THE SCIENCE AND PRACTICE OF INTENTIONAL RECHARGE IN ALMOND ORCHARDS

Room 312-313 | December 5 2017
CEUs – New Process

Certified Crop Advisor (CCA)
- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you wish to receive credits.*

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*Sign in sheets and verification sheets are located at the back of each session room.*
AGENDA

- Daniel Mountjoy, Sustainable Conservation, moderator
- Helen Dahlke, University of California, Davis
- Peter Nico, Berkeley National Laboratory
- Aaron Fukuda, Tulare Irrigation District
The Science and Practice of Intentional Recharge in Almond Orchards

Moderator: Daniel Mountjoy
Sustainable Conservation
The Potential Role of Almond Acreage for Recharge in the SGMA Era

DWR CASGEM Basin Prioritization

2014 Almond Acreage - LandIQ
The Potential Role of Almond Acreage for Recharge in the SGMA Era

DWR CASGEM Basin Prioritization

Almond Groundwater Recharge Suitability - LandIQ
What is the most cost-effective way to capture high flow events?
Timing of Water Availability for Recharge

Monthly Wet Year Merced River Flow (Nov-Mar)  
RMC 2015

Almonds June 2017
Research Questions to determine almond suitability for recharge

- **Crop Compatibility**: response to extra water during dormancy, growing season, and after harvest
  - UC Davis research on dormant season response
  - Bachand and Associates with Sustainable Conservation on growing season compatibility

- **Nutrient Management**: leaching out of root zone to groundwater
  - UC Davis and other public and private partners

- **Site Suitability**: Soil type, underlying geology, and depth to groundwater
  - Lawrence Berkeley National Lab research on underlying geologic variation
  - Stanford University School of Earth Sciences

- **Recharge methods**: flood, drip, alternate rows
  - Grower practice and experience

- **Incentives**: rewarding grower participation - the role of Groundwater Sustainability Agencies
  - Tulare Irrigation District experience
Panel Presenters

- **Helen Dahlke**, Assistant Professor in Physical Hydrology at the Department of Land, Air and Water Resources, UC Davis

- **Peter Nico**, Geologic Scientist, Lawrence Berkeley National Labs

- **Aaron Fukuda**, District Engineer, Tulare Irrigation District
Why study winter recharge in almonds?

• Since 1920s groundwater depletion has reached more than 160 million acre-feet of groundwater

• Sustainable Groundwater Management Act (SGMA) requires overdrafted groundwater basins to achieve balance by 2040

• Intentional recharge of flood water on agricultural land is a practice considered to achieve groundwater sustainability

http://www.ppic.org/main/publication_quick.asp?i=1160
Goal and Experimental Design

• Winter water application:
  – 24” of water were applied in addition to rainfall in Dec-Jan of 2015/16 and 2016/17

• Water balance & recharge
  – How much, how fast, where?
  – Quality of water as it moves through the soil

• Impact on tree
  – Water status (stem water potential)
  – Root growth
  – Yield
Site Information

• Modesto:
  – Nonpareil, Monterey
  – Stand age: 20 years
  – Flood irrigated
  – Dinuba, fine sandy loam
  – SAGBI: moderately good

• Delhi:
  – Butte, Padre, on Nemaguard
  – Sprinkler irrigated
  – Stand age: 14 years
  – Dune land, sand
  – SAGBI: excellent

• Orland:
  – Butte, Padre, Mission
  – Stand age: 25 years
  – Flood irrigated
  – Jacinto, fine sandy loam
  – SAGBI: moderately poor
Root zone hydrology

Fine sandy loam ~ 48 hrs

Sand ~ 6 hrs

Delhi - Flood - R9, T3/4

Modesto - Flood - R26, T10/11

Orland - Flood - R21 T24
How much of applied water went to recharge?

Summary of water inputs (rain & applied water) for October-March.

<table>
<thead>
<tr>
<th></th>
<th>Rain Applied Water</th>
<th>Total Deep Percolation from rain</th>
<th>Deep Percolation of applied water</th>
<th>Loss of applied water to soil storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>inches</td>
<td>inches</td>
<td>inches</td>
<td>%</td>
</tr>
<tr>
<td>2015/16 Delhi</td>
<td>12.94</td>
<td>26.15</td>
<td>29.09</td>
<td>4.79</td>
</tr>
<tr>
<td>2015/16 Modesto</td>
<td>9.91</td>
<td>24.00</td>
<td>21.90</td>
<td>2.55</td>
</tr>
<tr>
<td>2016/17 Delhi</td>
<td>17.44</td>
<td>25.80</td>
<td>33.03</td>
<td>7.43</td>
</tr>
<tr>
<td>2016/17 Modesto</td>
<td>12.46</td>
<td>24.00</td>
<td>27.94</td>
<td>4.78</td>
</tr>
<tr>
<td>2016/17 Orland</td>
<td>28.62</td>
<td>4.76</td>
<td>21.00</td>
<td>17.35</td>
</tr>
</tbody>
</table>

- At Modest and Delhi >80% of applied water went to deep percolation.
- Jacinto soil at Orland largely prevented deep percolation.
Soil Nitrate

How much residual soil nitrate is leached during groundwater recharge events?

- Soil cores (12 ft) were taken before and after recharge events
- Soil analysis: texture, pH, EC, soil nitrate, DOC
- Water analysis: nitrate concentration in the applied water
Soil Nitrate Leaching – 2015/16

• Root zone (upper 3 ft):
  – 167% increase across treatments
  – 56% increase in Flood treatment
  – 220% increase in Control

• Entire profile (12 ft):
  – 53% increase across treatments
  – 107% increase in Flood treatment
  – 20% increase in Control

➢ Most of the increase in soil nitrate occurred in the root zone as the result of nitrification
Soil Nitrate Leaching – 2015/16

• Root zone (upper 3 ft):
  – 88% decrease across treatments
  – 84% decrease in Flood treatment
  – 89% decrease in Control

• Entire profile (12 ft):
  – 7% decrease across treatments
  – 23% decrease in Flood treatment
  – No change in Control

➢ Rainfall caused a similar decrease in nitrate from the root zone in Control as flooding did in Recharge treatment.
## Yield Data

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modesto</td>
<td>Grower</td>
<td>2015</td>
<td>3220</td>
<td>3090</td>
<td>3900</td>
</tr>
<tr>
<td></td>
<td>(Dry Winter)</td>
<td>2016</td>
<td>3360</td>
<td>3290</td>
<td>2980</td>
</tr>
<tr>
<td></td>
<td>Recharge</td>
<td>2017</td>
<td>3430</td>
<td>3130</td>
<td>2990</td>
</tr>
<tr>
<td>Delhi</td>
<td>Grower</td>
<td></td>
<td>1230</td>
<td>1250</td>
<td>2200</td>
</tr>
<tr>
<td></td>
<td>(Dry Winter)</td>
<td></td>
<td>1190</td>
<td>1140</td>
<td>2640</td>
</tr>
<tr>
<td></td>
<td>Recharge</td>
<td></td>
<td>1410</td>
<td>1200</td>
<td>3110</td>
</tr>
<tr>
<td>Orland</td>
<td>Grower</td>
<td></td>
<td></td>
<td></td>
<td>1640 ± 190</td>
</tr>
<tr>
<td></td>
<td>Recharge</td>
<td></td>
<td></td>
<td></td>
<td>1520 ± 140</td>
</tr>
</tbody>
</table>

Underline = Max. yield per year

**DROUGHT**
Stem Water Potential

- Midday stem water potential was slightly higher (wetter) in the recharge treatment than in the control at beginning of growing season (Modesto, Delhi)
Root growth

- No difference in production of new roots (March-May) between treatments at Delhi and Modesto.

- Trees in Recharge treatment showed higher standing root length:
  - Standing root length: rate of root production minus rate of root death
  - Greater standing root length = longer root lifespan

- Median lifespan of roots was about 30-70% longer in the Recharge treatment than in the Control
  - Lifespan increased with depth except for 18-24” depth
  - Greatest difference between Control and Recharge treatment at 6-12” depth
Conclusions

- No obvious warning signs that winter irrigation (Dec/Jan) for groundwater recharge affects trees
- Sandy sites might benefit from winter flooding
- Moderately poor site turned out to perform poorly (no deep percolation possible)
- Sandy soils – clear nitrate loss from recharge
- Silt loams and complex soils with impeding layers – recharge might increase soil nitrate

- **Winter recharge is not a suitable practice for every grower!**
  - Check SAGBI map for soil suitability → know your soil!
- Undecided growers:
  - Keep your flood irrigation system if you have one
  - Talk to your irrigation/water district about options
Acknowledgements

• **Funding:**
  Almond Board of California

• **Farm advisors:**
  David Doll, Roger Duncan, Allan Fulton, and Danielle Lightle

• **Students and field helpers:**
  Seanna McLaughlin, Nicholas Murphy, Paul Martinez, Rebecca Scott, Colin Fagan, Juliana Wu
Importance of Subsurface Sediments on Water Movement

Peter S. Nico, Craig Ulrich, Yuxin Wu, Mark Conrad, Greg Newman, William Stringfellow, Christine Doughty and Yingqi Zhang
Lawrence Berkeley National Laboratory

Taqi Alyousuf; Jamie Rector
University of California, Berkeley

Hannah Waterhouse, Helen Dahlke
University of California, Davis

Nick Blom
The Arnold Farms
Roger Duncan and David Doll of UC ANR
Surface Soils are Complex
Subsurface as Complex as Surface Soil but Less Well Known
We Can Image What’s Below Ground
We Can Image What’s Below Ground

High Electrical Resistivity

Low Electrical Resistivity

Coarser

Finer

Control

No irrigation

Flood
We Can Watch Water Move
Water Doesn’t Stay Where It is Put

Delhi Orchard
There is a Lot of Variation Even Over Small Distances
There is a Lot of Variation Even Over Small Distances

Flood

Control

No irrigation

X [m]

Z [m]

0 20 40 60 80 100 120 140 160

0 -5 -10 -15 -20

1.5 2 2.5 3

California Almonds

Aerated Mound of California
There is a Lot of Variation Even Over Small Distances
We Can Build Computer Models of Where the Water Goes

What if......

applied 6 inches of water?
applied 24 inches of water?
there was nitrate or salt?
you used a different part of the orchard?
how sensitive are the answers to uncertainty in the model......?
Conclusions

• There are lots of differences in the subsurface below what looks like similar soils
• Water movement can vary a lot from place to place within even a single part of an orchard
• There could be ways to optimize recharge effectiveness even within a single orchard
• Knowing where the water goes can help with predicting/preventing negative impacts, e.g. nitrate movement
• We are working on ways to image more area, more quickly
Thank You!
Tulare Irrigation District
District Background

- 70,000 acres
- 300 miles of earthen canals
- 30 miles of pipeline
- 1,250 acres of recharge basins
- 190 users
- Crops: corn, wheat, alfalfa, walnuts, pistachios, almonds

Water Supply:

- 180,000 AF Surface Water
  - Pre-1914 water rights on the Kaweah River System
  - Friant Division of CVP (30,000 AF Class 1 & 141,000 AF Class 2)
- 120,000 AF Groundwater

- Kaweah Subbasin (SGMA)
  - Member of Mid-Kaweah GSA
On-Farm Recharge

- 2011 – Concept
- 2016 – Pilot Program Initiated
- 2017 – Pilot Program Implemented
  - On-Farm Recharge
  - Reduce Rate Surface Water ($10/AF)
  - Private Pond Recharge

<table>
<thead>
<tr>
<th>Total Number of Participants</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Farm Field Participants</td>
<td>6</td>
</tr>
<tr>
<td>On-Farm Pond Participants</td>
<td>8</td>
</tr>
</tbody>
</table>

On-Farm Field Recharge

- On-Farm Field Acreage: 650 Acres
- Total Recharge: 6,800 Acre-Feet
  - On-Farm Field Recharge: 2,500 Acre-Feet
  - On-Farm Pond Recharge: 4,300 Acre-Feet
2017 On Farm Conclusions

- Previous Recharge Capacity 350 CFS
- 2017 On-Farm Program = 650 CFS
  - Intake Capacity of 900 CFS
  - 250 CFS of increased recharge targeted
  - On-Farm achieved an average of 3.9 AF/Acre

- 2017 Water Year
  - 170,000 AF to Irrigation Turnouts
  - 190,000 AF to Groundwater Recharge
Future Landowner Participation / Costs in Groundwater Recharge

- Development of District Recharge Ponds
  - Landowner sells ground $20,000 - $35,000 per acre
  - Development costs are approximately $20,000 per acre

- Reduced rate winter surface water

- On-Farm Recharge
  - Current Approach: Free water in exchange for access for on-farm recharge
  - Future Approach: Reimburse landowner for access to field to “buy the crop”
    - Example: buy winter wheat planting @ $175 - $250 per acre
Finding the On-Farm Program

- Working with Sustainable Conservation we have developed the Groundwater Recharge Assessment Tool
Tulare Irrigation District

Flight lines

Mean subsidence from 2007-2010, cm/yr

- 0-2.5
- 2.5-5
- 5-7.5
- 7.5-10
- 10-12.5
- 12.5-15
- 15-17.5

Total of 104 line km (64 miles), 1 km (.6 mi) spacing between lines

20 kilometers

Stanford University
Cross-section provided by Kaweah Delta Water Conservation District
Tow-TEM
Conclusions

- Transitioned from extreme drought to extreme wet conditions
  - Growers participated in recharge efforts

- With SGMA ahead of us, we quickly implemented an aggressive groundwater recharge season
  - On-Farm Recharge
  - Existing Recharge Basin
  - Reduced Rate Water

- On-Farm Recharge was a success with lessons learned and future opportunities

- New projects ahead such as Sky-TEM, Tow-TEM and GRAT will assist in our future recharge programs
Aaron Fukuda
Tulare Irrigation District
6826 Avenue 240
Tulare, California 93274

Phone: 559-686-3425
Email: akf@tulareid.org
Thank you!
What’s Next

Tuesday, December 5 at 3:00 p.m.

• Research Update: Soil Health, Aerial Almond Mapping and Almond Lifecycle Assessment – Room 312-313

• Come See What’s Happening in D.C.! – Room 306-307

• How to Manage a Young Orchard – Room 308-309

• Technology in the Food Safety World: Tools Such as Whole Genome Sequencing – Friend or Foe? – Room 314
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Research Poster Sessions

Wednesday, December 6
3:00 p.m. – 5:00 p.m.

Featured topics:
• Irrigation, nutrient management
• Breeding
• Soils, if related to organic matter input
• Sustainability, irrigation improvement continuum, life cycle assessment, dust
• Food quality and safety

Thursday, December 7
1:30 p.m. – 2:30 p.m.

Featured topics:
• Insect and disease management
• Fumigation and alternatives
• Biomass (including biochar-related efforts)
• Pollination
• Almond Leadership Program
2017 Research Update Book

• Pickup your copy at the ABC Booth in Hall A+B

• Includes a one-page summary of every current ABC-funded research project