Meeting Future Urban Water Demand: Some Considerations as to Agriculture's Role and the Larger Issue of Water Scarcity

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<u>Presented at</u>:

Urban Water Demand Roundtable:

Bringing Together the Best in Current Research and Applications

Arizona State University, Tempe, Arizona

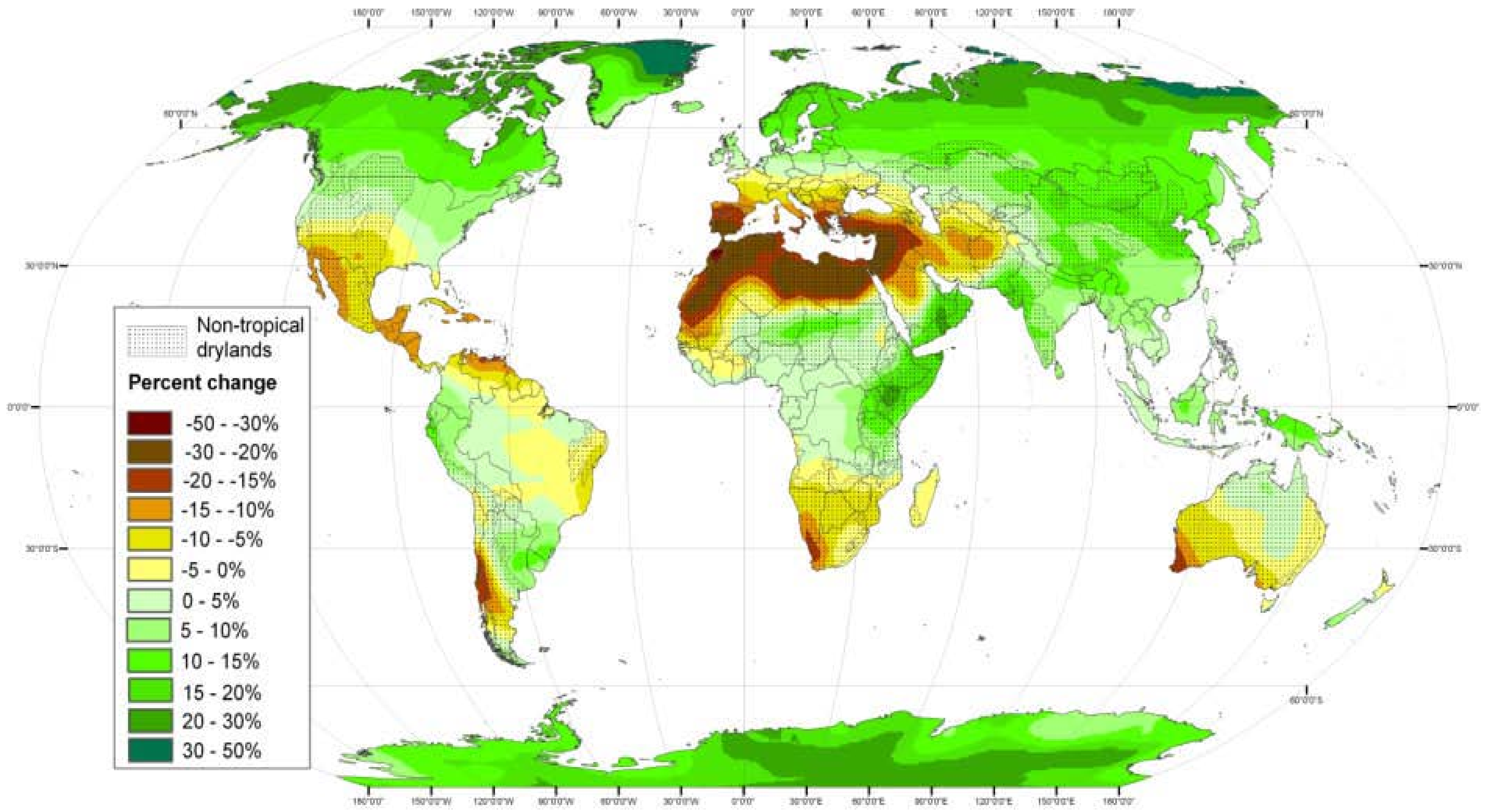
April 18th and 19th, 2013

Objectives

- Identify trends in biophysical characteristics and their potential impact on agricultural production practices
- Highlight possible water management strategies and institutional adjustments that might help address future water scarcity
- Stress the fact that water is a differentiated product with many characteristics (e.g., Mean, reliability, quality, timing)

=> Help better understand the level of competition urban water managers might confront from agriculture and the environment for water and generate some possible ideas for managing that competition

Relative change in mean annual precipitation 1980/1999-2080/2099



Source: GIS Unit ICARDA (based on partial maps from IPCC)

Possible Climate Implications for California and elsewhere

- Increase in annual average temperatures
- Decrease in precipitation in the Central Valley
- Increase in heat wave (drought) frequency and intensity
- Substantial reduction in snow pack in the Sierra Nevada Mountains
  - Shifts more runoff earlier in the season

    => can't capture yet

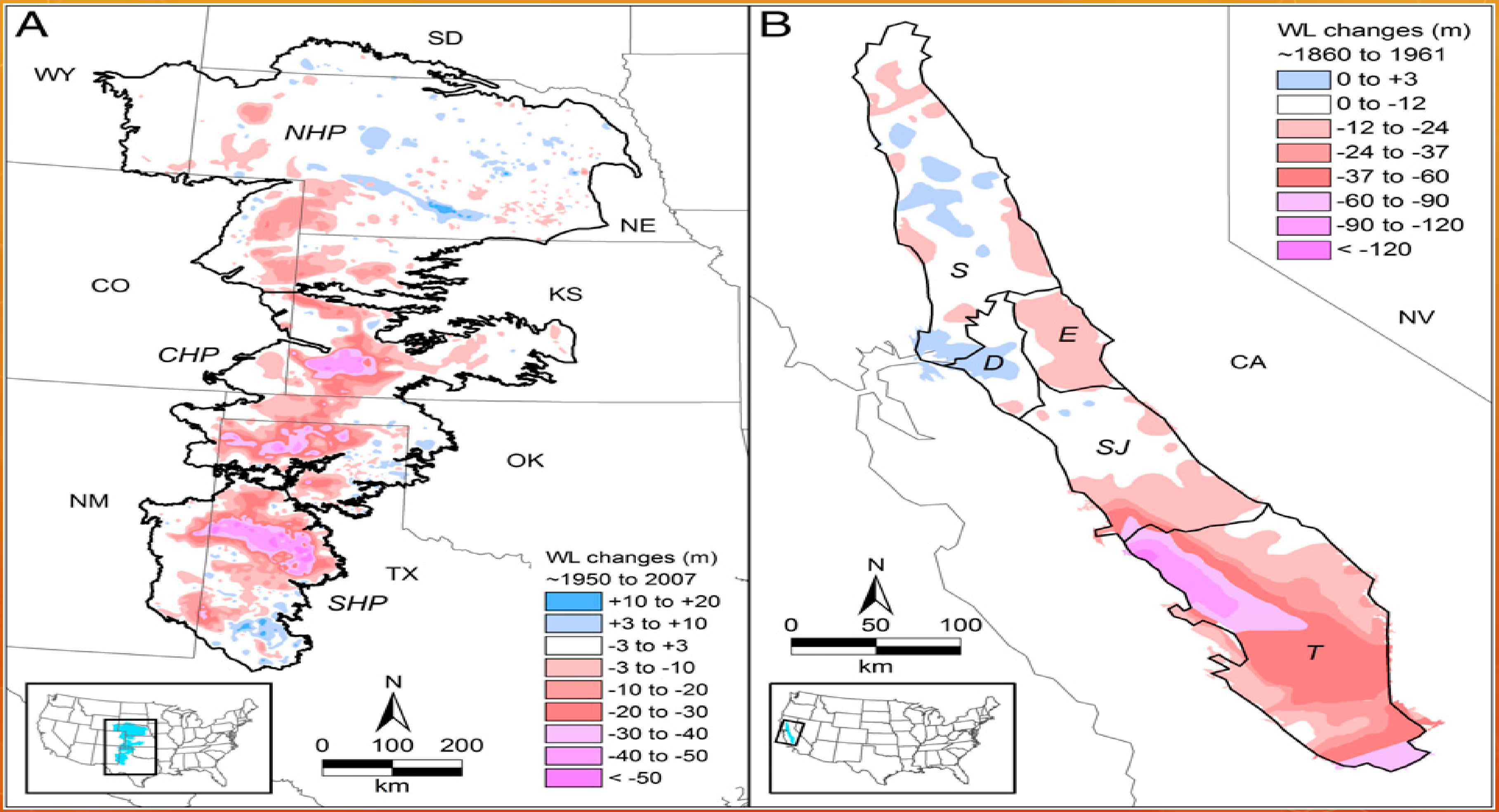
Seagar et al. 2007; Groisman and Knight 2008; Barnett et al., 2008; Vicuna et al. 2007.

Changes already Occurring

- California and Nevada
  - Warm season duration (warm periods w/o sizeable rainfall) increased by approximately 15 days per year from 1980s to present
- Australia
  - 1990s to 2009 considered driest on record

Changes in Groundwater Levels in the High Plains and Central Valley

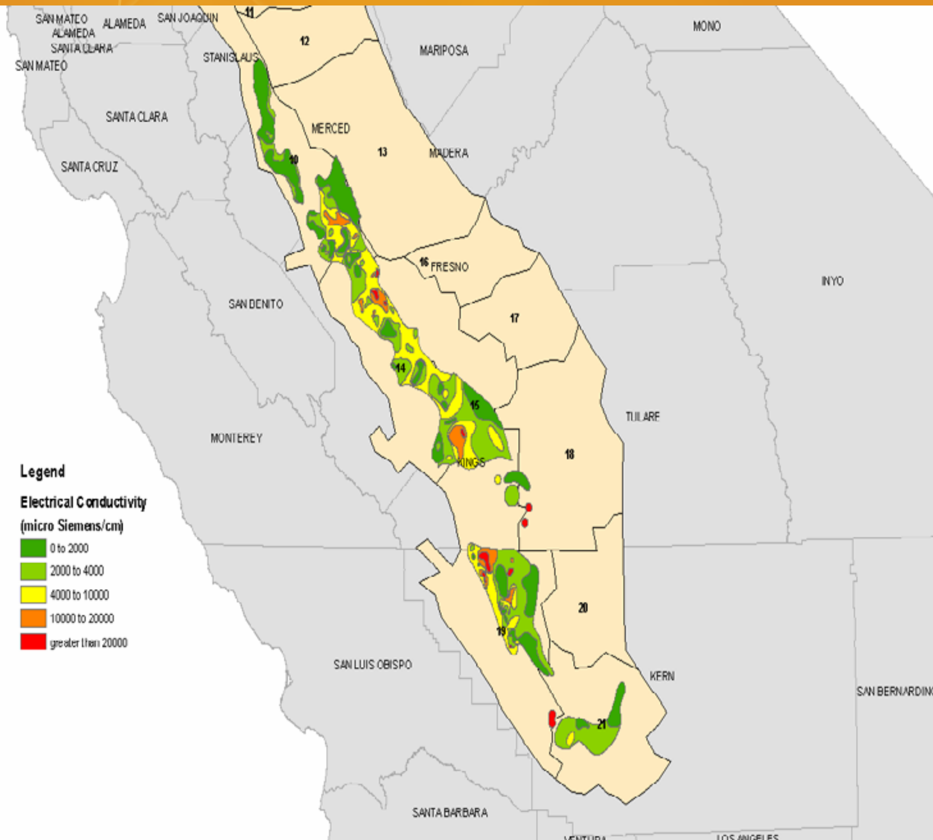
(Scanlon et al., *PNAS*, 2012)



(A) Measured groundwater level changes from predevelopment (~1950) to 2007 in the HP aquifer.

(B) Simulated groundwater level changes from predevelopment (~1860) to 1961 in the confined aquifer across Central Valley

Future Increases in Groundwater Salinity in the Central Valley



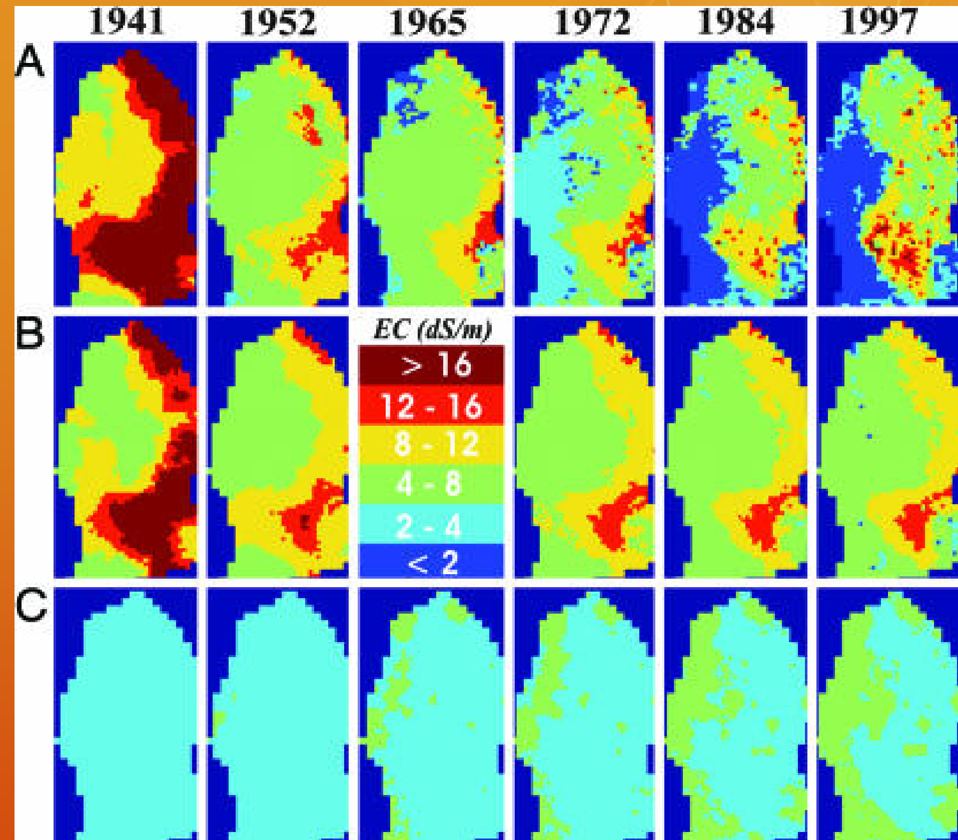


Table 3.34 Conversion of Non-saline Area to Saline Zones as a Result of Salt Accumulation by 2030

Zone	Salinity Level (EC in shallow groundwater (µS/cm))	Share of Non-saline Acres Transferred to the Saline Zone (%)
A	0-2,000	50
B	2,000-4,000	30
C	4,000-10,000	10
D	10,000-20,000	10
E	above 20,000	0

Source: Adapted from Howitt et al, 2008

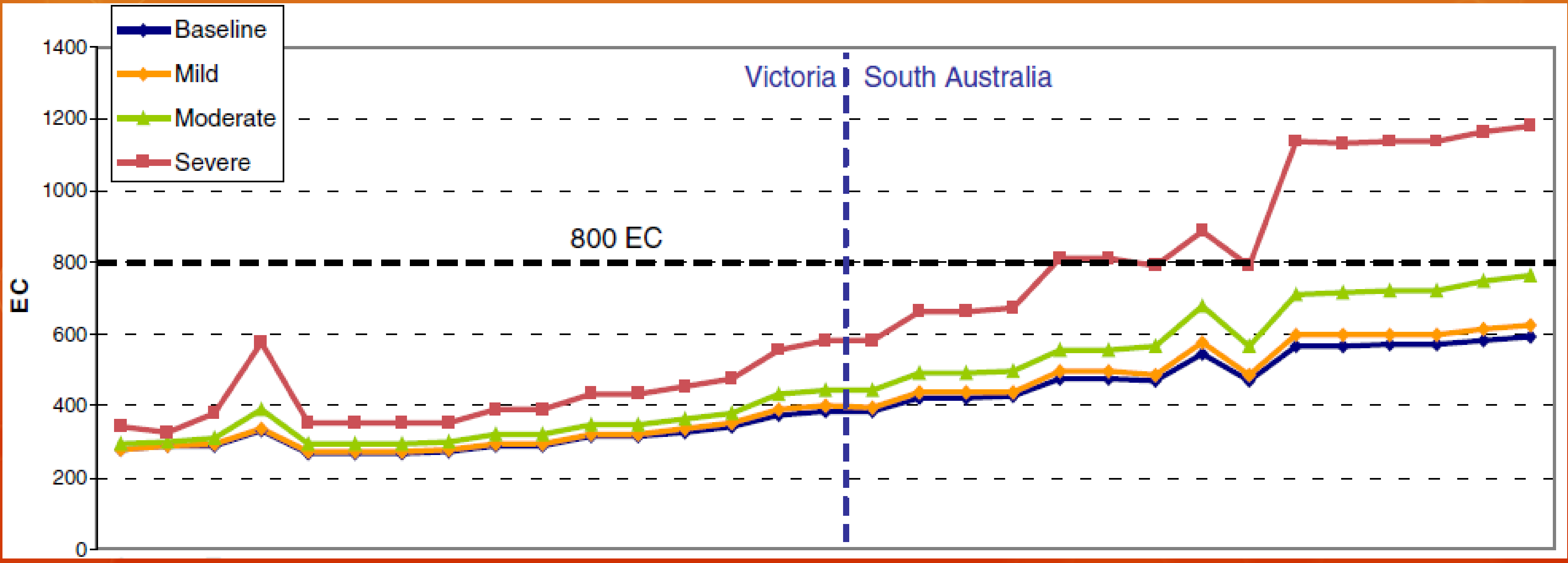
A: 0-2 meters below land surface
B: 6-19 meters below land surface
C: > 20 meters below land surface

Schoups et al. 2006

Predicted Climate Change Impacts in MDB, Australia

	Mild S1	Moderate S2	Severe S3
Temperature Change (°C)	**1**	**2**	**4**
Rainfall Change (%)	**-5**	**-15**	**-25**
Runoff Change (%)	**-13**	**-38**	**-63**

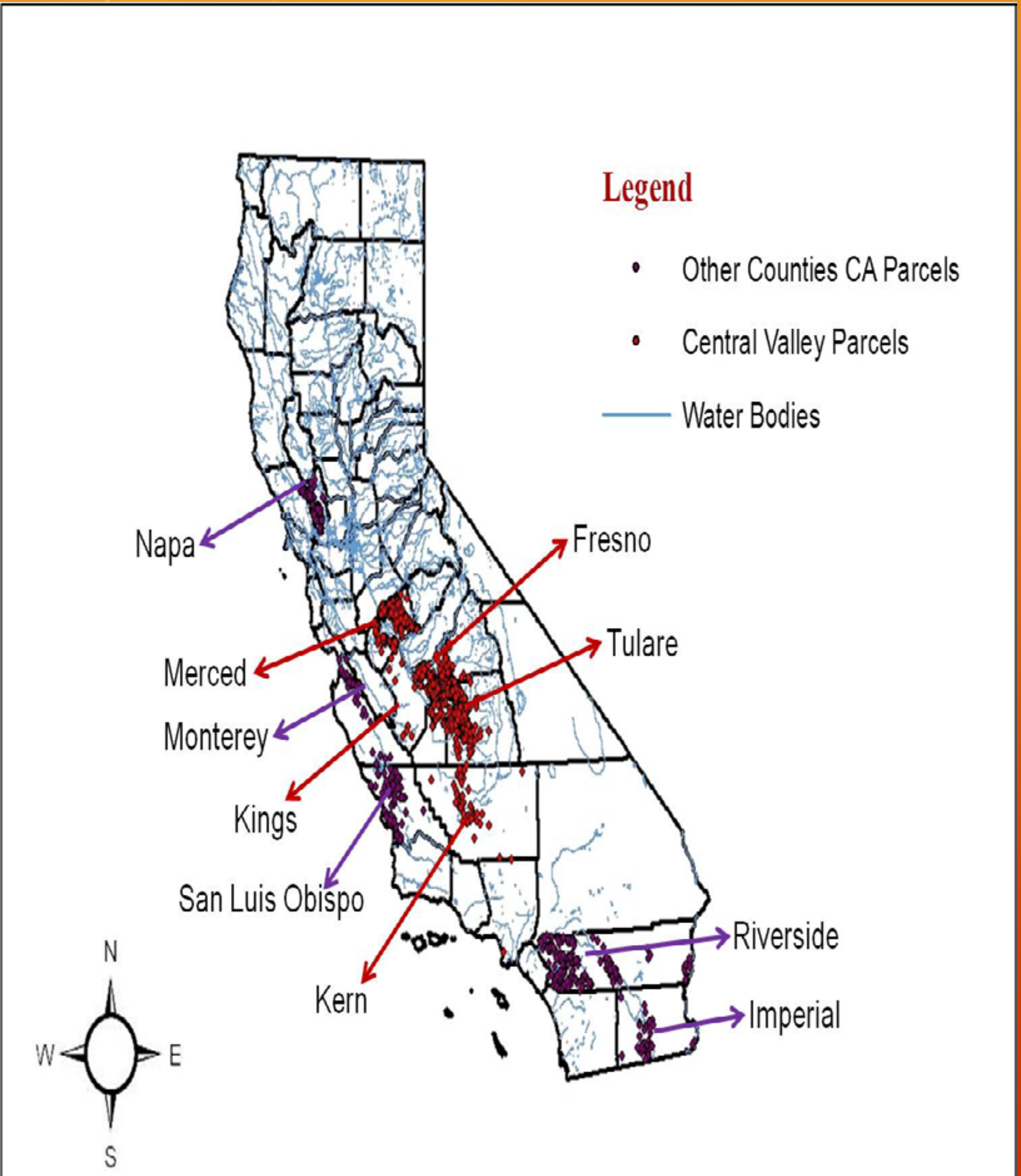
CSIRO and IPCC model projections (Bureau of Meterology 2007; CSIRO 2008)



Implications for Irrigated Agriculture

- Largest “user” of water in West and Australia
  - ~ 60 to 80% of all diversions in many semi-arid and arid regions
- Significant value
  - ~ 40% of global food production
  - > 50% of value of all crops in US
  - > 33% of value of all crops in Australia
  - Yields are often 3x greater than rainfed agriculture
- Heavily Reliant on groundwater
  - 48% of water used for irrigated ag in US is from pumping groundwater
  - Provides safety net in times of drought
- Susceptible to Salinity
  - Each plant has a threshold over which yield declines and may die
  - Requires excess water to leach salts out of rootzone

Estimating Impacts of Water Supply Characteristics on Irrigated Agriculture in California



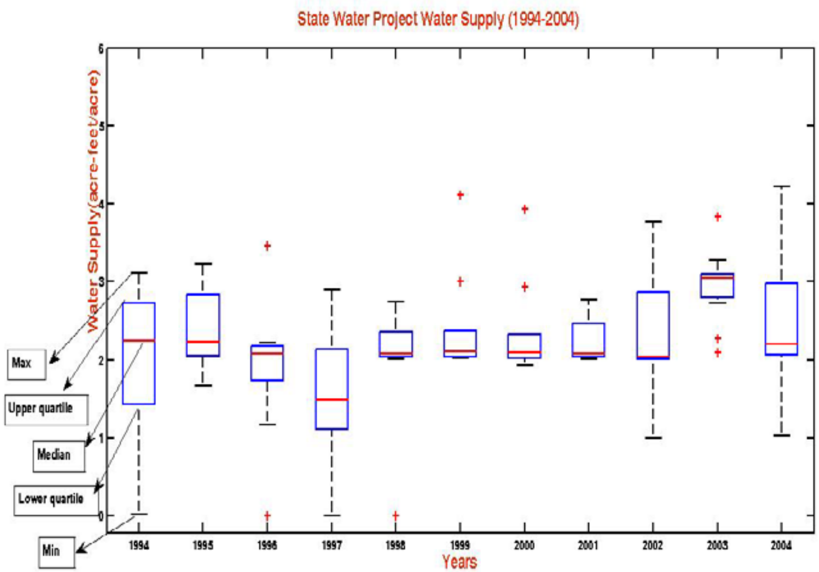
How do agricultural land values respond to changes in:

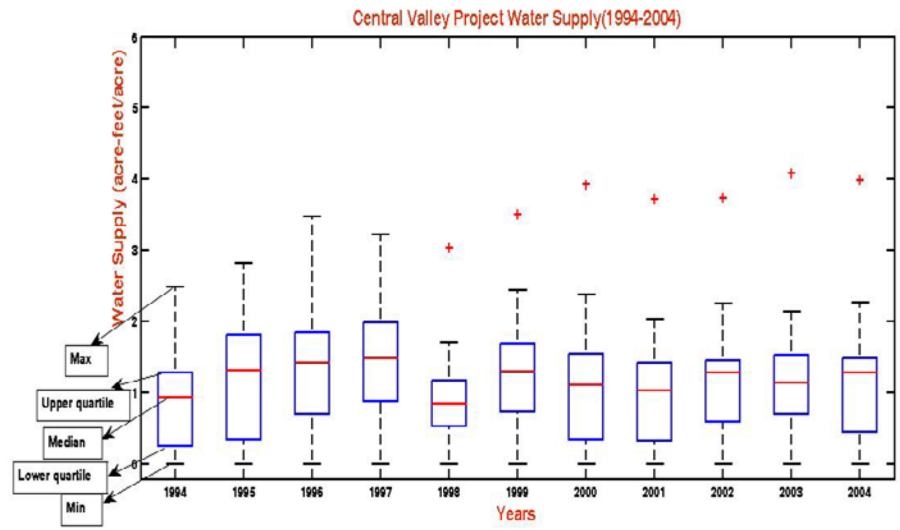
- mean water supplies
- variability of the water supply
- quality of groundwater
- accessibility of groundwater
- Availability of other water supply sources

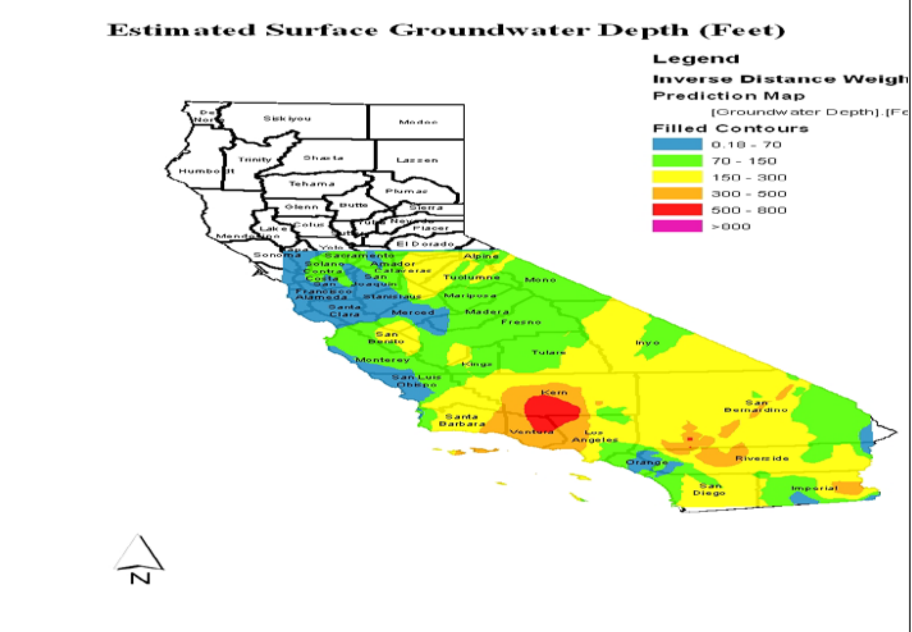
<u>Approach:</u>

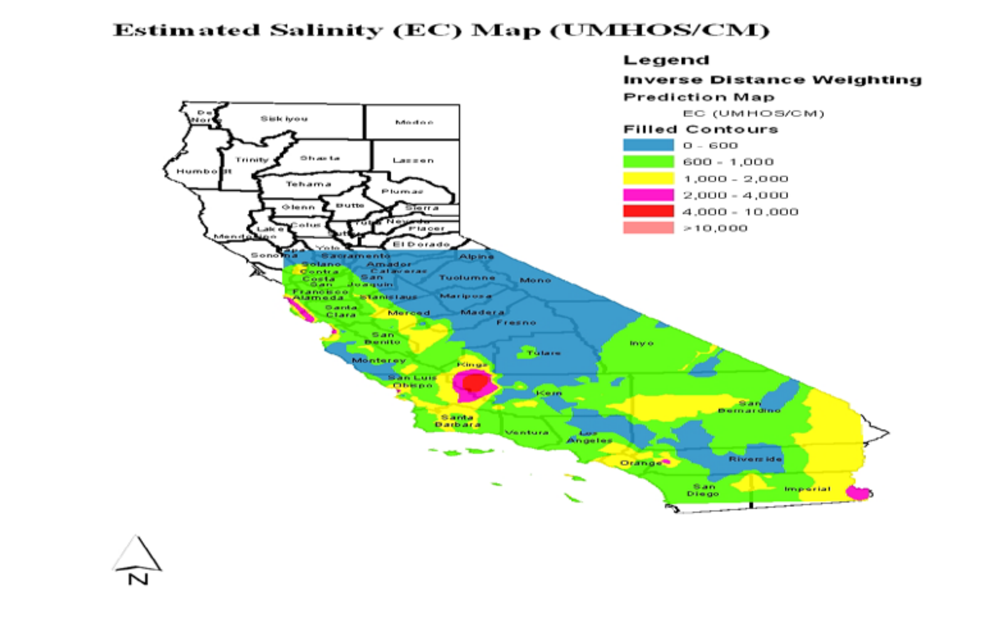
- Hedonic Method
- ~ 2000 farms
- Parcel-level sales prices (2004 to 2010) and characteristics

Water Supply Characteristics in California: Means, Variability, Depth and Quality for SWP, CVP, and Groundwater (Mukherjee 2013)









Agricultural Land Values and Water Supply Characteristics

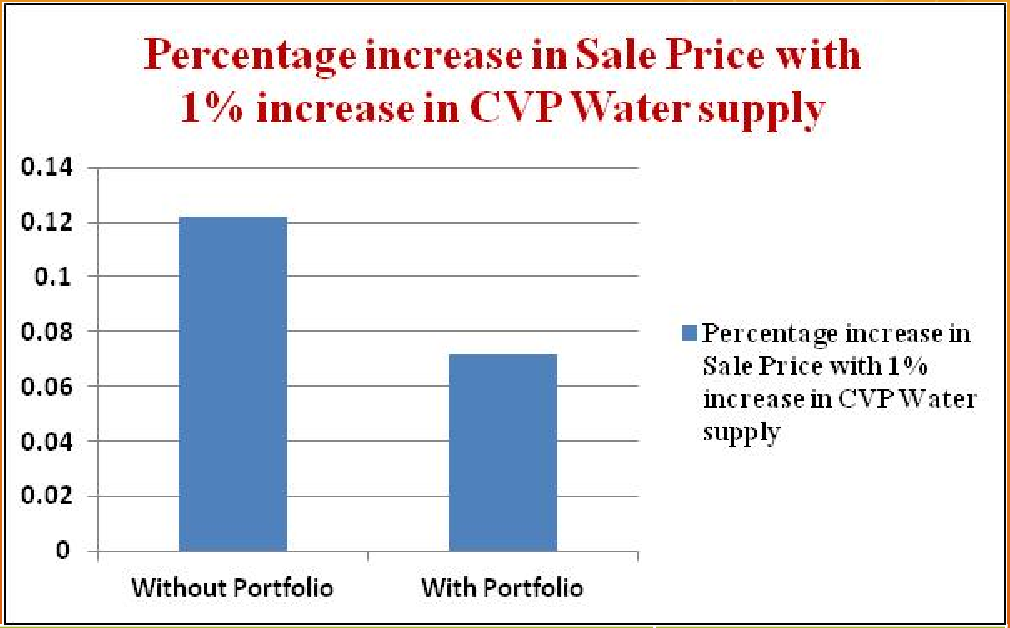
(Mukherjee and Schwabe 2013)

Water Characteristics

- Mean Supplies(CVP)
- Variance of Supplies (CVP)
- Depth to Groundwater
- Salinity (EC) of Groundwater
- Access to more than 1 source (Private water district & CVP)

Conclusion:

All characteristics matter



Variable	Coefficient (Elasticity)	Variable	Coefficient (Elasticity)
Mean CVP	0.293^{***}	LowSalt_*GWDepth	-0.060^{***}
Variance CVP	-0.020^{***}	ModeratelyLowSalt*GWDepth	-0.037^{**}
Private District	0.200^{***}	ModeratelyHighSalt*GWDepth	0.044^{*}
Land Quality	0.084^{***}	HighSalt*GWDepth	0.052^{***}

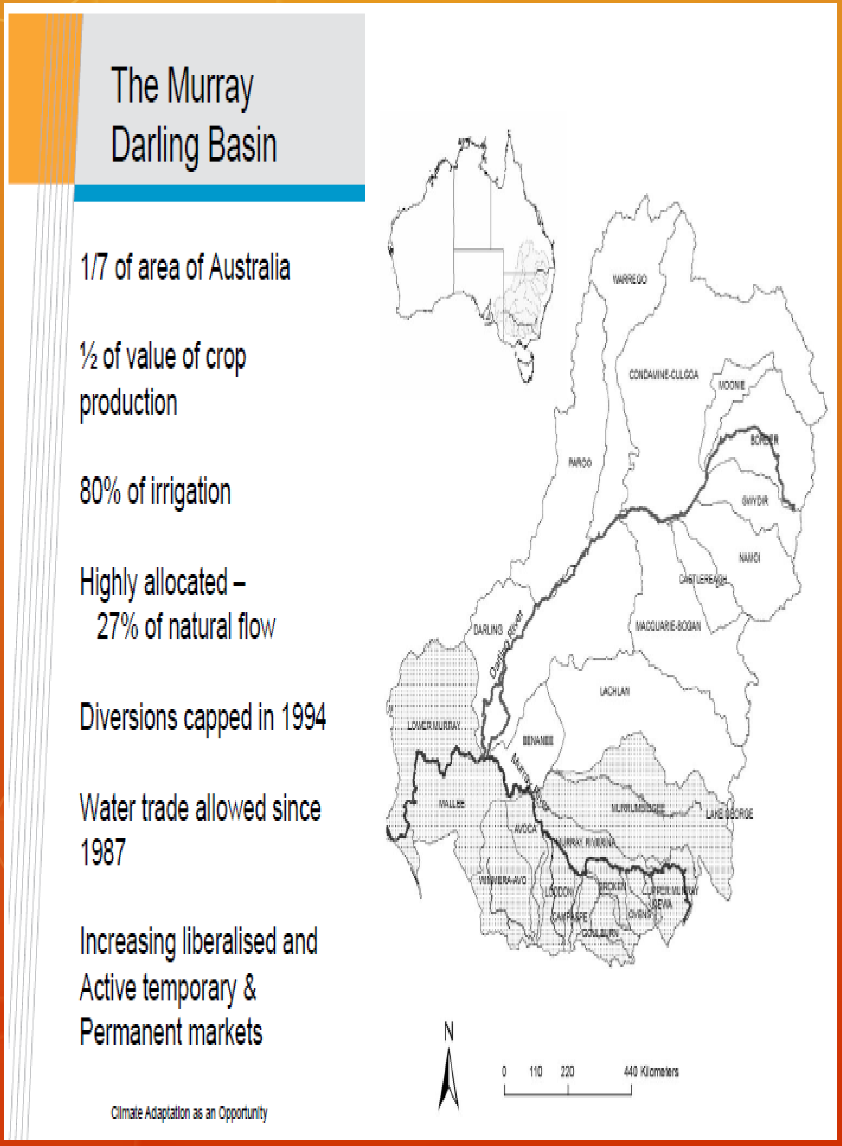
*,**,*** Statistically significant at 1,5, 10% levels

Overall Findings

- Changes in climate and water supplies impact agriculture via multiple pathways
  - Temperature effects (may be positive and negative)
  - Water quantity effects
  - Water reliability effects
  - Water quality effects
- Water supply portfolios are shown to….
  - reduces impact of salinity (degrading aquifers)
  - help growers adapt to lower and less reliable water supplies
  - reduce impacts of high summer temperatures

Mukherjee and Schwabe (2013a; 2013b)2012); Schwabe et al. (2006)

Analysis of Changes in Water Supply Characteristics on Agricultural Sustainability in Australia



- Decompose the impacts of climate change into a…
  - Mean effect
  - Variability effect
  - Quality (salinity) effect
- and illustrate impacts on irrigated agricultural
  - Profitability
  - Water use
  - Acreage allocations

(w/ Connor, Qureshi, Kirby, etc. 2007-13)

Decomposition of Climate Impacts on Lower Part of Murray Darling Basin, Australia

Model scenario	Climate scenario	Cropped area (hectares)	Water use (ML/hectare)	Profits (millions)
Baseline—(Model A)		6535	110.64	$49.28
Water scarcity—(Model B)	Mild climate change	−16%	−4%	−30%
	Moderate climate change	−28%	−5%	−48%
	Severe climate change	−46%	−7%	−69%
Water scarcity and variability—(Model C)	Mild climate change	−30%	−7%	−43%
	Moderate climate change	−48%	−8%	−64%
	Severe climate change	−59%	−10%	−76%
Water scarcity, variability and salinity (Model D)	Mild climate change	−31%	−5%	−44%
	Moderate climate change	−53%	0%	−70%
	Severe climate change	−68%	17%	−87%

[a] The percentages are measured from the baseline.

Overall Findings from Australia Research…

- Growers engage in both mitigation (short-run) and adaptation (long-run)
  - Reduce irrigated area (fallow year to year)
  - Reduce water applications (deficit irrigation)
  - Increase irrigation efficiency
  - Change crop mix
    - Move to perennials as water shortages occur
    - Move away from perennial as shortages become excessive
- Variability is important for perennial crop management
- Salinity can have significant effects to downstream users (and may lead to increases in water use per hectare if salinity becomes high enough)
- Water Markets are extremely important at reducing the impacts from reduced, more variable, and lower quality water

Water Management Options and Institutional Adjustments to Address Increases in Water Scarcity and More Frequent and Intense Drought Events

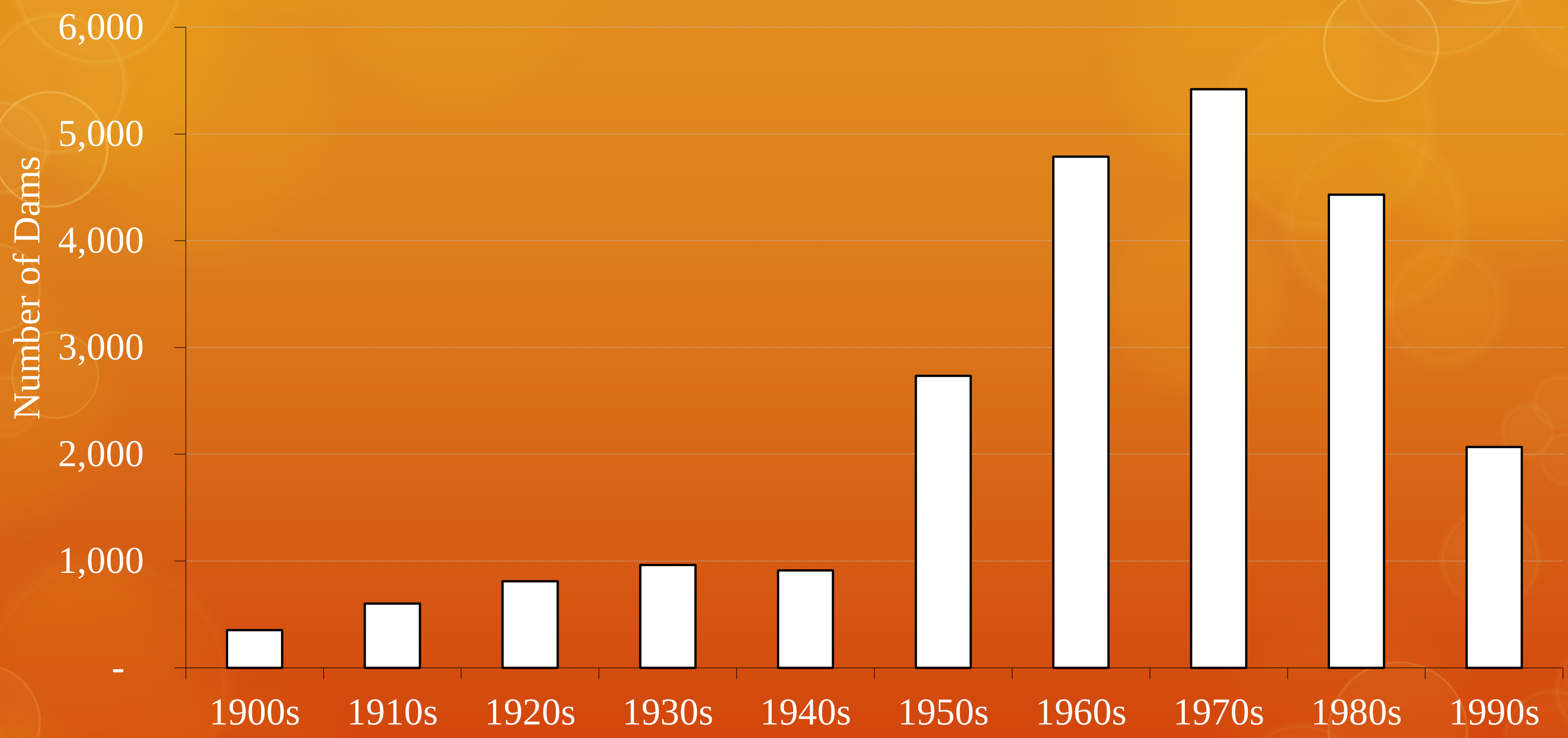
- Modifying Impact of Changes in Climate on Available Supply
  - Enhance or augment supplies
- Demand-side adjustments
  - Reduce use or economic reliance on water
- Institutional Adjustments

Enhance Supply via Increased Storage

Allows for opportunities to allocate water more efficiently across time and space

- Dams/Surface Storage
  - Australia’s MDB storage = 3 years worth of average withdrawals
  - Lakes Mead & Powell can store 4x mean annual flow of Colorado (Lord et al. 1995)
  - ***Future limited given limited availability of low-cost and well-suited sites***
- Snowpack
  - Sierra Nevada’ snowpack provides storage = 50% of all man-made storage
  - ***Climate change will cause change in seasonal distribution of runoff which California is not ready to capture***
- Aquifers/Water Banks
  - Conjunctive mgmt offers 4 to 30 times capacity of surface systems (Hanak et al. 2011)
  - 1990s California Emergency Drought Bank reduced drought damages by $104 million (Easter et al. 1998)

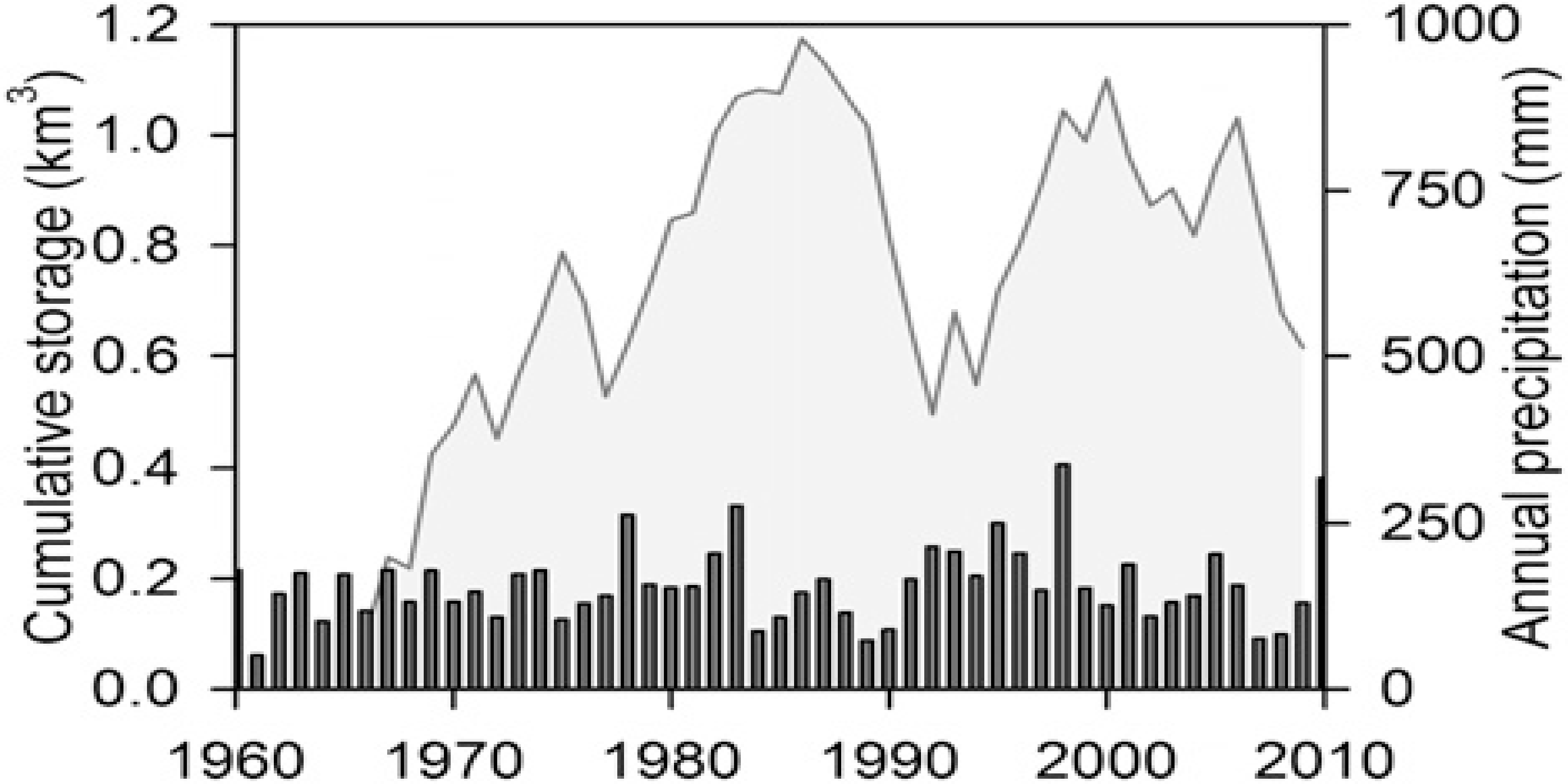
Surface Storage is Limited



Commissioning of Large Dams Globally from 1900 to 2000

(adapted from Table 15, World’s Water 2002-2003 Data, Gleick 2011)

Alternative Storage Options:
Aquifers via artificial recharge from surface water



Cumulative water storage in the Arvin Edison groundwater bank relative to precipitation. *Note: drought events*

Wastewater Recycling and Stormwater Capture

- Benefits include…
  - Access to locally reliable source
  - Less reliant on imports
  - Greater diversity in water portfolio (less risk)
  - Increase aquifer volume and quality
- Previously used to generate gray water in many cities
- Transitioning to use as drinking water via FAT/RO
  - Injected into aquifer or recharge basins
  - Orange County has largest system in world
    - .273 MAF into recharge basins => provides drinking water for 600,000 people

Ocean Desalinization

- Benefits include…
  - Access to locally reliable source for coastal communities
  - Less reliant on imports
  - Greater diversity in water portfolio (less risk)
- Ocean Desal Implemented Worldwide
  - > 13,000 industrial-scale plants
  - ~ 700 along Mediterranean coast
  - Large scale plants developed recently in Adelaide, Perth, Sydney, Melbourne and soon in Victoria
  - Some in California w/ 17 proposed facilities
- Costly => Energy intensive and environmental issues

Demand-side Adjustments in Water Use

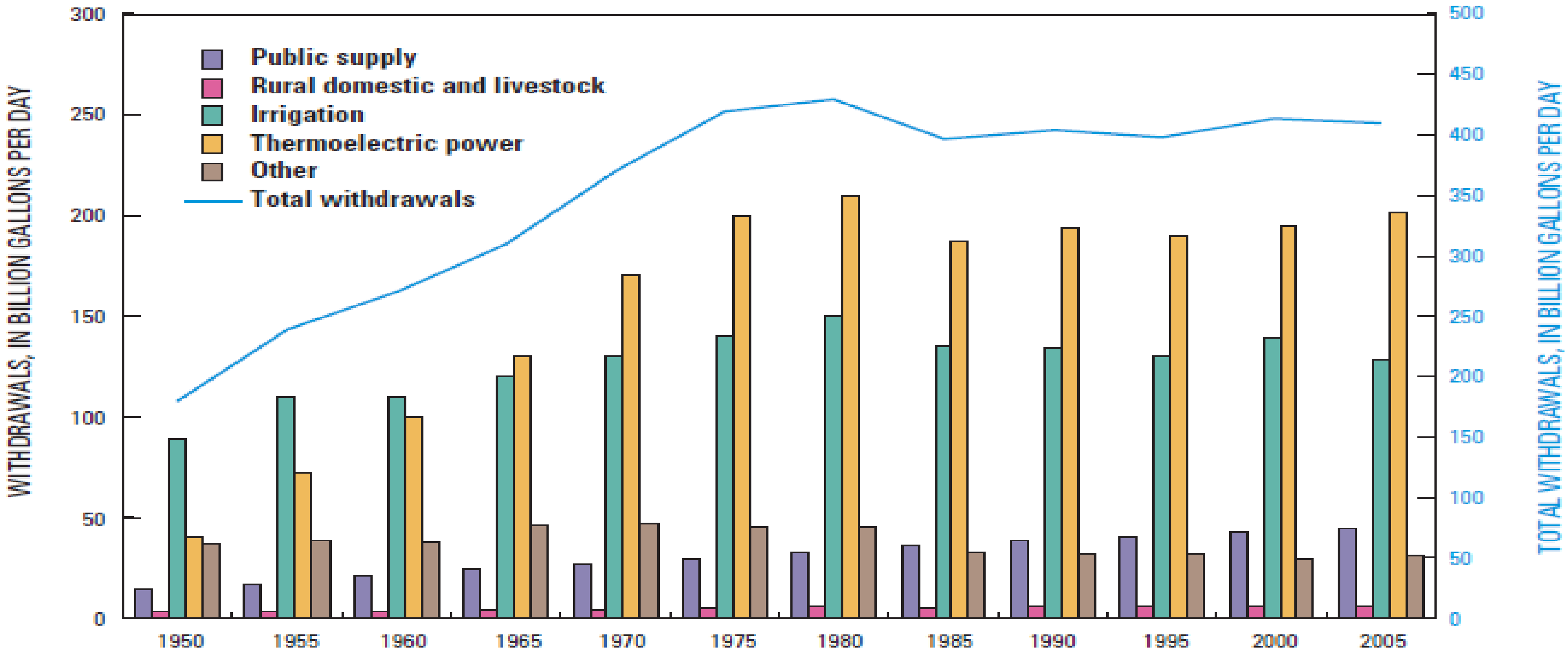
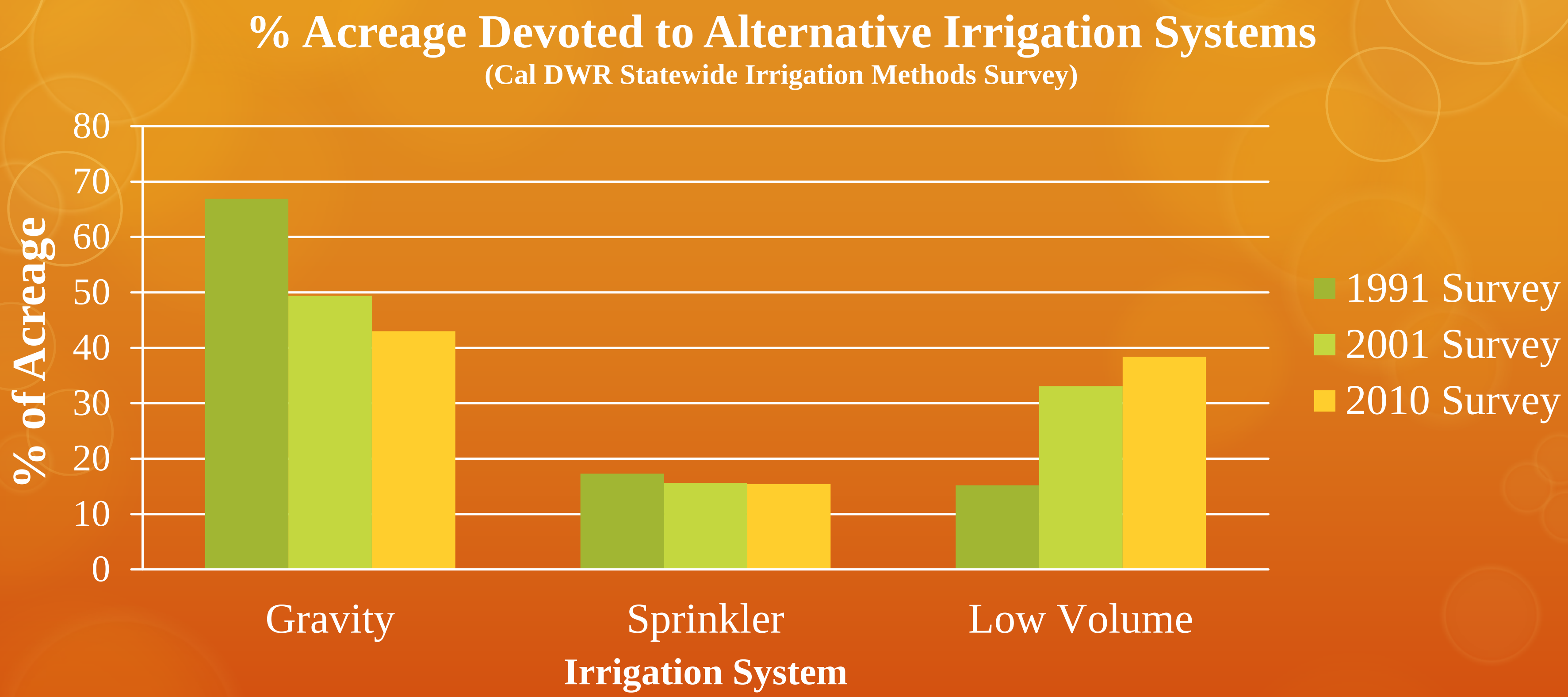


Figure 14. Trends in total water withdrawals by water-use category, 1950–2005.

- Cal. Ag: 75% water use / add < 2% to economy; < 4% labor force
- Adaptation Strategy: Move away from water intensive growth?

(Kenny et al. 2009; Hanak et al. 2011)

Agricultural Adaptation: Increasing Irrigation Efficiency



Observations/Notes:

- Still opportunities for efficiency improvements
- Must recognize need to flush many soils of salts (reduces potential efficiencies)
- Increases in field efficiency => lower return flows

Ag. Tend in West: Movement to Higher Valued Perennials

Table 1

Life span and trends in area and yield for six major California perennial crops

	Wine grapes	Almonds	Table grapes	Oranges	Walnuts	Avocados
Productive life[a] (years)	25	22–25	25	40	35	30
First harvest (age in years)	3	3	2–3	2–4	4	3
Full production (age in years)	5–6	6	4	12–13	8	7
Area change 1980–2003 (%)	116	69	68	22	26	−12
Yield change 1980–2003 (%)	9	57	25	9	24	−44
Average yields 2000–2003 (ton acre^{-1})	6.9	0.9	8.3	13.0	1.5	2.7

All crops are irrigated.

[a] Life span and production information from http://coststudies.ucdavis.edu/.

(Lobell et al. 2006)

Concerns: Require more reliable supplies

Require more water /ha/yr

Often less salt tolerant…

Water Markets and Water Banks

- Allows opportunity to allocate over time, space, and to higher valued users
- Australia ~ very well developed temporary and permanent water markets
  - 2007 to 2010…
    - 1/3rd of all water in Murray-Darling Basin was traded
    - Decreased economic impacts of drought by 50%
- California (Howitt et al.2011, 2013)
  - 500,000 ac-ft traded in San Joaquin Valley alone in 2009

Water Markets & Water Banks: Concerns & Opportunities

- Third-party effects on environment and other legal users
  - 1994 California Drought Water Bank and domestic well
- Assigning property rights?
- More conveyance allows more flexibility for interbasin transfers
- Need to monitor and meter groundwater usage
- More spot markets and risk-based transfer agreement
- Defining rights across different qualities and reliabilities
- Developing more water portfolios
- Streamlining trading approval process based on zone-based trading ratios and pre-approved trades

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Hanak et al. 2011; Schwabe et al. 2013; Palmer and Characklis 2009;

Increase Cooperation

- Abundant opportunities to allocate water throughout basin/catchment to reduce overall costs to catchment/basin (may be distributional issues)
- Benefits of cooperation less often realized when coordinated actions across devolved interests are required
- How to increase that cooperation? Subject of discussion….
  - Spain is a good example
    - Information Sharing
    - Stakeholder Involvement
    - Agreed upon and known river basin models that measure overall and distributional impacts
    - Up-to-date and transparent drought monitoring information

Hanak et al. 2011; Schwabe et al. 2013

Do we need Cooperation?
Central Valley Irrigation and Colorado River Flow

Central Valley, California…

- 1/6 of US irrigated land
- $21 billion in agricultural value
- Generates water vapor that ends up increasing streamflow in the Colorado River by 28% (56% in four corners region)
  - 325,000 ac-ft annually (supports apprx. 3 million people)
  - Increases precipitation by 15%
- Previous models overlooked anthropogenic loop
- Understanding of the linkages and cooperation across jurisdictional boundaries is important and offers opportunities

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Lo and Famiglietti. 2013. *Geophysical Research Letters.*

(National Taiwan University and UC-Irvine)

Conclusions

- Water is a differentiated product: Quantity, reliability, quality, timing
  - Changes in all of the water supply characteristics present both challenges and opportunities
- Significant short-run and long-run adaptation possible to address future water scarcity
  - *Agriculture*: deficit irrigation, fallowing, irrigation upgrades, changing the mix, timing, and location of agricultural production
  - *Institutional*: Increased storage, more flexible water markets and water banks, increased cooperation
- Requires planning, collaborations, and analyses


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