

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



Scenarios Analysis Project, California Energy Commission

Workshop on Linking Climate Change Impacts on ET and  
Agricultural Production to Water Resources Decision Making

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# Participants

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- UC Davis faculty
  - Agroecology: L.E. Jackson, F. Santos-Martin
  - 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)

# Project overview

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## □ Purpose

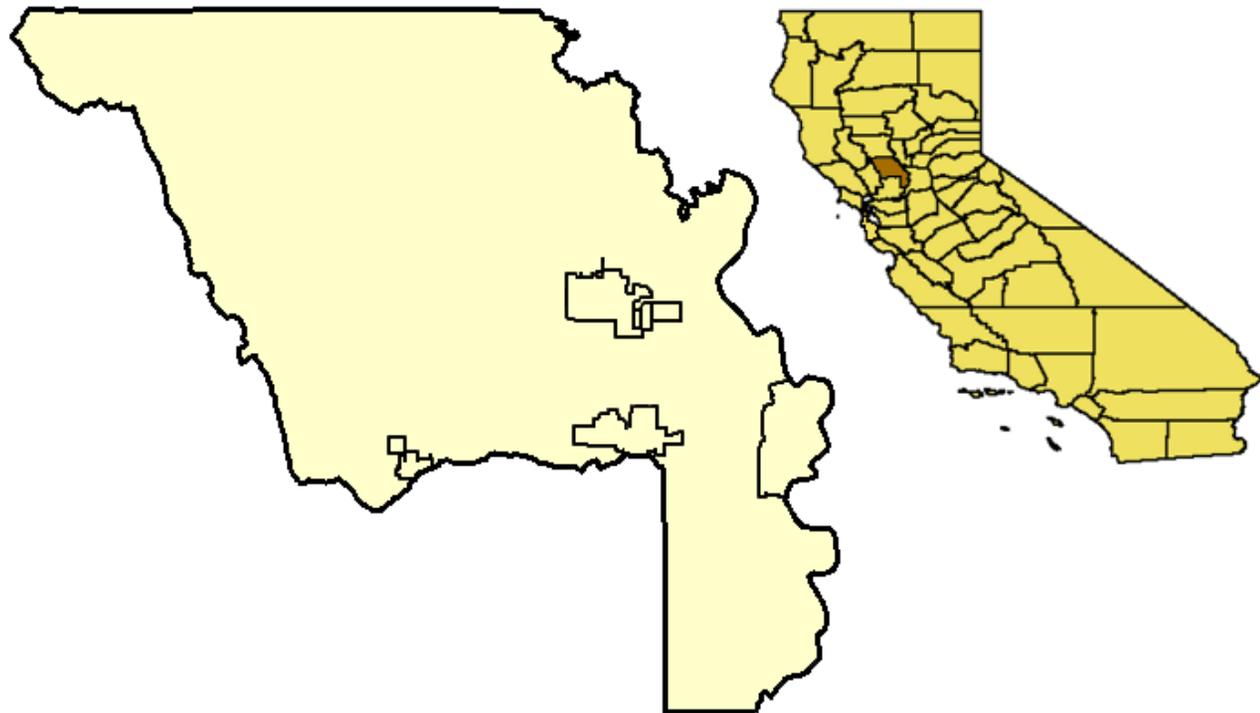
- Demonstrate climate change responses for a representative agricultural county in California
  - Yolo Co.: strong farmland conservation policies
  - IPCC-A2 (high), IPCC-B1 (low), and AB32-Plus (very low) emissions scenarios
  - 2010-2050
- Determine the potential role of agriculture in the GHG emissions cap-and-trade system
- Provide guidance for Yolo Co. agencies and decision-makers on adaptation to climate change

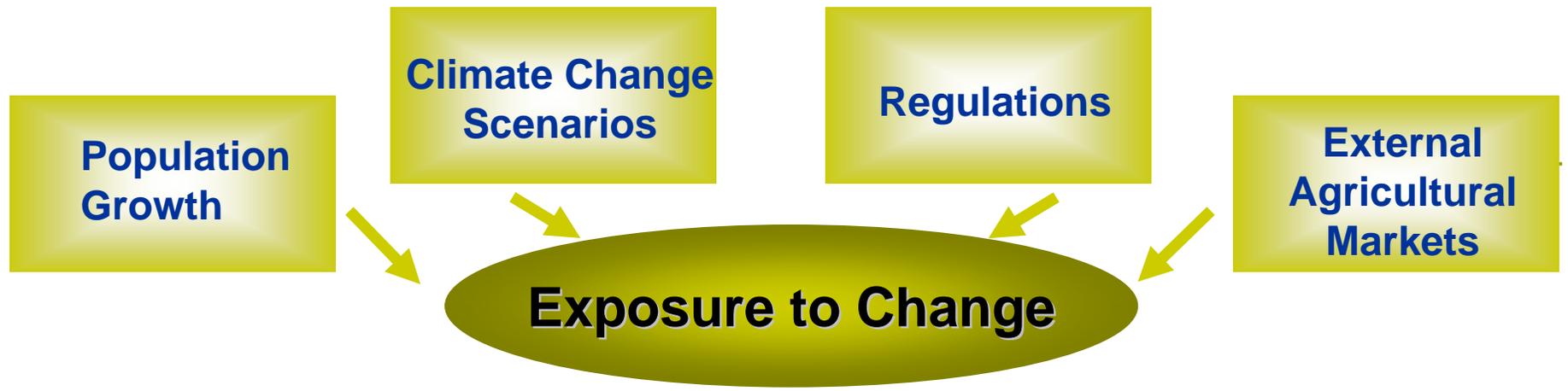
## □ Outcomes

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

# 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



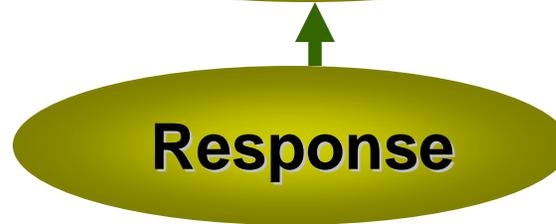


Regional planning issues

- *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.)*



**Mitigation of GHG emissions**

- *Less fossil fuel use*
- *Reduced net GHG emission from agriculture*
- *Changing fertilizer practices*

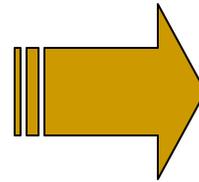
**Adaptation for agricultural sustainability**

- *Agricultural technology*
- *Land use for ecosystem services*
- *Public investment in resource mgmt*
- *Institutions for risk mgmt*

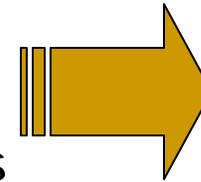
# Approaches

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- 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

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## 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

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## □ 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

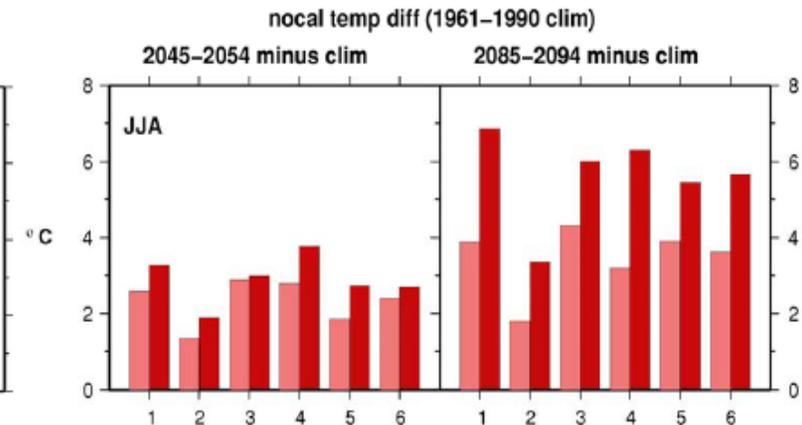
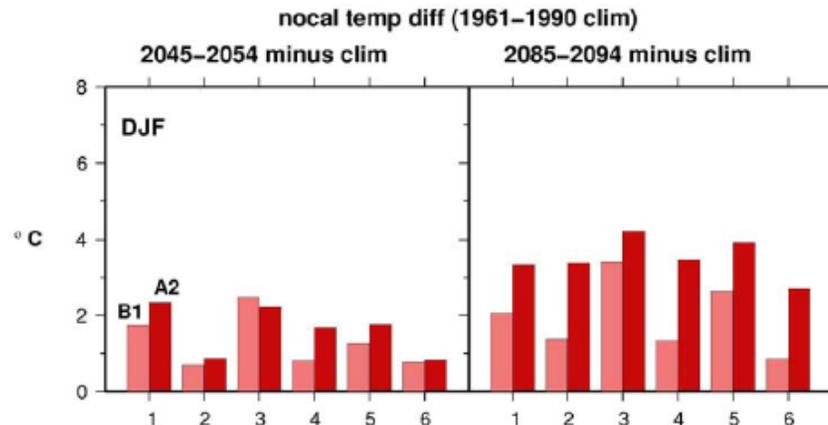
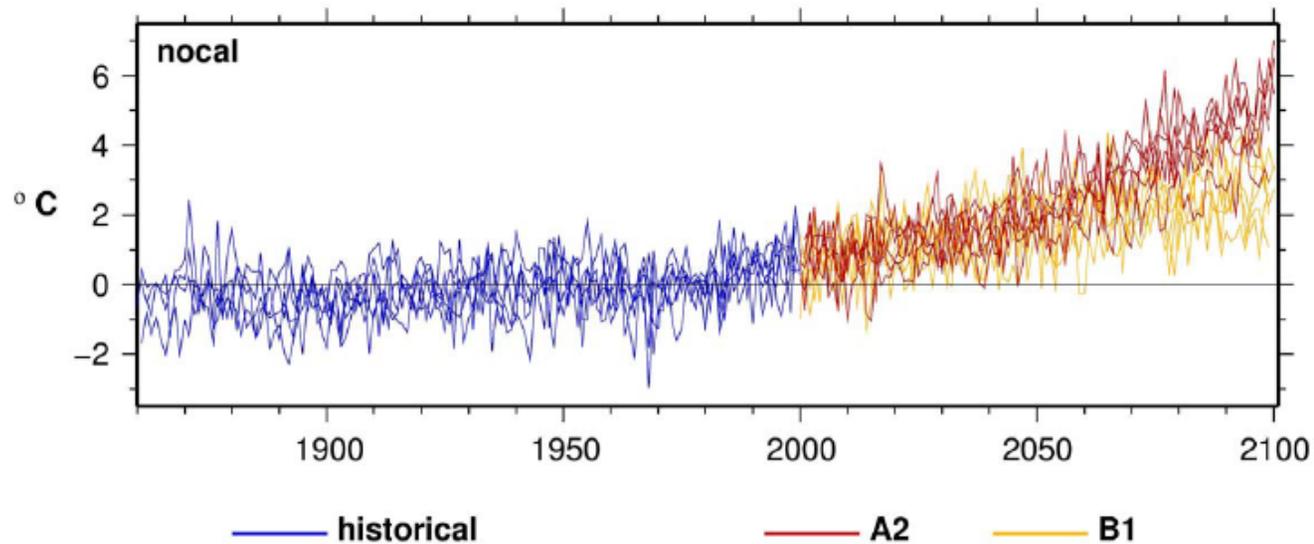
- IPCC B1 – Low climate change scenario
  - Low population growth
  - Low energy use
  - High land-use change
- Focus: Wider, global impacts of individual actions
- Lower environmental stress
- Environmental taxation and subsidies for mitigation and adaptation to climate change

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



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

Scenario	Regional Enterprise	Global Sustainability	Precautionary Change
	IPCC-A2	IPCC-B1	AB32-Plus
<b>PHYSICAL CONDITIONS</b>			
<b>2050 CO<sub>2</sub> LEVEL</b>	~550 ppm	~500 ppm	≤450ppm
<b>2050 TEMP.</b>	+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
<b>2050 STORYLINES</b>			
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)

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- 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)

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

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

# Examples of management tradeoffs

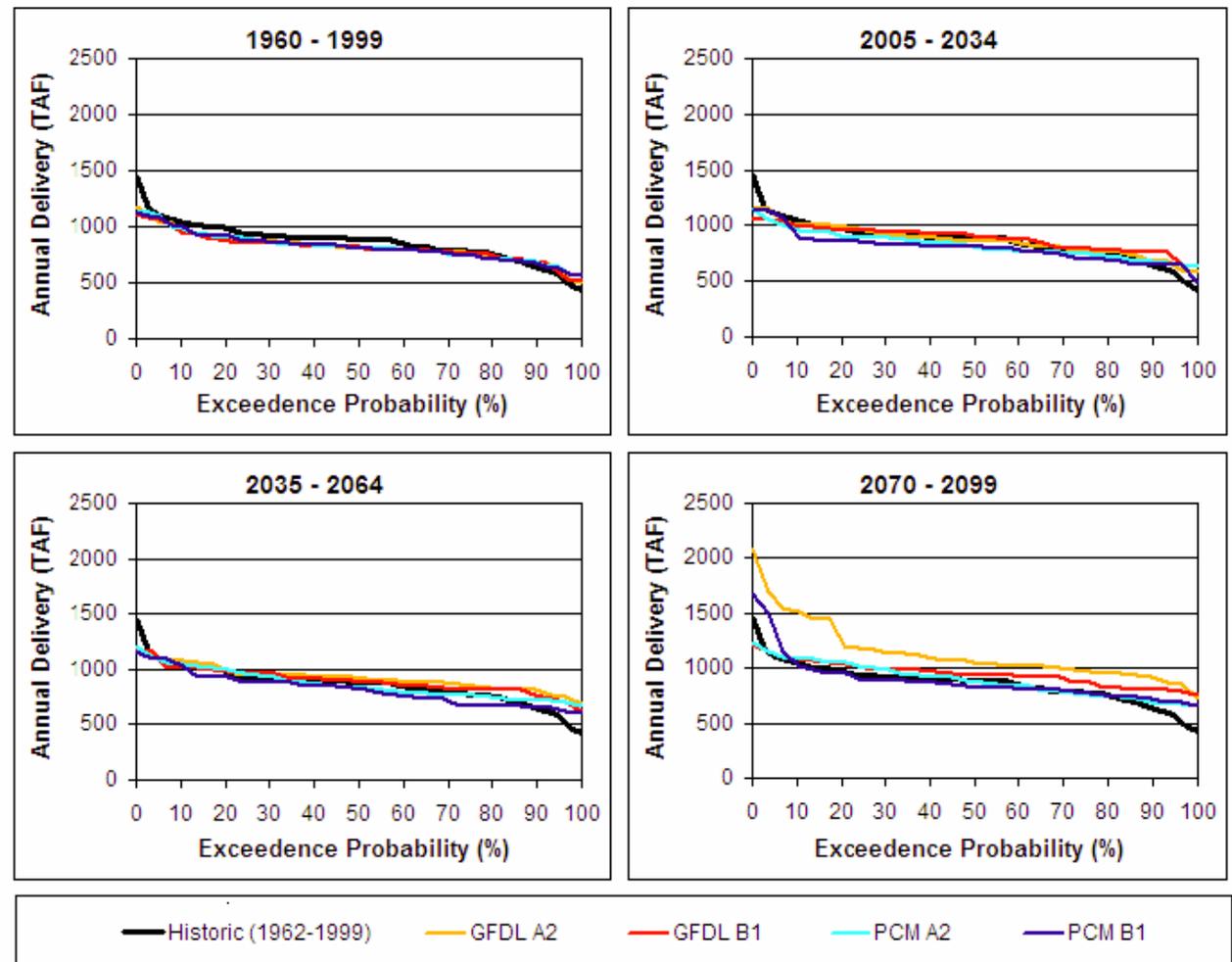
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- ❑ **Irrigation:** Shifts to drip irrigation reduce soil GHG emissions and water use, but demand new costs, fuel, labor and plastic disposal.
- ❑ **Fertilizer use:** Lower N use will decrease GHG emissions, but crops grown at eCO<sub>2</sub> are likely 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)

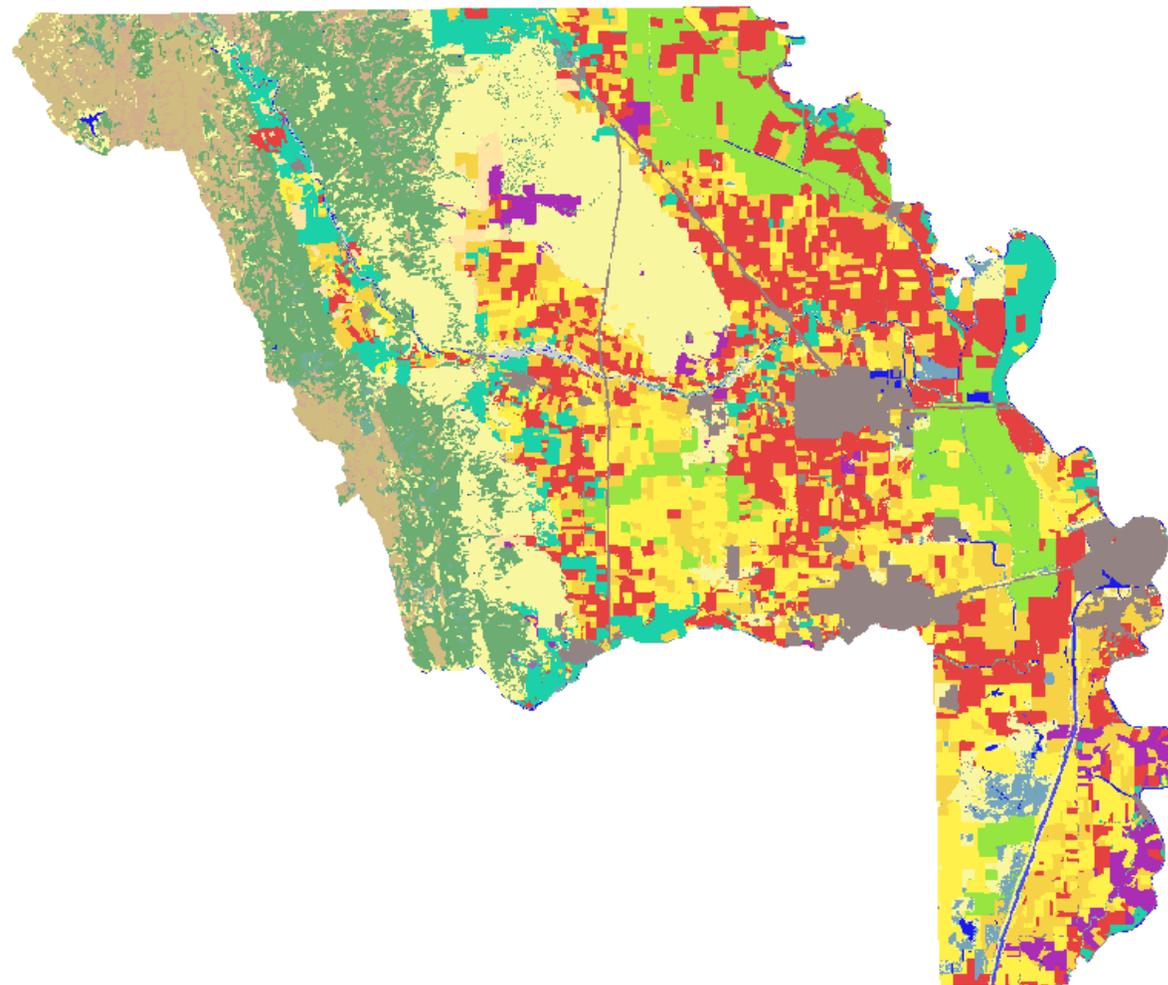
- Joyce et al. (2006)
- A2 & B1 scenarios (GFDL and PCM) for 2005-2034
  - Mean  $\uparrow 0.5-1.5^{\circ}\text{C}$  especially summer;  
 $\downarrow 0-250$  mm ppt/yr
  - Annual water supply requirements
    - $\uparrow 3-4\%$  than 1960-1999 (GFDL); no change (PCM)
- Little change in water deliveries 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

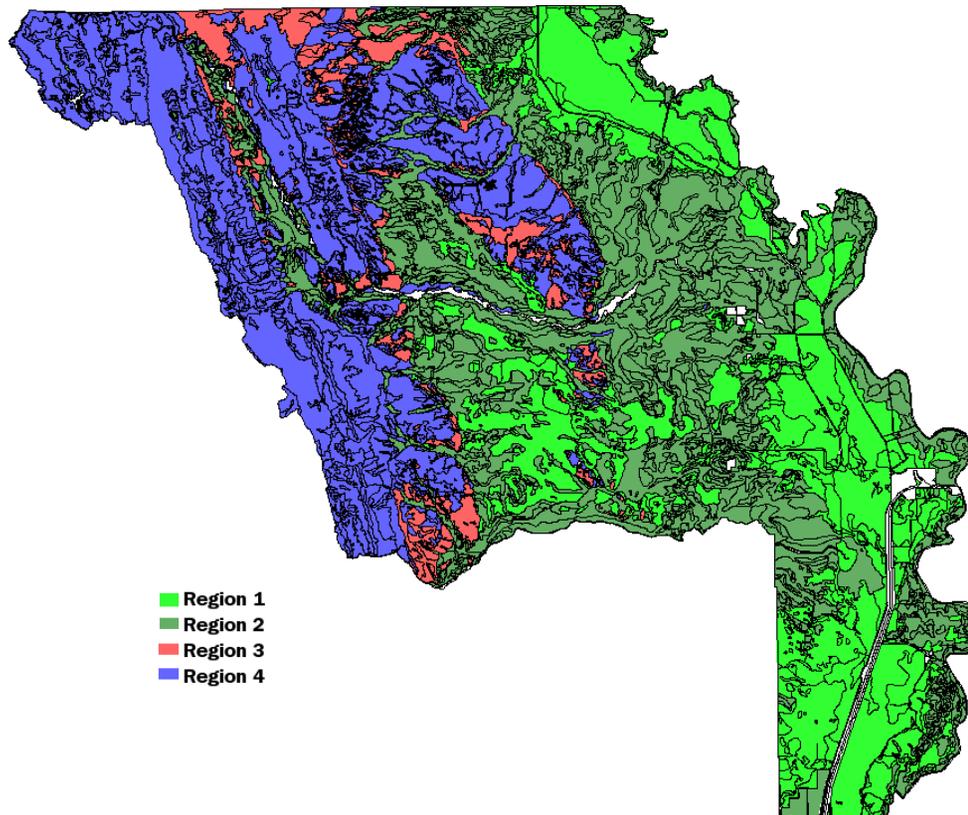
- 3) Annual Grassland
- 6) Barren
- 8) Blue Oak-Foothill Pine
- 9) Blue Oak Woodland
- 12) Chamise-Redshank Chaparral
- 22) Freshwater Emergent Wetland
- 28) Lacustrine
- 32) Mixed Chaparral
- 35) Montane Hardwood-Conifer
- 36) Montane Hardwood
- 39) Perennial Grassland
- 43) Riverine
- 53) Urban
- 55) 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

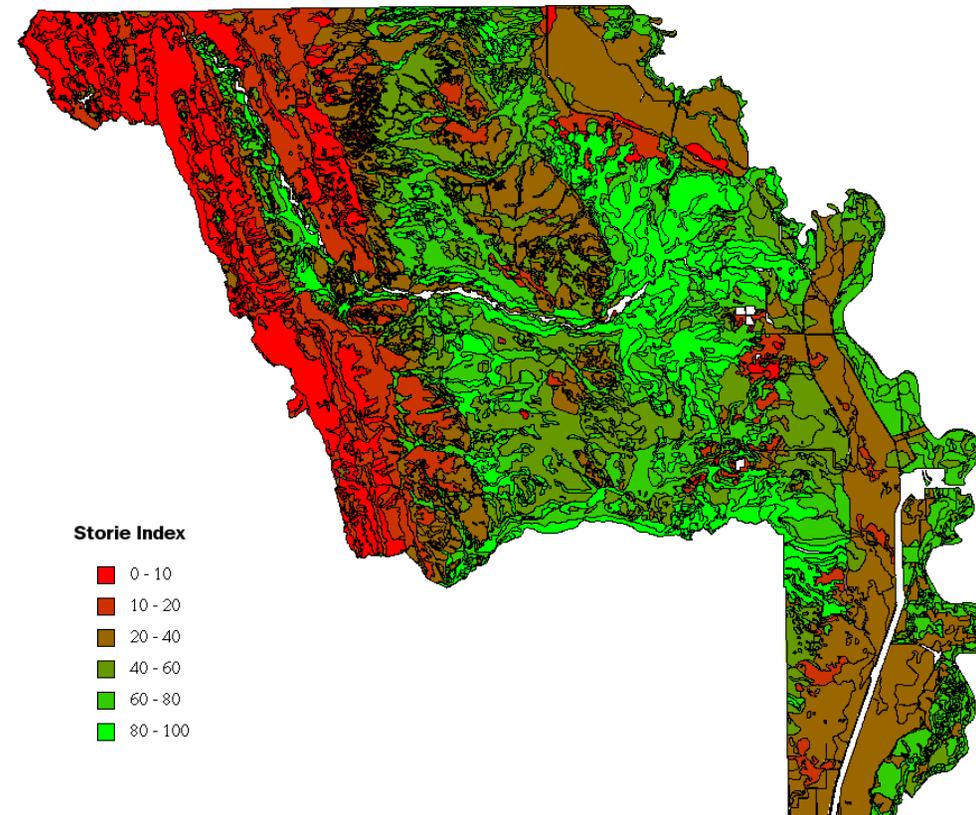
A. Hollander (2007)

# Using GIS queries of the landscape

Zonation of the landscape  
by soil taxonomy



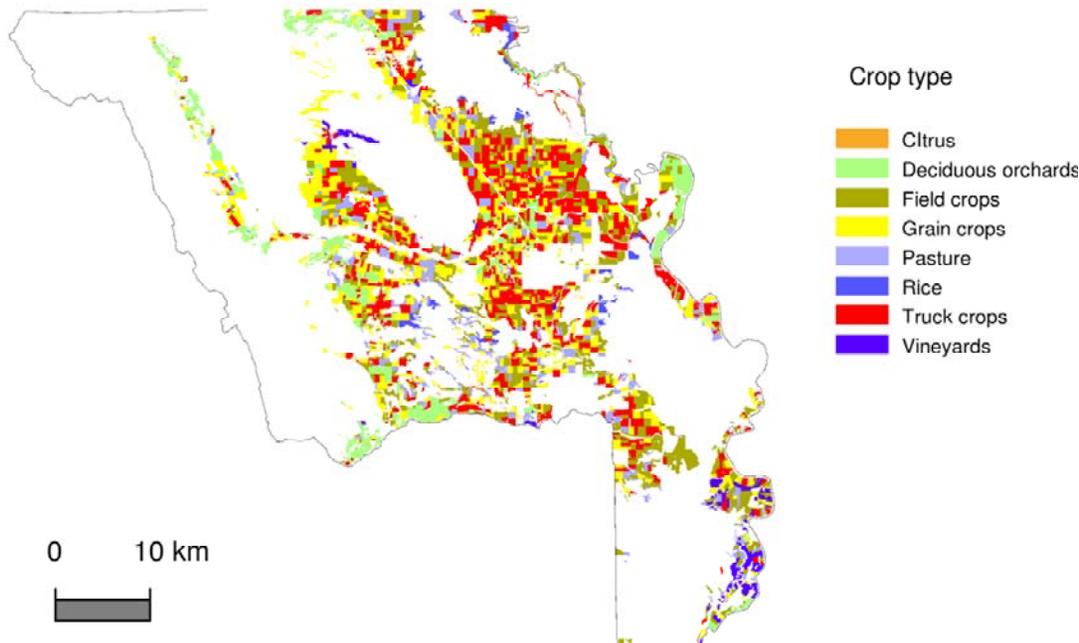
Zonation of the landscape  
by soil quality index



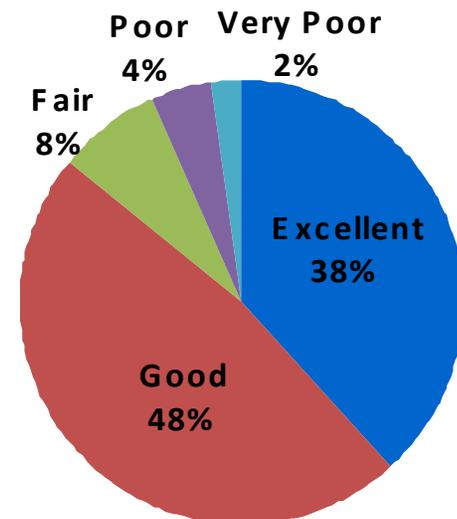
- For each region, alter crop mixtures, e.g. Merced Co. for A2
- Examine impacts of water, relative income, flooding

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

Crops In Region 2



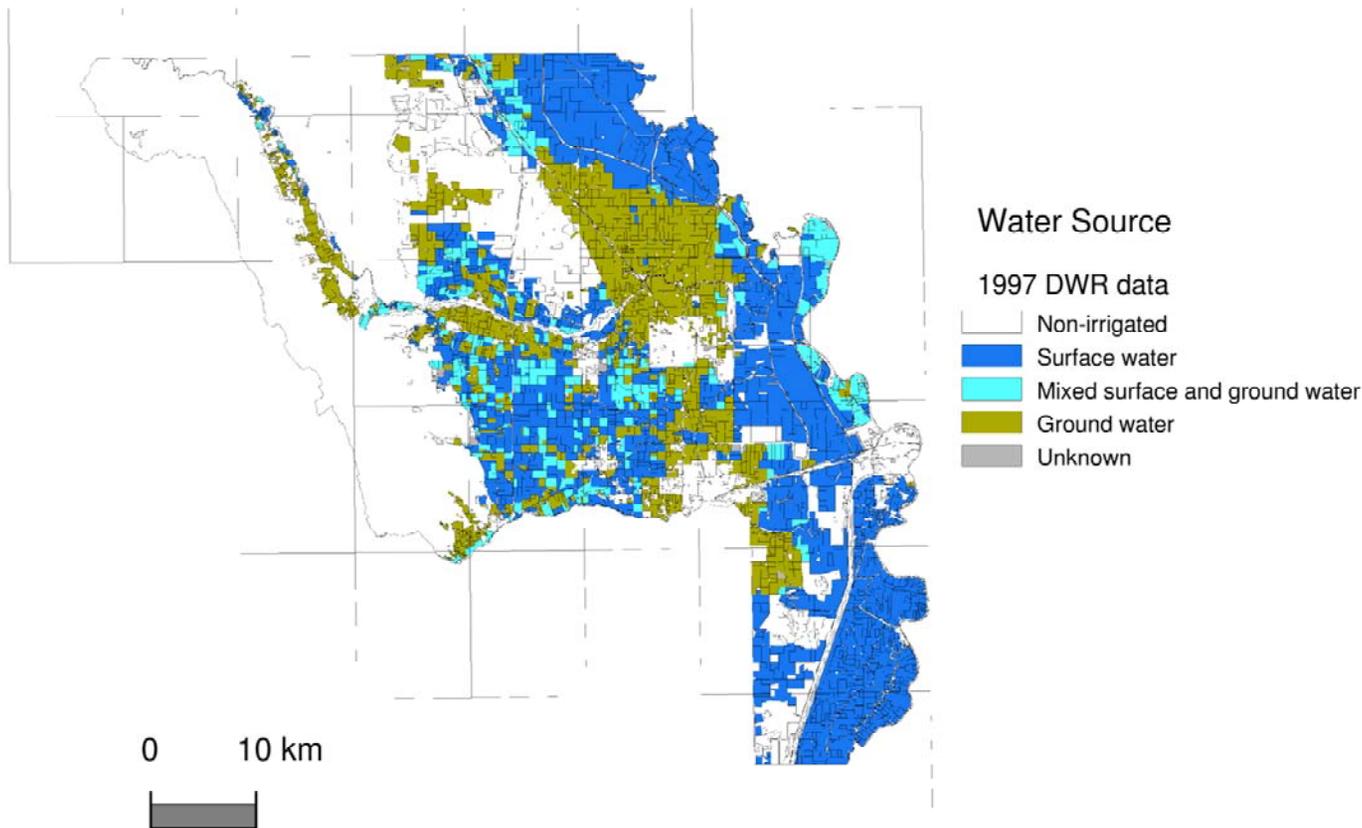
Region 2 Soil Quality (98,005 ha)



- 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

Irrigation Water Source

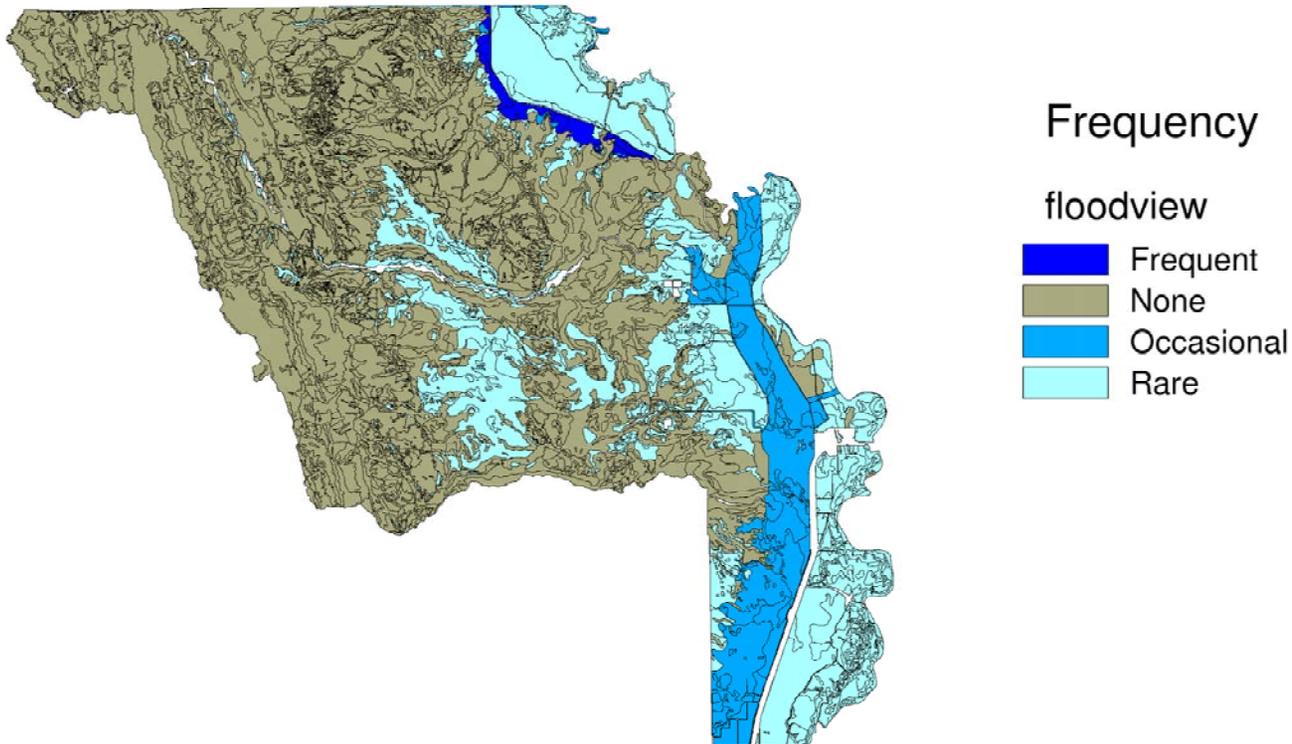


- Spatial variation in water source
- Reserves limited during drought
- Unlined canals
- Water quality esp. for urban use
- Needs more analysis

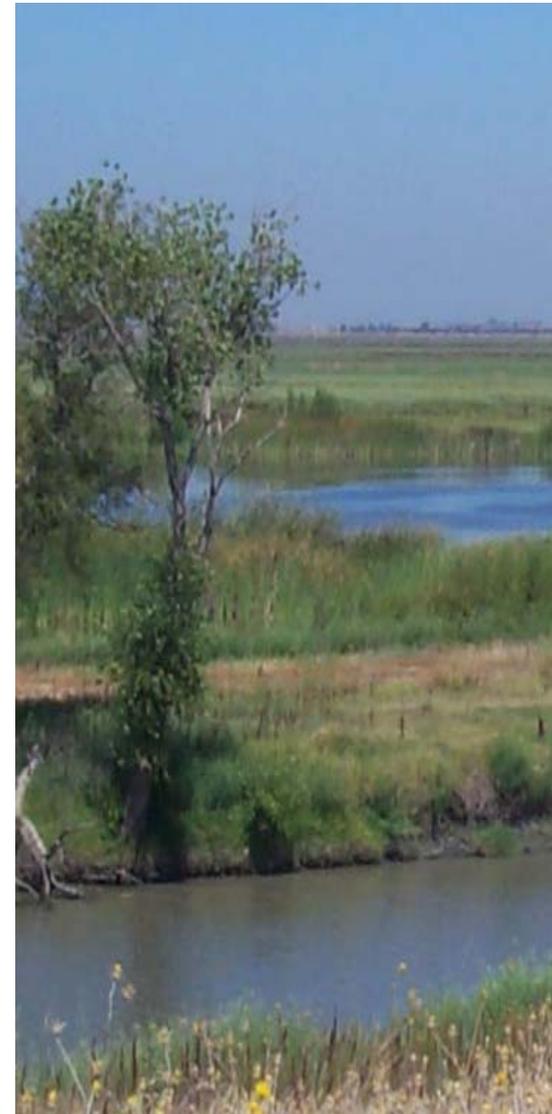
# Flooding frequency greatest near the Sacramento River (Region 1)

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## Flooding Frequency



Yolo Bypass

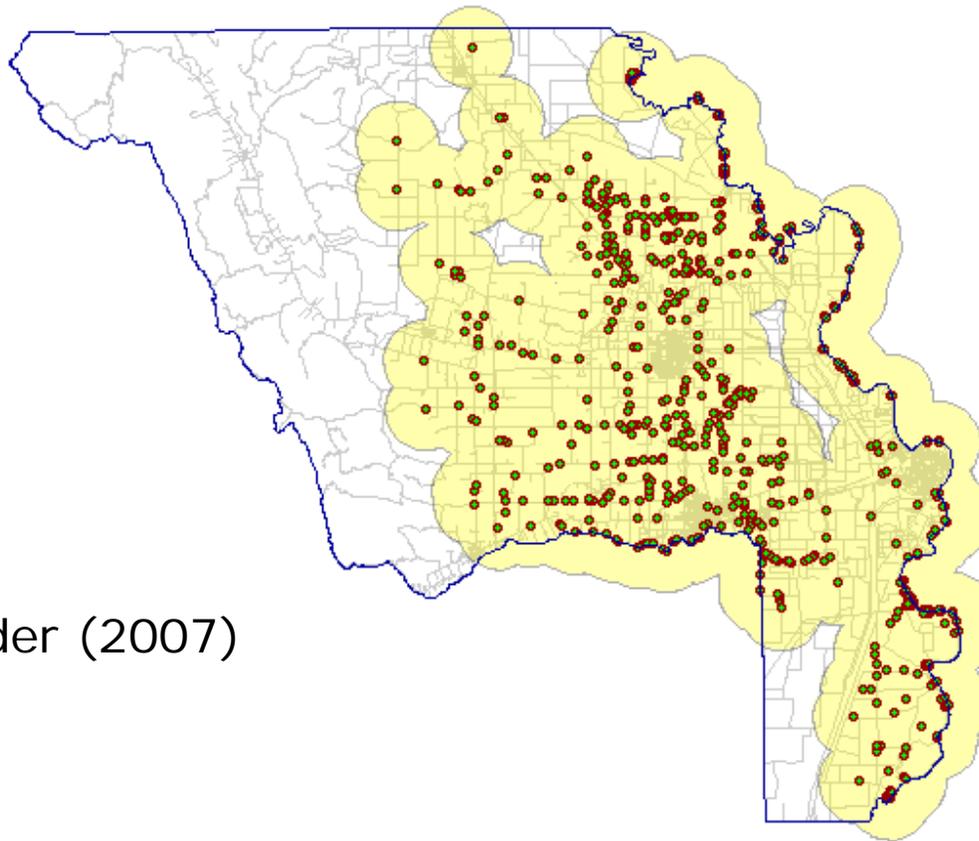


**Frequent** is defined as at least 1-2 times per year (2,334 ha); **Occasional** is at least 5 times every 50 years (16,904); **Rare** is once every 100 years (42,124). (USDA SSURGO).

# GIS query for Swainson's Hawk observations and habitats

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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

		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

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- 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:

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- ❑ 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