members)

Yolo County, California

- Sacramento Valley
- Delta to upland hills
- ~10% ag economy
- $370 million gross agriculture (2006)
- Climate is slightly cooler and wetter than the more productive agricultural counties further south




Population Growth
Climate Change Scenarios
Regulations
External Agricultural Markets
Exposure to Change
Regional planning issues
• Urbanization & land use change
• GHG emission mgmt
• Institutions & time frame
Agricultural Vulnerabilities to Climate Change
Local production issues
• Crop yields & crop mix
• Agricultural economics
• Resources (water, fertility, energy, biodiversity etc.)
Response
Mitigation of GHG emissions
• Less fossil fuel use
• Reduced net GHG emission from agriculture
• Changing fertilizer practices
Adaptation for agricultural sustainability
• Agricultural technology
• Land use for ecosystem services
• Public investment in resource mgmt
• Institutions for risk mgmt

Approaches

- Yolo Co. statistics
  - Crop commodities, historical trends in water use, land use, revenues, water resources, etc.
- Crop modeling
- GIS queries
- Farmer surveys
- Interviews with county agencies

→

- County overviews
- Sub-region analyses
- Case studies
- Hot-spots

→

Adaptive Management with Tradeoffs

Participatory process

Input from:

- Yolo County
  - County Administrator
  - County Climate Change Coordinator
  - Agricultural Commissioner
  - Univ. of California Cooperative Extension
  - Habitat Conservation Program
  - Flood Control & Water Conservation District
  - Planning Resources & Public Works Dept
- Regional
  - California Dept. of Food and Agriculture
  - California Dept. of Water Resources
  - California Resources Agency
  - California Farm Bureau
- NGOs
  - Audubon Society
  - Environmental Defense

Idea exchange:

- Planning (including CEQA compliance)
- Public outreach to farmers for decision support
- Potential for water conservation & water transfers
- Plans for wildlife habitat restoration and wildland mgmt
- Views on optimal cap-&-trade policy

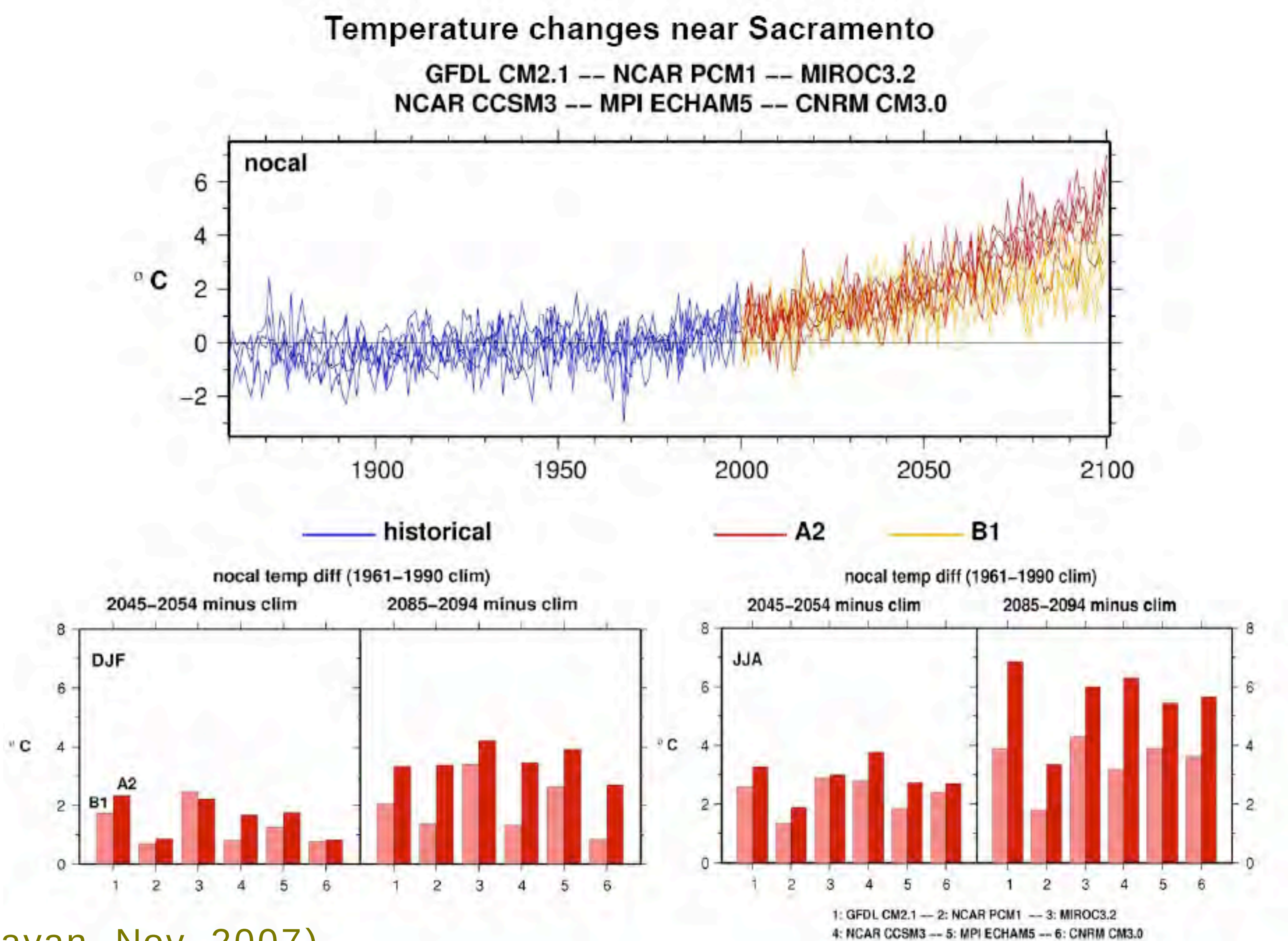
Climate change scenarios

- Regional Enterprise
  - IPCC A2 – High climate change scenario
    - High population growth
    - High energy use
    - Med/High land-use change
  - Focus: Self reliance, preservation of local entities
  - Higher environmental stress
  - Environment = commodity which can be traded
  - ag subsidies & exposure to global markets

- Global Sustainability
  - IPCC B1 – Low climate change scenario
    - Low population growth
    - Low energy use
    - High land-use change
  - Focus: Wider, global impacts of individual actions
  - Lower environmental stress
  - Environmental taxation and subsidies for mitigation and adaptation to climate change

AB 32-Plus Scenario: Precautionary Change

GCM models (run by Scripps Institution)



(Dan Cayan, Nov. 2007)

A2, B1, and AB32-Plus storylines

Scenario	Regional Enterprise	Global Sustainability	Precautionary Change
	IPCC-A2	IPCC-B1	AB32-Plus
	PHYSICAL CONDITIONS		
2050 CO_2 LEVEL	~550 ppm	~500 ppm	≤450ppm
2050 TEMP.	+1.3ºC to +2ºC (+2.3ºF to +3.6ºF)	+1.3ºC to +1.6ºC (+2.3ºF to +2.9ºF)	Not modeled yet
	2050 STORYLINES		
Population growth	High population growth with a doubling from 180K to 394 K and the SACOG 'Scenario B' for job and household projections for 2050	Mid-range population reaching 335 K and the SACOG 'Scenario C' for job and household projections for 2050	Low population growth reaching only 235 K and the SACOG 'Scenario D' for job and household projections for 2050
Economic growth	Continued high growth in northern CA; market-driven growth; greater inequities	Moderate growth; shift in emphasis from quantitative production of goods to quality of life	Moderate growth; ag production decrease & less use of resources but highest quality of life

Scenario analysis and outcomes

A2 Scenario:
Regional Enterprise
Urbanization, ag monocultures, high resource use

B1 Scenario:
Global Sustainability
Ag preservation & diversification, □GHG, efficient resource use

AB32-Plus Scenario:
Precautionary Change
Stable population, major ag change, high resource conservation

VULNERABILITIES TO CLIMATE CHANGE: 2010-2050

HYPOTHESIZED RESPONSE

Agrobiodiversity
Crop species & cultivars
Crop rotations
Pests and diseases
‘Food systems’

Soil & land mgmt
Tillage & fertilization
C sequestration
Farm margin mgmt
Land use change

Water resources
Technologies to reduce ET
Regional sources
Ag vs. urban use

OUTCOMES FOR AG SUSTAINABILITY: A2 < B1 < AB 32-PLUS

A2: □crop yield loss, □crop diversity, □adoption of innovative technologies

B1 and AB 32-PLUS: Greater mitigation and adaptation strategies increase resilience to climate change

Crop vulnerabilities (2010-2050)

- Literature review for Yolo County crops
  - Yield loss for horticultural crops at higher temperatures
    - Horticultural crops more sensitive to short-term environmental stresses than field crops: reproductive biology, water content, visual appearance, and flavor
  - Shifts to hot season crops
  - Lack of chilling degree days for fruit and nut crops
  - Uncertainty on potential disease, pest and weed problems
- Yolo County case studies
  - More high cash value crops
  - 2nd generation biofuel crops more likely than corn for ethanol
- Research necessary to avoid costly trial and error strategies, e.g.,
  - Crop breeding for specialty crops
  - Diversification potential
  - Lower ET and water use; ozone effects
  - Short- vs. long-term economics
  - Local, regional and world markets

DAYCENT Model for Yolo County field crops (2046-2050)

Commodity	Emission scenario	Baseline climate change		Heat waves only				Heat waves & drought
				May	June	July	May-July	May-July
		ton ha^{-1}	change % from 2002	Additional % change from baseline				
Alfalfa	A2	17.0	3.5	1.2	0.0	-0.4	1.0	1.2
	B1	17.8	7.3	1.1	0.4	-0.5	1.1	1.4
Maize	A2	13.5	-2.4	-4.4	-5.4	-0.2	-11.2	-11.2
	B1	13.4	-1.6	-3.5	-6.4	-0.9	-7.3	-7.3
Rice	A2	9.5	1.7	-3.8	0.0	-0.1	-6.1	-6.9
	B1	9.4	1.7	-4.1	-0.7	-1.1	-6.9	-8.0
Sunflower	A2	1.3	-7.9	-9.5	-5.2	-1.9	-18.5	-20.3
	B1	1.3	-5.4	-6.5	-7.1	-2.9	-18.7	-20.3
Tomato	A2	97.4	3.0	-1.5	-0.6	-0.8	-3.2	-4.8
	B1	97.2	1.4	-1.4	-0.3	-0.7	-2.9	-4.8
Wheat	A2	5.8	-2.4	-0.1	0.0	0.0	-0.1	-0.1
	B1	5.6	-2.6	0.0	0.0	0.0	-0.1	-0.1

Lee and Six 2008

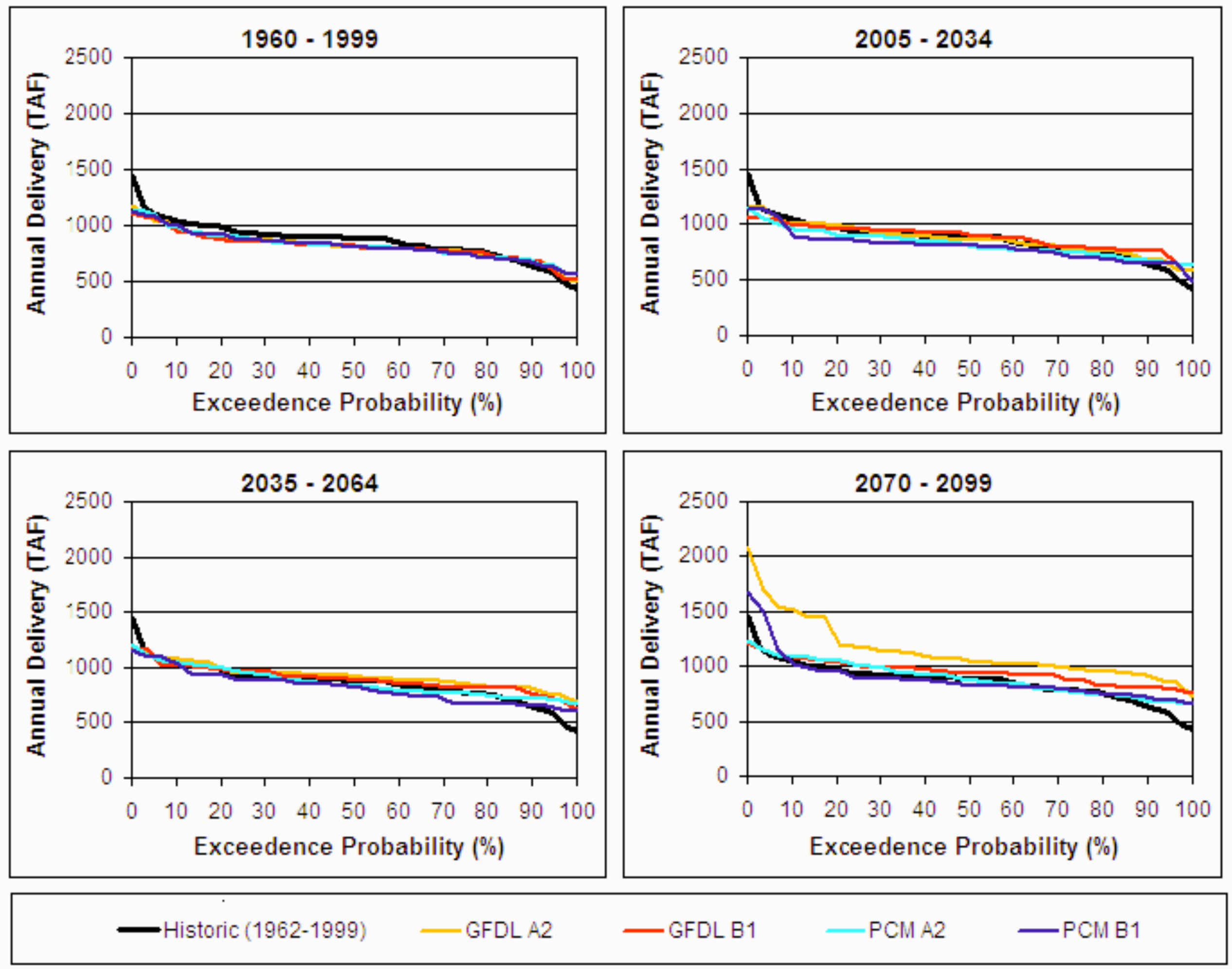
10 day heatwaves at 46°C per month; drought is 75% of water holding capacity

Examples of management tradeoffs

- Irrigation: Shifts to drip irrigation reduce soil GHG emissions and water use, but demand new costs, fuel, labor and plastic disposal.
- Fertilizer use: Lower N use will decrease GHG emissions, but crops grown at eCO_2 are likely to be more N-limited.
- Cover cropping: Cover crops improve fertility and reduce GHG emissions but prevent the possibility of cool weather cash crops.
- Tillage: Low tillage can decrease GHG emissions but has production constraints, e.g., seed establishment or water movement.
- Manure management: Methane digesters are useful for dairy production, but most livestock in Yolo County are beef cattle.
- Farmscaping: Perennial vegetation along farm margins and riparian corridors, mitigate GHG, and benefit water quality, habitat, and biodiversity, but are difficult to establish.
- Carbon sequestration in tree crops and vines: Perennial woody crops offer a potential opportunity for growers to receive GHG mitigation credits, but such a mechanism does not yet exist.
- Organic production: Yolo County has >50 organic farms, with a diverse mix of crops for local markets, but yields can be low, and new markets are needed to support expanded organic production.
- Shifts in crop mix and diversification: New crops and cv. may be less vulnerable to heatwaves, but crop mix may be limited by processing facilities nearby and by market demand.

Water availability for Sacramento Valley agriculture

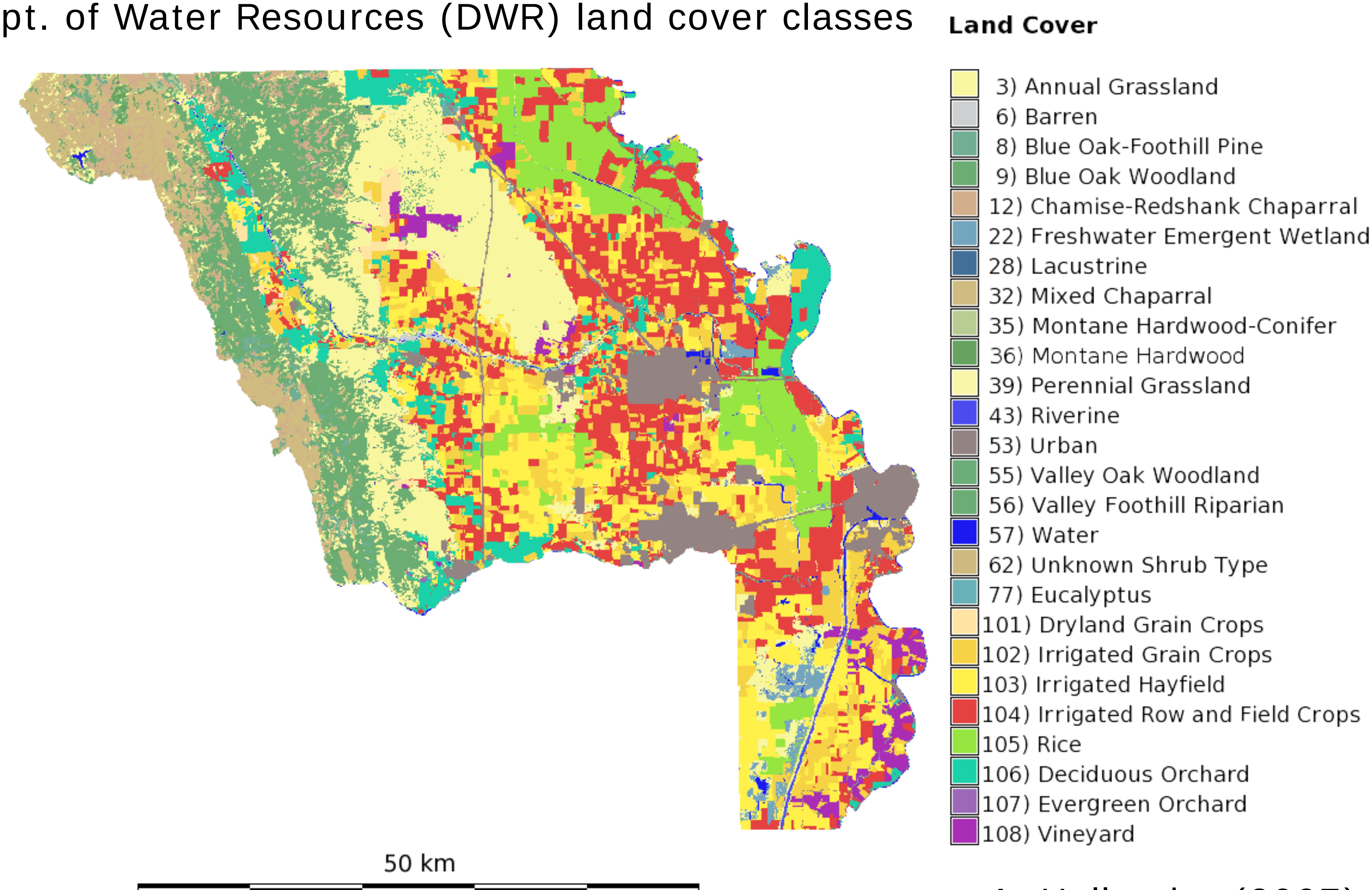
- Hydrologic model (WEAP)
  - Joyce et al. (2006)
  - A2 & B1 scenarios (GFDL and PCM) for 2005-2034
    - Mean □0.5-1.5°C especially summer; □0-250 mm ppt/yr
    - Annual water supply requirements
      - □3-4% than 1960-1999 (GFDL); no change (PCM)
  - Little change in water deliveries or groundwater pumping (2005-2034)



Predicted groundwater pumping for Sacramento River agriculture

Yolo County land cover

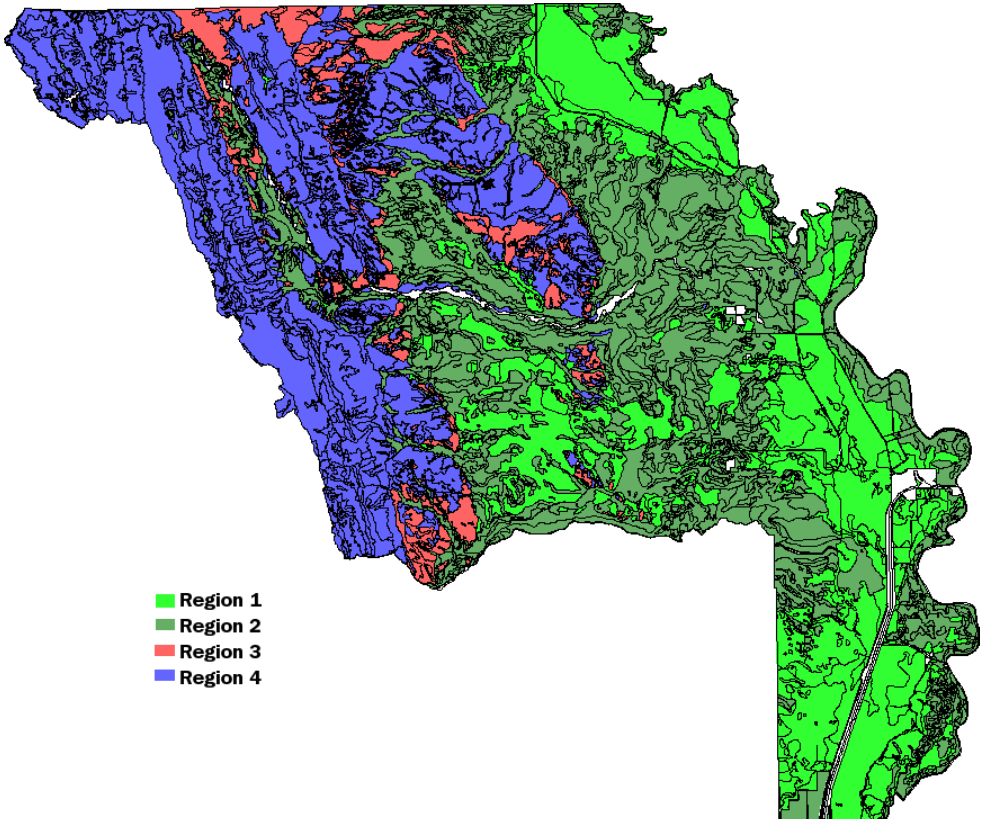
California Wildlife Habitat Relationship (CWHR) and
Dept. of Water Resources (DWR) land cover classes



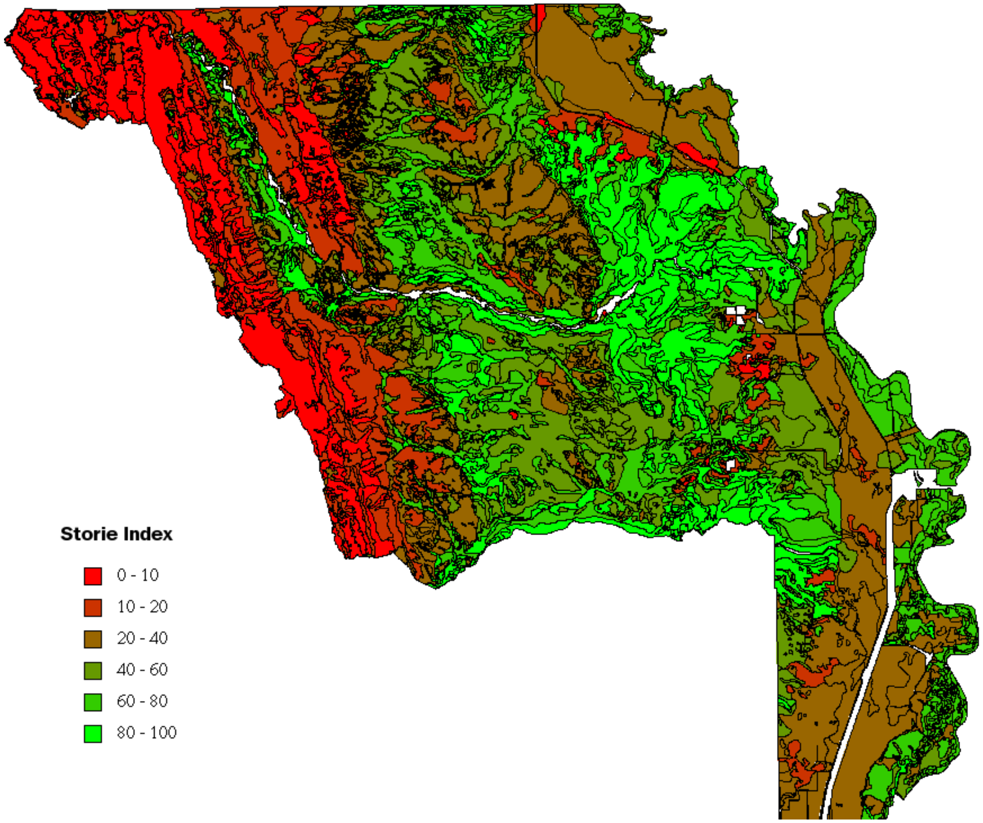
A. Hollander (2007)

Using GIS queries of the landscape

Zonation of the landscape
by soil taxonomy

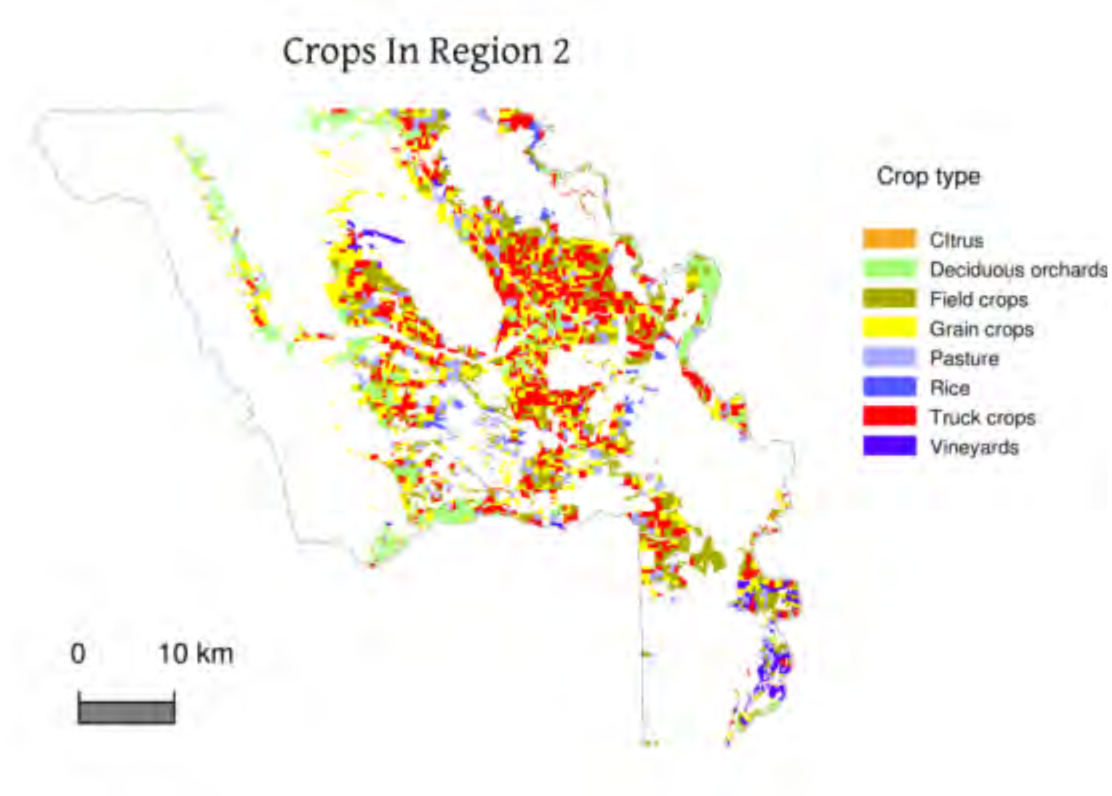


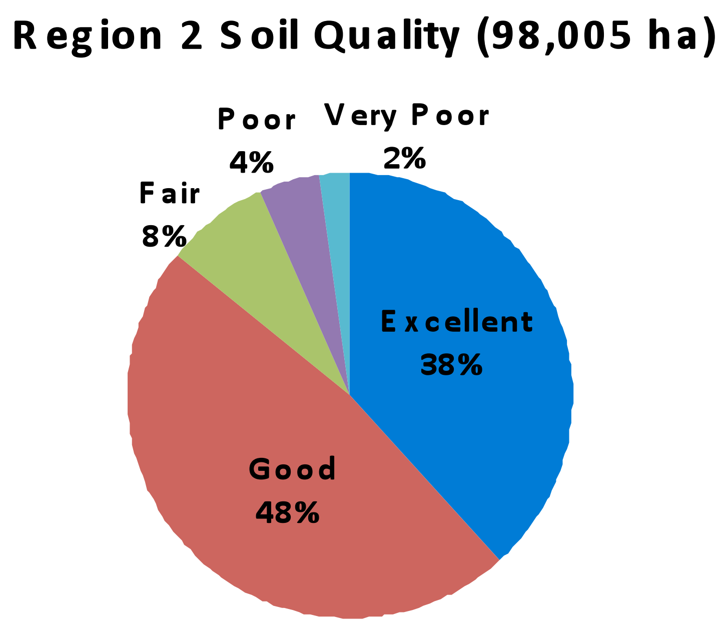
Zonation of the landscape
by soil quality index



- For each region, alter crop mixtures, e.g. Merced Co. for A2
- Examine impacts of water, relative income, flooding

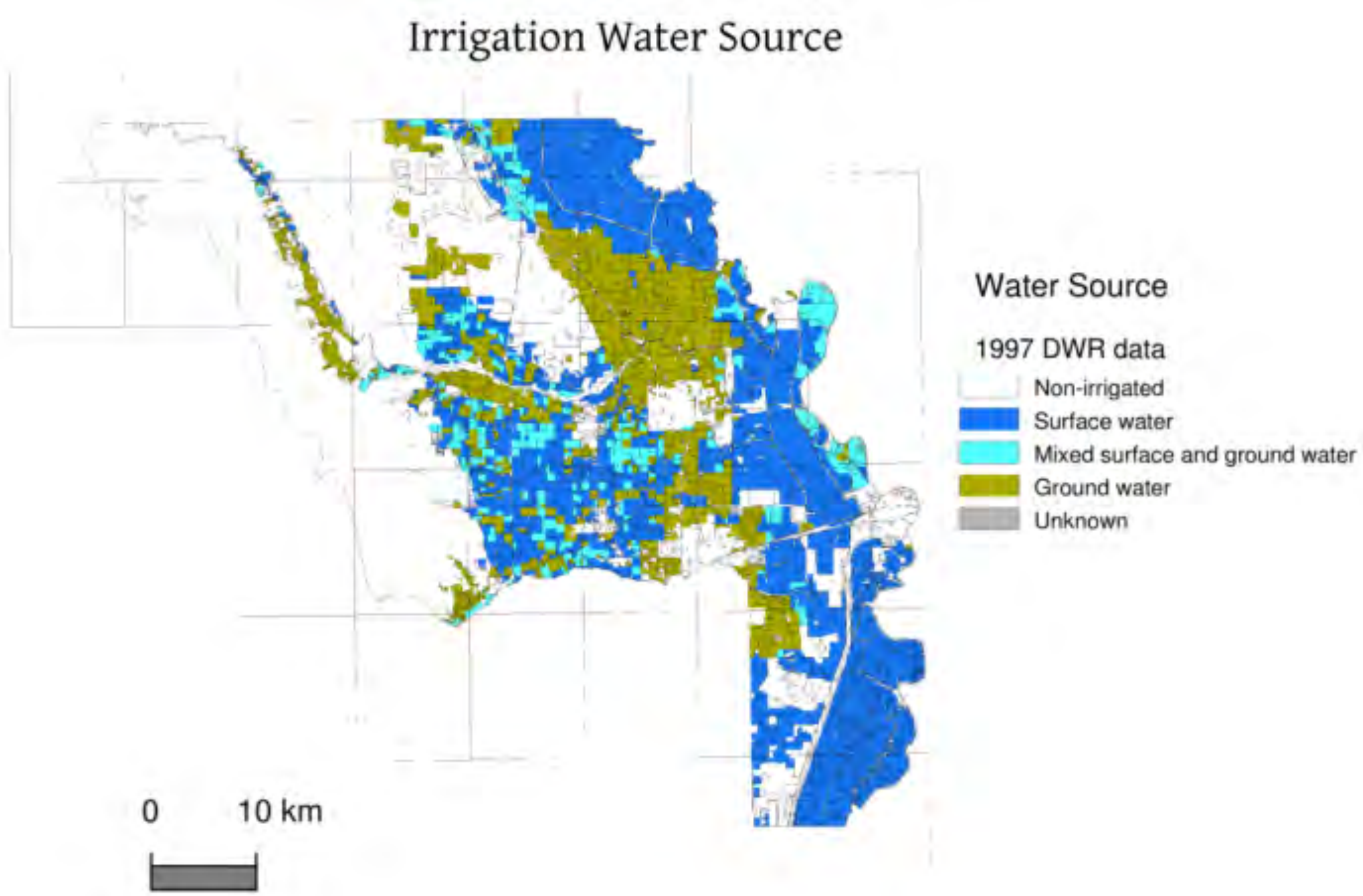
Low crop diversity may reduce adaptive capacity (Region 2)





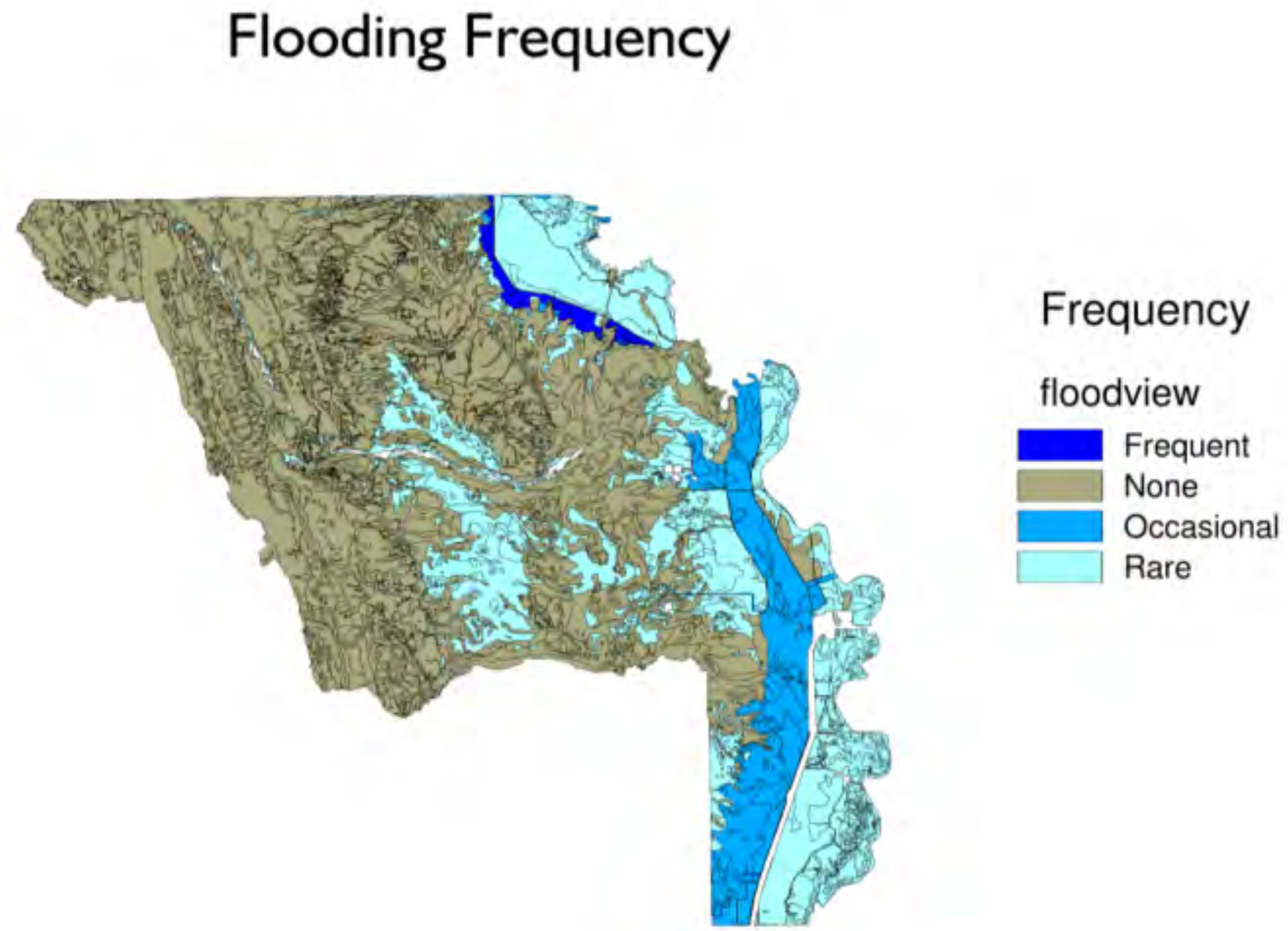
- Irrigated ag production greatest on recent alluvial soils in mid-county
- Low diversity:
  - Tomato and wheat: 50% of the land area
  - Walnuts and almonds: 12% of the land area
  - 25 other crops: 16% of the land area
- Diversification: increase long-term income (& decrease vulnerability?)

Groundwater supplies vary across regions



- Spatial variation in water source
- Reserves limited during drought
- Unlined canals
- Water quality esp. for urban use
- Needs more analysis

Flooding frequency greatest near the Sacramento River (Region 1)

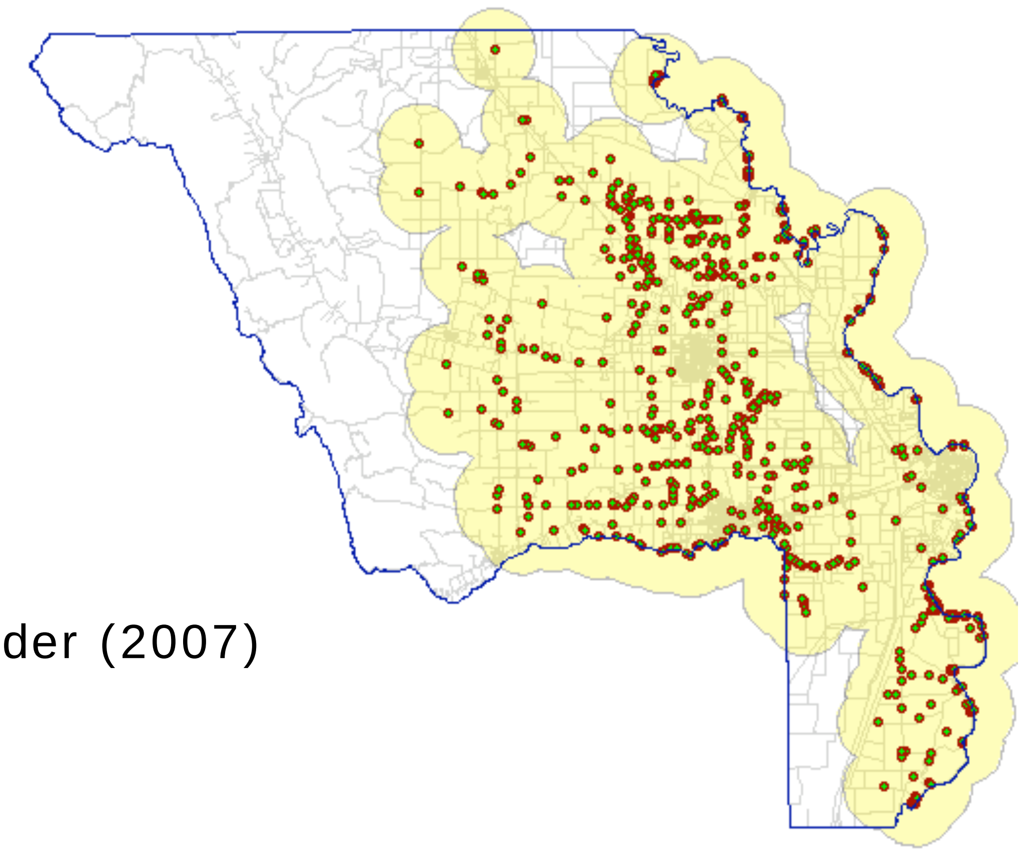


Yolo Bypass

Frequent is defined as at least 1-2 times per year (2,334 ha); **Occasional** is at least 5 times every 50 years (16,904); **Rare** is once every 100 years (42,124). (USDA SSURGO).

GIS query for Swainson’s Hawk observations and habitats

CNDDB Swainson's Hawk Observations



A. Hollander (2007)

Nesting observations of Swainson's Hawks from the California Natural Diversity Database are overlaid on a map of Yolo County.

The area in light yellow is the polygon resulting from merging the 3.5 km (mean home range) buffers around each nest site.

A shift away from irrigated crop agriculture could significantly reduce foraging habitat for the Swainson's Hawk, impairing its status as a species of special concern inYolo County.

Grower survey on importance of climate change issues

		Importance of climate change issues on production decisions					
		Very impor-tant	Somewhat important	Neutral	Somewhat unimpor-tant	Very unimpor-tant	Total
Importance of climate change issues on investment decisions	Very important	7	3	0	1	0	11
	Somewhat important	1	4	7	1	0	13
	Somewhat unimpor-tant	0	0	2	3	3	8
	Very unimpor-tant	0	1	0	2	1	4
	Total	8	8	9	7	4	36

Orlove and Tomich 2008

Conclusions

- Synthesis of interdisciplinary information
- Involve users from the onset
  - Stimulate local planning
  - Keep academic research relevant
  - Enlist funding support for the future
- Generate awareness of climate change issues
  - Local and regional levels
- Use of scenarios facilitates exploration
- Join mitigation and adaptation efforts
- Main outcome: Research and planning for adaptation now across multiple sectors will reduce agricultural impacts later.

AND

Many thanks to:

- Funding from the California Energy Commission and the UC Davis Agricultural Sustainability Institute
- Members of our steering committee
  - Don Bransford, Farmer
  - Tony Brunello, CA Resources Agency
  - Cynthia Cory, CA Farm Bureau
  - Jim Durst, Farmer
  - Guido Franco, CA Energy Commission
  - Rick Landon, Yolo Co. Agricultural Commissioner
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