Sustainability of Irrigated Agriculture in the Central Valley of California

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California agriculture

Farms and ranches cash receipts in 2019: over $50 billion dollars

- Dairy, Milk: $7.34 billion
- Almonds: $6.09 billion
- Grapes: $5.41 billion
- Cattle: $3.06 billion
- Strawberries: $2.22 billion
- Pistachios: $1.94 billion
- Lettuce: $1.82 billion
- Walnuts: $1.29 billion

Sources: CDFA, Sacbee, Visalia Times, UC Davis, BEEF,
Unique climate allows year-round production

Percentage of Total US Production by County

- 99% of all US almonds
- 99% of all US walnuts
- 98% of all US pistachios
- 90% of all US tomatoes

Unique water delivery infrastructure

Source: USDA & Mother Jones
Sustainability challenges in the Central Valley
Sustainable Groundwater Management Act (SGMA)

Priority basins for sustainability plans:
- Critically overdrafted
- High priority
- Medium priority
- Low priority

San Joaquin River hydrologic region
Tulare Lake hydrologic region

Source: DWR
Irrigated Lands Regulatory Program (ILRP)

Goal: Protect groundwater quality from nitrate contamination

Coalitions help growers and ranchers comply with Waste Discharge Requirement General Orders
Salt and Nitrate Management Plan (SNMP)

- Provide safe drinking water to affected residents
- Regulated dischargers: irrigators, dairies, ranchers, food processors, wineries, and municipalities
- Compliance pathways: individual or management zone
Salt and Nitrate Management Plan (SNMP)

250,000 acres taken out of production

1.5 million acres are salinity impaired

Potential direct annual costs up to $1.5 billion by 2030

Kisekka and Hopmans (2021)
Managing irrigation to optimize agroecosystem services
Agroecosystem services

Food Production

Water Quality

Soil Health

Air Quality

Climate Resilience

Carbon Sequestration

**Agroecosystem Irrigation**: Irrigation engineering and management that seeks to optimize agroecosystem services
Agroecosystem Irrigation: Food production

1. Drip irrigation important for meeting crop ET
2. Sprinkler irrigation important for reducing salinity problems
3. Prevent Crop stress
4. Apply and incorporate fertilizers and chemicals
5. Prepare Orchard floor for Harvest
1. Cover crops in almond orchards improve soil health, bee habitat
2. Microsprinklers can be used for both the primary crop and cover crops
3. Cover crops can improve infiltration & soil structure
4. Soil microbes help in recycling and storage of nutrients

Agroecosystem Irrigation: Carbon sequestration through WOR

1. Sprinkler irrigation is important for managing wood chips from whole orchard recycling (WOR)
2. Total soil carbon (+58%)
3. Total soil nitrogen (+17%)
4. Organic matter (+42%)
5. Soil aggregation (+19%)
6. Water holding capacity (+32%)
7. Soil microbial biomass carbon (+47%)

https://orchardrecycling.ucdavis.edu/sf-soil-health/
Agroecosystem Irrigation: Air quality

1. Microsprinkler irrigation can be used to prepare the orchard floor for harvest
2. Microsprinkler irrigation can be used to control spider mites

https://ucanr.edu/sites/lassen/index4.cfm?blogtag=nuts&blogasset=10590
Agroecosystem Irrigation: Water quality

1. Nitrate accumulated below effective root zone following poorly timed fertigation event
2. Can increase N leaching under AgMAR or winter rainfall
3. Need for better coordination between irrigation and nutrient management

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Agricultural-Managed Aquifer Recharge (AgMAR)
Agroecosystem Irrigation: Water quality can benefit from dual irrigation systems

Dual irrigation systems provide management flexibility for irrigation and fertigation

Drip: Fertigation and during harvest

MS: For irrigation to meet crop evapotranspiration
Agroecosystem Irrigation: Climate resilience through managed aquifer recharge (using exiting irrigation infrastructure)

https://water.ca.gov/Programs/All-Programs/Flood-MAR

Selected projects
Site-specific Irrigation Management by Orchard Age
Field Site: Corning, CA

LE = Rn – H - G
Almond acreage in California

Source: NASS 2019
Canopy size affects water use
Crop coefficients of young almond orchards

\[ y = -0.0606x^2 + 0.5276x - 0.1495 \]
\[ R^2 = 0.9417 \]

\[ y = -2.6155x^2 + 2.6788x + 0.2926 \]
\[ R^2 = 0.6879 \]

Table 15 Crop coefficient as a function of percent PAR intercepted by the canopy in relation to %ET\(_c\) of a mature almond orchard

<table>
<thead>
<tr>
<th>Percent PAR Intercepted by the Canopy</th>
<th>ET(_c)/ET(_a)</th>
<th>Mature K(_c) (June/July Average from Sanden, 2007)</th>
<th>% ET(_c) of a Mature Almond Orchard</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.53</td>
<td>1.05</td>
<td>51</td>
</tr>
<tr>
<td>20</td>
<td>0.72</td>
<td>1.05</td>
<td>69</td>
</tr>
<tr>
<td>30</td>
<td>0.86</td>
<td>1.05</td>
<td>82</td>
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<tr>
<td>40</td>
<td>0.95</td>
<td>1.05</td>
<td>90</td>
</tr>
<tr>
<td>50</td>
<td>0.98</td>
<td>1.05</td>
<td>94</td>
</tr>
</tbody>
</table>

Drechsler, Fulton, Kisekka (2020)
Site-specific Irrigation Management by Variety
Experimental Design

2019 Overall Treatment

- 100-75-100% ET based on nonpareil growth stages (in all varieties)
- 100-75-100% ET based on variety-specific growth stages (in all varieties)
- 100-50-100% ET based on nonpareil growth stages (in all varieties)
- 100-50-100% ET based on variety-specific growth stages (in all varieties)
- 100-100-100% ET based on nonpareil growth stages (in nonpareil only) with single dripline during harvest season
- 100-100-100% ET based on nonpareil growth stages (in nonpareil only) with double dripline during harvest season
Site-specific irrigation management by variety

Compare the effects of:

1. irrigating according to Nonpareil hull-split timing
2. irrigating according to variety specific hull-split timing
Site-specific irrigation management by variety

Irrigation by variety almond yield 2019

- **S1**: 100-75-100% ET based on nonpareil growth stages (in all varieties)
- **S2**: 100-75-100% ET based on variety-specific growth stages (in all varieties)
- **S3**: 100-50-100% ET based on nonpareil growth stages (in all varieties)
- **S4**: 100-50-100% ET based on variety-specific growth stages (in all varieties)
- **S5**: 100% ET based in nonpareil with single dripline and 2x runtime during harvest season in 2019 (not in 2020).
- **S6**: 100% ET based in nonpareil with double dripline and 1x runtime during harvest season in 2019.
Site-specific irrigation management by variety

Irrigation by variety strategies

S1: 100-75-100% ET based on nonpareil growth stages (in all varieties)
S2: 100-75-100% ET based on variety-specific growth stages (in all varieties)
S3: 100-50-100% ET based on nonpareil growth stages (in all varieties)
S4: 100-50-100% ET based on variety-specific growth stages (in all varieties)
S5: 100% ET based in nonpareil with single dripline and 2x runtime during harvest season in 2019 (not in 2020).
S6: 100% ET based in nonpareil with double dripline and 1x runtime during harvest season in 2019.

Need to repeat this experiment with varieties, ages, environments, irrigation systems.
Zone Irrigation Management in Almonds
Soil spatial variability is related to canopy growth and yield variability
Zone irrigation management by soil type
Smart irrigation scheduling technologies in almonds

Large area cosmic ray soil moisture sensing

Automated osmometer for measuring stem water potential
Comparison of neutron probes

In-situ neutron probe

- Active radiation source
- Relates slow neutrons to water content
- Footprint is ~30 cm
- Cannot be automated
- Regulated

Cosmic-ray neutron probe

- Passive sensor, uses cosmic-ray neutrons as source
- Relates fast neutrons to water content.
- Footprint radius ~ 150 m (492 ft).
- Can be automated
- Not regulated
Cosmic-ray neutrons detection

In drier soil, more neutrons escape

In moister soil, fewer neutrons escape

Source: Marek
Orchard scale proximal soil moisture sensing using cosmic ray neutron probe

Cosmic ray neutron probe provides areal averaged soil moisture in the top 2 to 3 ft of the soil profile for an area ~ 30 to 50 acres.
Automated stem water potential monitoring

Comparing pressure bomb versus calibrated Saturas osmometer
Evaluating performance of micro-tensiometers against pressure chamber

After calibration osmometer show good correlation with pressure chamber
B3: Morphology ID 7970457

- **Plant Height (feet):** 23.21
- **Canopy Diameter (feet):** 16.61
- **Trunk Diameter (feet):** 0.88
- **Canopy Density (percent):** 0.512
- **Canopy Volume (volume):** 3,068.33
B4: Morphology ID 7973437

- Plant Height (feet): 22.72
- Canopy Diameter (feet): 14.97
- Trunk Diameter (feet): 0.9
- Canopy Density (percent): 0.56
- Canopy Volume (volume): 2,571.19
Distribution Uniformity

Global System $DU_{10}^* = 0.89$

The field Global System $DU_{10}$ is considered Good

* $DU_{10} = \text{Distribution Uniformity of the Lowest Quarter} = \frac{\text{Avg of Lowest Quarter}}{\text{Overall Average}}$

Percent of Total Non-Uniformity due to Each Problem

<table>
<thead>
<tr>
<th>Problem</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure difference:</td>
<td>52%</td>
</tr>
<tr>
<td>Difference between hose inlet pressure across the field:</td>
<td>11 PSI</td>
</tr>
<tr>
<td>Maximum pressure difference within a hose:</td>
<td>3 PSI</td>
</tr>
<tr>
<td>Other causes of flow variation:</td>
<td>44%</td>
</tr>
<tr>
<td>Unequal drainage:</td>
<td>4%</td>
</tr>
<tr>
<td>Spacing:</td>
<td>0%</td>
</tr>
</tbody>
</table>

Source: Jeff Davids CSU Chico
Alfalfa Acreage Century Outlook 1919-2019

Alfalfa Production Century Outlook 1919-2019

Source: USDA NASS 2019 Survey
Alfalfa Hay VS Almond Acres in California
2006 to 2019

Source: USDA/NASS    Note: 2019 Non-Bearing Acres Estimated
Summary

➢ Irrigated agricultural sustainability challenges in the CV
➢ Agroecosystem irrigation as a new paradigm to irrigation engineering and management
➢ Selected smart irrigation projects
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