

# 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

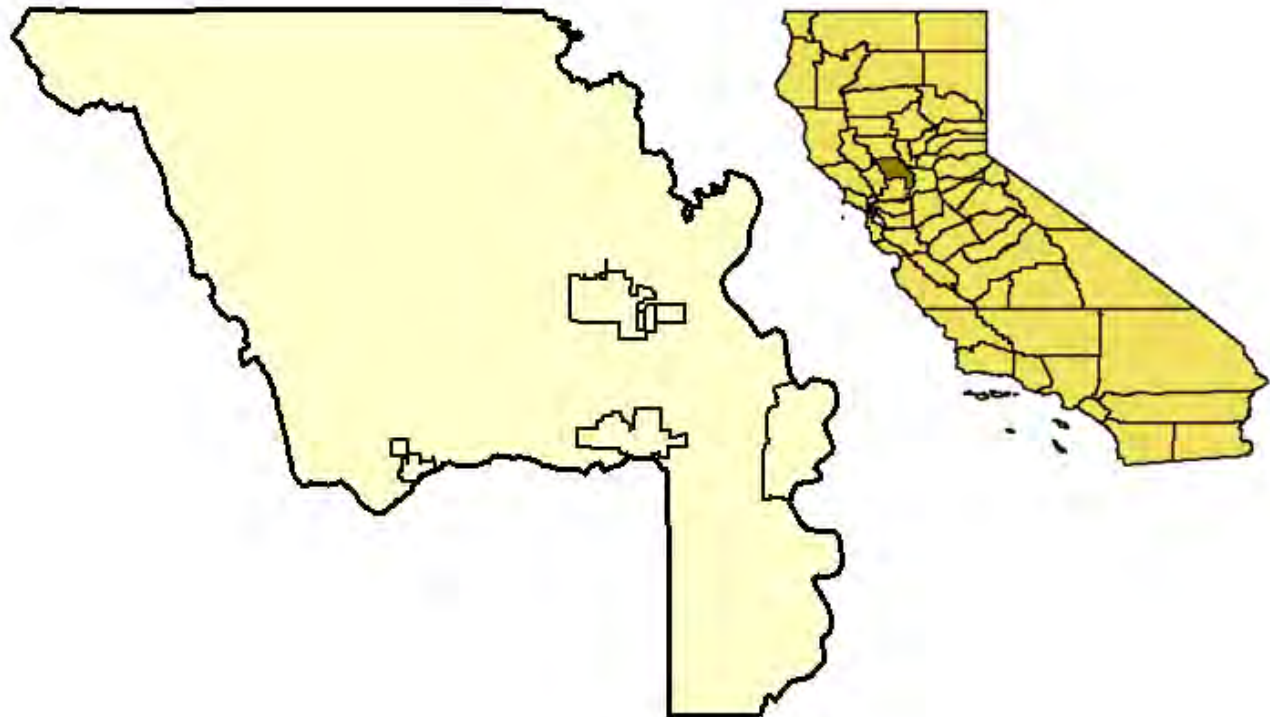
- Ground-based analysis cross-cutting biophysical and social sciences
- Impact on county-wide planning for climate change responses
- Template for other California counties

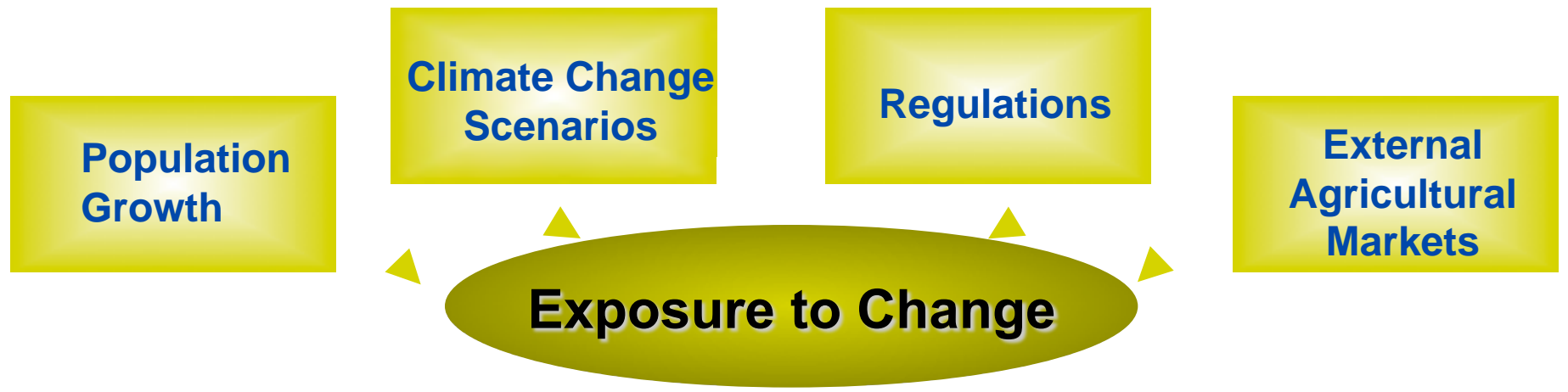
# Participants

- 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





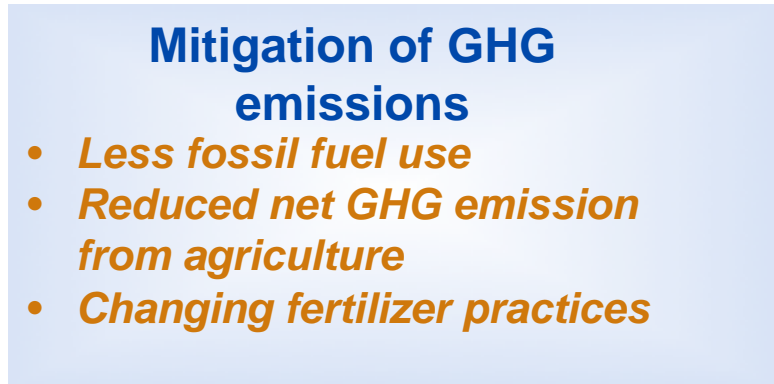
Regional planning issues

- *Urbanization & land use change*
- *GHG emission mgmt*
- *Institutions & time frame*



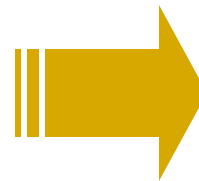
Local production issues

- *Crop yields & crop mix*
- *Agricultural economics*
- *Resources (water, fertility, energy, biodiversity etc.)*

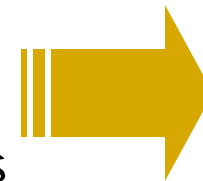


# Approaches

- 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



# 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

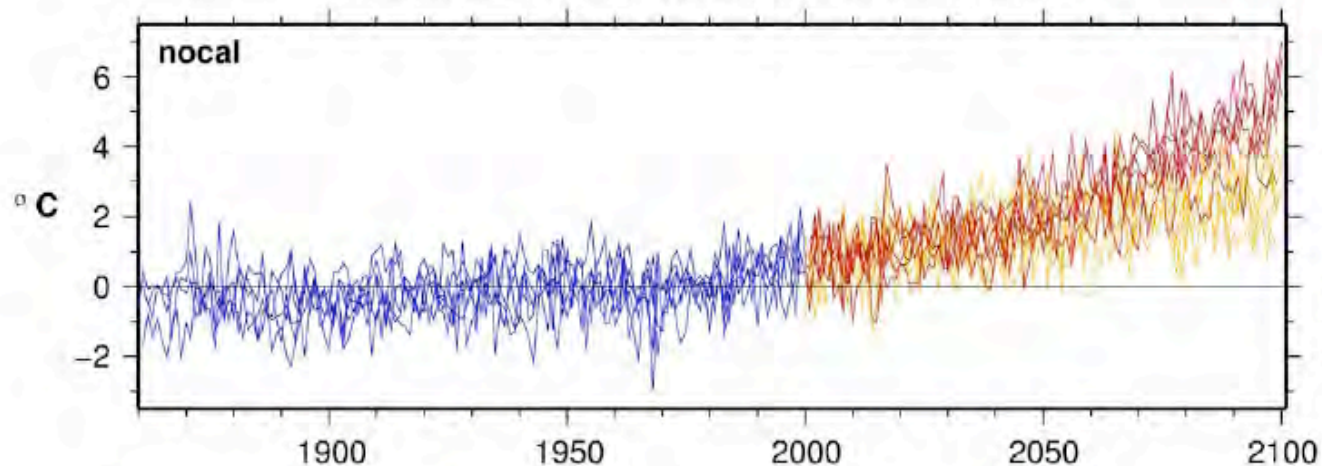
- IPCC B1 – Low climate change scenario
  - Low population growth
  - Low energy use
  - High land-use change
- Focus: Wider, global impacts of individual actions
- Lower environmental stress
- Environmental taxation and subsidies for mitigation and adaptation to climate change

AB 32-Plus Scenario: Precautionary Change

# GCM models (run by Scripps Institution)

## Temperature changes near Sacramento

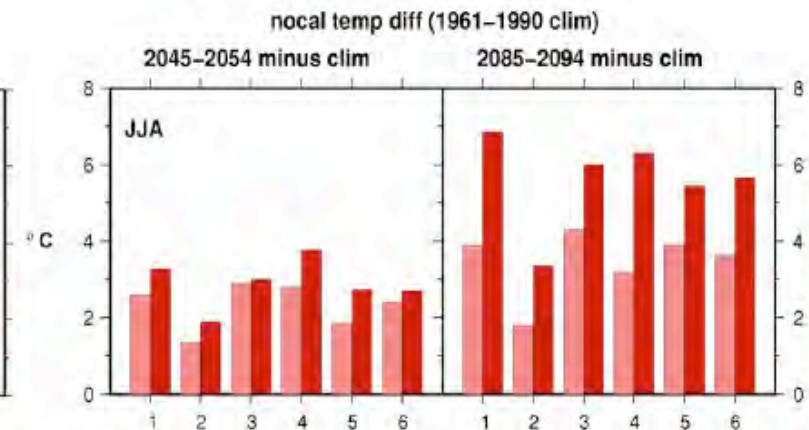
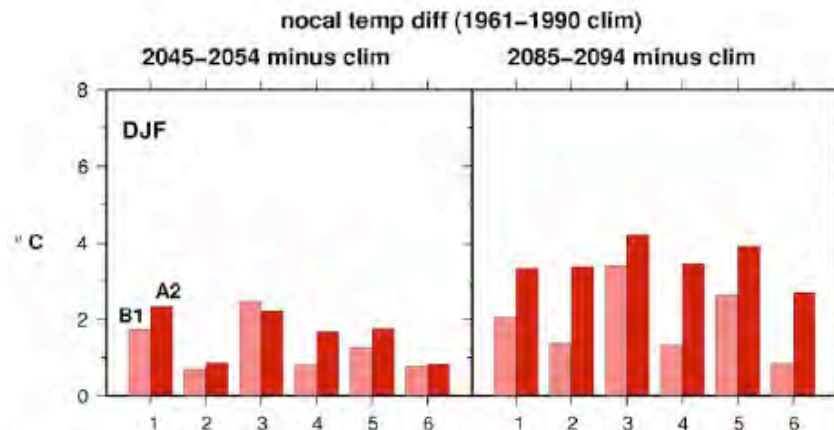
GFDL CM2.1 -- NCAR PCM1 -- MIROC3.2  
 NCAR CCSM3 -- MPI ECHAM5 -- CNRM CM3.0



— historical

— A2

— B1



1: GFDL CM2.1 — 2: NCAR PCM1 — 3: MIROC3.2  
 4: NCAR CCSM3 — 5: MPI ECHAM5 — 6: CNRM CM3.0

# A2, B1, and AB32-Plus storylines

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Scenario	Regional Enterprise IPCC-A2	Global Sustainability IPCC-B1	Precautionary Change AB32-Plus
PHYSICAL CONDITIONS			
2050 CO <sub>2</sub> LEVEL	~550 ppm	~500 ppm	≤450ppm
2050 TEMP.	+1.3°C to +2°C (+2.3°F to +3.6°F)	+1.3°C to +1.6°C (+2.3°F to +2.9°F)	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
  - 2<sup>nd</sup> 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)

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Commodity	Emission scenario	Baseline climate change		Heat waves only			Heat waves & drought	
		ton ha <sup>-1</sup>	change % from 2002	May	June	July	May-July	May-July
				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

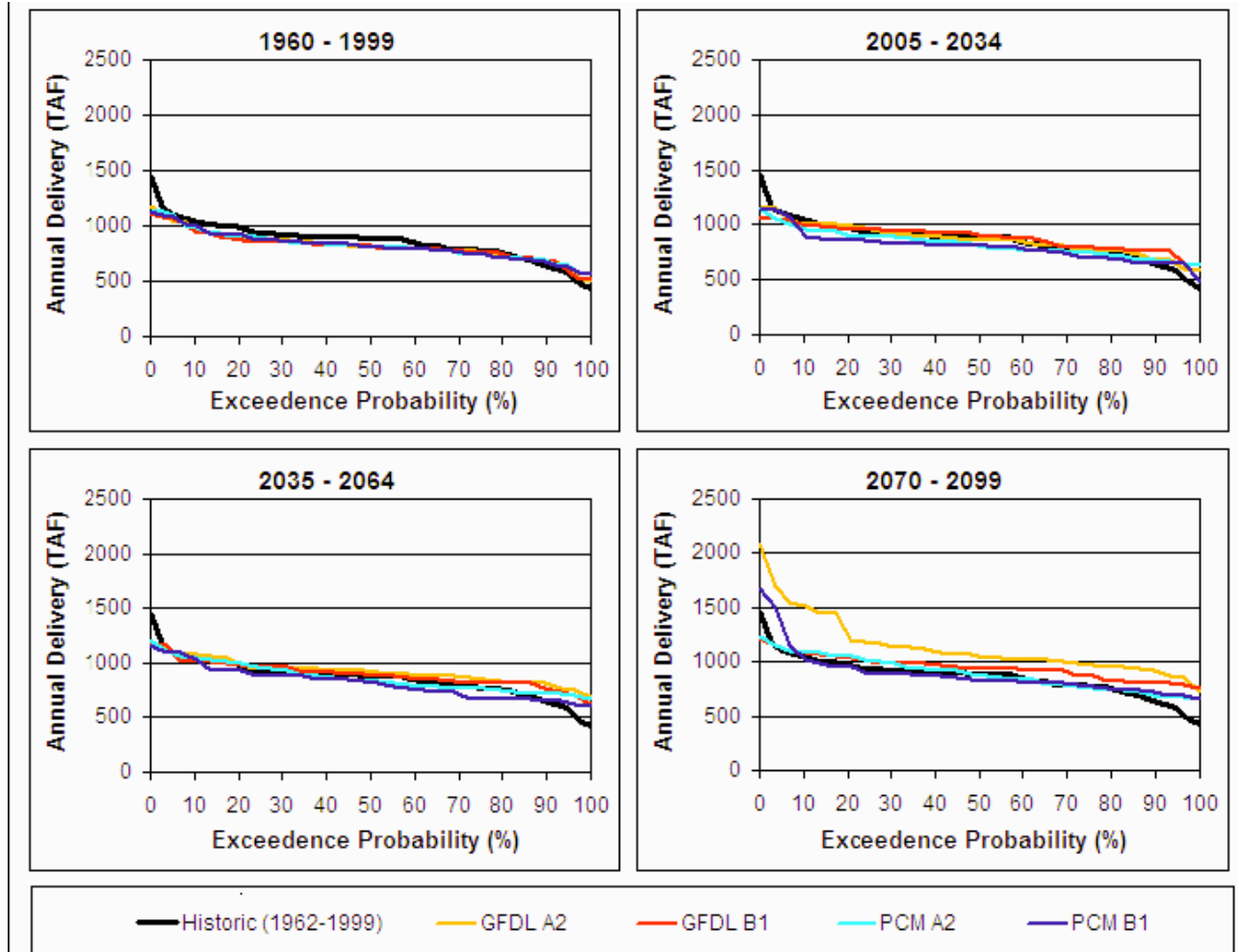
# Examples of management tradeoffs

- ❑ 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<sub>2</sub> 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  $\pm 0.5-1.5^{\circ}\text{C}$  especially summer;  $\pm 0-250$  mm ppt/yr
  - Annual water supply requirements
    - $\pm 3-4\%$  than 1960-1999 (GFDL); no change (PCM)
- Little change in water deliveries or groundwater pumping (2005-2034)

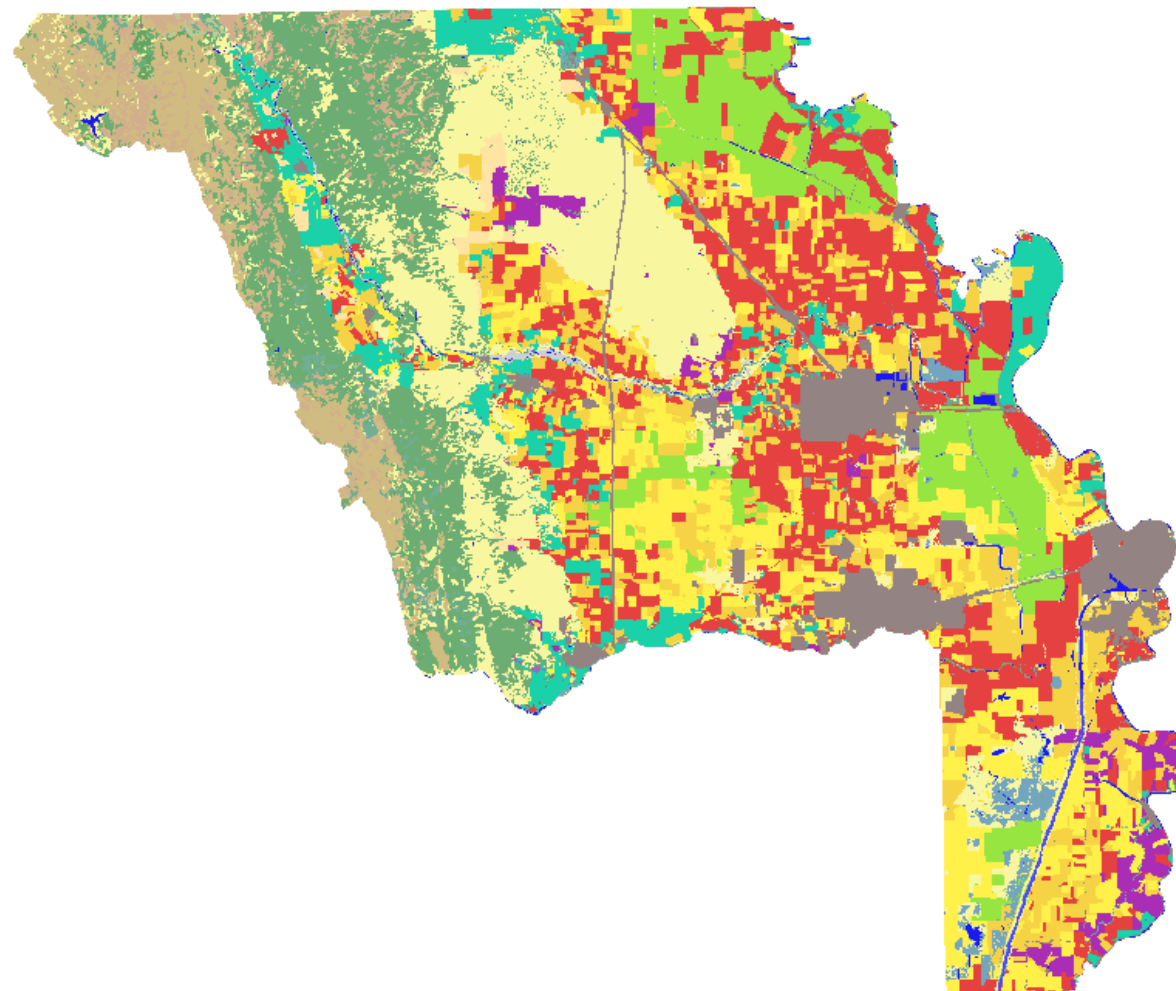


Predicted groundwater pumping for Sacramento River agriculture



# Yolo County land cover

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



## Land Cover

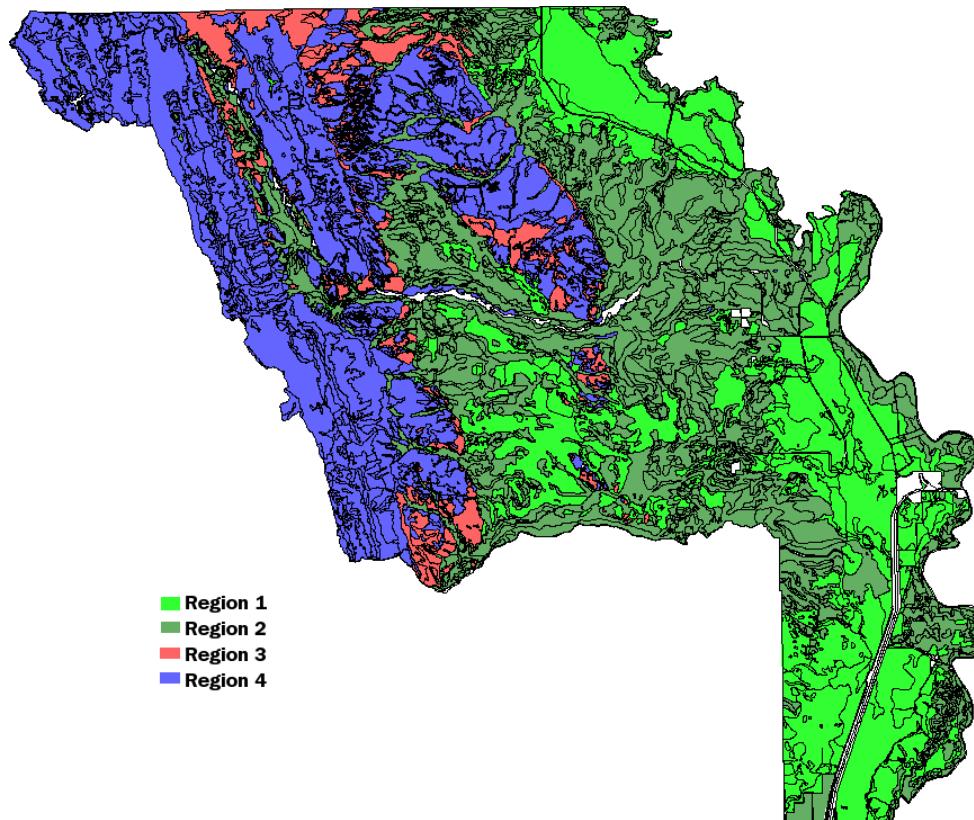
- 3) Annual Grassland
- 6) Barren
- 8) Blue Oak-Foothill Pine
- 9) Blue Oak Woodland
- 12) Chamise-Redshank Chaparral
- 22) Freshwater Emergent Wetland
- 28) Lacustrine
- 32) Mixed Chaparral
- 35) Montane Hardwood-Conifer
- 36) Montane Hardwood
- 39) Perennial Grassland
- 43) Riverine
- 53) Urban
- 55) Valley Oak Woodland
- 56) Valley Foothill Riparian
- 57) Water
- 62) Unknown Shrub Type
- 77) Eucalyptus
- 101) Dryland Grain Crops
- 102) Irrigated Grain Crops
- 103) Irrigated Hayfield
- 104) Irrigated Row and Field Crops
- 105) Rice
- 106) Deciduous Orchard
- 107) Evergreen Orchard
- 108) Vineyard

50 km

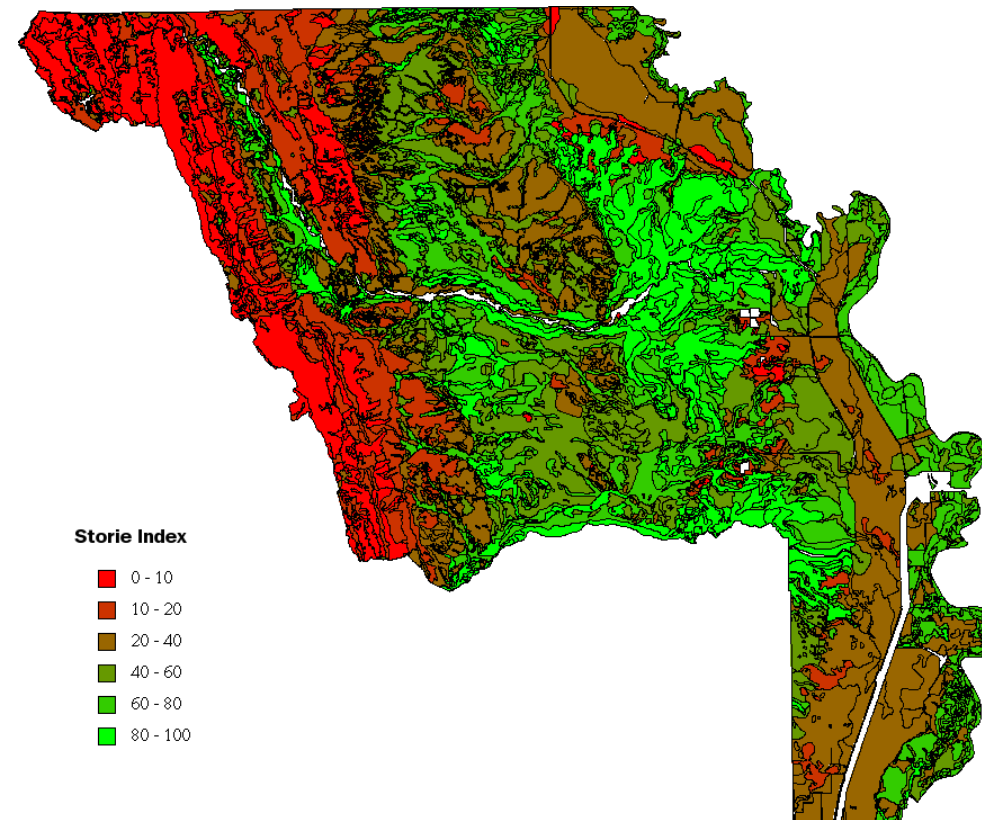
A. Hollander (2007)

# Using GIS queries of the landscape

Zonation of the landscape  
by soil taxonomy

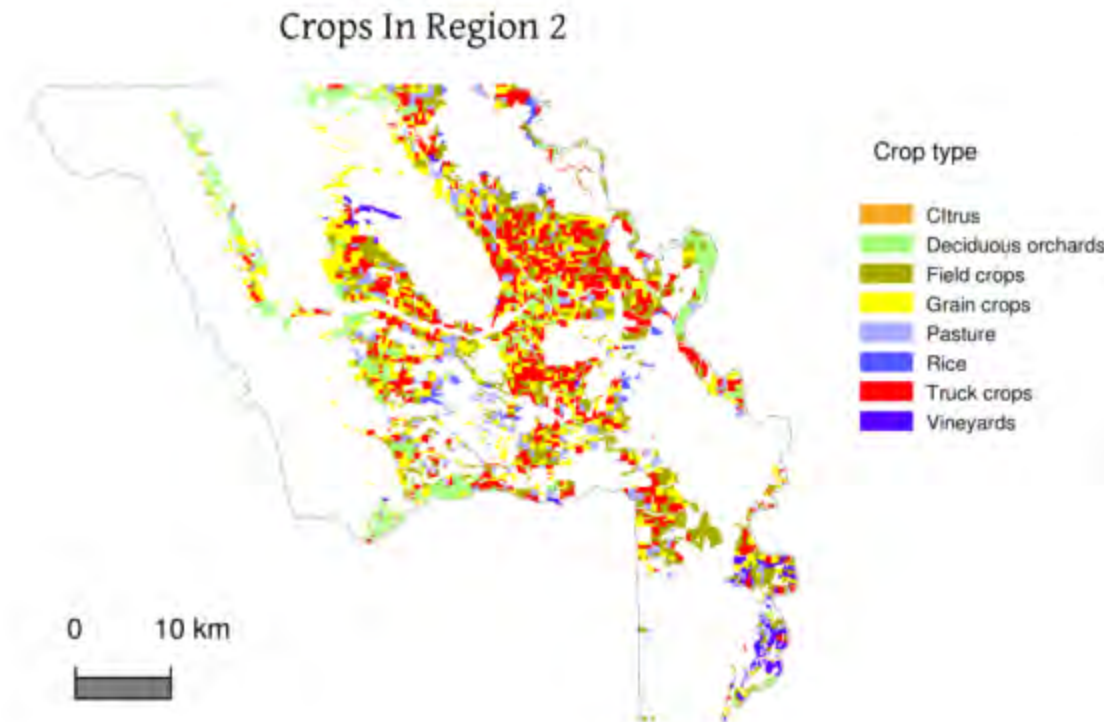


Zonation of the landscape  
by soil quality index

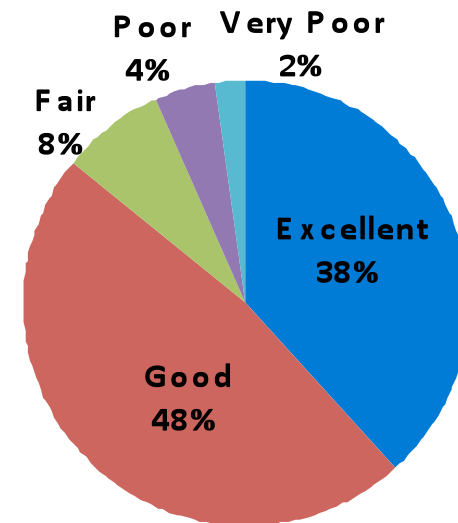


- For each region, alter crop mixtures, e.g. Merced Co. for A2
- Examine impacts of water, relative income, flooding

# Low crop diversity may reduce adaptive capacity (Region 2)

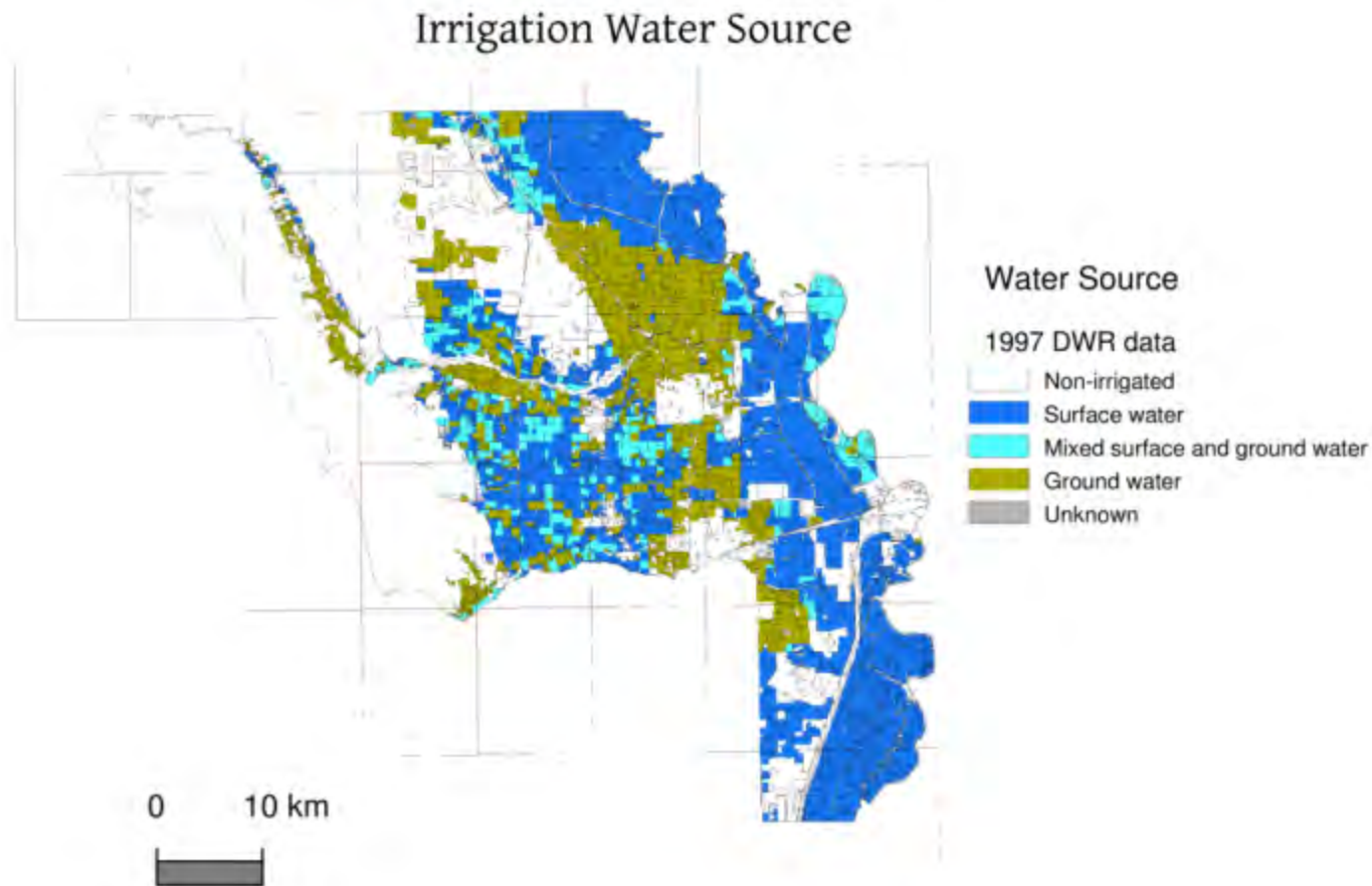


Region 2 Soil Quality (98,005 ha)



- 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?)

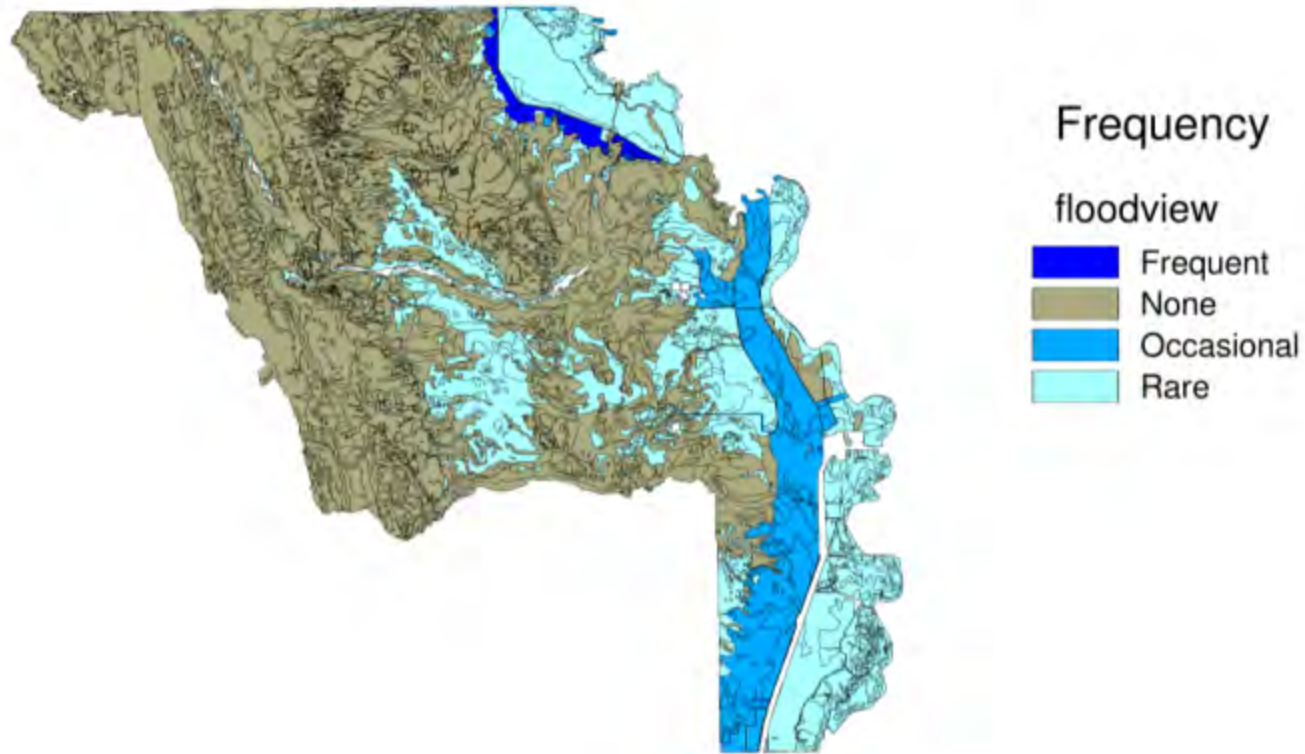
# Groundwater supplies vary across regions



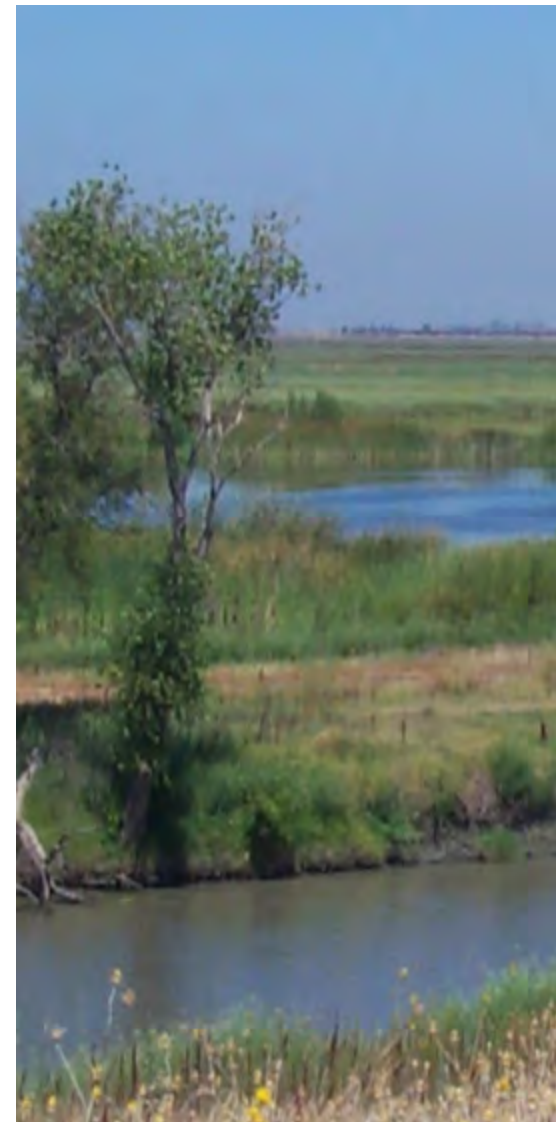
- Spatial variation in water source
- Reserves limited during drought
- Unlined canals
- Water quality esp. for urban use
- Needs more analysis

# Flooding frequency greatest near the Sacramento River (Region 1)

## Flooding Frequency



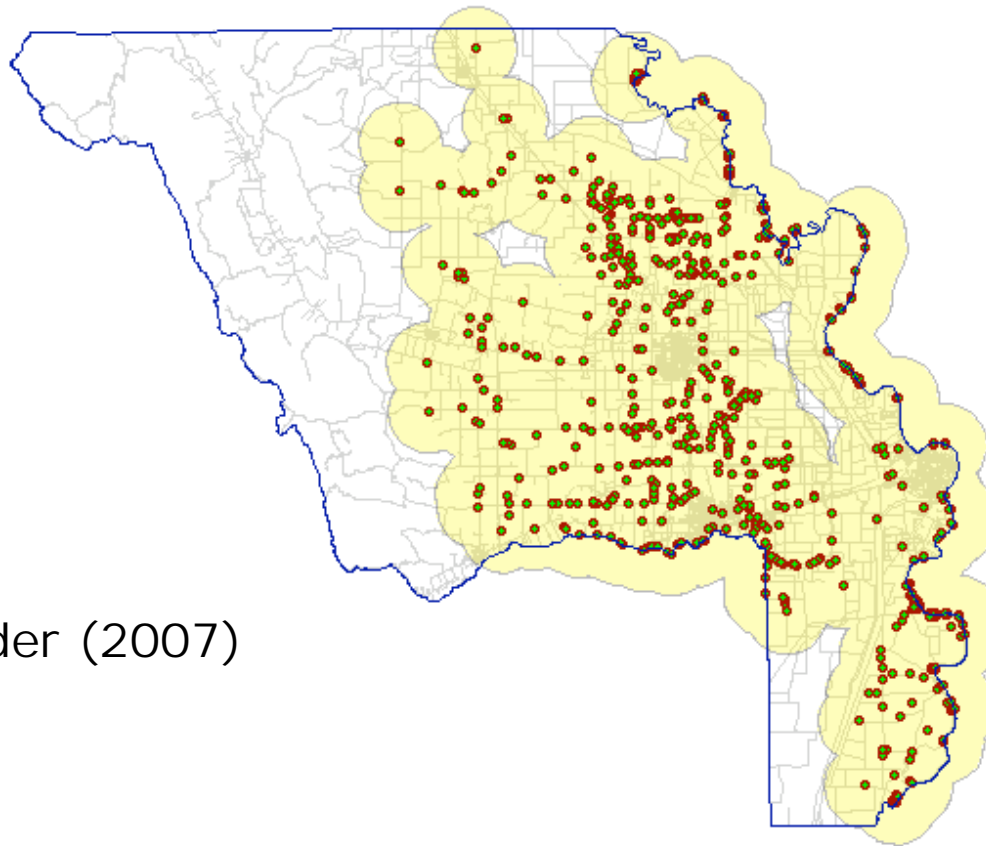
Yolo Bypass



**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

CNDDDB Swainson's Hawk Observations



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. Hollander (2007)

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 in Yolo County.

# Grower survey on importance of climate change issues

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## Importance of climate change issues on production decisions

		Very important	Somewhat important	Neutral	Somewhat unimportant	Very unimportant	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 unimportant	0	0	2	3	3	8
	Very unimportant	0	1	0	2	1	4
	Total	8	8	9	7	4	36

# 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.



# 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
  - Steve Shaffer, CA Dept. Food and Agriculture
- People in county and state agencies who provided information, especially
  - Dirk Brazil, Yolo Co. Deputy Administrator
  - John Mott-Smith, Yolo Co. Climate Change Coordinator
- Joel Kramer and Shannon Sokolow, research assistance