Water, Delta, and Agriculture in California

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CaliforniaWaterBlog.com
Mostly dry, but many demands
Water use has changed California
Major Inflows to Delta (maf/month) (mean annual flows)

Sacramento River

Diversions
23% 1949-1968
26% 1968-2005

San Joaquin River

Diversions
57% 1949-1968
55% 1968-2005
Native Habitat and Fishes

California’s freshwater fishes are losing their habitats. The chart shows the percentage of wetlands remaining from 1900 to 2002. The data indicates a significant loss, with a majority of the wetlands classified as Special Concern or Listed, and a small percentage listed as Extinct.

- **OK** (22%): 44
- **Special Concern** (69%): 50
- **Listed** (31%): 14
- **Extinct** (7%): 7

The chart highlights the critical need for conservation efforts to protect remaining habitats and the freshwater fishes within them.
1) Human water use peaked?

2) Economy depends less on water abundance

3) Water markets can shift use and civilize change

4) We agree we have a problem

Source: Hanak et al. 2011
California's Water Supply System

- Extensive network of aqueducts, reservoirs, and groundwater

- Sacramento-San Joaquin Delta is the major "hub"
Who depends on the Delta?

- S. California – 30% of water supplies
- Bay Area – 30% of water supplies directly, another 40% upstream
- Southern Central Valley – 4 maf directly and 4 maf upstream
- Delta farmers – 1+ maf
- Sacramento Valley – 4+ maf taken upstream; water sales to south
1. Pre-European Delta

- Formed 6,000 years ago
- Estuary from a drowned river confluence
- 740,000 acres of marshland & waterways
- Largest estuary in the western Pacific Ocean

Delta, 1905
San Francisco Estuary and Delta: 1848 and today

http://sfbay.wr.usgs.gov/access/yearbook.html
Central Valley connection - 1873

- Immense connected wetlands
- Delta entirely wetland
- Pacific Flyway
- San Joaquin valley was very different
2. Agricultural Delta

- 1850s - present
- Early major irrigation
- 540,000 acres diked & drained for farming
- 1,100 miles of levees
- Rapid subsidence
- Greater costs to maintain levees
- Early extinctions
Poldering simplifies the Delta

Delta Island Subsidence

Pre-1880: Freshwater Tidal Marsh
- Main Channel
- Anaerobic Decay: CO₂, CH₄
- Vertical Accretion of Marsh Platform
- Water Table

1900’s: Elevation Loss
- Main Channel
- Microbial Oxidation: CO₂
- Wind Erosion, Burning
- Compostion

2000’s: Increased Levee Maintenance
- Main Channel
- Decreased Levee Stability
- Increased Pumping Costs
- Increased Seepage Rates
- Lateral Deformation
- Sea Level Rise

or Levee Failure

Land Subsidence in the Delta

- Above sea level
- Sea level to -10 feet
- -10 feet to -15 feet
- -15 feet and deeper

Delta Atlas reprinted 1995
3. Water Supply Delta

- 1950s - present
- Major water export projects
- Freshwater flow Regulation
- 540,000 acres of farmland
- Continued subsidence
- Worsening water quality and risks for export users
  - Drinking water treatment
  - Salinity and crop yields
Historical Water Use (annual in maf/yr)

- Delta Outflow
- CVP/SWP Delta exports
- In-Delta diversions
- Upstream

Data courtesy of TNC
Historical Salinity Variability

X2 Distance from Golden Gate Bridge (km)

Percent Exceedence of X2 Location

- 1921-2003 Unimpaired
- 1949-1968 Historical
- 1986-2005 Historical

Locations:
- CQ
- MZ
- CH
- CO
- EM
- RV

A
B
C
### Disrupted Internal Delta Flows

**Upstream flows** to **Natural downstream flows** (cfs)

<table>
<thead>
<tr>
<th>Curve</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green (A)</td>
<td>1925-2000 Unimpaired</td>
</tr>
<tr>
<td>Blue (B)</td>
<td>1949-1968 Historical</td>
</tr>
<tr>
<td>Red (C)</td>
<td>1986-2005 Historical</td>
</tr>
</tbody>
</table>
Desirable and Undesirable Species On A Salinity Gradient With Seasonal and Annual Fluctuations

High seasonal and interannual fluctuations

Salt

Fresh

Overbite clam
Siberian prawn
Jellyfish

Delta smelt
Striped bass
Longfin smelt
Splittail
Mysid shrimp
Tule perch

Largemouth bass
Bluegill
Brazil waterweed
Water hyacinth
Asian clam

Anchovy
Surf perches
Marine fish
Problems of California's Sacramento-San Joaquin Delta

- Physical instability
  - Land subsidence
  - Sea level rise
  - Floods
  - Earthquakes
- Ecosystem instability
  - Habitat alteration
  - Invasive species
- Prohibitive costs for maintaining all islands
- Worsening water quality for agric. & urban users
The “Big Gulp”: 6.5 Magnitude Earthquake causing 20-Island Failure

0 - 6 hours: Islands flood with fresh water
6.5 Magnitude Earthquake causing 20-Island failure

RMA Salinity Modeling

12 – 24 hours: Salt water intruding into Delta
6.5 Magnitude Earthquake causing 20-Island failure
We can’t go on like this.
Delta of Tomorrow Will be Different, No Matter What We Do

- Earthquake and flood risks ➔ Large bodies of open water and higher sea level
- Losses of 15-20 islands where repair costs prohibitive
- Major changes in:
  - Water supply
  - Water quality
  - Delta land use

Based on economic value of land and assets, many islands not worth repairing after flooding (blue)
Comparing Water Export Strategies Long-Term (to Mid-Century)

- Current Strategy: through the Delta
- Peripheral Conveyance: around the Delta
- Dual Conveyance: both through and around the Delta
- No Exports: use other water sources and use less
What's Best?

Economic Cost ($Billions/year)

Likelihood of Fish Viability (%)

No Exports
Peripheral Canal
Dual Conveyance
Through-Delta Exports

Delta smelt
Is there a better tradeoff?

Economic Cost ($Billions/year)

Likelihood of Fish Viability (%)

Delta smelt

Peripheral Canal++?

Peripheral Canal

Through-Delta Exports

No Exports
4. The New Delta

- Island failure - more saline, more open water.
- Levee policy?
- Worse for water users, but likely better for fish
- Delta water exports - change location or face extinction
- Less water exports?
- Better for fish & economy?
Elevation is destiny for habitat

- Tidal marsh?
- Deep water/lake?
- Riparian?
- Floodplain?
Reconciliation Strategy: Specialize Areas for Human and Ecosystem Functions

Current fish habitat

Future specialized areas

**Current Land Elevation**
- 0-5 ft above sea level (potential marshland with sea level rise)
- Within tidal range
- 0-3 ft below sea level
- 3-6 ft below sea level
- 6-9 ft below sea level
- 9 ft or more below sea level

**SAN JOAQUIN SALMON**
- Migration

**SPLITTAIL**
- Rearing and spawning

**DELTA SMELT**
- Rearing and spawning

**LARGEMOUTH BASS**
- Resident area

**SACRAMENTO SALMON**
- Migration and rearing

**Potential San Joaquin River Migratory Corridors**

**Lower San Joaquin Floodplain**
- Partially restored marsh & seasonal floodplain

**Sacramento River & Bypass Habitat Arc**
- Freshwater seasonal floodplain, tidal marshlands, & riverine habitat: delta smelt, splittail, salmon, other native fish

**Eastside Rivers**
- Freshwater riparian, floodplain species, local salmon rearing

**Central Delta Lowlands & Lakes**
- Deep freshwater lake species

*Splittail movements to other parts of the Delta are omitted because of poor understanding of their patterns.*
Agricultural Losses from Salinity in the Sacramento San Joaquin Delta

Josué Medellín-Azuara
Richard Howitt
Ellen Hanak
Bill Fleenor
Jay Lund

Bay Delta Science Conference
October 30, 2014
Physical Forces and Management Decisions will Shape the Delta

- Permanent flooding of subsided islands
- Habitat development
- Changes in water salinity
  - From water management
  - Sea level rise
- What are the economic impacts?

Source: Hanak et al. (2013) Delta Stressors
Where is Agriculture?

Source: Medellin & Howitt (2013) ET study for the Sacramento-San Joaquin Delta, with data from DWR and SEBAL
Changes Mainly will Affect Inner Delta

- Most residents (98%), economic activity (96%), and growth in the more urbanized “secondary zone”
- “Primary zone” economy is heavily agricultural

Source: Medellin-Azuara et al. (2012) Delta Economy
A Suite of Models

Salinity Scenarios
  - Historical, through Delta
  - 1 ft SLR, through Delta
  - 3 ft SLR, through Delta
  - Historical, Dual Conveyance
  - 1 ft SLR, through Delta
  - 3 ft SLR, through Delta

  - Current conditions Irrig. Seas.
  - 5 Western Islands Irrig. Seas.
  - Current conditions Non-Irrig. Seas.
  - 5 Western Islands Non-Irrig. Seas.

Crop Salinity Response Models (Hoffman 2010)

Delta Agricultural Production Model (DAP)

Fixed Salinity Scenarios
- Current conditions
- 1% of avg. seawater salinity
- 3% of avg. seawater salinity
- 5% of avg. seawater salinity
- 10% of avg. seawater salinity


SWAP Model Production Cost Data (Howitt et al. 2012)

Land Use Data 2007 DWR Survey

Base production data

Salinity

Agricultural Production

Cropping Patterns
Crop Revenues

Source: Medellin-Azuara et al. (2014) Ag. Losses from Salinity
Delta Agricultural Production Model (DAP)

- Self-calibrated model
- Production terminated for flood and habitat
- Salinity effects,

Source: Medellin-Azuara et al. (2014) Ag. Losses from Salinity

Van Genuchten and Hoffman (1994)
No Significant Changes in Salinity Expected with Sea Level Rise, or Dual Conveyance

- WAM Historical hydrology, operations and exports, 4.9 MAF/yr of exports and 20 year time period (1980-2000)

Source: Medellin-Azuara et al. (2014) Ag. Losses from Salinity
Salinity is Usually Higher During the Non-Irrigation Season.

Source: Medellin-Azuara et al. (2014) Ag. Losses from Salinity

RMA 2-D model (2002-2004) 5 western islands flooded
Changes in Crop Revenues

Hydrodynamic modeling

Fixed Salinity Scenarios

Source: Medellin-Azuara et al. (2014) Ag. Losses from Salinity
## Potential Delta Losses by 2050

<table>
<thead>
<tr>
<th></th>
<th>Water Quality</th>
<th>Land Availability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dual 1ft SLR</td>
<td>Western Flooding</td>
<td>Habitat</td>
</tr>
<tr>
<td>Jobs</td>
<td>16</td>
<td>2</td>
<td>397</td>
</tr>
<tr>
<td>Revenue</td>
<td>1.4</td>
<td>0.3</td>
<td>38</td>
</tr>
<tr>
<td>Value Added</td>
<td>0.8</td>
<td>0.2</td>
<td>21</td>
</tr>
<tr>
<td>State &amp; Local Taxes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Monetary values in $2008 million

Source: Medellín-Azuara et al. (2012) Delta Economy
Idle land according to NASA
Policy Implications

1. Hydrodynamics-based scenarios indicate small changes in salinity and crop revenues

2. Water operations under dual conveyance may increase salinity and revenue losses during dry year, yet these remain small (1% of current revenues)

3. Flooding of five western islands increase salinity mostly in the non-irrigation season
Policy Implications

4. Revenue losses from salinity remain small as the affected areas currently grow lower-value crops.

5. Fixed salinity scenarios show that EC > 3% of seawater results in large revenue losses.

6. A better understanding of the combined effects of flooding, sea level rise and operations can be achieved with 3D models.

7. More research is needed!
Mostly dry, but many demands

- Water supplies
- Floods
- Environmental habitat
- Hydropower
- Recreation
Changes for Agriculture

1) More permanent & high value crops
2) More environmental flows
3) Tighter groundwater management
   a) More wet-year recharge (field and artificial recharge)
   b) More reliable wells and drought supplies
4) Nitrate groundwater contamination is inevitable
5) Some land lost to salinization and Delta flooding
6) Less landscape ET:
   a) Longer fallowing rotations and some permanent fallowing
   b) More habitat
7) Irrigation efficiency? Recharge vs. NO3 and salts
Water for S. Central Valley

1) Outflows
   – Total consumptive water use (ET) about 15.3 maf/yr
     Mostly for 5 million acres of irrigated agriculture
   – San Joaquin R. outflow average 2.7 maf/year (increasing)

2) Supplies
   – About 13 maf/year in local inflows (climate change?)
   – About 4 maf/year of Delta imports (decreasing)
   – 1-2 maf/year in groundwater overdraft (decreasing)

3) Difference
   – About 2 – 4 maf/year, ~ 1+ million acres
   – Some acres retire due to salinity anyway
   – Most retire due to water scarcity
   – Likely growing profitability anyway
Resistance is Futile

1) Flooding in parts of the Delta
2) Reduced Delta diversions
3) Less irrigated land in the southern Central Valley
4) Less urban water use, more reuse & storm capture
5) Some native species unsustainable in the wild
6) Funding solutions mostly local and regional
7) State’s leverage is mostly regulatory, not funding
8) Nitrate groundwater contamination is inevitable
9) Groundwater will become more tightly managed
10) The Salton Sink will be largely restored

We cannot drought-proof, but we can manage better.
Today’s Challenges

1) Limits of traditional management

2) Major problems
   - Native species and their habitats (esp. wetlands)
   - Reconciling for permanent scarcity
   - Groundwater – depletion, degradation, rights
   - Weak state and federal governments

3) Modernizing statewide system
   - Serving many goals (conflict and mutual need)
   - Rebuilding or abandoning the Delta
   - Locally-driven portfolios in a statewide system
   - Challenges for state government and regulation
Suggested Readings

Hanak et al. (2011) *Managing California’s Water*, PPIC.org

Hanak et al. (2010) *Myths of California Water*, PPIC.org


Pisani (1983), *From Family Farms to Agribusiness*, UC Press

Mavensnotebook.com

CaliforniaWaterBlog.com
Reservoirs
Will next year be dry?
(from historical data, 1906-2013)

<table>
<thead>
<tr>
<th>Next Year</th>
<th>Sacramento Valley</th>
<th>San Joaquin Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Historical</td>
<td>Critical now</td>
</tr>
<tr>
<td>Critical</td>
<td>0.13</td>
<td>0.29</td>
</tr>
<tr>
<td>Dry</td>
<td>0.21</td>
<td>0.35</td>
</tr>
<tr>
<td>Below Normal</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>C,D</td>
<td>0.34</td>
<td>0.64</td>
</tr>
<tr>
<td>C,D, BN</td>
<td>0.52</td>
<td>0.71</td>
</tr>
<tr>
<td>AN, W</td>
<td>0.48</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Streamflow and El Nino (maf)
El Nino and drought

![Graph showing the relationship between ENSO Index and Annual Runoff, maf](image)

- **Blue Diamond Line**:
  - Equation: $y = 2.5259x^2 + 0.7059x + 16.614$
  - $R^2 = 0.0841$

- **Red Square Line**:
  - Equation: $y = 1.0243x + 18.412$
  - $R^2 = 0.012$

- **Orange Square Line**:
  - Equation: $y = 0.7698x^2 + 0.5695x + 5.3473$
  - $R^2 = 0.0725$

- **Green Square Line**:
  - Equation: $y = 0.6666x + 5.8953$
  - $R^2 = 0.0312$
Nov.-March Runoff as Percent of Annual, Central Valley

% Annual runoff in Winter

Year

\[ y = 0.001x - 1.4657 \]
\[ R^2 = 0.0702 \]
Annual Runoff of Central Valley, taf

\[ y = 87.732x - 143904 \]

\[ R^2 = 0.0216 \]
Water Storage Capacity and Uses in California

1. Conclusions

![Bar chart showing water storage capacity and uses in California.](chart.png)

- **Total Capacity**
- **Seasonal Storage**
- **Drought Use**

### Categories
- **Groundwater Capacity**
- **Surface Storage**
- **Proposed Expansions**
Conclusions

1) Statewide water system, with local governance and fragmented regulation
2) Limited State and Federal abilities
3) Local government is most important
4) Complexity enriches possibilities
5) Integrated portfolios are the future
6) Nature and economics eventually prevail over indecision and existing law
7) Droughts remind us to change
Transitions for the Delta Economy
Josué Medellín-Azuara, Ellen Hanaki, Richard Howitt, and Jay Lund
January 2012

Enormous changes—from natural forces to management decisions—are coming to California’s fragile Delta region and will have broad effects on its residents. This report finds that in the first half of this century, the Delta as a whole is likely to experience a loss of 1 percent of economic activity as a result of these changes. It also identifies planning priorities for managing the Delta's future.

This research was supported with funding from the Watershed Sciences Center at UC Davis.

More information and questions

Free download at: https://escholarship.org/uc/jmie_sfews

Josué Medellín: jmedellin@ucdavis.edu
Agriculture in California

1) 400+ crops
2) $45 billion/year sales
3) Most agricultural value of any US state
4) 4 million irrigated hectares
5) 40 BCM water use/yr.
6) <4% of labor force and state GDP
### Agriculture in California

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigated Crop Area (1000 hectares)</th>
<th>Applied Water (MCM)</th>
<th>Application rate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>443</td>
<td>7,356</td>
<td>1.7</td>
</tr>
<tr>
<td>Almonds, Pistachios*</td>
<td>416</td>
<td>5,174</td>
<td>1.2</td>
</tr>
<tr>
<td>Vine*</td>
<td>365</td>
<td>2,413</td>
<td>0.7</td>
</tr>
<tr>
<td>Vegetables (“truck”)</td>
<td>354</td>
<td>1,965</td>
<td>0.6</td>
</tr>
<tr>
<td>Corn</td>
<td>345</td>
<td>3,329</td>
<td>1.0</td>
</tr>
<tr>
<td>Pasture</td>
<td>328</td>
<td>4,558</td>
<td>1.4</td>
</tr>
<tr>
<td>Grain</td>
<td>288</td>
<td>1,649</td>
<td>0.6</td>
</tr>
<tr>
<td>Orchards*</td>
<td>270</td>
<td>3,314</td>
<td>1.2</td>
</tr>
<tr>
<td>Field (other)</td>
<td>270</td>
<td>2,407</td>
<td>0.9</td>
</tr>
<tr>
<td>Rice</td>
<td>230</td>
<td>3,478</td>
<td>1.5</td>
</tr>
<tr>
<td>Subtropical*</td>
<td>185</td>
<td>2,013</td>
<td>1.1</td>
</tr>
<tr>
<td>Processing Tomato</td>
<td>121</td>
<td>1,047</td>
<td>0.9</td>
</tr>
<tr>
<td>Cotton</td>
<td>111</td>
<td>1,117</td>
<td>1.0</td>
</tr>
<tr>
<td>Safflower</td>
<td>46</td>
<td>291</td>
<td>0.6</td>
</tr>
<tr>
<td>Cucurbits</td>
<td>39</td>
<td>259</td>
<td>0.7</td>
</tr>
<tr>
<td>Onion Garlic</td>
<td>31</td>
<td>305</td>
<td>1.0</td>
</tr>
<tr>
<td>Dry Bean</td>
<td>30</td>
<td>230</td>
<td>0.8</td>
</tr>
<tr>
<td>Tomato (fresh)</td>
<td>15</td>
<td>109</td>
<td>0.7</td>
</tr>
<tr>
<td>Potato</td>
<td>15</td>
<td>119</td>
<td>0.8</td>
</tr>
<tr>
<td>Sugar Beet</td>
<td>15</td>
<td>201</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>3915</strong></td>
<td><strong>41,331</strong></td>
<td><strong>1.1</strong></td>
</tr>
</tbody>
</table>
Local and Statewide Activities

Local Activities:
- Conservation and use efficiency
- Wastewater reuse
- Desalination (brackish & ocean)
- Groundwater use and recharge
- Surface reservoir operations
- Water markets and exchanges

Statewide Activities:
- Inter-regional water conveyance
- Surface reservoir operations
- Plumbing codes & conservation incentives
- Groundwater banking and recharge
- Water market support and conveyance
- Wastewater reuse subsidies

Integrating mix of actions – portfolio planning.
Droughts test water systems!

1. Water systems and the societies they serve are always changing.
2. Droughts bring attention to needs for change.
3. This drought is helping California improve water management.
4. Every generation needs at least a threatening drought, and a threatening flood.
Sac. Valley Precipitation index

Northern Sierra Precipitation: 8-Station Index, November 03, 2014

Percent of Average for this Date: 106%

- 1982-1983 (wettest) 88.5
- 2005-2006 Daily Precip. 80.1
- Average (1922-1998) 50.0
- 2012-2013 Daily Precip. 44.3
- 2013-2014 Daily Precip. 31.3
- 1923-1924 (driest) 19.0
- 1976-1977 (2nd driest & driest thru Aug) 17.1

2014: 8th driest in 106 years
Snowpack:
Trinity/Feather/Truckee.
Yuba-Tahoe-Merced-Walker.
San Joaquin-Kern-Owens.
## 2014 Impact Summary of Drought Impacts

### Water supply, 2014 drought

<table>
<thead>
<tr>
<th>Impact</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water reduction</td>
<td>6.6 million acre-feet</td>
</tr>
<tr>
<td>Groundwater pumping increase</td>
<td>5 million acre-feet</td>
</tr>
<tr>
<td>Net water shortage</td>
<td>1.6 million acre-feet</td>
</tr>
</tbody>
</table>

### Statewide Economic Impacts

<table>
<thead>
<tr>
<th>Impact</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop revenue loss</td>
<td>$810 million</td>
</tr>
<tr>
<td>Additional pumping cost</td>
<td>$454 million</td>
</tr>
<tr>
<td>Livestock and dairy revenue loss</td>
<td>$203 million</td>
</tr>
<tr>
<td>Total direct costs</td>
<td>$1.5 billion</td>
</tr>
<tr>
<td><strong>Total economic costs</strong></td>
<td><strong>$2.2 billion</strong></td>
</tr>
<tr>
<td>Total job losses</td>
<td>17,100</td>
</tr>
</tbody>
</table>
2014 Estimated Crop Acreage Reductions

- Cotton Grain Oilseed
- Vegetables & Mellons
- Fruit and Nut trees
- Feed and Other Crops

Sacramento, Delta and East of Delta
San Joaquin River
Tulare Lake Basin
Other Regions
2014 Estimated Gross Revenue Reduction

- Cotton Grain Oilseed
- Vegetables & Melons
- Fruit and Nut trees
- Feed and Other Crops

<table>
<thead>
<tr>
<th>Region</th>
<th>Millions/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento, Delta and East of Delta</td>
<td>70</td>
</tr>
<tr>
<td>San Joaquin River</td>
<td>120</td>
</tr>
<tr>
<td>Tulare Lake Basin</td>
<td>180</td>
</tr>
<tr>
<td>Other Regions</td>
<td>5</td>
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</tbody>
</table>
# Food Price Index Projections

<table>
<thead>
<tr>
<th>Consumer Price Indexes</th>
<th>Trend</th>
<th>% change 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>All food</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>Food away from home</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>Food at home</td>
<td></td>
<td>2.9</td>
</tr>
<tr>
<td>Meats, poultry, and fish</td>
<td></td>
<td>8.8</td>
</tr>
<tr>
<td>Meats</td>
<td></td>
<td>11.8</td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>Eggs</td>
<td></td>
<td>9.7</td>
</tr>
<tr>
<td>Dairy products</td>
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<tr>
<td>Fats and oils</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>Fruits and vegetables</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Fresh fruits &amp; vegetables</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>Processed fruits &amp; vegetables</td>
<td></td>
<td>-0.4</td>
</tr>
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</table>

Alfalfa Hay Prices in California

http://future.aae.wisc.edu/data/monthly_values/by_area/2053?tab=feed
NASA Summer Idle Land Estimates Early August
Lessons for water policy

- Droughts are inevitable in California
- Portfolio approach
- Groundwater
- Water markets
- Need for state agencies to work better together
- Information
  - Better water accounting and water use data, made more available with better modeling
  - Potential of remote sensing estimates
  - Retrospective assessment of drought
Suggested Readings

Hanak et al. (2011) *Managing California’s Water*, PPIC.org
Hanak et al. (2010) *Myths of California Water*, PPIC.org
Pisani (1983), *From Family Farms to Agribusiness*, UC Press
Mavensnotebook.com
CaliforniaWaterBlog.com