Climate Change and Agriculture in California: How Do We Plan for Migration + Adaptation?

Louise Jackson, Professor and Extension Specialist, UC Davis

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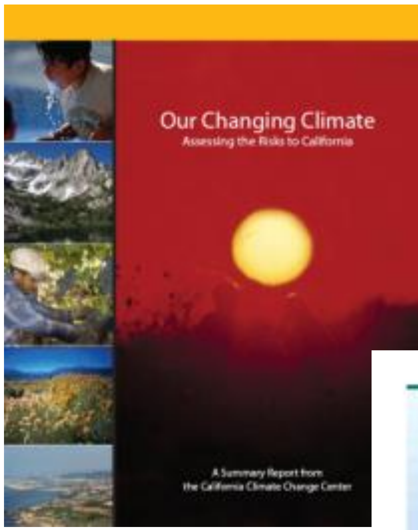
UC ANR Statewide Conference

Climate change risks and responses

Government publications



AB32: Global Warming Solutions Act

CAS: California Adaptation Strategy

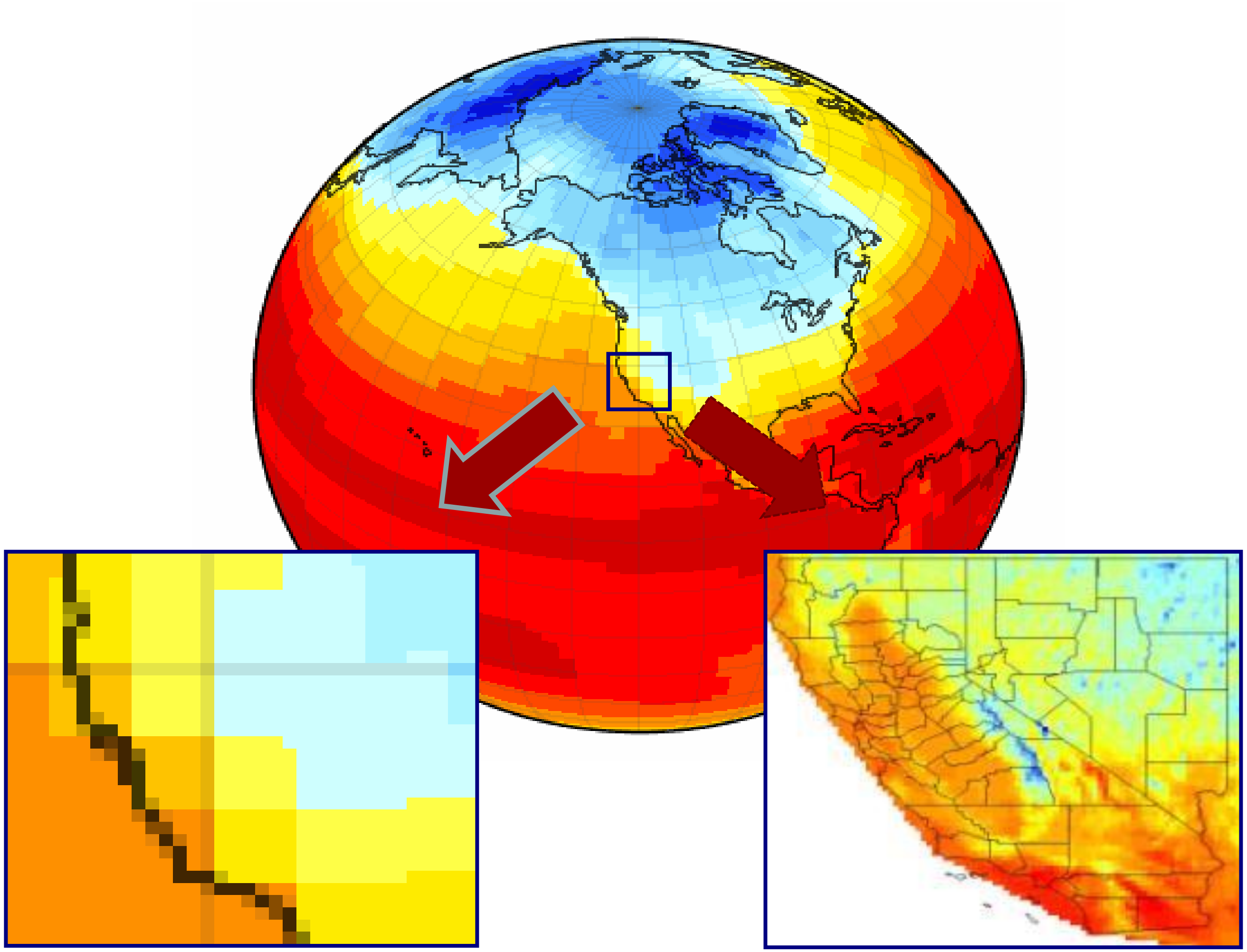
California's Public Interest Energy Research Program (PIER)

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

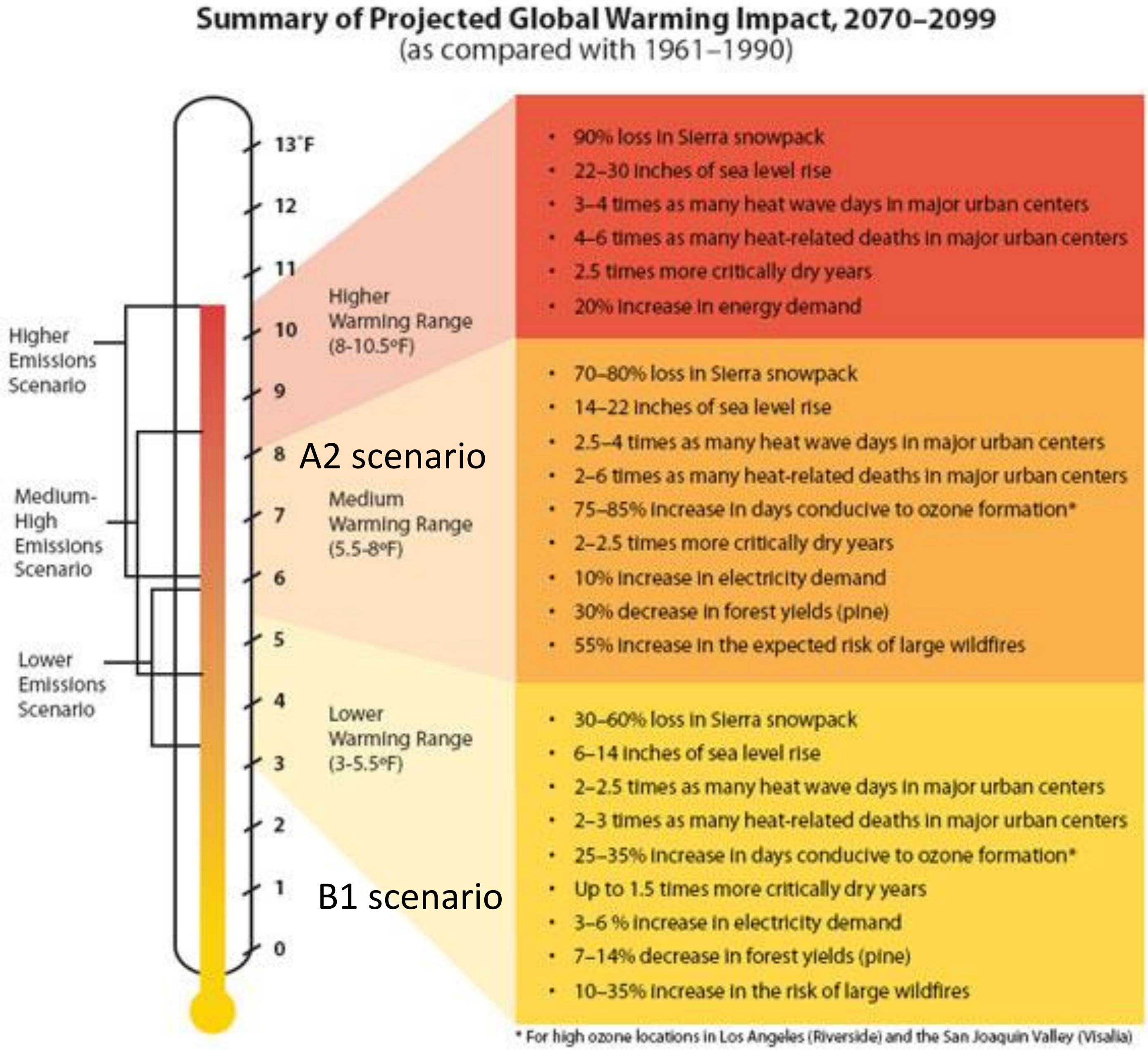
-Provided credible results from the scientific community.

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

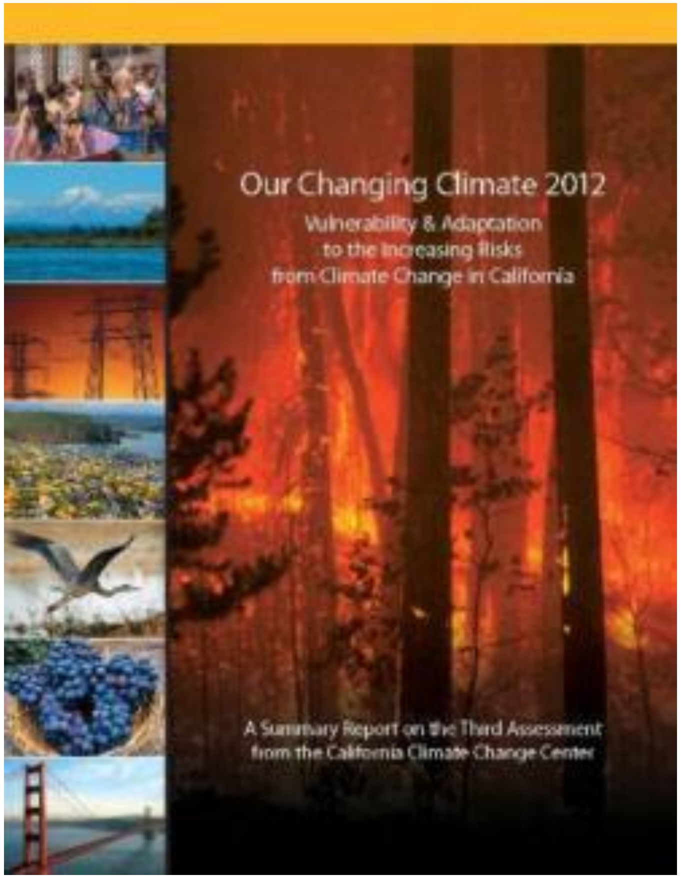
PIER Climate Program: downscaling regional climate models



California climate change by the end of the century



2012 Climate Change Vulnerability and Adaptation Reports



- Emphasis on assessing vulnerable sectors in California and coping strategies
- Agriculture
  - Statewide issues
    - Water
    - Energy
    - Land use change
  - Case study for one county (Yolo)

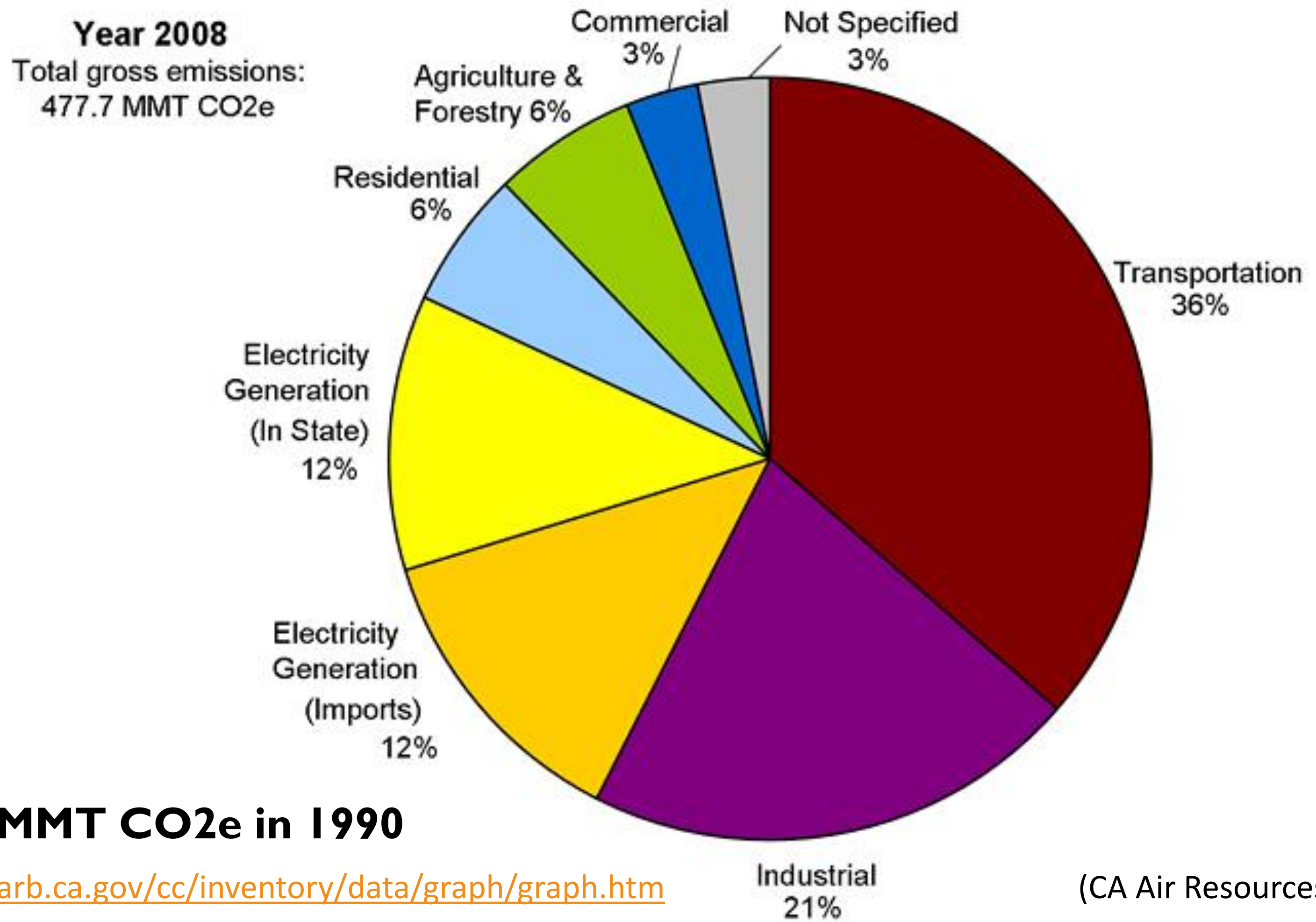
http://www.climatechange.ca.gov/adaptation/third_assessment/

Agricultural responses to climate change

- Mitigation
  - Reducing the concentrations of greenhouse gases (GHG) in the atmosphere
    - Nitrous oxide, carbon dioxide and methane
  - AB 32: 1990 emissions in 2020
    - Agriculture has very small role in its cap and trade policy
    - Offset potential for trade; now not in the cap
  - SB 375: connect land use planning with implementation of AB 32
    - Higher GHG emissions from urbanized than ag land

- Adaptation
  - Acting to tolerate higher GHG, warming, drought and other climate changes
  - Newer emphasis in CA state agencies
  - Changes in climate have already begun
  - Without adaptation strategies, land use may likely urbanize with loss of many benefits
  - Food security and agricultural livelihoods at risk?

Greenhouse gas emissions in California



433 MMT CO2e in 1990

http://www.arb.ca.gov/cc/inventory/data/graph/graph.htm

(CA Air Resources Board)

California agricultural production

- Highest agricultural crop value in 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
  - $30 billion as income each year
- Only state producing commercial quantities of almonds, artichokes, clingstone peaches, figs, raisins, walnuts, pistachios, nectarines, olives, dates, and prunes

- Without climate change adaptation, is urban conversion more likely?
  - Agriculture: only 6% of statewide greenhouse gas emissions at present

Research needs: responses to higher temperatures and CO_2

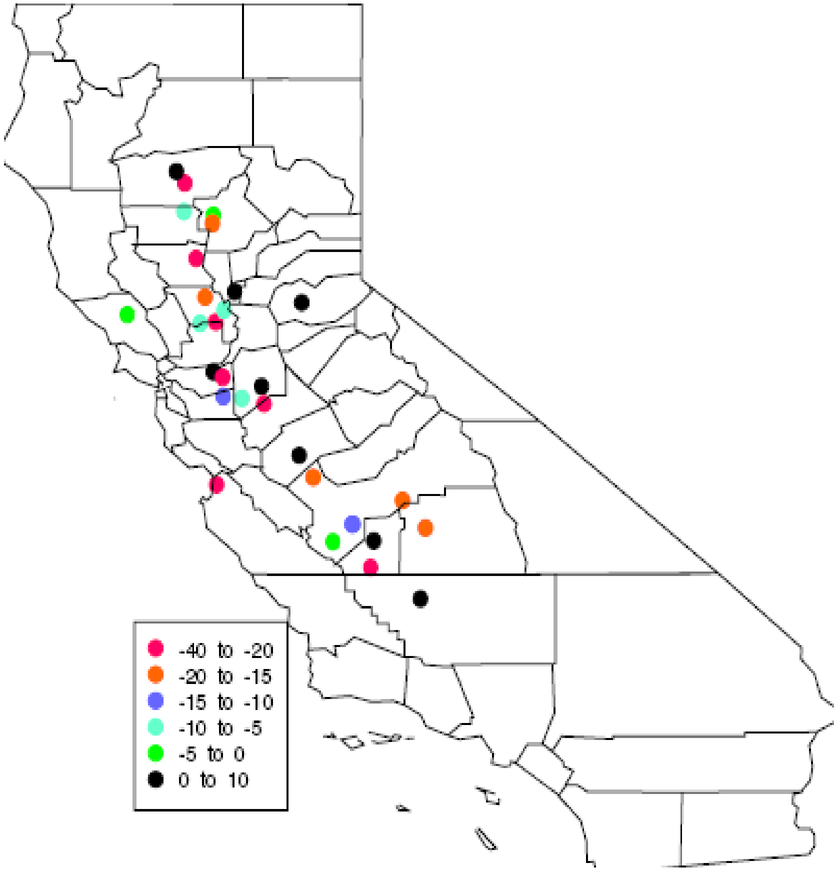
- Higher CO_2 may slightly increase total vegetative growth
- Many fruit, nut and vegetable commodities are harmed by high temperatures and heat waves
- Less rainfall predicted -- Water use efficiency?
- Ozone phytotoxicity will increase (VOCs + NO_X)
- Crop pests--unknowns
  - Diseases increase with warm/wet compared to warm/dry scenarios?
  - Insect pests will survive winter?
  - Weeds: new species?
- Cattle and dairy cows
  - Higher winter pasture production if wetter
  - Lower summer milk yield

Cavagnaro et al. 2005. *Climate Change: Challenges and Solutions for CA Agricultural Landscapes. CEC-500-2005-189-SF.*

Insufficient chill hours for grapes and fruit trees

- Chill hours are hours below 45° needed for a successful crop
  - 3 million acres of orchards with chilling requirements
- Chill hours on decline and predicted to continue declining[1]
  - Reduction seen for all climate change scenarios[2]
- Potential for crop failure especially for cherries, apricots and other stone fruit

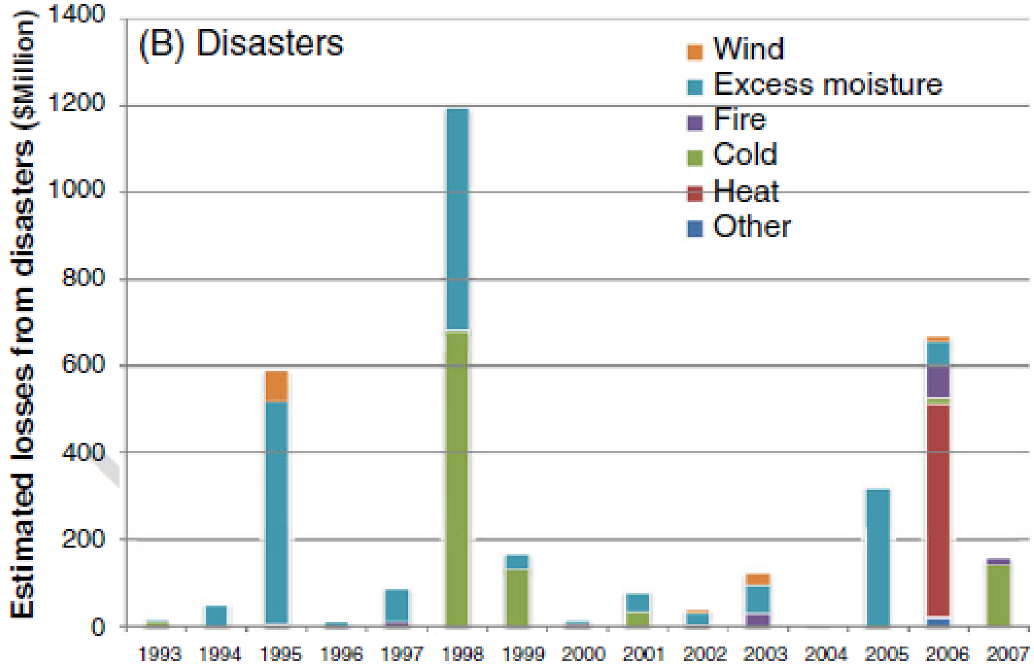
Map of trends in chill hours/year since 1950[3]



[1-2] Baldocchi D. and S. Wong. 2008. Luedeling, E. et al. 2009. [3] Moser, S. et al. 2009.

Largest ag disasters in California (1993-2007)

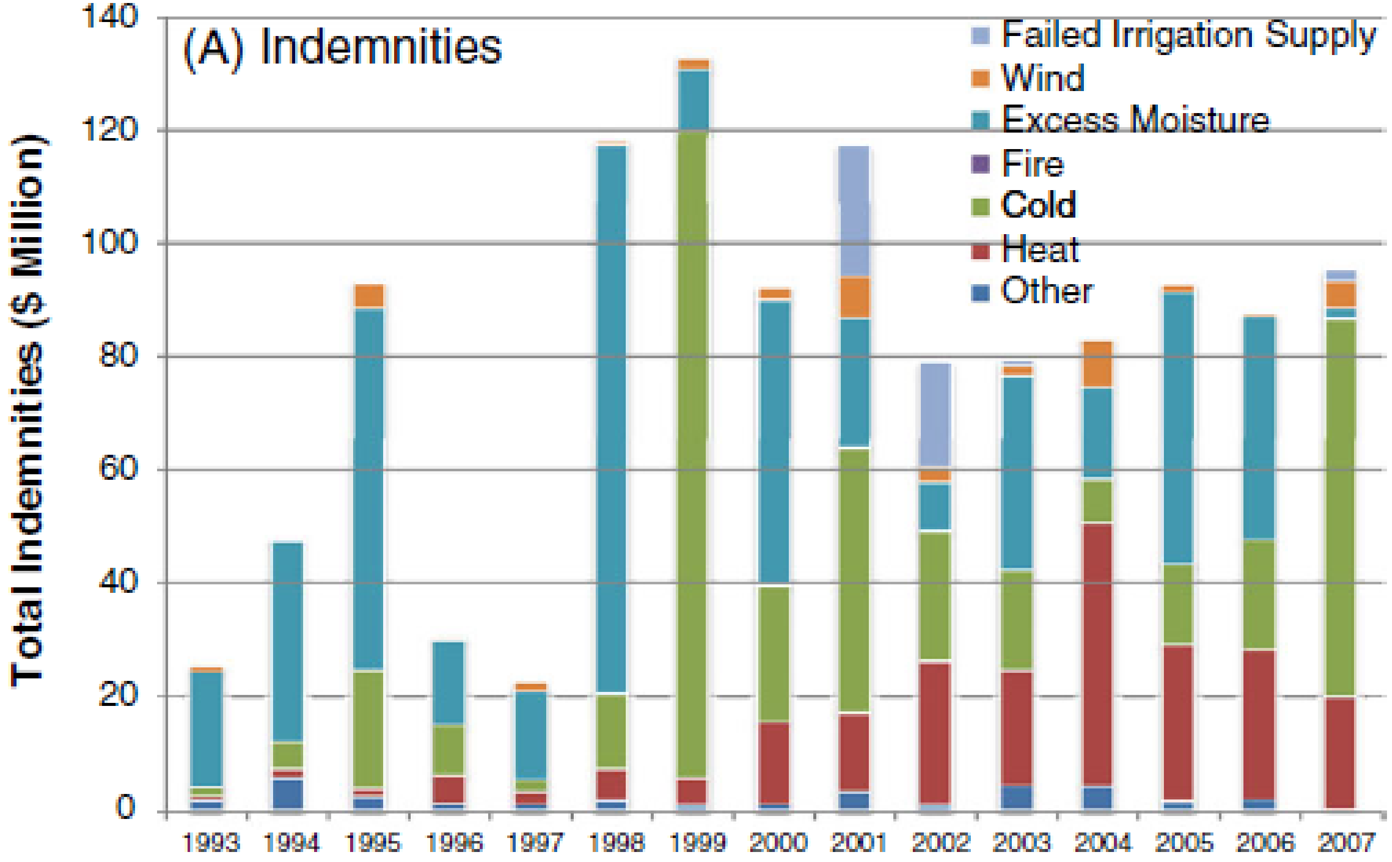
- Top 10 events (1993-2007) in California
  - NOAA data set
  - Based on estimated cost
- Freeze in December 1998
  - Oranges, lemons, olives and cotton
- Heat wave in July 2006
  - Livestock industry
- Heavy rainfall in spring and winter months
  - Next three most damaging episodes



Total amount of estimated total losses from disasters for each year, by type of extreme event

Lobell et al. 2012. *Climate Extremes in California Agriculture. CEC-500-2009-040-D.*

Indemnity payments for ag from disasters



Total amount of indemnity payments from disasters for each year by type of extreme event (USDA Risk Management)

Most costly overall:

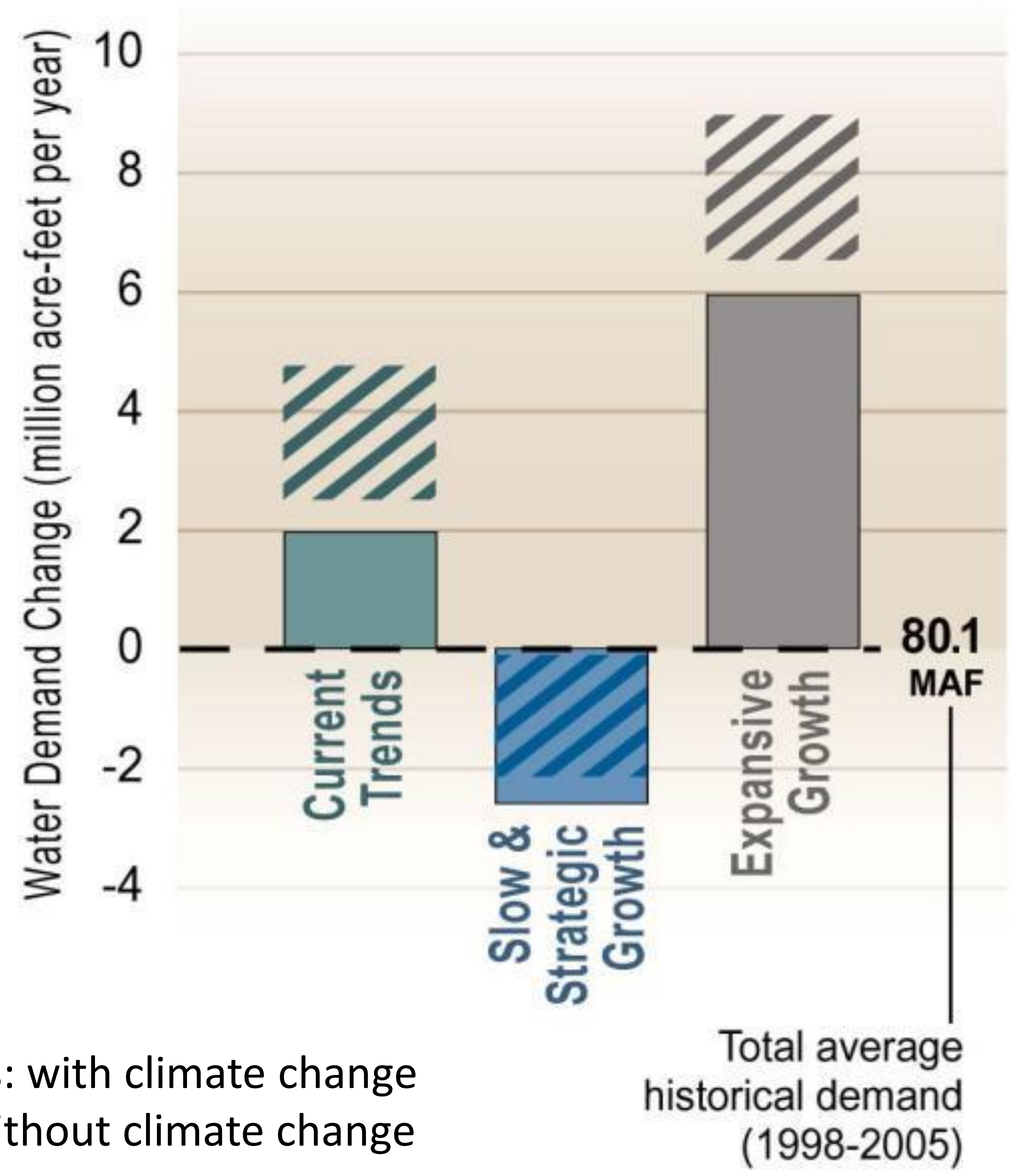
1) Excess moisture
2) Cold spells
3) Heat waves

Lobell et al. 2012. *Climate Extremes in California Agriculture. CEC-500-2009-040-D.*

Statewide water demand change for 2050 scenarios

Without & with climate change

High regional variation

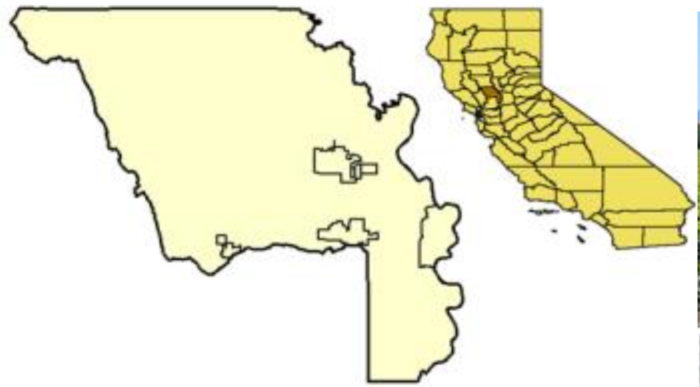


Hatched boxes: with climate change
Solid boxes: without climate change

CEC -funded case study on climate change and agriculture in Yolo County

- Crop management & production
- Econometric analysis of past and future impacts of climate on agricultural acreage
- Hydrologic model for water supply and demand for local irrigation district
- Inventory of county's agricultural GHG emissions
- Survey of farmer views on climate change impacts and local responses
- Model of local urban growth scenarios and GHG emissions
- Guidance from a steering committee of local agricultural stakeholders

(Jackson, Haden, Hollander, Lee, Lubell, Mehta, O'Geen, Niles, Perlman, Purkey, Salas, Sumner, Tomuta, Dempsey, and Wheeler)



Jackson et al. 2012. *Adaptation Strategies for Agricultural Sustainability in Yolo Co., California*. *CEC-500-2012-031.*

GHG emissions estimates for Yolo Co. agriculture, 1990 and 2008, for the Climate Action Plan

Inventory estimates based on local agricultural acreage data, UCCE recommended input rates for fertilizer and fuel, and default emission factors from the Intergovernmental Panel on Climate Change (IPCC).

Source Category	1990 Emissions		2008 Emissions		Change since 1990
	Total	Annual	Total	Annual	
	kt CO_2e	%	kt CO_2e	%	%
Direct N_2O from soil	126	37.0	97	31.8	- 23.1
Indirect N_2O	36	10.7	27	8.7	- 26.8
Mobile farm equipment (CO_2, N_2O, CH_4)	72	21.0	70	23.0	- 2.2
Irrigation pumping (CO_2, N_2O, CH_4)	40	11.7	41	13.5	3.5
Livestock[1] (CH_4)	26	7.8	32	10.5	20.0
Rice cultivation (CH_4)	26	7.7	31	10.2	20.2
Residue burning[2] (N_2O, CH_4)	7	2.0	2	0.8	- 63.4
Lime (CO_2)	4	1.3	2	0.8	- 46.7
Urea (CO_2)	4	1.2	35	1.1	- 16.7
Total	342	--	306	--	- 10.4

[1]N_2O excreted by livestock assumed to be manure or urine applied to soil; only included as direct and indirect N_2O

[2]CO_2 from residue burning (105 kt in 1990 and 43 kt in 2008) considered a biogenic emission and was not included. indirect N_2O

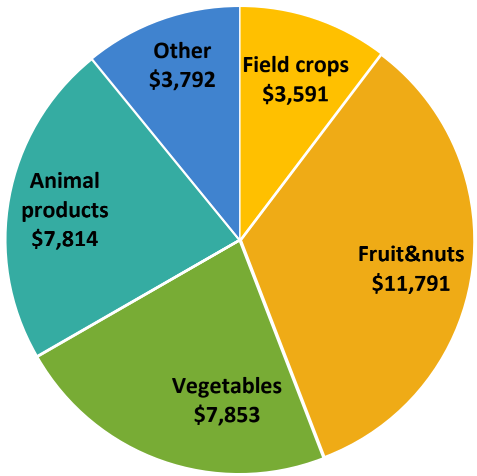
Farm management to reduce GHG emissions and tradeoffs

- **Irrigation:** Drip irrigation reduces soil GHG emissions and water use, increases yields, but demands new costs, fuel, labor and plastic disposal, without groundwater recharge.
- **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 needs a mechanism.
- **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.

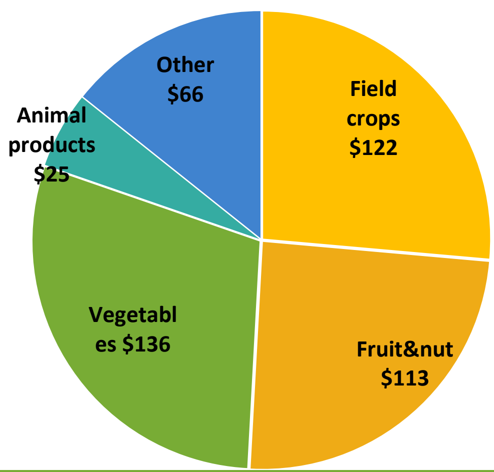
Jackson et al. 2011. *Climatic Change*

Farm revenue ($ million) in 2009 and long-term changes in acreage

California

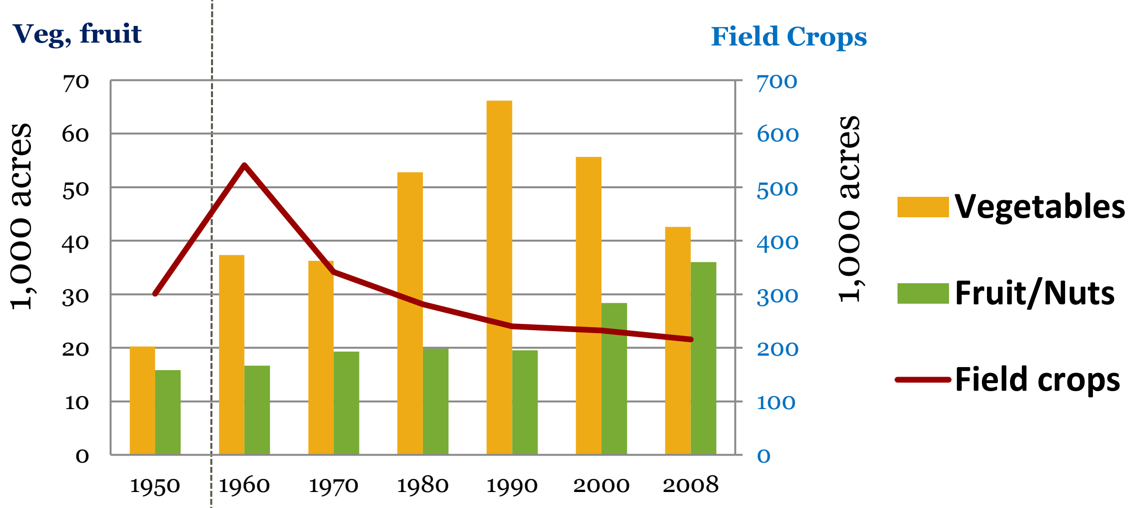


Yolo County



- Yolo County has less animal products and more field crops than statewide
- Considerable changes in commodities in the last 50 years
- Large recent increase in fruit/nuts

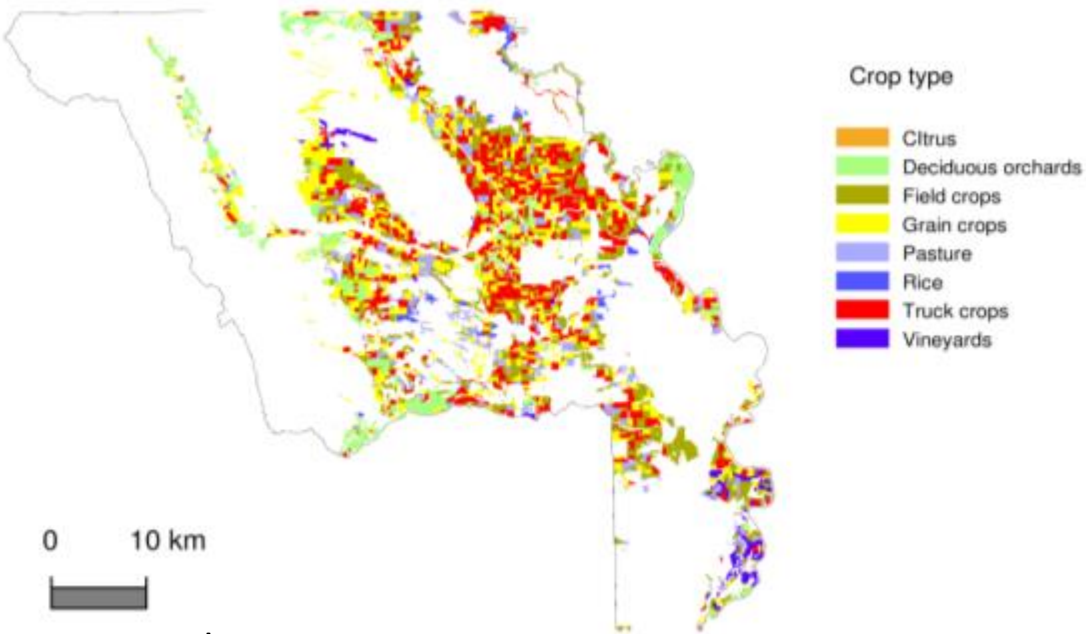
Historic Crop Acreage (1,000 acres) by Crop Category in Yolo County

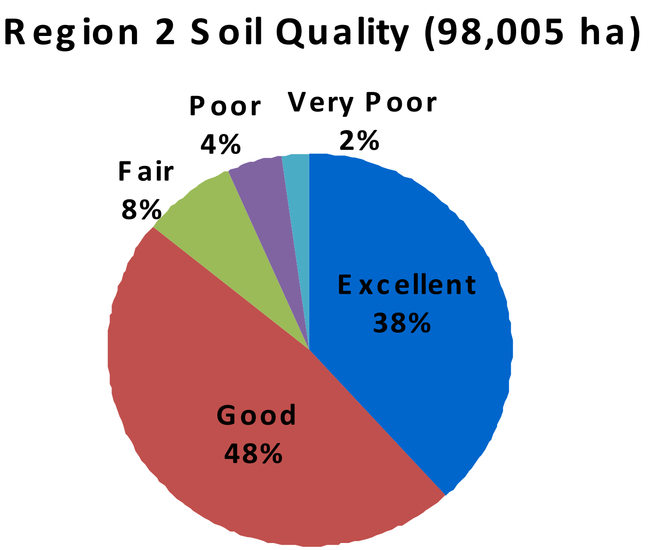


Lee & Sumner, in Jackson et al. 2012. *CEC-500-2012-031.*

Diversification: adaptation + mitigation?

Irrigated ag production on recent alluvial soils in Yolo County





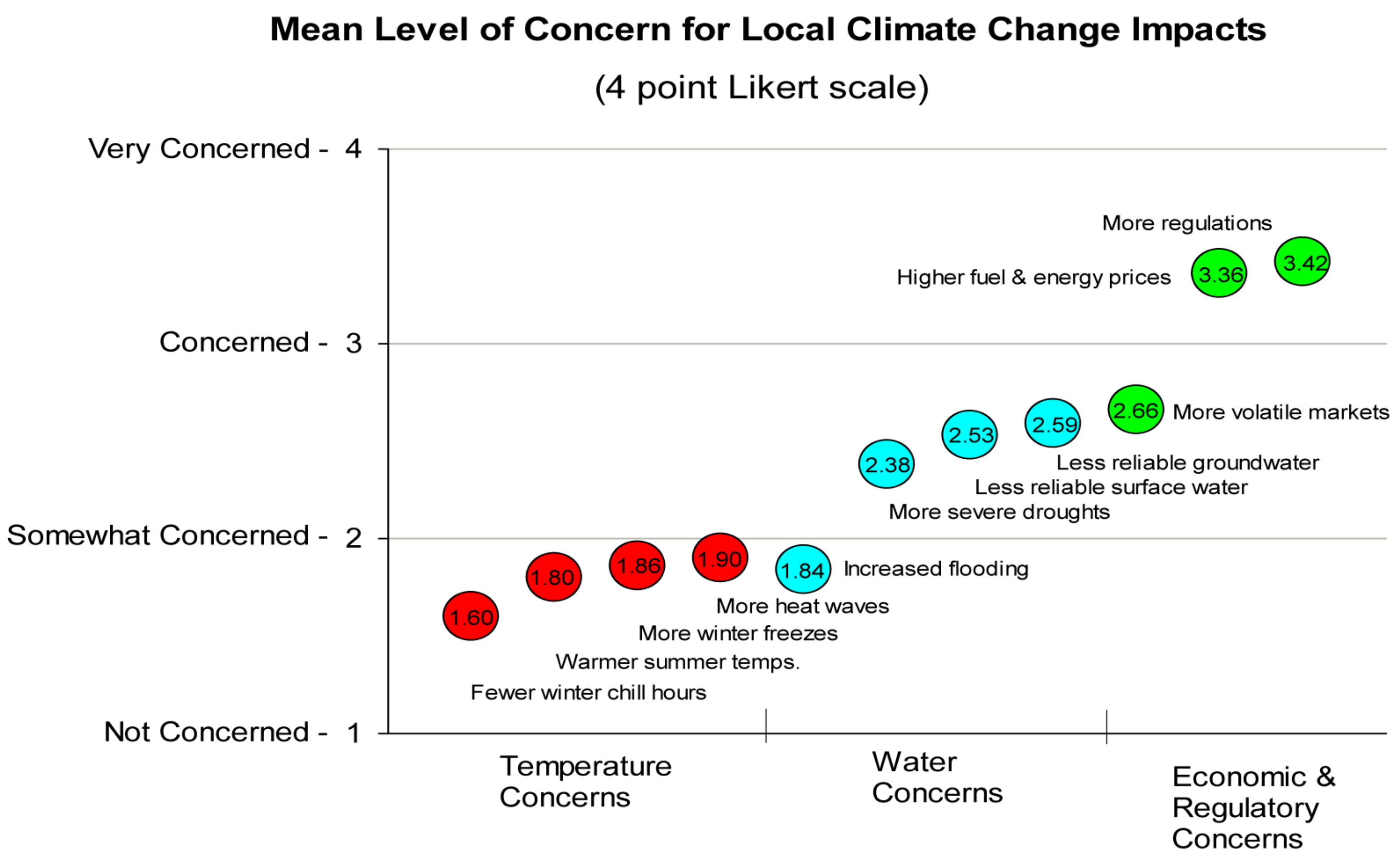
Low crop diversity:

- 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: Decrease vulnerability? Try low-input management?

Jackson et al. 2009.*Potential for Adaptation to Climate Change in an Agricultural Landscape in CA*. *CEC-500-2009-044-F*

Survey of Yolo Co. farmers: Are they concerned about climate change, extreme events and how to adapt?



Jackson et al. 2012. *Adaptation Strategies for Agricultural Sustainability in Yolo Co., California*. *CEC-500-2012-031.*

GHG mitigation through farmland preservation

Land-Use Category	Yolo Co. Land Area		Average Emissions Rate	
	1990	2008	1990	2008
	----- acres -----		--- MT CO_2e $acre^{-1}$ yr^{-1} ---	
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 GHG emissions than rangeland or cropland per acre; 86% of county's GHG emissions on 4.6% of the land
- Need better methods for agricultural GHG emissions inventory
  - Now use UC cost & return studies for 1990 and 2008 and IPCC equations
- Preserving agricultural land from development is essential if the county is to stabilize and reduce its GHG emissions

Yolo Co. Climate Action Plan 2011; Jackson et al. 2012; Haden et al. 2012. *Environmental Planning and Management*.

AB 823: California Farmland Protection Act

- A proposal to establish clear minimum requirements for mitigating the loss of agricultural land related to a project:
  - Conserve agricultural lands of same acreage as converted farmland
  - Establish that the soil quality is comparable
  - Ensure an adequate water supply for agricultural purposes
  - Aim that both locations are in close proximity
- Additional steps for full mitigation of loss of agricultural land
- Authorship: Assemblymembers Susan Talamantes Eggman (D-Stockton) and Das Williams (D-Santa Barbara)
- Co-sponsors: CalCAN, American Farmland Trust, Community Alliance with Family Farmers
- April 15: bill heard by Assembly Natural Resources Committee
- More information on AB 823: http://calclimateag.org/california-farmland-protection-act-ab-823

Conclusions

- Farmers’ perceptions of climate change and extreme events
  - Low current awareness/concern for agricultural vulnerability to climate change
  - High spatial variability in the impacts of heat waves, drought and flooding
  - Uncertainty in new pests and diseases
- Major concern is a long-term drought
  - Economic growth from agriculture will slow down
  - Adaptation: WUE crops with high cash value + technological improvements
  - Changes in crop commodities could fit changing dietary preferences
- Diversification as a resilience strategy
  - “Insurance” value for the future, but costly now to research and implement
  - New crops and livestock to be added: where? when?
  - On-farm renewable inputs (nutrients, energy) that also add to GHG mitigation
  - Diversification needs new markets, e.g. more local food systems
- Institutional support is needed
  - The "California Agricultural Vision: Strategies for Sustainability" calls for assuring that all sectors of agriculture can adapt to climate change
  - Infrastructure to avoid land use change and loss of food security and ag livelihoods

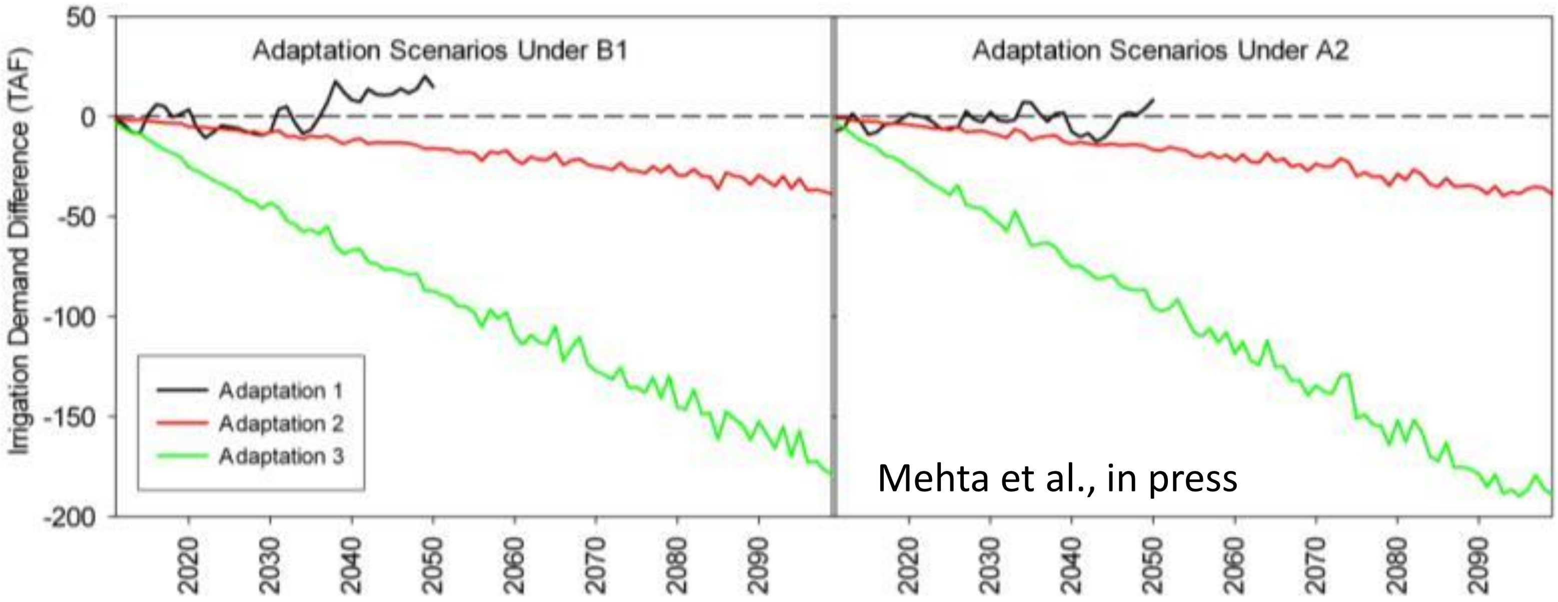
Thank you for listening

- Acknowledgments
  - CEC PIER programs on climate change
  - Kearney Foundation of Soil Science
  - USDA CDFA Specialty Crop Block Grant program
  - Landowners in Yolo and Mendocino Counties
  - State agencies: DWR, CDFA, Dept of Conservation and others
  - Yolo Co. agencies: UC Cooperative Extension, Planning Dept, Ag Commissioner, Farm Bureau, Flood Control District and others……

What is needed?

- Better monitoring systems
- Emphasize renewable resources and inputs
- Plan for future, on-going changes for diversification
- Develop more flexible markets
- Avoid infrastructure breakdown
- Prioritize ag research for climate change
  - Drought preparedness
  - Crop breeding and IPM
  - Technological improvements
  - Diversification strategies
  - Sustainability

WEAP hydrologic model: ag adaptation scenarios in Yolo Co.



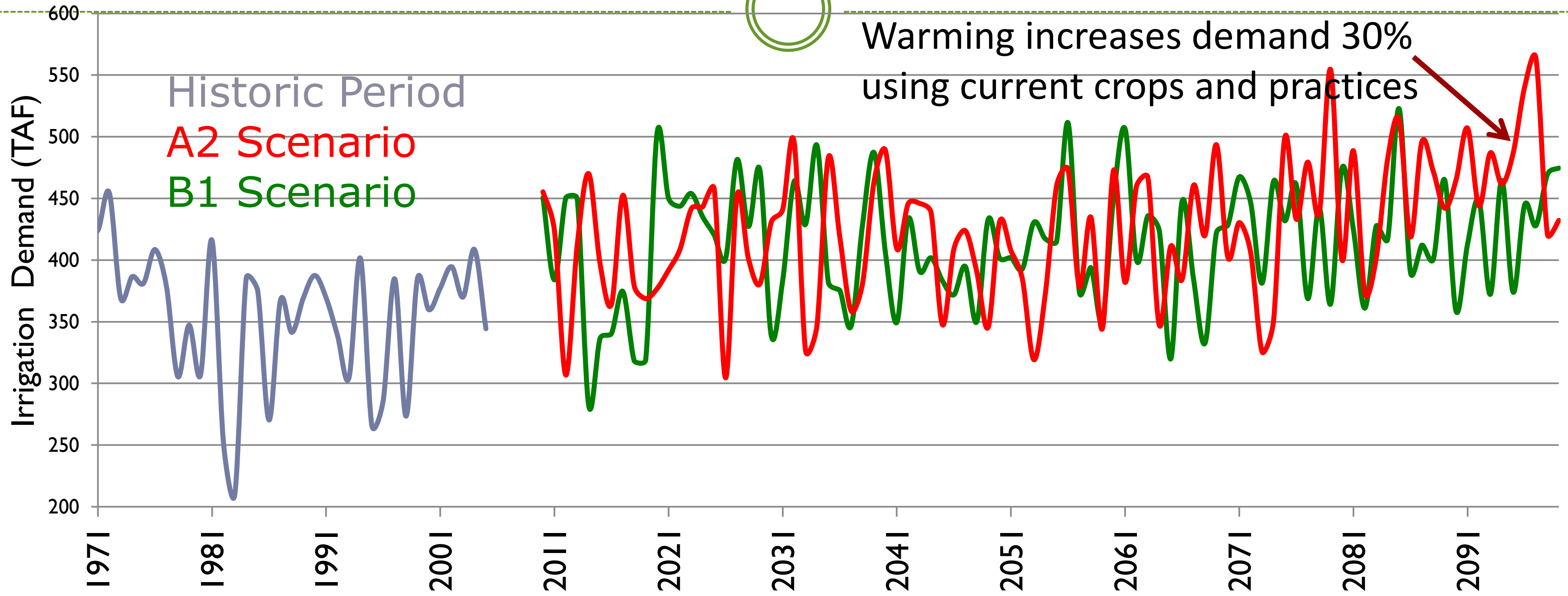
Adaptation Scenarios:

1. Cropping pattern changes projected by econometric models based on current trends (black)
2. Hypothetical cropping pattern changes (diverse water efficient crops) (red)
3. Wide adoption of improved irrigation technology (e.g. drip) plus (green) hypothetical cropping pattern

The diversified / water efficient cropping pattern reduces future irrigation demand to average historic levels (1971-2008).

Mehta et al., *In Press, Agricultural Water Management*

2100 crop irrigation demand (modeled)



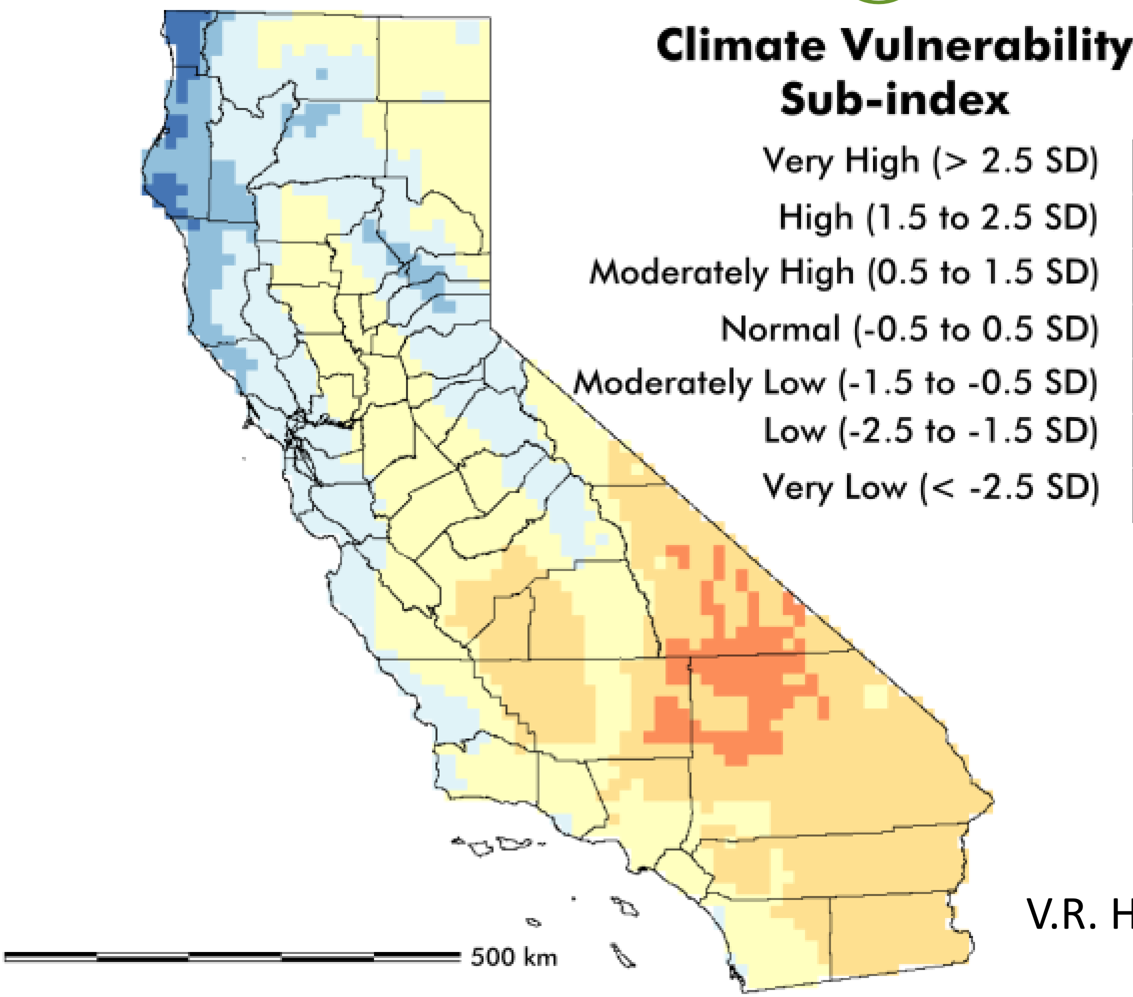
What can be done to keep irrigation demand in the historic range?

Adaptation Scenarios:

1. Cropping pattern changes projected by econometric models
2. Hypothetical cropping pattern changes (diverse water efficient crops)
3. Wide adoption of low irrigation technology plus hypothetical cropping pattern

Mehta et al., *In Press, Agricultural Water Management.*

Agricultural vulnerability index: climate variability sub-index



Climate vulnerability sub-index which integrates agriculturally relevant climate variables derived from GFDL climate model data for California during the recent 30 yr historical period.

See next slide for variables that were used.

V.R. Haden et al., in progress

Jackson et al. *Vulnerability and Adaptation of Agriculture to Climate Change in California. CEC-500-2012-032*