Climate Change and Agriculture in the Delta Region

Stephen M. Wheeler, Associate Professor, UC Davis
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The Science Behind Delta Climate Change Impacts Workshop

Based on research by Drs. Louise Jackson, Van R. Haden, Ben Orlove, Mark Lubell, Johan Six, Dan Sumner, Hyunok Lee Richard Howitt, Tom Tomich, J. B. Kramer, Toby O'Geen, Vishal K. Mehta., David Purkey, Stephen M. Wheeler, and others




Agricultural responses to climate change

- Mitigation
  - Need to reduce ag-related greenhouse gas (GHG) emissions
    - 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
  - Need to adapt to higher GHG, warming, drought and other climate changes
  - Changes in climate have already begun
  - Without adaptation strategies, some ag land may urbanize with loss of many benefits
  - Food security and agricultural livelihoods at risk?

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 can mitigate GHGs and benefit water quality, habitat, and biodiversity, but is hard 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:** Can reduce GHG emissions from N fertilizers 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.

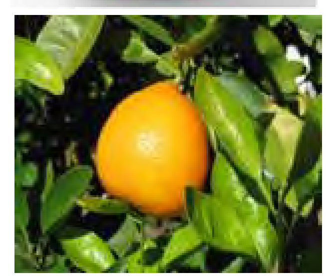
Jackson et al. 2011. *Climatic Change*

Potential Climate Change Impacts on Agriculture

- 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/periods of drought => less water for crops
- 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 and increase?
  - Weeds: new species?
- Cattle and dairy cows
  - Higher winter pasture production if wetter
  - Lower summer milk yield

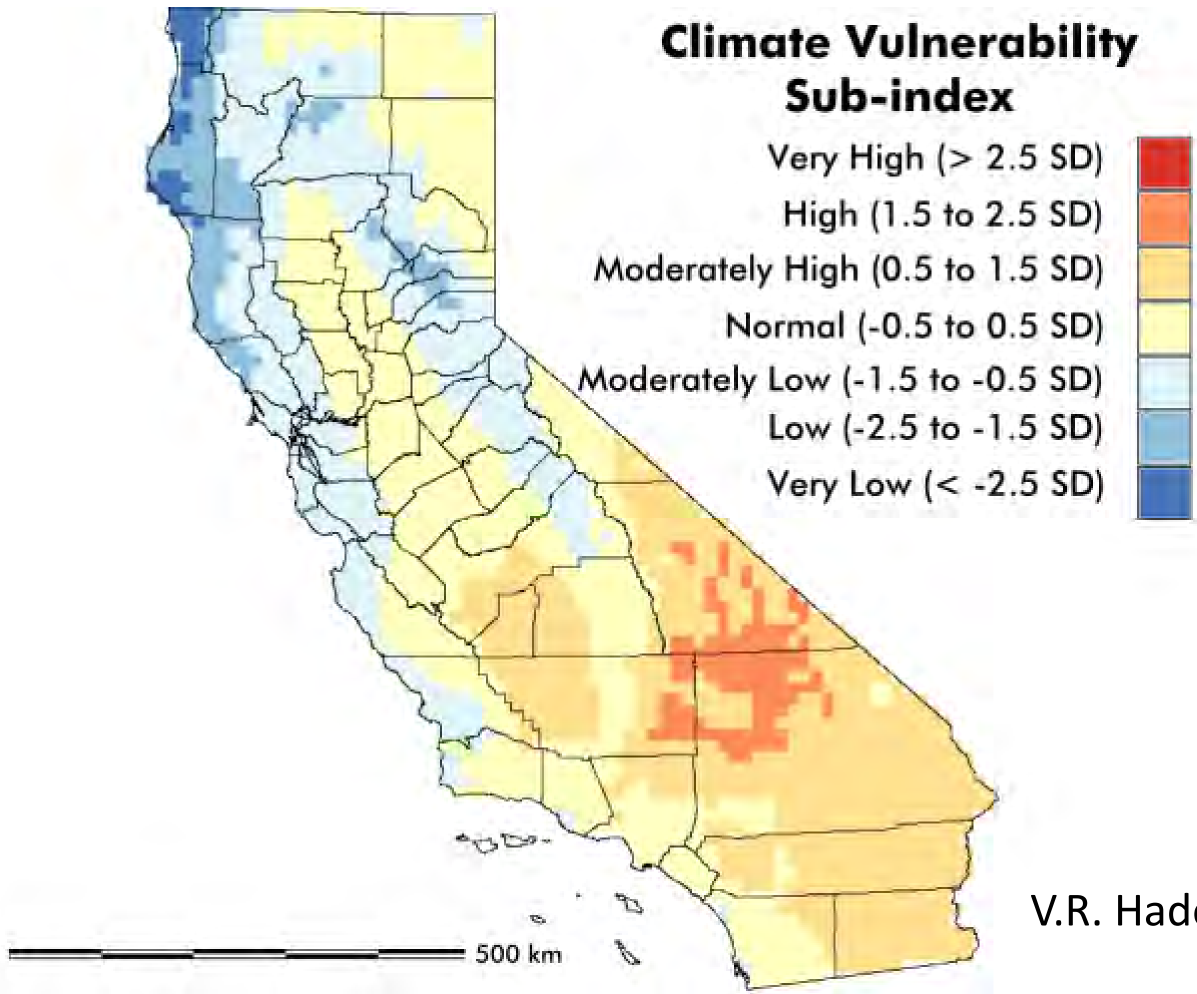







Cavagnaro et al. 2005. *Climate Change: Challenges and Solutions for CA Agricultural Landscapes. CEC-500-2005-189-SF.*

Agricultural vulnerability index: climate variability sub-index



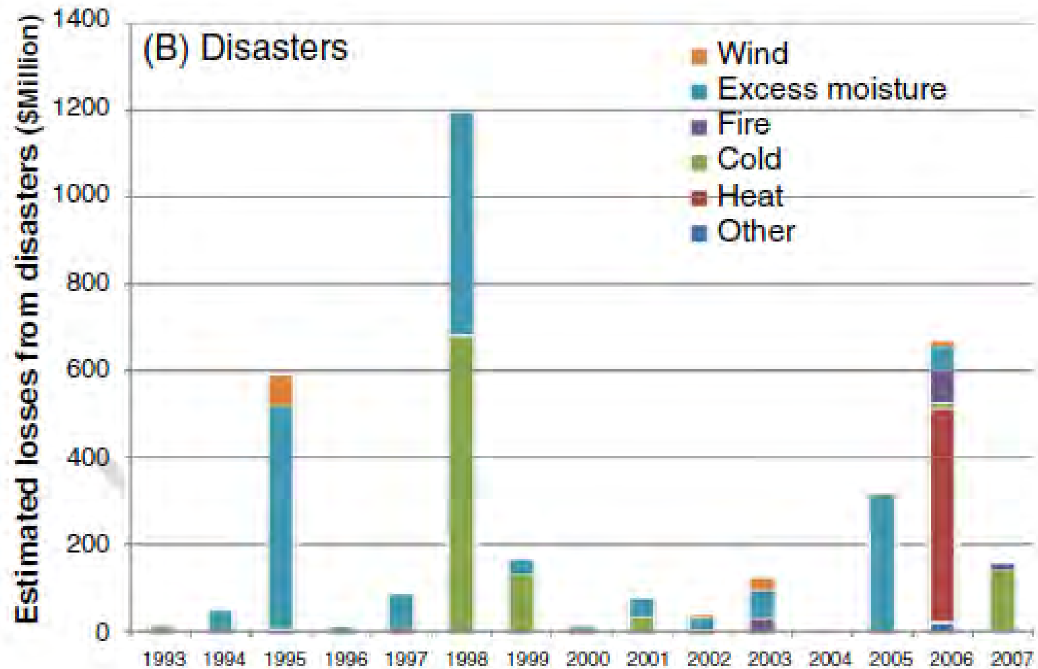
Climate vulnerability sub-index which integrates agriculturally relevant climate variables derived from GFDL climate model data for California during the recent 30 yr historical period.

V.R. Haden et al., in progress

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

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



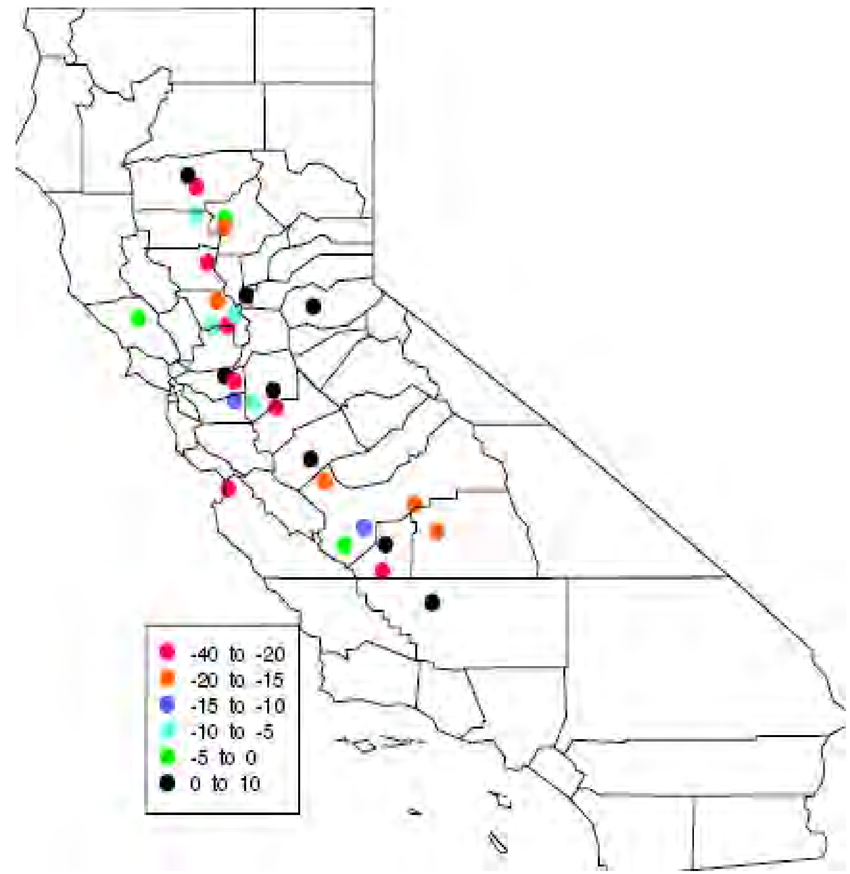
Total amount of estimated total losses from disasters for each year, by type of extreme event

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

Insufficient chill hours for grapes and fruit trees

- Chill hours are hours below 45^{o} 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]

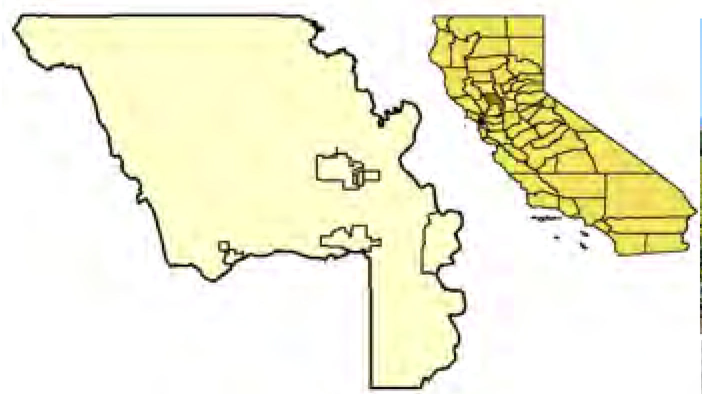


[1-2] Baldocchi D. and S. Wong. 2008. Luedeling, E. et al. 2009. [3] Moser, S. et al. 2009.

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

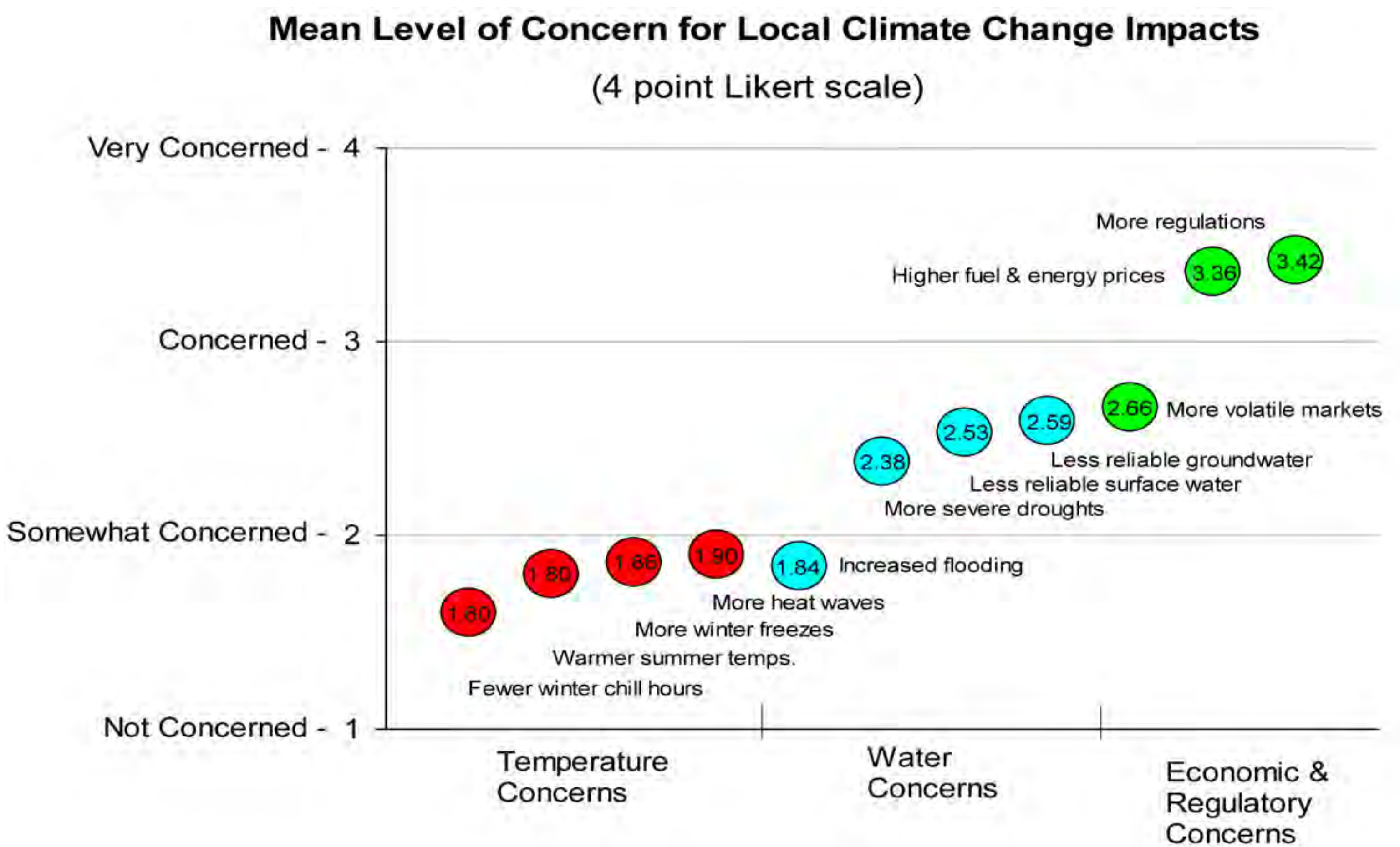
Inventory estimates based on local agricultural acreage data, UCCE recommended input rates for fertilizer and fuel, and default emission factors from the Intergovernmental Panel on Climate Change (IPCC).

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

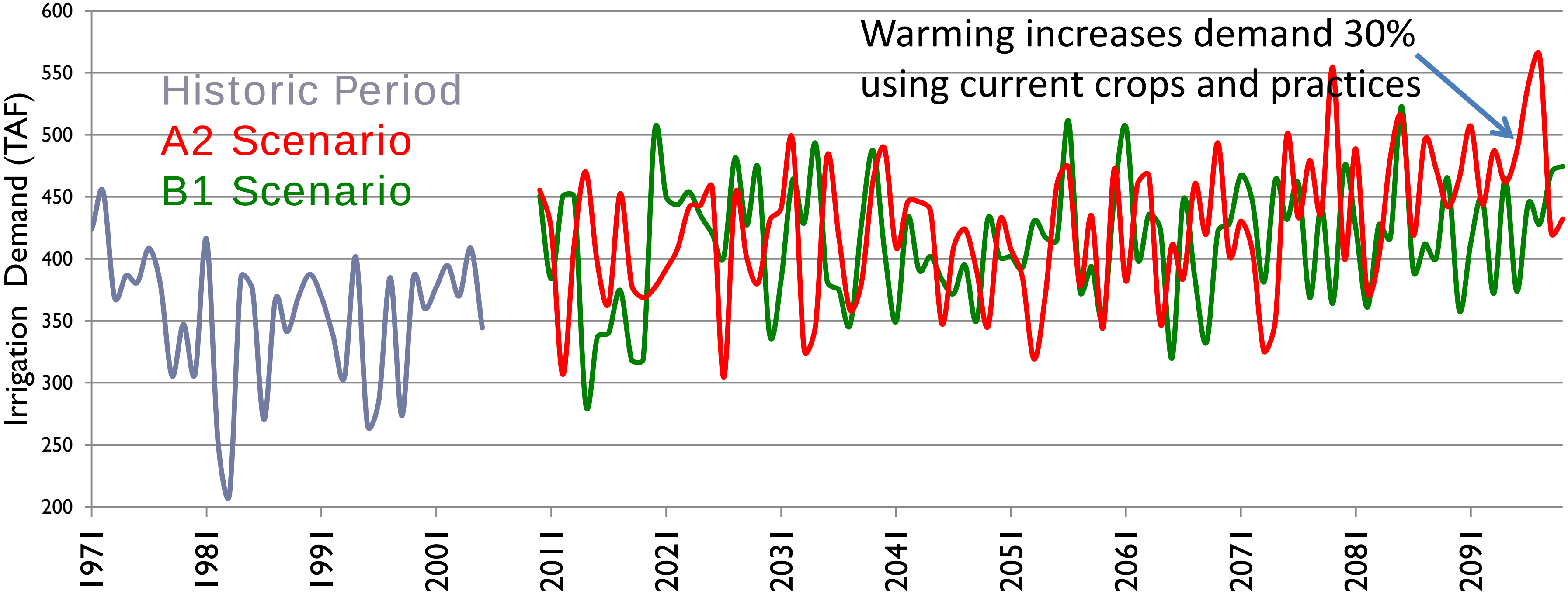
[2]CO_2 from residue burning (105 kt in 1990 and 43 kt in 2008) considered a biogenic emission and was not included. indirect N_2O

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



Jackson et al. *Adaptation Strategies for Agricultural Sustainability in Yolo Co., California*. CEC report, submitted.

2100 crop irrigation demand (modeled)



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

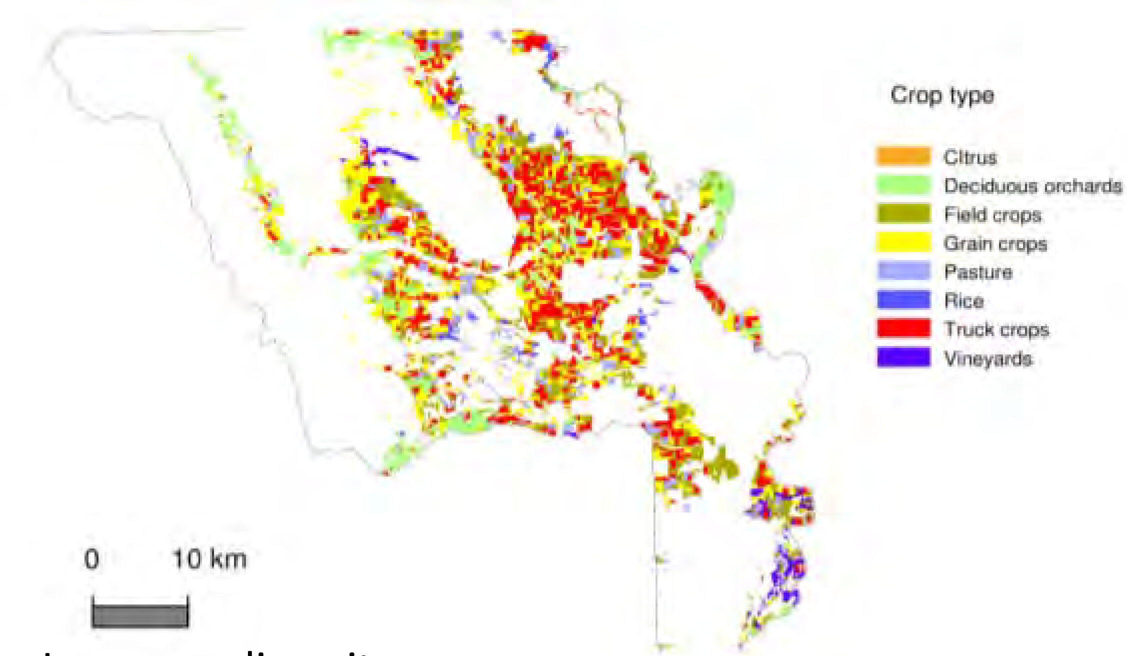
Adaptation Scenarios:

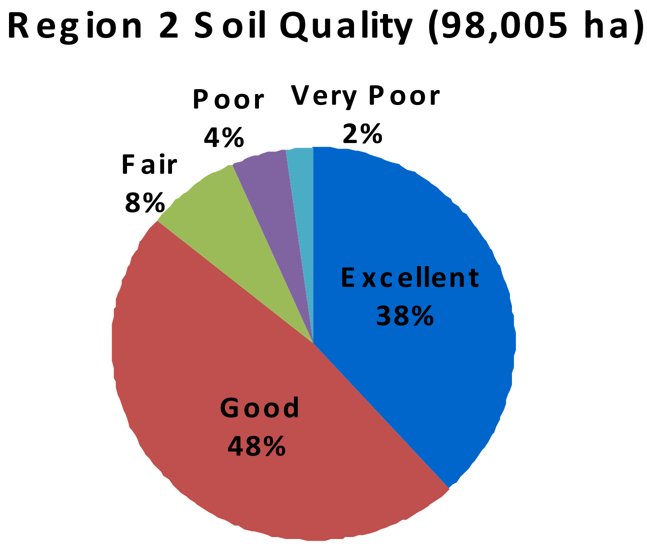
1. Cropping pattern changes projected by econometric models
2. Hypothetical cropping pattern changes (diverse water efficient crops)
3. Wide adoption of low irrigation technology plus hypothetical cropping pattern

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

Agricultural 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*

GHG mitigation through farmland preservation

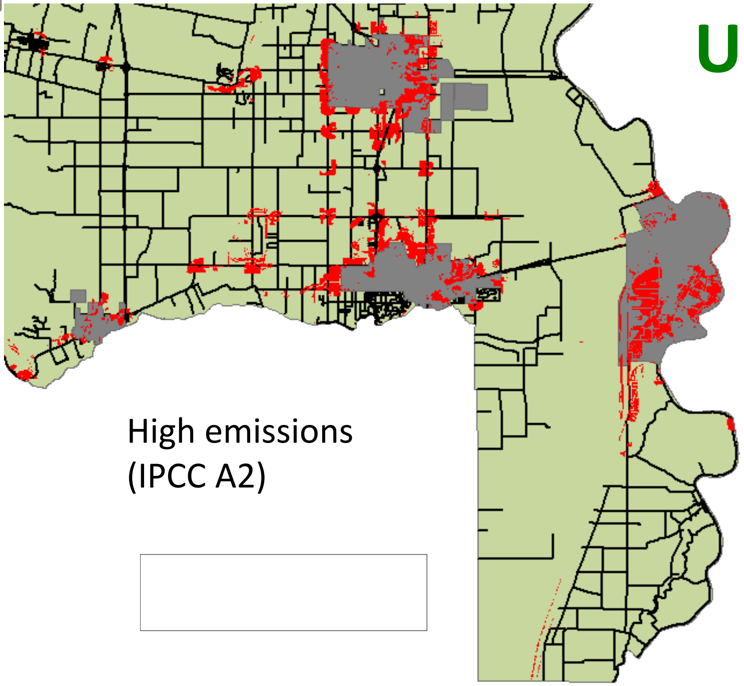
Land-Use Category	Yolo Co. Land Area		Average Emissions Rate	
	1990	2008	1990	2008
	----- acres -----		--- MT CO_2e $acre^{-1}$ yr^{-1} ---	
Rangeland	131,945	135,717	0.28	0.32
Cropland	344,335	324,654	0.87	0.80
Urban	22,471	29,881	61.50	--

*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**

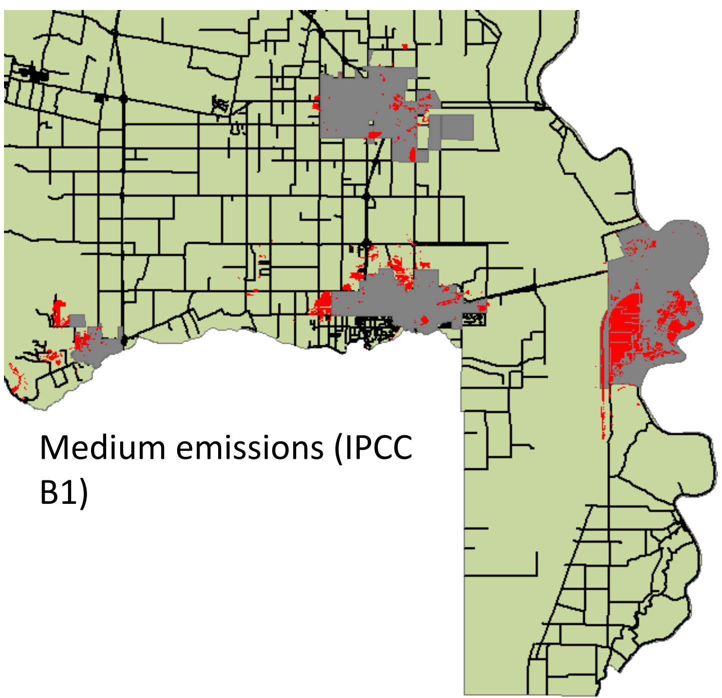
Yolo Co. Climate Action Plan 2011; Jackson et al. 2012; Haden et al. 2012. *Environmental Planning and Management*.

UPLAN urbanization results

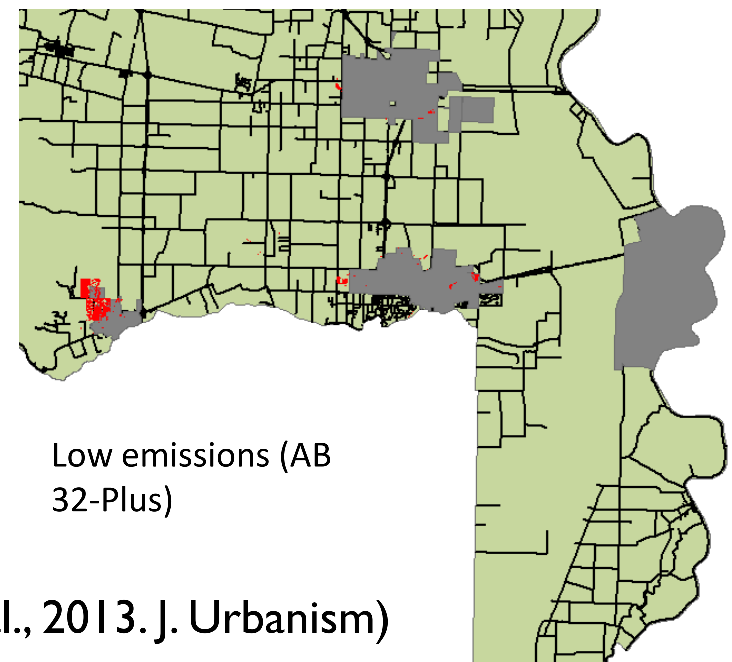


High emissions
(IPCC A2)

Land Use Type	New acres developed in 2050		
	A2	B1	AB 32-Plus
	---------- acres ---------		
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



Medium emissions (IPCC B1)



Low emissions (AB 32-Plus)

(Wheeler et al., 2013. J. Urbanism)

Vision for a new rural-urban framework

- **Rural-urban consensus** on high investment for agricultural adaptation to climate change: research, extension, outreach, and funding for implementation
- **Land use policies** to bolster rural and urban sectors
  - Strong agricultural zoning; for example, requiring minimum parcel sizes
  - Mitigation fee requirements on developers, purchase of development rights, transfer of development rights along with conservation easements, and funding of the Williamson Act
  - Urban growth boundaries, urban service boundaries, to establish sharp edges more securely than through zoning
  - Municipal policies to facilitate infill development near town and neighborhood centers, major employers, and transit-accessible locations
- Linking **farmland preservation** to quality of life for all
- Expanded **county and regional planning** to develop large-scale land use plans identifying, for example, desirable habitat conservation corridors through both urban and agricultural lands
- Strategies to promote **long-term agricultural viability** and improved farm-to-table connections within the region

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- 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
- CalCAN