

# What are agriculture's best strategies for coping with climate change?

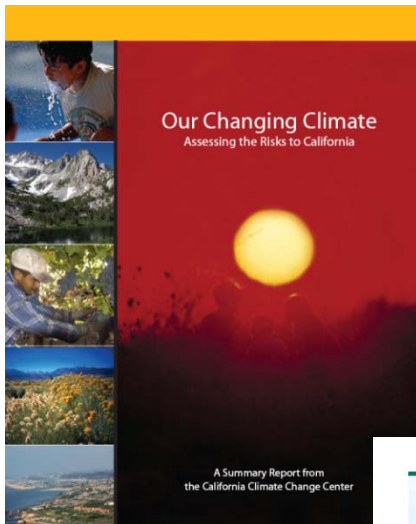
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B. Orlove, J. Perlman, D. Purkey, D. Sumner, M. Tomuta, S. Wheeler

# Climate change risks and responses

## California's Public Interest Energy Research Program (PIER)



### AB32: Global Warming Solutions Act



California's two-pronged approach to managing its climate risks:

- Mitigation: strengthening its efforts to reduce greenhouse gas emissions to slow down global warming
- Adaptation: planning for adaptation to deal with the impacts that are already underway and can no longer be avoided.

Global warming is no longer a matter of if, but when or where. In some, neither climate change is already evident in the state, and it is happening now. These local changes are consistent with the emerging evidence across the globe and largely driven by human activities such as the burning of fossil fuels, agriculture, and clearing of forests. They release carbon dioxide (CO<sub>2</sub>) and other gases into the atmosphere, changing its composition and trapping increasing amounts of heat that would otherwise escape into space. If these heat-trapping gas emissions are not curbed, the related impacts are not reduced. California faces tremendous impacts on its natural resource base's ecological resources and the basic health and well-being of its citizens.

Fortunately, the state is exemplary for its commitment to scientifically examine the climate risks it faces and for its ongoing efforts to confront already apparent and emerging climate challenges. This summary is an interim update that addresses the rapidly evolving science and further demonstrates the undeniable urgency of the overall problem. It demonstrates the growing need for a two-pronged approach to managing California's climate risks: to strengthen efforts in reducing greenhouse gas emissions to slow down global warming and to begin planning for adaptation to deal with the impacts that are already underway and can no longer be avoided. Together, mitigation and adaptation will help minimize the potential harm and take advantage of opportunities that may arise as the climate continues to change.

PIER's goals:

-Outreach efforts are essential to disseminate science information to decision makers.

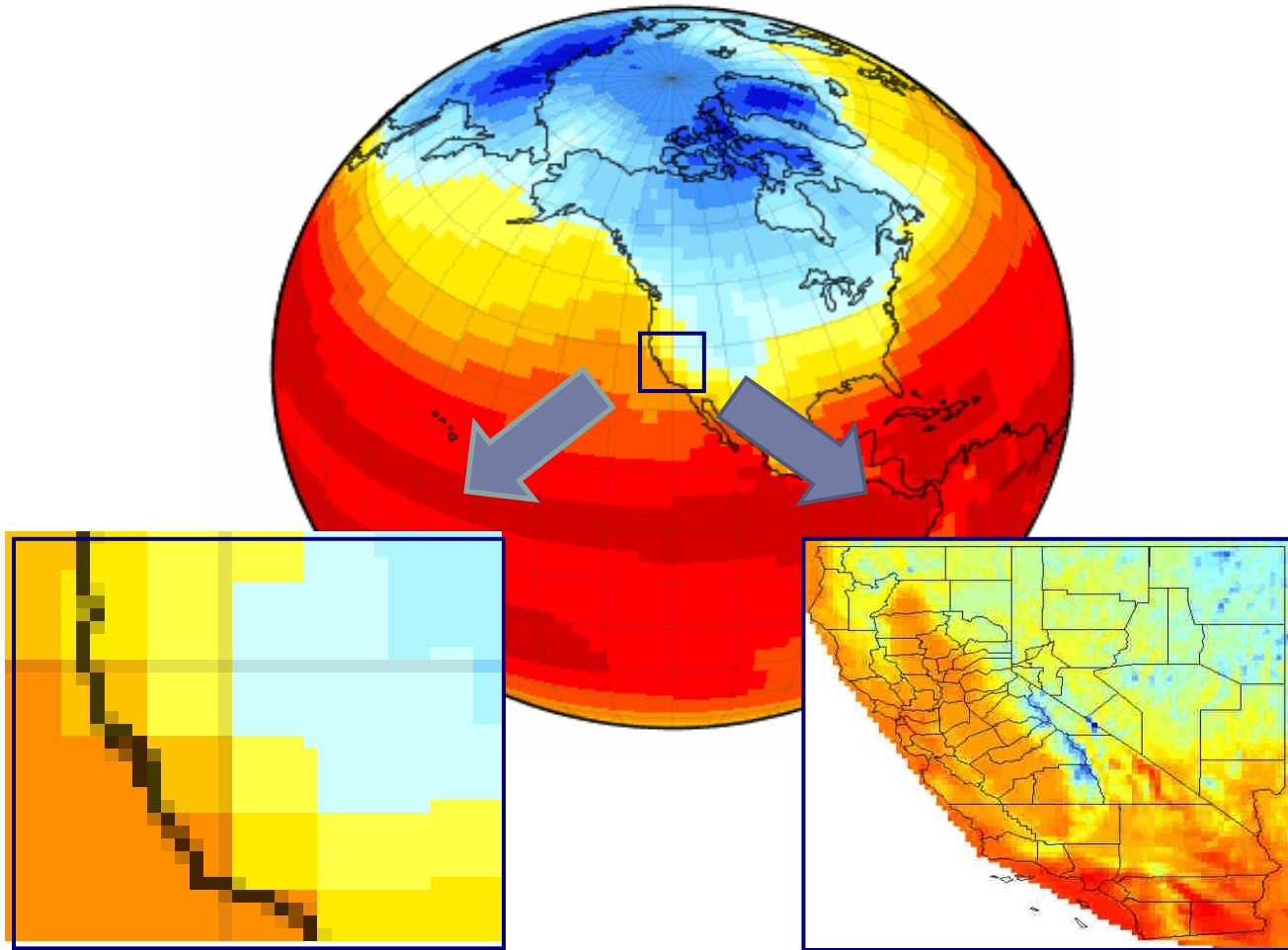
-Provide credible results from the scientific community.

-The California Climate Change Center publishes non-technical brochures summarizing large bodies of scientific research.

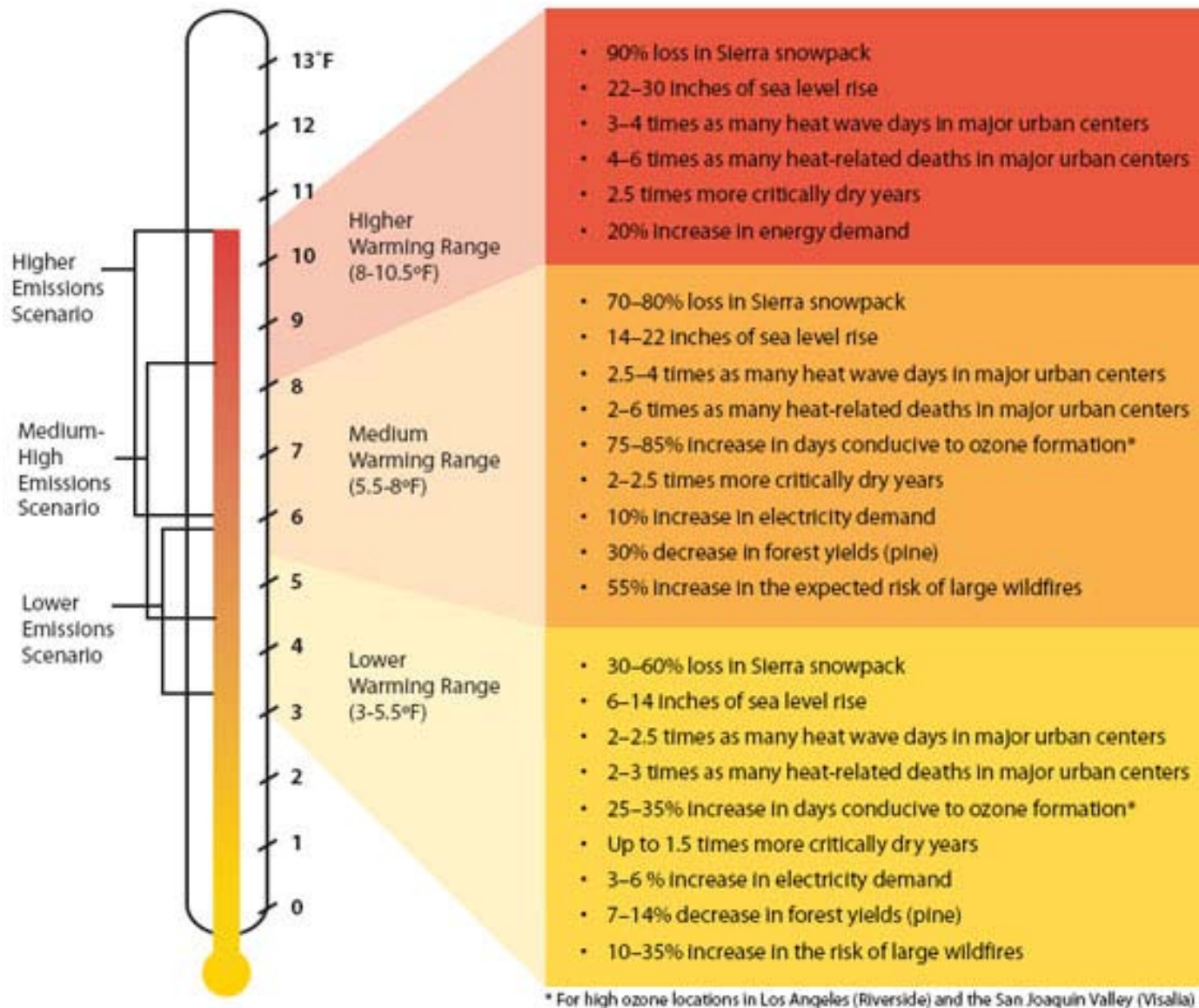
### CAS: California Adaptation Strategy

# PIER Climate Program: downscaling regional climate models

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## Summary of Projected Global Warming Impact, 2070–2099 (as compared with 1961–1990)



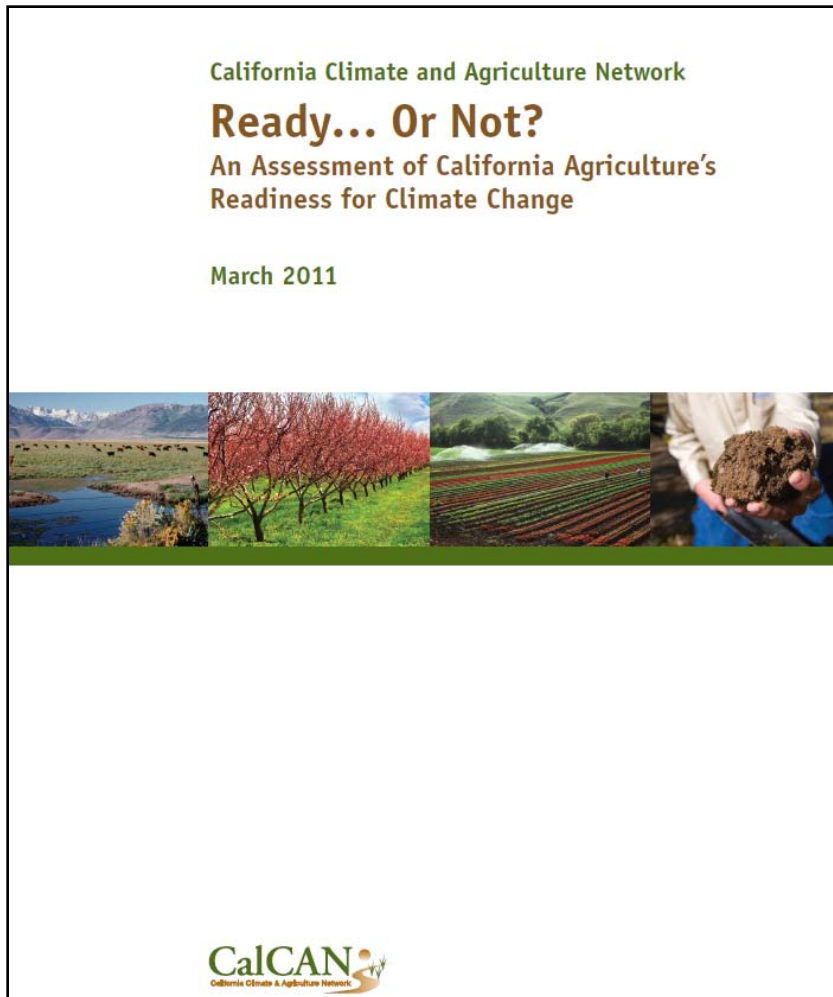
\* For high ozone locations in Los Angeles (Riverside) and the San Joaquin Valley (Visalia)

California  
climate  
change  
by the  
end of  
the  
century



# CalCAN's assessment

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1. To identify state and federally funded research projects that address climate change mitigation and adaptation strategies specific to California agriculture.
2. To assess the extent to which sustainable and organic agricultural perspectives are incorporated in publicly funded California climate change and agriculture research.
3. To assess the state of technical assistance resources available to California farmers and ranchers.
4. To assess the availability of conservation incentives for California farmers and ranchers.

# California agricultural production

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- ▶ **Our assets:**
  - ▶ Mild, summer-dry climate; deep and rich soils; irrigation water transport; labor availability
- ▶ **Highest agricultural crop value in the USA for >50 consecutive years**
- ▶ **>28 million acres in some type of agricultural production**
  - ▶ 8.5 million = harvested crops
  - ▶ Half of the fruits, nuts and vegetables in the USA
  - ▶ Leading producer of >80 crops
- ▶ **\$34.8 billion as income (2009); 81,500 farms**
- ▶ **Only state producing commercial quantities of almonds, artichokes, clingstone peaches, figs, raisins, walnuts, pistachios, nectarines, olives, dates, and prunes**



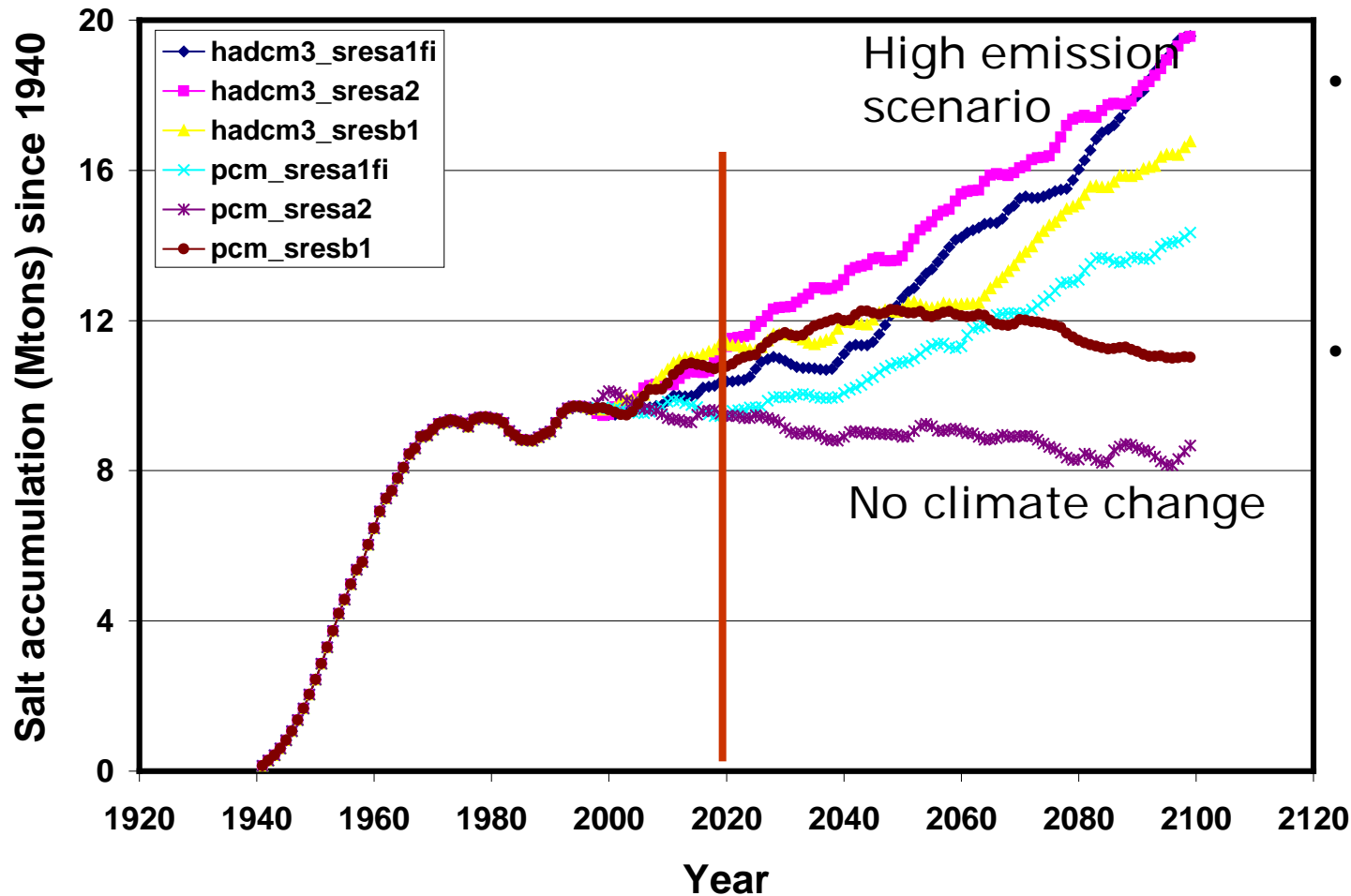
# Research: predicting response to higher temperatures and CO<sub>2</sub>

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- ▶ Higher CO<sub>2</sub> may slightly increase total vegetative growth
- ▶ Many fruit, nut and vegetable commodities are harmed by high temperatures and heat waves
- ▶ Less rainfall predicted -- Water use efficiency?
- ▶ Ozone phytotoxicity will increase (VOCs + NO<sub>x</sub>)
- ▶ Crop pests--unknowns
  - ▶ Diseases increase with warm/wet compared to warm/dry scenarios
  - ▶ Insect pests will survive winter
  - ▶ Weeds: new species?
- ▶ Cattle and dairy cows
  - ▶ Higher winter pasture production in wetter scenarios
  - ▶ Lower summer milk yield



# Research: Regional salt accumulation increases with climate change



- Lower imported canal water with climate change
- More groundwater will be pumped to the surface to meet crop needs

# Two vulnerable wildland ecosystems in agricultural landscapes

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## ▶ Riparian/wetland ecosystems

- ▶ Rich habitats for plants & wildlife
- ▶ Only a small fraction still remains
- ▶ Loss due to higher downstream channel flood capacity?



## ▶ Grassland and oak savanna ecosystems

- ▶ Biodiversity decline?
- ▶ Productivity increase or not?
- ▶ Grasslands may replace shrublands due to warming and fire, but will exotic species dominate?



# Change has characterized California agriculture over the past 100 years

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- ▶ Top production areas and top commodities have changed
- ▶ Commodities have moved geographically around the state
- ▶ Technological advances have steadily increased through the past century
- ▶ Agricultural policies have changed, e.g., water use, labor, sustainable agriculture
- ▶ California agriculture has the agility and ability to respond favorably to climate change, given adequate investment. . . .
- ▶ Keeping land in agriculture can be a key strategy to stabilize and ultimately reduce statewide greenhouse gas emissions



# Agricultural adaptation to climate change

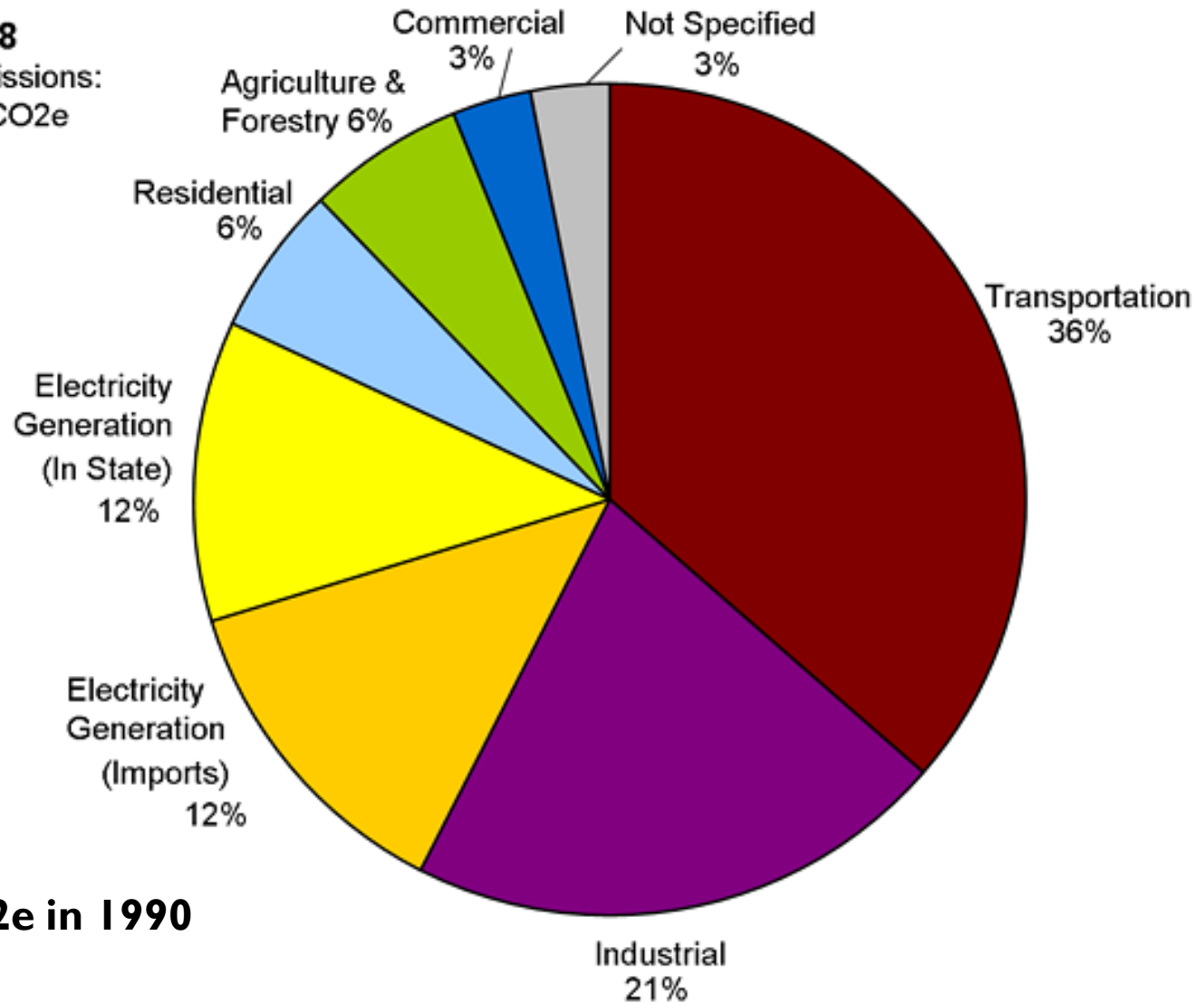
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- ▶ Assembly Bill 32 (2006): 1990 emissions in 2020
- ▶ New emphasis in CA state agencies
- ▶ Changes in climate have already begun
  - ▶ Awareness→Analysis→Action
- ▶ California agriculture is important nationwide
- ▶ Without adaptation strategies, land use will likely urbanize
  - ▶ Precarious livelihoods for farmers
  - ▶ Less open space and associated ecosystem services
  - ▶ Higher greenhouse gas emissions from urbanized land
    - ▶ Agriculture: only 6% of statewide greenhouse gas emissions



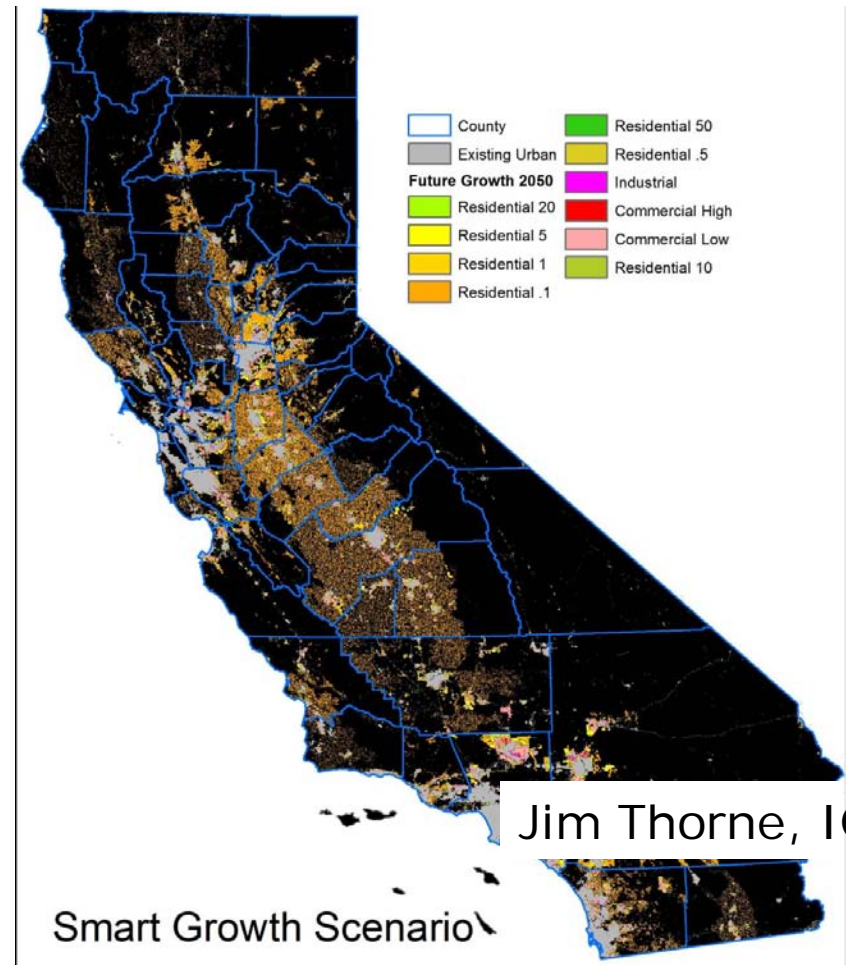
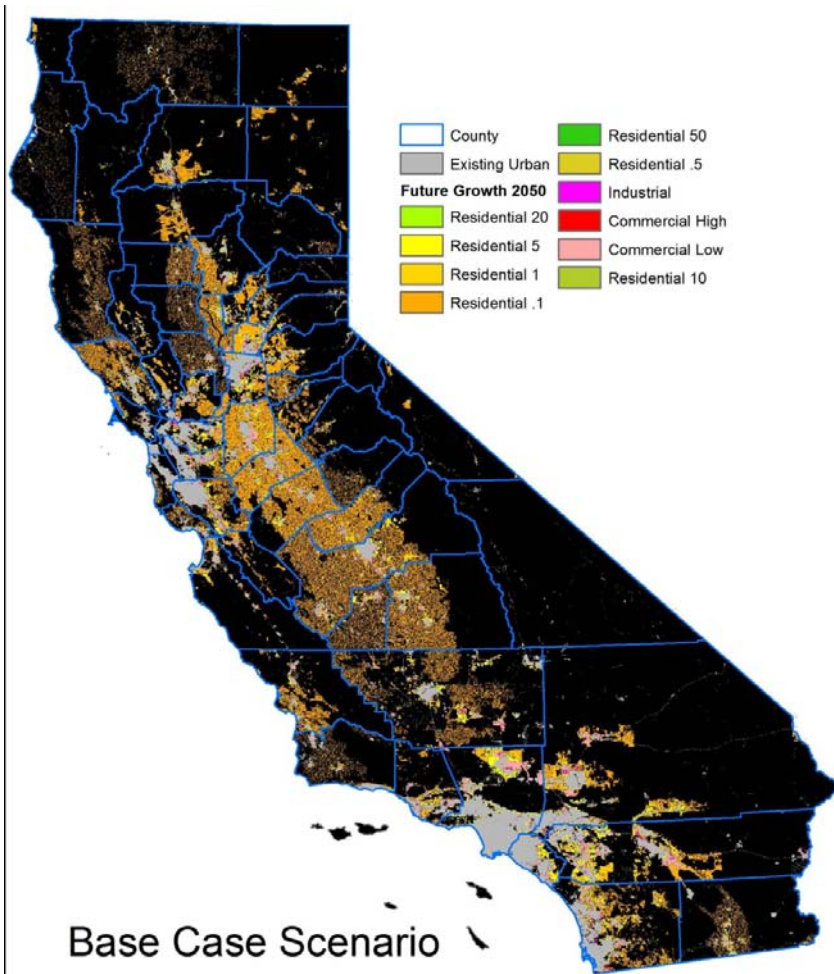
# GHG emissions in California

**Year 2008**  
Total gross emissions:  
477.7 MMT CO<sub>2</sub>e



**433 MMT CO<sub>2</sub>e in 1990**

# Projections for urban growth



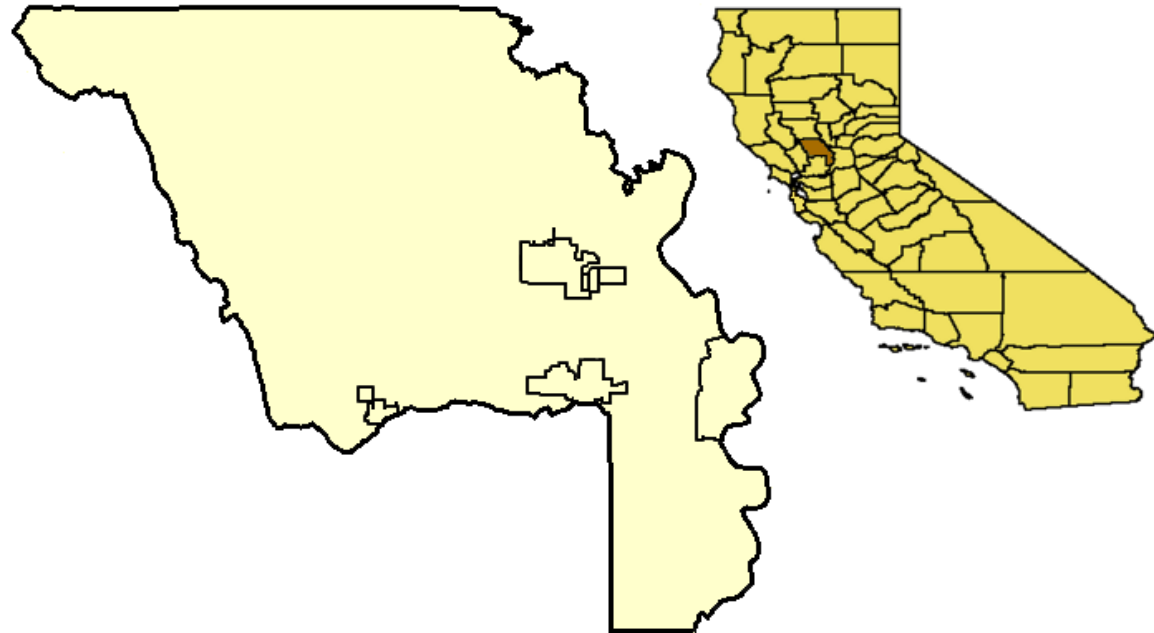
Jim Thorne, ICE

▶ Preliminary analysis: work in progress

# Yolo County, California

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- ▶ 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



# CA Energy Commission 2010-2011 Project (PIER )

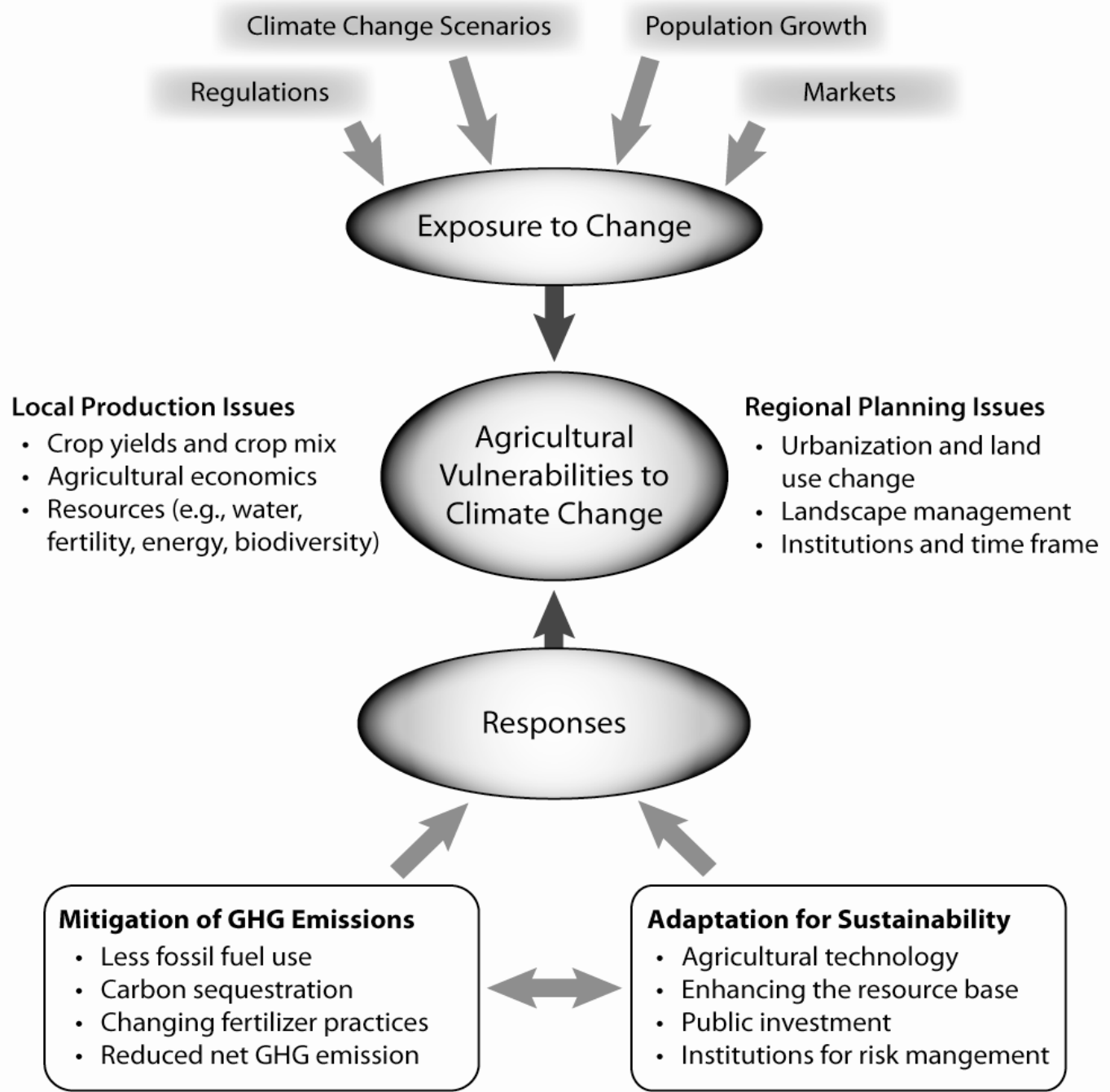
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- ▶ Demonstrate the broad mechanisms by which agriculture may react to climate change, along with other simultaneous changes in landscape pressures
- ▶ Develop a place-based case study to examine climate change scenarios using interpretations of GIS layers for ecological, agricultural, urban planning, and natural resource indicators
- ▶ Provide a science-based exploration tool for scientists, farmers, policymakers and the general public to better understand the complexity of risks and responses to climate change, and the adaptation options for increasing agricultural sustainability
- ▶ Interdisciplinary team: agroecology, anthropology, hydrology, soil science, economics, land use planning, and political science
- ▶ Builds on a 2008 CEC PIER Scenarios Analysis Project:

Jackson, L.E., F. Santos-Martin, A.D. Hollander, W.R. Horwath, R.E. Howitt, J.B. Kramer, A.T. O'Geen, B.S. Orlove, J.W. Six, S.K. Sokolow, D.A. Sumner, T.P. Tomich, and S.M. Wheeler. 2009. Potential for adaptation to climate change in an agricultural landscape in the Central Valley of California. Report from the California Climate Change Center. CEC-500-2009-044-D. 170 pp. <http://groups.ucanr.org/jacksonlab/files/66086.pdf>

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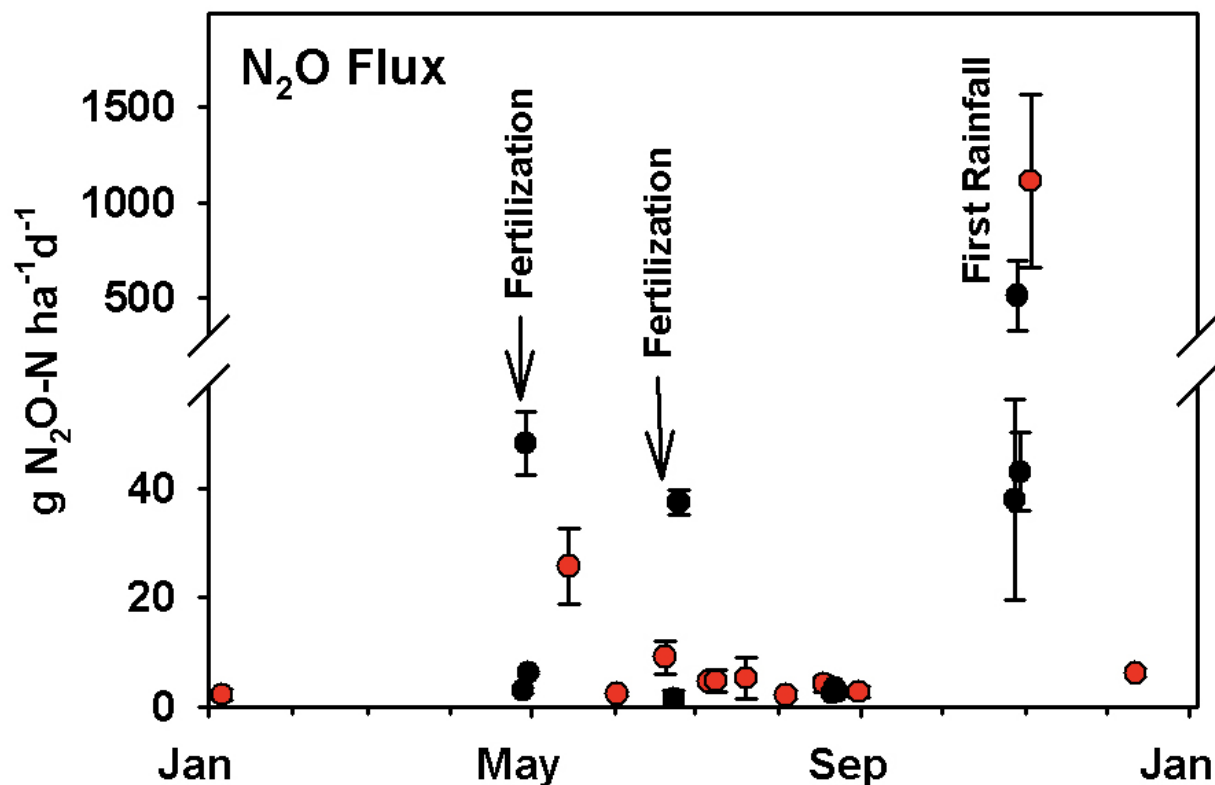
# Farm management to reduce GHG emissions (PIER Yolo County study)

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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 lower, and new markets are needed to support expanded organic production.
- ▶ **Shifts in crop mix and diversification:** New crops may be less vulnerable to heatwaves, but may be limited by processing facilities nearby and by market demand.



# Nitrous oxide emissions tend to be event based



- Controls are well-known, e.g.,
  - Soil water content
  - Soil texture
  - Carbon availability
  - Nitrogen availability
  - Temperature

BUT....

- Magnitude of emissions hard to predict in the field

# UCD trial: no-till vs. standard tillage

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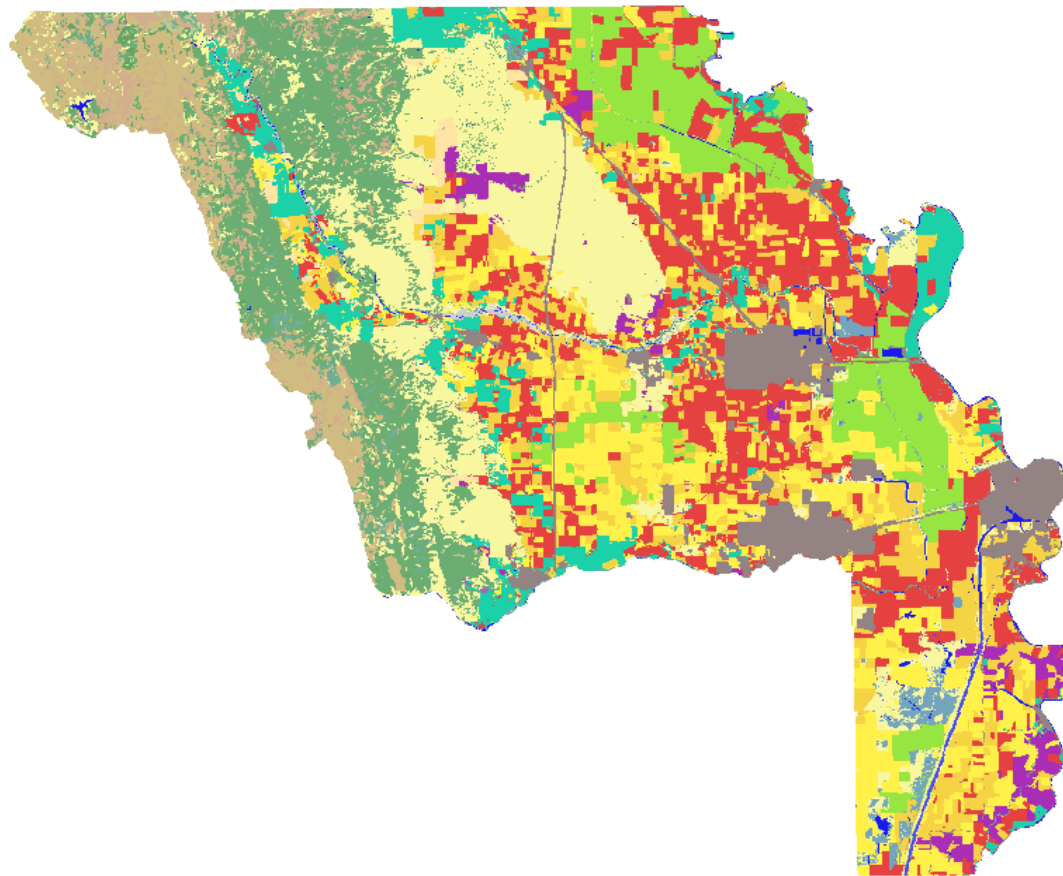


- ▶ Treatments for  $\approx 1.5$  years at SAFS/LTRAS (UC Davis)
  - ▶ No-till, continuous crop (NTCC)
  - ▶ No-till, intermittent fallow (NTF)
  - ▶ Standard till, continuous crop (STCC)
  - ▶ Standard till, intermittent fallow (STF)
- ▶ Results
  - ▶ Soil C increased
  - ▶ Size and composition of microbial & nematode groups changed
  - ▶ Crop yields decreased
  - ▶ Weeds increased

# Yolo County land cover

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

## Land Cover



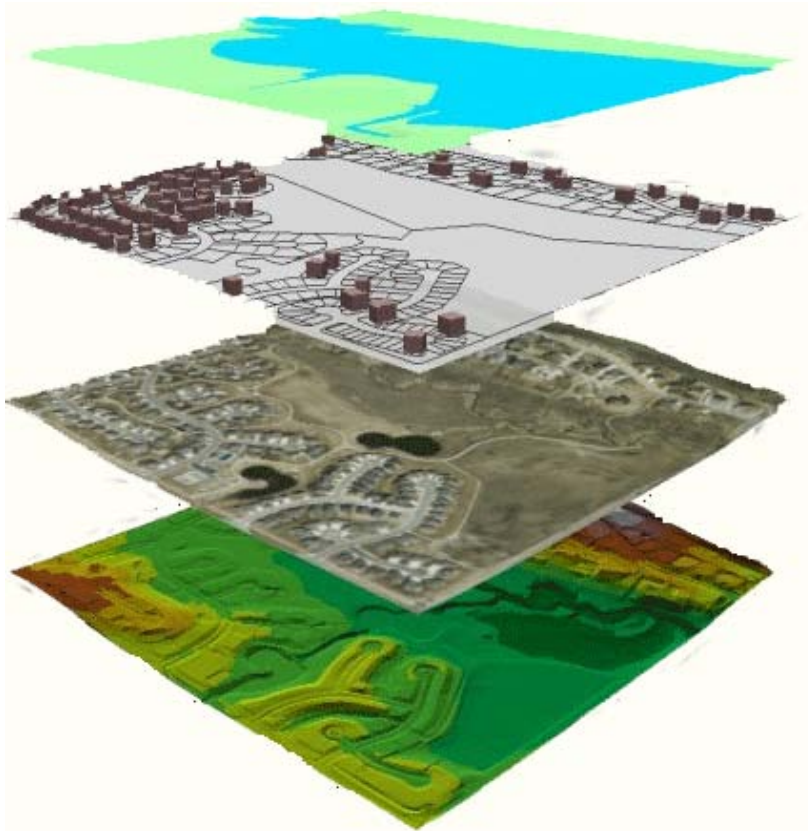
- 3) Annual Grassland
- 6) Barren
- 8) Blue Oak-Foothill Pine
- 9) Blue Oak Woodland
- 12) Chamise-Redshank Chaparral
- 22) Freshwater Emergent Wetland
- 28) Lacustrine
- 32) Mixed Chaparral
- 35) Montane Hardwood-Conifer
- 36) Montane Hardwood
- 39) Perennial Grassland
- 43) Riverine
- 53) Urban
- 55)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

# UPLAN discouragements or masks

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## **“Features that discourage development”**

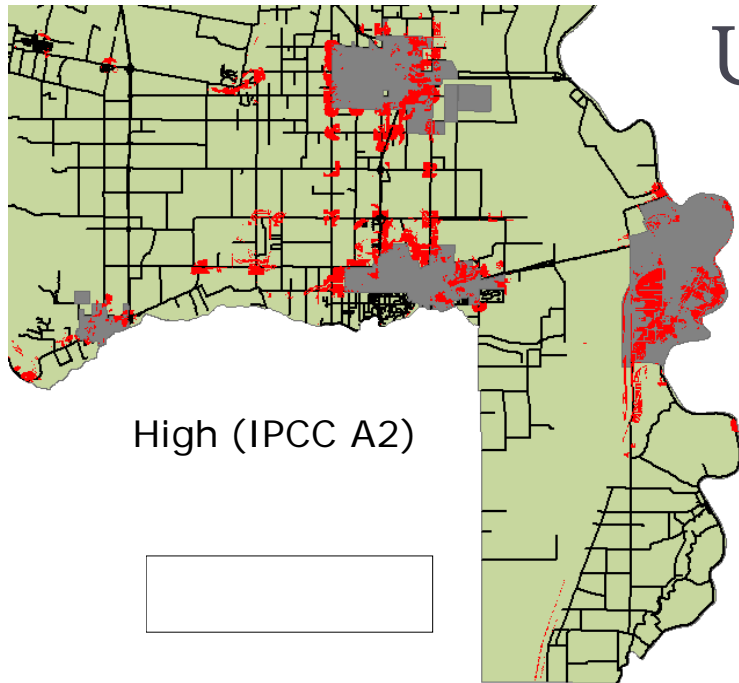
- 100 yr Floodplains
- Natural Diversity Areas
- Storie Class Excellent Soil
- Storie Class Good Soil
- Vernal Pools
- Wetlands
- Williamson Act Land

Features are chosen based on the Yolo Co. storylines for A2, B1, and AB-32 scenarios

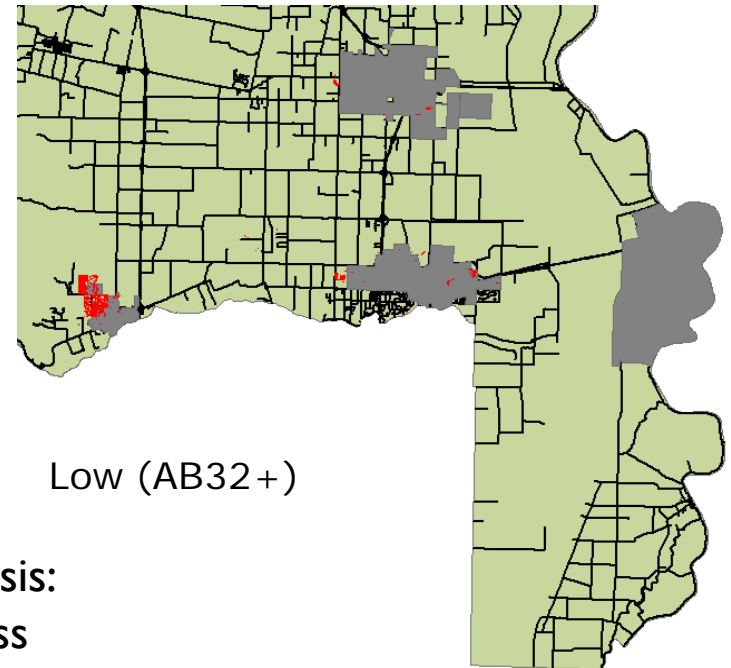
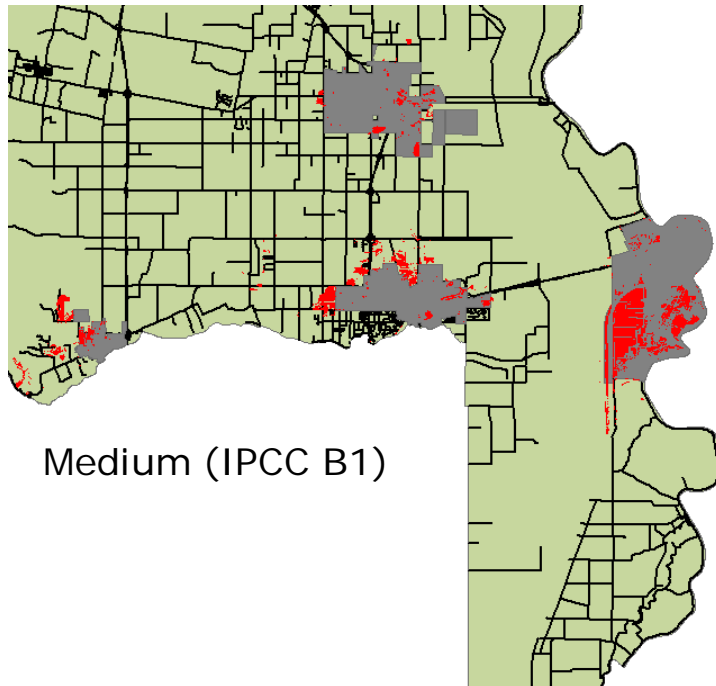
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# UPLAN urbanization model



Land Types	New Acres Developed		
	A2	B1	AB32+
Floodplains	2170	227	0
Natural Diversity Areas	1114	150	0
Storie Class Excellent	3166	225	0
Storie Class Good	4867	1731	257
Vernal Pools	47	Mask	0
Wetlands	380	11	0
Williamson Act Lands	2110	0	0



Preliminary analysis:  
work in progress

# Yolo County greenhouse gas emissions

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Land-Use Category	Land Area		Average Emissions Rate	
	1990	2008	1990	2008
	----- acres -----		--- MT CO <sub>2</sub> e acre <sup>-1</sup> yr <sup>-1</sup> ---	
Rangeland	131,945	135,717	0.28	0.32
Cropland	344,335	324,654	0.87	0.80
Urban	22,471	29,881	61.50	--

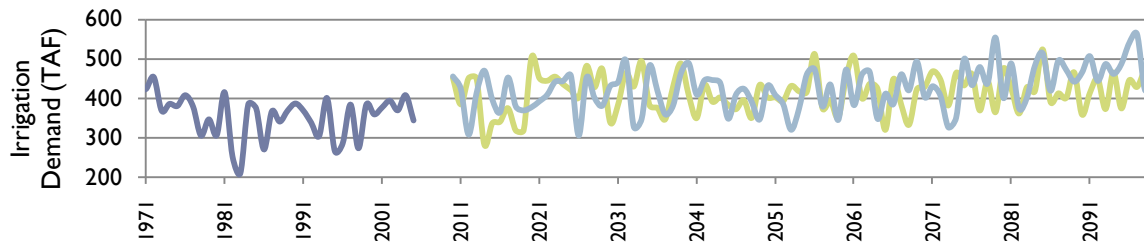
\*Countywide urban emissions for 2008 are not yet available

- Urban land use has much higher emissions than rangeland or cropland.
  - Calculations based on UC cost of production studies for 1990 and 2008 and IPCC equations.
  - Need better methods to estimate GHG emissions across a wide range of land-use types.
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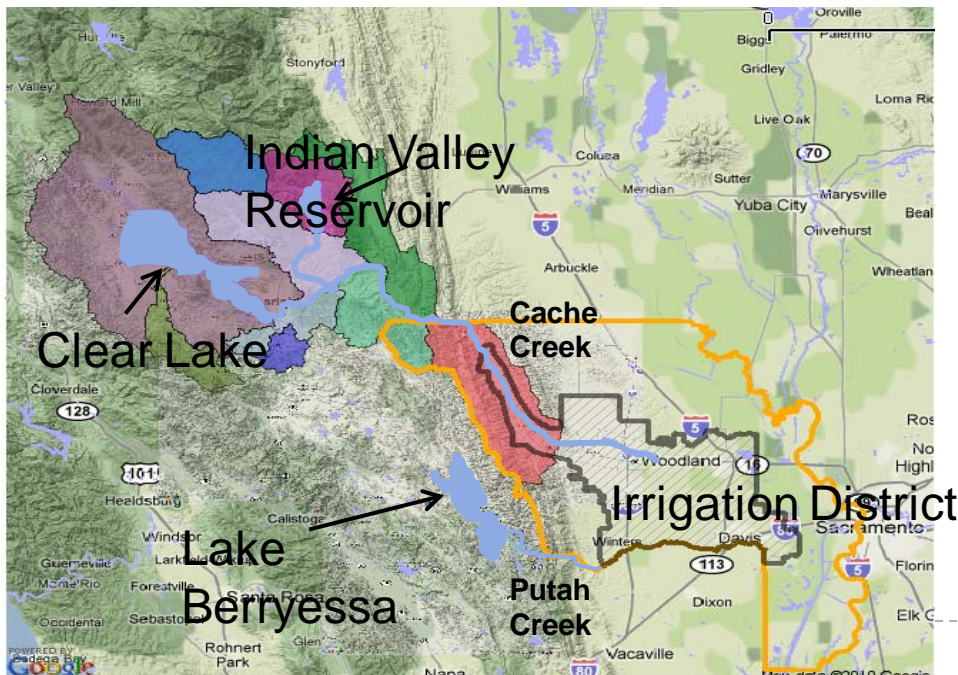


# Water Evaluation And Planning (WEAP)

- ▶ WEAP hydrologic model of Cache and Putah Creek Watersheds
- ▶ Calibrated with historical climate, crop, reservoir & stream data
- ▶ Model run using multiple future climate projections (2010-2050)



WEAP projection of irrigation needs  
(thousands of acre feet (TAF))  
A2=blue; B1=green; historical= dark blue



## Planning Options

Water storage and ground water recharge?

## Risk Assessment

Prolonged drought effects on water availability and crop water demand?

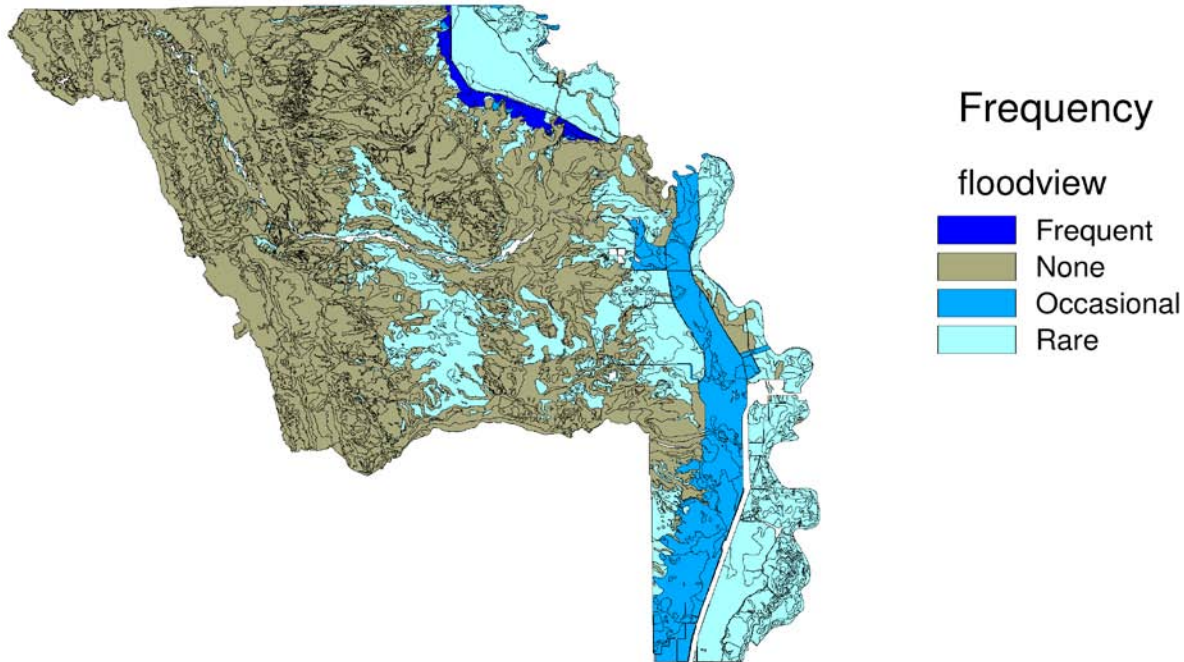
## Test Potential Adaptation Strategies

More efficient irrigation technologies or changing crops?

# Flooding frequency near the Sacramento River

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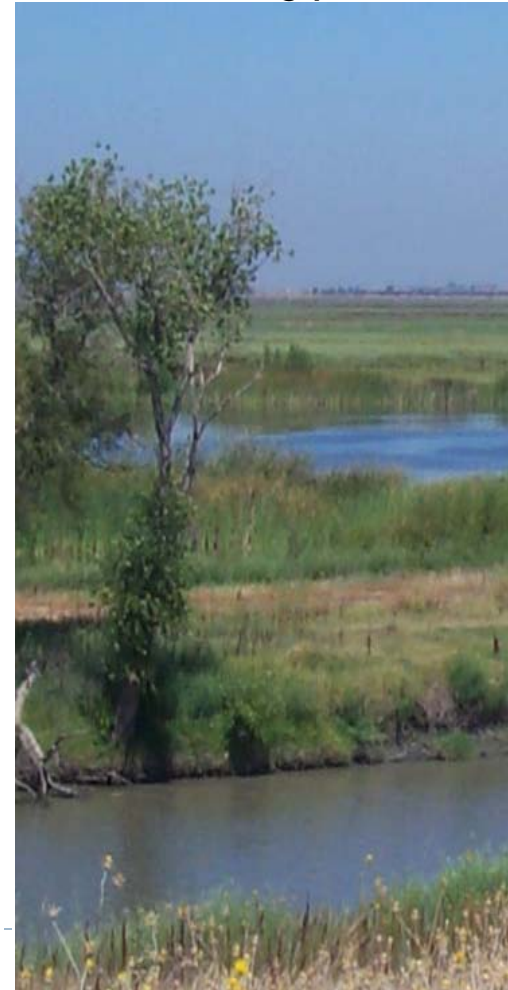
## Flooding Frequency



**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 ha); **Rare** is once every 100 years (42,124 ha). (USDA SSURGO).

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## Yolo Bypass



# Sacramento River Floods, 1999



# Farmer involvement in climate change issues



**UCDAVIS**

Coming This Winter:

Survey of Yolo Farmers' Views on Water Scarcity and Climate Change



We Invite Yolo farmers to share their thoughts on how California agriculture can adapt to future challenges posed by water scarcity and climate change.  
See reverse side for details

# Summary

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- ▶ Reaching 2020 and 2050 targets of AB32 requires long-term planning to keep agriculture in business
  - ▶ Agriculture land has much lower GHG emissions (per acre) than urban, industrial or freeway land
  - ▶ Even so, we need innovation to reduce GHG emissions by agricultural production and processing
- ▶ As global warming increases, so do the impacts on California agriculture
  - ▶ Extreme events, e.g. heat waves cause crop damage, especially fruits and vegetables
  - ▶ Eventual loss of important commodities, e.g. some fruit trees
  - ▶ Crop shifts: specialty crops shift north and south
  - ▶ Dry scenarios: water scarcity brings high economic costs
  - ▶ Groundwater salinity will increase and degrade soil quality
  - ▶ Urbanization may increase as a result of agricultural uncertainty
- ▶ Support research and policy to keep California's agriculture sustainable over the long-term



# Acknowledgments

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- ▶ Ryan Haden
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- ▶ Ben Orlove
- ▶ David Purkey
- ▶ Dan Sumner
- ▶ Steve Wheeler
- ▶ Landowners and agencies in Yolo County
- ▶ Kearney Foundation of Soil Science
- ▶ USDA Organic Research and Education Initiative
- ▶ PIER California Climate Change Scenarios Analysis Program

