RESEARCH UPDATE: SOIL HEALTH, AERIAL ALMOND MAPPING AND ALMOND LIFECYCLE ASSESSMENT

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.

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)

• Pickup scantron at the start of the day at first session you attend; complete form.
• Sign in and out of each session you attend.
• Pickup verification sheet at conclusion of each session.
• Turn in your scantron at the end of the day at the last session you attend.

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

• Bob Curtis, Almond Board of California, moderator
• Amélie Gaudin, University of California, Davis
• Dani Lightle, UC Cooperative Extension – Glenn County
• Teamrat Ghezzehei, UC Merced
• Brent Holtz, UCCE San Joaquin County
• Sat Darshan Khalsa, University of California, Davis
• Alissa Kendall, University of California, Davis
• Joel Kimmelshue, Land IQ
DEVELOPING COVER CROP SYSTEMS FOR ALMOND ORCHARDS

C.Creze, J.Mitchell, A.Westphal, D.Doll, D.Lightle, M.Culumber, M.Yaghmour, B.Hanson, N.Williams, A.Hodson
WINTER COVER CROPS ARE NOT FREQUENTLY PLANTED IN CALIFORNIA ORCHARDS

CONCERNS

- Risk of frost
- Increase in water usage
- Issues at harvest
- Additional difficulties in management
  - Weed control
  - Winter sanitation
  - Vertebrate pest management
- Cost and uncertainties of economic return
- Lack of information on cover crop management (species, planting dates, termination…)

Resident vegetation is common
Clean berms, unmanaged middles
Mowed during bloom
 Allowed to die or terminated prior to harvest
DESPITE POTENTIAL BENEFITS

- Build up of organic matter and healthier soils
  - Decrease compaction
  - Improve aggregation/infiltration
  - Conservation of precip water - iWUE
  - Earlier field access
  - Dust reduction
- Pollinator health
- Management of problematic weeds
- Management of soil born pests
OUR OBJECTIVES AND MAIN RESEARCH QUESTIONS

#1: develop feasible and practice winter cover crop systems for almond growers which maximize agronomic benefits and reduce operational concerns

What levels of C and N capture and increased in *soil health* may be provided by common cover crop mixtures or natural vegetation during the winter?

Do cover crop *use or help conserve* water in our climate?

How does it impact soil and surface temperature and *frost risk* at blooming?

Can cover crops be used to deter soil born-pests such as *nematodes*?

Do cover crop impact weed pressure and help *control noxious weeds*?

What is the impact on *pollination* of almond orchards?

*How to best manage cover crops to maximize benefits?*
STUDY SITES ACROSS RAINFALL GRADIENT

- **PAM "Pollinator mix"**
  Bracco White Mustard, Diakon Radish, Nemfix Yellow Mustard, Common Yellow Mustard, Canola

- **Soil mix**
  Bracco White Mustard, Diakon Radish, Merced ryegrass, Berseem clover, Common vetch

- **Perennial resident vegetation**
  Conventional herbicide control

4 treatments, replicated designs

**Temp/FROST MONITORING**
Soil, surface and tree

**TERMINATION DATES**
Before bloom or summer

**NEMATODE SUPPRESSION**
Infected orchard

**CONPACTION**
Compare to ripping
WHERE ARE WE AT?

• 1st field season – 3-year study
• All sites recently planted

Measurements

• Cover crop establishment and biomass (C/N inputs)
• Soil health parameters (including aggregation, compaction, OM, salinity…)
• Soil food web and macro fauna
• Winter water dynamics and storage (neutron probes), tree water status in the spring (SWP)
• Weed pressure and species
• Flower visitation by pollinators
• Yields
GROWER SURVEY – WE WANT TO HEAR FROM YOU

Online

Visit us @ our poster location
# 58

https://ucdavis.co1.qualtrics.com/jfe/form/SV_3UepPhXFE82QvS5
PROJECTED PROJECT OUTCOMES

Opportunities

Mostly Agronomic

• Regionalized and updated data relevant to a large number of grower

• Systems approach to help you evaluate benefits and potential tradeoffs in your system/region

• Strong basis to start optimizing cover crop mixes and management according to your objectives

Concerns

Mostly Operational
THANK YOU

AGAUDIN@UCDAVIS.EDU
WEB: GAUDIN.UCDAVIS.EDU
ORCHARD ALMOND HULL INCORPORATION

Dani Lightle, UCCE Glenn, Butte & Tehama
David Doll, UCCE Merced
Amelie Gaudin, Plant Sciences, UC Davis
ALMOND INDUSTRY ‘BY-PRODUCT’: HULL & SHELL

Current value/ton:

• Prime hull: $45-65
• Hull/shell mix: $15-40
• Pure shell: $0-6

Potential future uses:

• Biochar
• CoGen
• Sugar for ethanol production

Supply is increasing while demand is decreasing.
ALMOND INDUSTRY ‘BY-PRODUCT’: HULL & SHELL

Current value/ton:

• Prime hull: $45-65
• Hull/shell mix: $15-40
• Pure shell: $0-6

Potential future uses:

• Biochar
• CoGen
• Sugar for ethanol production

Reapplication of hull & shell to almond orchards
POSSIBLE ADVANTAGES FOR ADDING TO ORCHARDS

- Reduced food safety risk relative to manure based composts
- Nutrient analysis

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Average hull content (%)</th>
<th>Pounds of nutrient per ton</th>
<th>Estimated value³</th>
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</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>0.96</td>
<td>17.4</td>
<td>$8.70</td>
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<tr>
<td>Phosphorous</td>
<td>0.10</td>
<td>2.1²</td>
<td>$1.70</td>
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<tr>
<td>Potassium</td>
<td>2.00</td>
<td>43.5²</td>
<td>$34.80</td>
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<tr>
<td>Calcium</td>
<td>0.20</td>
<td>3.6</td>
<td>$0.90</td>
</tr>
<tr>
<td><strong>Total per ton</strong></td>
<td></td>
<td></td>
<td><strong>$46.10</strong></td>
</tr>
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</table>
OBJECTIVES

This study evaluates tree health and yield to determine if:

1. Almond hulls and shells can be reapplied to orchard floors without impacting production
2. Rates of almond hull and shell application influence tree performance
3. In-season compost applications are as effective as almond hull and shell application.
### METHODS

<table>
<thead>
<tr>
<th>Butte County</th>
<th>Merced County</th>
</tr>
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<tbody>
<tr>
<td>Almond hull/shell mix (2T/ac)</td>
<td>Almond hull and shell mix (1T/ac)</td>
</tr>
<tr>
<td>Almond shell (2T/ac)</td>
<td>Almond hull and shell mix (2T/ac)</td>
</tr>
<tr>
<td>Locally sourced compost tea</td>
<td>Almond shell (1T/ac)</td>
</tr>
<tr>
<td>Untreated control</td>
<td>Locally sourced compost (1T/ac)</td>
</tr>
<tr>
<td></td>
<td>Untreated control</td>
</tr>
</tbody>
</table>
OBJECTIVE 1: DETERMINE IF ALMOND HULL AND SHELL CAN BE RE-APPLIED TO ORCHARD FLOORS WITHOUT INTERFERING WITH PRODUCTION PRACTICES

Merced

March

April

July

University of California
Agriculture and Natural Resources
OBJECTIVES 2 & 3: DOES APPLICATION AFFECT TREE PERFORMANCE; AND HOW DO APPLICATIONS COMPARE TO COMPOST?

• Leaf samples collected in July

• Soil samples also collected & are being analyzed
OBJECTIVES 2 & 3: DOES APPLICATION AFFECT TREE PERFORMANCE; AND HOW DO APPLICATIONS COMPARE TO COMPOST?

- Leaf samples collected in July
- Soil samples also collected & are being analyzed
- No differences in nutrient status between treatments
- May need multiple seasons to see effects on soil &/or leaf tissue analysis
- If interested in specific leaf analysis values, see our poster
OBJECTIVES 2 & 3: DOES APPLICATION AFFECT TREE PERFORMANCE; AND HOW DO APPLICATIONS COMPARE TO COMPOST?

Butte County Average Kernel lbs/ac

Merced County Average Kernel lbs/ac

Kernel pounds

Control Compost tea Hull and shell (two ton) Shell (two ton)

Control Hull and shell (two ton) Shell (one ton)

AB AB B A

AB

Kernel pounds

Control Hull and shell Hull and shell Shell (one ton)

Kernel pounds

Control Shell (one ton)

University of California
Agriculture and Natural Resources
OBJECTIVES 2 & 3: DOES APPLICATION AFFECT TREE PERFORMANCE; AND HOW DO APPLICATIONS COMPARE TO COMPOST?

- Average kernel weight did not differ between treatments at other sites.
- Treatments were applied after bloom & nut set.
- Therefore differences in yield may have been to other factors (e.g. bacterial blast or brown rot incidence).
ACKNOWLEDGEMENTS

• Cooperating growers: Rory Crowley with Nicolaus Nut Company, Burroughs Family Farms, and Hilltop Ranch Inc.

• Cooperating personnel: Anthony Cantu, Giovanni Marquez, Cindy Montes, & Allen Vizcarra

• Funding: Almond Board of California
Teamrat Khalsa
WHOLE ORCHARD RECYCLING

Holtz, B.¹, Browne, G.², Doll, D.³, Westphal, A.⁸, Gaudin, A.⁴, Culumber, M.⁵, Yaghmour, M.⁶, Marvinney, E.⁴, Gordon, P.⁷, Niederholzer, F.⁹, and Jahanzad, E.⁴

University of California Cooperative Extension, San Joaquin¹, Merced³, Fresno⁵, Kern⁶, Madera⁷, and Colusa-Sutter-Yuba Counties⁹, USA
²USDA-ARS, University of California, Davis, USA
⁴Plant Science, University of California, Davis, USA
⁸Nematology, University of California, Riverside, USA
Can whole orchards be incorporated into the soil when they are removed and not burned in the field or in a co-generation plant?

Can we return this organic matter to our orchard soils without negatively effecting the next orchard that will be planted?
The Iron Wolf
a 100,000 lb (45,000 kg) rototiller

http://ucanr.edu/?blogpost=16603&blogasset=74534
Two Treatments:
Orchard Grinding with Iron Wolf
Pushing and Burning Trees
2009 First leaf trees growing in grinding plot

2010 Second leaf trees

No difference in tree circumference

The Grinding did not stunt the second generation orchard
<table>
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<tr>
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<th>2010</th>
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<td></td>
<td>Grind</td>
<td>Burn</td>
<td>Grind</td>
<td>Burn</td>
<td>Grind</td>
<td>Burn</td>
</tr>
<tr>
<td>Ca (meq/L)</td>
<td>4.06 a</td>
<td>4.40 b</td>
<td>2.93 a</td>
<td>3.82 b</td>
<td>4.27 a</td>
<td>3.17 b</td>
</tr>
<tr>
<td>Na (ppm)</td>
<td>19.43 a</td>
<td>28.14 b</td>
<td>13.00 a</td>
<td>11.33 b</td>
<td>11.67 a</td>
<td>12.67 a</td>
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<tr>
<td>Mn (ppm)</td>
<td>11.83 a</td>
<td>8.86 b</td>
<td>12.78 a</td>
<td>9.19 b</td>
<td>29.82 a</td>
<td>15.82 b</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>32.47 a</td>
<td>26.59 b</td>
<td>27.78 a</td>
<td>22.82 b</td>
<td>62.48 a</td>
<td>36.17 b</td>
</tr>
<tr>
<td>Mg (ppm)</td>
<td>0.76 a</td>
<td>1.52 b</td>
<td>1.34 a</td>
<td>1.66 a</td>
<td>2.05 a</td>
<td>1.46 b</td>
</tr>
<tr>
<td>B (mg/L)</td>
<td>0.08 a</td>
<td>0.07 a</td>
<td>0.08 a</td>
<td>0.08 a</td>
<td>0.08 a</td>
<td>0.05 b</td>
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<tr>
<td>NO$_3$-N (ppm)</td>
<td>3.90 a</td>
<td>14.34 b</td>
<td>8.99 a</td>
<td>11.60 a</td>
<td>19.97 a</td>
<td>10.80 b</td>
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<tr>
<td>NH$_4$-N (ppm)</td>
<td>1.03 a</td>
<td>1.06 a</td>
<td>2.68 a</td>
<td>2.28 a</td>
<td>1.09 a</td>
<td>1.06 a</td>
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<tr>
<td>pH</td>
<td>7.41</td>
<td>7.36</td>
<td>6.96 a</td>
<td>7.15 b</td>
<td>6.78 a</td>
<td>7.12 b</td>
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<tr>
<td>EC (dS/m)</td>
<td>0.33 a</td>
<td>0.64 b</td>
<td>0.53</td>
<td>0.64</td>
<td>0.82 a</td>
<td>0.59 b</td>
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<tr>
<td>CEC (meq/100g)</td>
<td>7.40 a</td>
<td>8.47 b</td>
<td>8.04</td>
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<td>OM %</td>
<td>1.22 a</td>
<td>1.38 b</td>
<td>1.24</td>
<td>1.20</td>
<td>1.50 a</td>
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<tr>
<td>C (total) %</td>
<td>0.73 a</td>
<td>0.81 a</td>
<td>0.79 a</td>
<td>0.73 a</td>
<td>0.81 a</td>
<td>0.63 b</td>
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<tr>
<td>C-Org-LOI</td>
<td>0.71 a</td>
<td>0.80 b</td>
<td>0.72</td>
<td>0.70</td>
<td>0.87 a</td>
<td>0.68 b</td>
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<tr>
<td>Cu (ppm)</td>
<td>6.94 a</td>
<td>6.99 a</td>
<td>7.94 a</td>
<td>7.54 a</td>
<td>8.87 a</td>
<td>7.92 b</td>
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Blue Pair = grinding significantly less than burning

Yellow pair = grinding significantly greater than burning
## Soil Analysis

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<td></td>
<td>Grind</td>
<td>Burn</td>
<td>Grind</td>
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<td>Burn</td>
<td>Grind</td>
<td>Burn</td>
<td>Grind</td>
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<tr>
<td>Ca (meq/L)</td>
<td>3.78</td>
<td>3.25</td>
<td>7.55</td>
<td>5.45</td>
<td>4.02</td>
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<td>Na (ppm)</td>
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<td>1.21</td>
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<tr>
<td>Mn (ppm)</td>
<td>26.35</td>
<td>5.71</td>
<td>14.46</td>
<td>10.65</td>
<td>7.31</td>
<td>4.67</td>
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<tr>
<td>Fe (ppm)</td>
<td>32.56</td>
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<td>38.58</td>
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<td>24.29</td>
<td>17.21</td>
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<td>Mg (ppm)</td>
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<td>B (mg/L)</td>
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<td>0.07</td>
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<td>0.05</td>
<td>0.07</td>
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<td>NO₃-N (ppm)</td>
<td>20.11</td>
<td>12.27</td>
<td>26.53</td>
<td>18.89</td>
<td>20.64</td>
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<td>1.36</td>
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<td>0.65</td>
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<td>K (mg/L)</td>
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<td>19.76</td>
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<td>7.27</td>
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<td>EC (dS/m)</td>
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<td>0.90</td>
<td>0.38</td>
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<td>CEC(meq/100g)</td>
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<td>OM %</td>
<td>1.55</td>
<td>1.06</td>
<td>1.21</td>
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<td>1.37</td>
<td>1.08</td>
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<tr>
<td>C (total) %</td>
<td>0.87</td>
<td>0.51</td>
<td>0.71</td>
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<td>0.66</td>
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<tr>
<td>C-Org-LOI</td>
<td>0.87</td>
<td>0.61</td>
<td>0.70</td>
<td>0.54</td>
<td>0.79</td>
<td>0.62</td>
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<tr>
<td>Cu (ppm)</td>
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<td>7.73</td>
<td>7.51</td>
<td>7.03</td>
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**Blue Pair** = grinding significantly less than burning

**Yellow pair** = grinding significantly greater than burning
## Soil Analysis

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<tr>
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<th>2016</th>
<th>2017</th>
<th>2018</th>
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<td>Burn</td>
<td>Grind</td>
<td>Burn</td>
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<tr>
<td>Ca (meq/L)</td>
<td>5.53 a</td>
<td>2.66 b</td>
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<td>3.05</td>
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<tr>
<td>Na (ppm)</td>
<td>1.50 a</td>
<td>1.20 b</td>
<td>0.89 a</td>
<td>0.72 b</td>
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<tr>
<td>Mn (ppm)</td>
<td>10.86 a</td>
<td>7.66 b</td>
<td>9.03 a</td>
<td>6.79 b</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>30.25 a</td>
<td>23.15 b</td>
<td>33.23 a</td>
<td>28.01 b</td>
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<td>Mg (ppm)</td>
<td>2.60 a</td>
<td>1.29 b</td>
<td>1.46</td>
<td>1.43</td>
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<td>B (mg/L)</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
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<td>NO₃-N (ppm)</td>
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<td>12.66</td>
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<td>1.15 a</td>
<td>0.98 b</td>
<td>1.39</td>
<td>1.31</td>
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<td>K (mg/L)</td>
<td>54.78 a</td>
<td>11.33 b</td>
<td>11.06</td>
<td>11.68</td>
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<tr>
<td>pH</td>
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<td>7.37 b</td>
<td>6.94</td>
<td>7.02</td>
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<td>8.35</td>
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<td>7.78</td>
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<tr>
<td>OM %</td>
<td>1.41 a</td>
<td>1.10 b</td>
<td>1.52 a</td>
<td>1.07 b</td>
</tr>
<tr>
<td>C (total) %</td>
<td>0.82 a</td>
<td>0.55 b</td>
<td>0.79 a</td>
<td>0.55 b</td>
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<td>C-Org-LOI</td>
<td>0.82 a</td>
<td>0.64 b</td>
<td>0.88 a</td>
<td>0.62 b</td>
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<tr>
<td>Cu (ppm)</td>
<td>8.43</td>
<td>8.20</td>
<td>9.25</td>
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</table>

**Blue Pair = grinding significantly less than burning**

**Yellow pair = grinding significantly greater than burning**
### Trunk Diameter

<table>
<thead>
<tr>
<th>Year</th>
<th>Grind</th>
<th>Burn</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>4.87</td>
<td>4.96</td>
<td>P= 0.19</td>
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<tr>
<td>2010</td>
<td>14.56</td>
<td>15.22</td>
<td>P=0.07</td>
</tr>
<tr>
<td>2011</td>
<td>22.39</td>
<td>22.72</td>
<td>P=0.38</td>
</tr>
<tr>
<td>2012</td>
<td>30.53</td>
<td>30.23</td>
<td>P=0.18</td>
</tr>
<tr>
<td>2013</td>
<td>38.52</td>
<td>37.73</td>
<td>P=0.09</td>
</tr>
<tr>
<td>2014</td>
<td>46.50</td>
<td>45.24</td>
<td>P=0.01</td>
</tr>
<tr>
<td>2015</td>
<td>55.71</td>
<td>53.79</td>
<td>P=0.01</td>
</tr>
<tr>
<td>2016</td>
<td>63.15</td>
<td>60.58</td>
<td>P=0.007</td>
</tr>
</tbody>
</table>

2017

Trunk Diameter
<table>
<thead>
<tr>
<th>Year</th>
<th>Grind</th>
<th>Burn</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>687.40 lbs/ac</td>
<td>687.37 lbs/ac</td>
<td>0.03 lbs/ac (P= 0.49)</td>
</tr>
<tr>
<td>2012</td>
<td>1,472.40 lbs/ac</td>
<td>1,379.42 lbs/ac</td>
<td>92.98 lbs/ac (P=0.19)</td>
</tr>
<tr>
<td>2013</td>
<td>1909.64 lbs/ac</td>
<td>1667.91 lbs/ac</td>
<td>241.73 lbs/ac (P=0.05)</td>
</tr>
<tr>
<td>2014</td>
<td>2272.11 lbs/ac</td>
<td>1767.25 lbs/ac</td>
<td>504.86 lbs/ac (P=0.12)</td>
</tr>
<tr>
<td>2015</td>
<td>1,072.90 lbs/ac</td>
<td>877.54 lbs/ac</td>
<td>195.36 lbs/ac (P=0.11)</td>
</tr>
<tr>
<td>2016</td>
<td>1,341.97 lbs/ac</td>
<td>1,206.96 lbs/ac</td>
<td>135.01 lbs/ac (P=0.14)</td>
</tr>
<tr>
<td>2017</td>
<td>1956.01 lbs/ac</td>
<td>1539.17 lbs/ac</td>
<td>416.84 lbs/ac (P=0.07)</td>
</tr>
<tr>
<td>Total</td>
<td><strong>10,712.43 lbs/ac</strong></td>
<td><strong>9,125.62 lbs/ac</strong></td>
<td><strong>1,586.81 lbs/ac</strong></td>
</tr>
<tr>
<td>Year</td>
<td>Grind</td>
<td>Burn</td>
<td>Difference</td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>-------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>2014</td>
<td>2,147.02 lbs/ac</td>
<td>1,957.97 lbs/ac</td>
<td>189.05 lbs/ac (P=0.02)</td>
</tr>
<tr>
<td>2016</td>
<td>2,821.86 lbs/ac</td>
<td>2,386.02 lbs/ac</td>
<td>435.84 lbs/ac (P=0.03)</td>
</tr>
<tr>
<td>2017</td>
<td>2,246.66 lbs/ac</td>
<td>1,871.86 lbs/ac</td>
<td>374.80 lbs/ac (P=0.01)</td>
</tr>
<tr>
<td>Total</td>
<td>10,712.43 lbs/ac</td>
<td>9,125.62 lbs/ac</td>
<td>999.69 lbs/ac</td>
</tr>
</tbody>
</table>
The trial went 57 days without an irrigation during harvest. Trees growing in the grind plots had less water stress.
POTENTIAL OF WHOLE ORCHARD RECYCLING TO INCREASE RESILIENCY OF ALMOND PRODUCTION TO WATER SHORTAGES


University of California Cooperative Extension, San Joaquin 1, Merced 3, Fresno 5, Counties, USA

2 USDA-ARS, University of California, Davis, USA

4 Plant Science, University of California, Davis, USA
Stem Water Potential (Grind vs Burn)

- **Burn**
- **Grind**

<table>
<thead>
<tr>
<th>Date</th>
<th>Burn</th>
<th>Grind</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soil Organic Matter and Available Water Capacity
by
Berman D. Hudson
J. Soil and Water Cons. 49(2):189-194.

We estimate that Whole Orchard recycling has increased the water holding capacity of our soil by 15% based on this curve and that SOM has increased from in 1.07 (burn) to 1.52 (grind) (2017 results).
WHOLE ORCHARD RECYCLING HAS:

• Increased soil organic matter
• Increased soil organic carbon
• Increased soil nutrients
• Increase soil microbial diversity
• Increased orchard productivity
WILL WHOLE ORCHARD RECYCLING:

- Increase water holding capacity?
- Bind pesticides and fertilizers?
- Increase Nitrogen efficiency?
- Increase/decrease Green House Gas production?
- Provide carbon credits to farmers?
A few growers have used manure spreaders to spread wood chips back on the soil surface.
G & F Ag Services orchard removal typically involves 5 machines and costs ~$600 acre
G & F Ag Services in Ripon has purchased two Kuhn & Knight Spreaders and modified them for spreading wood chips.

Keeping the chips and having them spread back onto your orchard floor will cost an additional $400 per acre.

Wood chips are spread uniformly over the entire field surface.
When 64 tons of wood chips are returned to the soil per acre:

N= 0.31 %, 396 lbs/ac
K= 0.20 %, 256 lbs/ac
Ca= 0.60 %, 768 lbs/ac
C= 50 %, 64,000 lbs/ac

The nutrients will be released gradually and naturally
In areas of the orchard where the wood chips where heavily applied there is total weed control.

We are trying to make sure the trees don’t stunt—applying nitrogen through water weekly.
This Duratech grinder is mobile and spreads the wood chips evenly as it grinds.

Efficiencies are improved every year that whole orchard recycling is performed.
ORGANIC MATTER AMENDMENTS

Sat Darshan S. Khalsa
University of California Davis
RESEARCH

• Integrated management
• Composted sources
  • Dairy manure
  • Green waste
• Timing
  • October
  • April
• Rate – 4 tons/ac
• Placement – Tree berm
• Analyses
  • Soil nutrients
  • Nitrogen availability
APPROACH

Control

Treatment

20 in

H₂O

NH₄⁺

+ NO₃⁻

H₂O

NH₄⁺

+ NO₃⁻
## SOIL ORGANIC MATTER

<table>
<thead>
<tr>
<th>Source</th>
<th>Total organic carbon</th>
<th>Total nitrogen</th>
<th>$p$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.72 b</td>
<td>0.49 b</td>
<td>0.03</td>
</tr>
<tr>
<td>Composted manure</td>
<td>5.12 b</td>
<td>0.53 b</td>
<td></td>
</tr>
<tr>
<td>Green waste compost</td>
<td>5.90 a</td>
<td>0.60 a</td>
<td></td>
</tr>
<tr>
<td>April application</td>
<td>5.12 b</td>
<td>0.54 b</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>October application</td>
<td>5.90 a</td>
<td>0.59 a</td>
<td>0.04</td>
</tr>
</tbody>
</table>

- $g \text{ C kg}^{-1} \text{ soil}$
- $g \text{ N kg}^{-1} \text{ soil}$
## SOIL NUTRIENTS

<table>
<thead>
<tr>
<th>Source</th>
<th>NH$_4^+$-N</th>
<th>NO$_3^-$-N</th>
<th>PO$_4^{3-}$-P</th>
<th>K$^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg N kg$^{-1}$ soil</td>
<td>mg N kg$^{-1}$ soil</td>
<td>mg P kg$^{-1}$ soil</td>
<td>mg K kg$^{-1}$ soil</td>
</tr>
<tr>
<td>Control</td>
<td>0.66 a</td>
<td>12.3 a</td>
<td>6.86 a</td>
<td>142 b</td>
</tr>
<tr>
<td>Composted manure</td>
<td>0.39 a</td>
<td>11.9 a</td>
<td>10.5 a</td>
<td>178 a</td>
</tr>
<tr>
<td>Green waste compost</td>
<td>0.66 a</td>
<td>13.8 a</td>
<td>10.0 a</td>
<td>166 b</td>
</tr>
<tr>
<td>p value</td>
<td>0.22</td>
<td>0.34</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Timing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>April application</td>
<td>0.56 a</td>
<td>22.0 a</td>
<td>8.07 b</td>
<td>154 b</td>
</tr>
<tr>
<td>October application</td>
<td>0.50 a</td>
<td>8.80 b</td>
<td>12.4 a</td>
<td>193 a</td>
</tr>
<tr>
<td>p value</td>
<td>0.66</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
CONCLUSIONS

• Gains in soil organic matter including soil N
• Building of soil P and K
• Largest effects in October treatment
• Composted manure viable K source
• Increasing N availability
• Risk of N leaching from April application
• See our poster for effects on soil moisture and tree stress
ALMOND LCA MODEL UPDATES: CHANGING BIOMASS CO-PRODUCT FATES

Dr. Elias Marvinney and Prof. Alissa Kendall
Dept. of Civil & Environmental Engineering, UC Davis
LIFE CYCLE ASSESSMENT (LCA)
A method for characterizing, quantifying, and interpreting environmental flows for a product or service from a “cradle-to-grave” perspective.

Our previous model focused on energy use, global warming potential, and air pollution. Our future model focuses on an expanded group of environmental impact categories and detailed modeling of direct and indirect water use.
LCA BASELINE AND SCENARIO ANALYSIS RESULTS

Baseline Results for Brownskin Almond

<table>
<thead>
<tr>
<th>GWP₁₀₀ (kg CO₂e)</th>
<th>Total Energy (MJ/10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Operations</td>
<td></td>
</tr>
<tr>
<td>Hulling &amp; Shelling</td>
<td></td>
</tr>
<tr>
<td>Harvest</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td></td>
</tr>
<tr>
<td>Biomass Management</td>
<td></td>
</tr>
<tr>
<td>Nutrient Management</td>
<td></td>
</tr>
<tr>
<td>Pest Management</td>
<td></td>
</tr>
<tr>
<td>Co-Product Credit</td>
<td></td>
</tr>
<tr>
<td>△ Net Results from Displacement</td>
<td></td>
</tr>
</tbody>
</table>

Comparison to other unprocessed foods

<table>
<thead>
<tr>
<th></th>
<th>GWP₁₀₀ (g CO₂eq kcal⁻¹)</th>
<th>GWP₁₀₀ (kg CO₂eq kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Walnut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Walnut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Almond</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmed Trout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pork</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 0.29 kg CO₂eq per kg kernel
- 0.15 g CO₂eq per nutritional calorie
SCENARIO ANALYSIS SHOWS THE BIOMASS FATE IS MOST IMPORTANT FACTOR

Biggest potential for deep reductions in carbon intensity of almonds
UPDATES FOCUS ON BIOMASS FATE

- Biomass utilization is focused on orchard removal biomass, though shells and prunings are also biomass generated by orchards.
- Options for biomass fate are changing fast:
  - Biomass plant closures happening across the valley, changing the potential for energy recovery from orchard removals.
  - New research on the potential for long term carbon storage through whole-orchard recycling could provide deep reductions in almond carbon intensity.
- Ongoing research is focusing on these two areas.
NEW DATA: CLEARING RECORDS

Extracted data on orchard biomass feedstock from clearing company records and estimate

- Transport Cost
- Transport Distance
- Feedstock Value at Power Plant

Refined estimates of almond biomass production using aerial imagery to correct acreage estimates (BDT per acre)
BIOMASS POWER PLANT ECONOMIC “BREAKEVEN” RADIUS

- Calculated using the following data:
  - EOL biomass transport cost
  - Power plant payment for feedstock
  - Distance from orchard clearing site
- Determines which power plants can feasibly accept biomass co-product from almond orchards
UPDATE TO EXTENT AND AGE OF ALMOND ORCHARDS IN CALIFORNIA

• Allows LCA model to consider each orchard block as an individual entity to account for variation in age-specific factors

• For example, likelihood of orchard removal in any given year, which can be used to model future biomass supply to power plants
Estimated Almond Biomass to Energy (Central Valley)

**Scenario 1:** currently active power plants maintained through 2050

**Scenario 2:** Most currently active BMPPs closed by 2020, only new projects/proposals active through 2050

**Scenario 3:** Current plants maintained through 2050, plus currently idled BMPPs returned to active status starting in 2020 (2 reactivated every 5 years)
TEMPORARY CARBON STORAGE AND ORCHARD RECYCLING

- Carbon Pools (Stocks) and Flows in the Orchard System
- Pools: standing biomass, woodchips in soil, soil carbon, atmosphere and aquifers
- Flows: transfer of carbon between pools
- Data being analyzed from Brent Holtz’s barrel experiments
  - Chipped woody biomass, unincorporated
  - Chipped woody biomass, incorporated
Early estimates for effect of surface mulch

Surface Mulch with Soil C Max at 6.6% (barrel experiments)

Net GHG Impact at EOL 1: -6.74E+04 kg CO₂eq ac⁻¹

Net GHG Impact at EOL 2: -3.19E+04 kg CO₂eq ac⁻¹
Early estimates for effects of whole orchard recycling

**Whole Orchard Recycling with Soil C Max at 6.6%**

![Graph showing Early estimates for effects of whole orchard recycling](image)

- **Net GHG Impact at EOL 1:** 
  -6.74E+04 kg CO₂eq ac⁻¹

- **Net GHG Impact at EOL 2:** 
  -5.35E+04 kg CO₂eq ac⁻¹
FUTURE AND ONGOING WORK

• Continued research on LCA model improvements include
  - Continued modeling of soil carbon dynamics under recycling
  - Continued modeling of biomass powerplant commissioning and decommissioning effect on orchard biomass fate
  - Improved modeling of market dynamics for almond co-products (e.g. hulls) in LCA model
  - Improved and spatially resolved modeling of irrigation water-related energy
AERIAL ALMOND MAPPING

Joel Kimmelshue, PhD, CPSS
Land IQ
Cooperators and Resources

• Primary Cooperators
  – Almond Board of California (ABC)
  – Land IQ, LLC

• Main Resources
  – United States Department of Agriculture (USDA) National Agricultural Imaging Program (NAIP) imagery
  – Landsat and other imagery
  – California Department of Water Resources (DWR) County Crop Mapping
  – USDA-National Agricultural Statistics Service (NASS) CropScape Mapping
  – USDA-NASS Tabular Records
  – California Department of Pesticide Regulation (DPR) Records
  – County Agricultural Commissioner Crop Reports
  – Grower Knowledge
  – Agronomic and Remote Sensing Expertise
ACREAGE RESULTS
ACREAGE RESULTS - BEARING

• USDA-NASS and Land IQ Acreage Comparisons

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA-NASS</td>
<td>770,000</td>
<td>820,000</td>
<td>880,000</td>
<td>940,000</td>
</tr>
<tr>
<td>Land IQ</td>
<td>810,386</td>
<td>885,575</td>
<td>938,441</td>
<td>981,813</td>
</tr>
<tr>
<td>Difference</td>
<td>40,386</td>
<td>65,575</td>
<td>58,441</td>
<td>41,813</td>
</tr>
<tr>
<td>% Difference</td>
<td>5.2%</td>
<td>8.0%</td>
<td>6.6%</td>
<td>4.4%</td>
</tr>
</tbody>
</table>

• Key Conclusions
  • Algorithms and approaches have been developed and implemented with a remote sensing approach
  • Ground truthing, accurate field boundaries, agronomic knowledge, key algorithms are all key components
  • Accuracy = 98.8%
ACREAGE RESULTS – NON BEARING

• USDA-NASS and Land IQ Acreage Comparisons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA-NASS</td>
<td>85,000</td>
<td>110,000</td>
<td>170,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Land IQ</td>
<td>124,568</td>
<td>118,595</td>
<td>189,505</td>
<td>280,102</td>
</tr>
<tr>
<td>Difference</td>
<td>39,568</td>
<td>8,595</td>
<td>19,505</td>
<td>(19,898)</td>
</tr>
<tr>
<td>% Difference</td>
<td>46.6%</td>
<td>7.8%</td>
<td>11.5%</td>
<td>-6.6%</td>
</tr>
</tbody>
</table>

• Key Conclusions
  • Non-Bearing acreage is the most difficult to estimate
  • Cannot be remotely sensed
  • Must rely on ground truthing information and other non-spatial information
  • Implementing some modifications to ground truthing in 2017
  • Accuracy = 93.9%
ACREAGE RESULTS – TOTAL

• USDA-NASS and Land IQ Acreage Comparisons

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>USDA-NASS</td>
<td>855,000</td>
<td>930,000</td>
<td>1,050,000</td>
<td>1,240,000</td>
</tr>
<tr>
<td>Land IQ</td>
<td>934,954</td>
<td>1,004,170</td>
<td>1,127,946</td>
<td>1,261,915</td>
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<tr>
<td>Difference</td>
<td>79,954</td>
<td>74,170</td>
<td>77,976</td>
<td>21,915</td>
</tr>
<tr>
<td>% Difference</td>
<td>9.4%</td>
<td>8.0%</td>
<td>7.4%</td>
<td>1.8%</td>
</tr>
</tbody>
</table>

• Key Conclusions
  • Combination of bearing and non-bearing
  • Continuing to increase year over year
  • Large increase in removed orchards in Kern, Kings, and Tulare counties from 2014 to 2016
  • Large increase in plantings as well statewide
  • Accuracy = 98.1%
WEB MAP APPLICATION
WEB MAP APPLICATION

- www.almonds.com/maps
- It’s a “living” map and will continually be updated over time as new analysis results become available (e.g. 2016 mapping).

- Web map components:
  - Various map backgrounds
  - Age Analysis by Orchard
  - Recharge Suitability by Orchard
  - Irrigation/Water Supply Districts
  - Irrigated Lands Regulatory Program Boundaries
  - State Assembly, State Senate and Congressional District Boundaries
APPLICATIONS OF MAPPING

California Almonds
Almond Board of California
AGE ANALYSIS

• Question: Can you also determine the age of each orchard?
• Answer: Yes
  • Once orchards are mapped, only then can age be determined
  • A backwards looking approach (through 1984) at various imagery sources is conducted
  • Once “signature” appears as open ground, then this establishes planting date
  • +/- 1-2 years
  • Accuracy = 90-95%

• Significance: Potential Uses
  • Yield forecasts/enhancements
  • Biomass/carbon accumulation
GROUNDWATER RECHARGE

• Question: Given increased interest in winter recharge, can you tell which areas are most suitable for intentional recharge in almonds?

• Answer: Yes

The index provides a locating tool for determination of suitable areas for intentional groundwater recharge in any crop.

• Significance

✓ Resulted in approximately 600,000 acres of suitable almond orchards
✓ Allows growers and water providers the ability to locate most suitable orchards in relation to water supply infrastructure
✓ Prioritizes land for recharge opportunities
✓ Does not replace site-specific investigations
✓ Allows for interaction with other researchers for assessing impact on crop, soils, leaching, etc.
CROP EXPANSION

• Question: Can you determine what was there before almonds, was it irrigated and how much water did it use?

• Answer: Yes
  • By knowing where almonds are on an orchard by orchard basis AND the age of orchards,
  • A comparison between the statewide mapping and previous DWR county mapping results from 10-15 years prior can be made.

• Significance
  • Comparison of water use by crop
  • Consumptive use vs. applied water
  • Efficiency

<table>
<thead>
<tr>
<th>Previous crop</th>
<th>Acres converted to almonds within change analysis period</th>
<th>Percentage of total analyzed almond acres converted within change analysis period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>40,074</td>
<td>9%</td>
</tr>
<tr>
<td>Almonds</td>
<td>101,522</td>
<td>23%</td>
</tr>
<tr>
<td>Citrus</td>
<td>1,127</td>
<td>0%</td>
</tr>
<tr>
<td>Corn</td>
<td>15,210</td>
<td>4%</td>
</tr>
<tr>
<td>Cotton</td>
<td>46,331</td>
<td>11%</td>
</tr>
<tr>
<td>Developed</td>
<td>2,245</td>
<td>1%</td>
</tr>
<tr>
<td>Fallow/Idle</td>
<td>6,921</td>
<td>2%</td>
</tr>
<tr>
<td>Field and Row Crops</td>
<td>21,241</td>
<td>5%</td>
</tr>
<tr>
<td>Forage</td>
<td>36,845</td>
<td>9%</td>
</tr>
<tr>
<td>Grains/Cereals</td>
<td>3,117</td>
<td>1%</td>
</tr>
<tr>
<td>Grapes</td>
<td>43,621</td>
<td>10%</td>
</tr>
<tr>
<td>Melons and Squash</td>
<td>5,657</td>
<td>1%</td>
</tr>
<tr>
<td>Native</td>
<td>34,302</td>
<td>8%</td>
</tr>
<tr>
<td>Other Fruit/Nut Tree</td>
<td>8,578</td>
<td>2%</td>
</tr>
<tr>
<td>Pasture</td>
<td>11,015</td>
<td>3%</td>
</tr>
<tr>
<td>Peaches and Nectarines</td>
<td>8,350</td>
<td>2%</td>
</tr>
<tr>
<td>Plums/Prunes</td>
<td>5,506</td>
<td>1%</td>
</tr>
<tr>
<td>Rice</td>
<td>4,424</td>
<td>1%</td>
</tr>
<tr>
<td>Root and Tuber Crops</td>
<td>3,344</td>
<td>1%</td>
</tr>
<tr>
<td>Seed Crops</td>
<td>2,451</td>
<td>1%</td>
</tr>
<tr>
<td>Specialty</td>
<td>2,551</td>
<td>1%</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>21,443</td>
<td>5%</td>
</tr>
<tr>
<td>Vegetable Crop</td>
<td>1,633</td>
<td>0%</td>
</tr>
<tr>
<td>Walnuts</td>
<td>4,579</td>
<td>1%</td>
</tr>
</tbody>
</table>
SCHOOL PROXIMITY ANALYSIS

• Question: Driven by regulations at the Department of Pesticide Regulation, can you determine how many orchards would be impacted by a notification to spray rule.

• Answer: Yes
  • By knowing where almonds are on an orchard by orchard basis AND the location of schools and daycares, a proximity analysis was conducted to determine how many orchards would be impacted.

• Significance
  • Approximately 51,450 acres would be impacted
  • Average orchard size was 34 acres
  • Representing 1,513 orchards
SOLAR FACILITIES

• Question: Can you determine the extent of solar installations and generation in almond orchards and processing facilities?

• Answer: Yes

  • By knowing where almonds are on an orchard by orchard basis AND the location of hullers, shellers, processors and handles, a spatial point layer was created to identify solar facilities.

• Significance

  • Nearly one-third (29%) of almond facilities use solar energy.
  • Just seven percent (7%) of almond orchards have a solar facility within or immediately adjacent to the orchard.
NITROGEN ASSESSMENT

• Question: As a result of pending legislation, can you determine how many almond orchards are within areas of concern for high concern for nitrogen concentrations?

• Answer: Yes
  
  By knowing where almonds are on an orchard by orchard basis AND the areas identified as high concern for nitrogen through various regulatory programs and spatial analysis can be completed.

• Significance
  
  • Over half (55.6%) of the almond acreage in the state falls in a high vulnerability area for ILRP.
  
  • One third of the almond acreage (30.4%) falls in Priority 1 Basins for CV-Salts.
Acknowledgements

- Almond Board of California
- Land IQ
  - Mica Heilmann, BS, CPSS
  - Zhongwu Wang, PhD
  - Seth Mulder, MS, CPAg, CCA
  - Stephanie Tillman, MS, CPAg
  - Chris Stall, MS
  - Casey Gudel, MS
  - Naveed Sami, MS
  - Justin Sitton, BS
  - Cody Fink, MS
  - Andrew Loberg, BS
  - Nolan Schultz
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.

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)
- Pickup scantron at the start of the day at first session you attend; complete form.
- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.
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
What’s Next

Tuesday, December 5 at 4:15 p.m.

• State of the Industry – Hall C

Be sure to join us at 5:30 p.m. in Hall A+B for Dedicate Trade Show Time and Opening Reception, sponsored by The Bank of Stockton