AGENDA

• Sebastian Saa, Almond Board of California, moderator
• Guangwei Huang, Almond Board of California, moderator
• Jesse Roseman, Almond Board of California
• Sergio Capareda, Texas A&M
• Ted Strauss, NRCS
• Chris Simmons, UC Davis
Reducing Dust from Almond Harvest

Research, Regulations and Tracking Progress

- 80% of almonds within San Joaquin Valley Air Basin (NASS, Land IQ)

- Extensive research by ABC for over 10 years into how to reduce dust emissions, partly to contribute to PM10 Attainment
  - 2012 white paper reduced estimated PM10 Emission Factor by 31%

- To track progress, California Almond Sustainability Program (CASP) has asked questions about dust reduction practices since 2009

<table>
<thead>
<tr>
<th>Agricultural Harvest Operation Emission Factor</th>
<th>Lbs. PM10/ Acre/ Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond Shaking</td>
<td>3.47</td>
</tr>
<tr>
<td>Almond Sweeping</td>
<td>4.15</td>
</tr>
<tr>
<td>Almond Pickup</td>
<td>23.6</td>
</tr>
<tr>
<td>Almond Total</td>
<td>31.2</td>
</tr>
</tbody>
</table>
CASP: Reducing Harvest Dust Practice Adoption

• To prepare for 2025 Goals, SureHarvest looked at related questions

• All 10 CASP harvest dust questions align with ABC’s Harvest Dust website content and publications.

• 7 questions 90% or greater adoption
  – Growers are reporting they’re doing well preparing orchard floor, directing dust into canopy, etc.

• 3 practices show room for improvement
  – 41% used sweeper head with wire tines only
  – 67% used sweepers designed to minimize passes and reduce dust
  – 68% used a low dust harvester
## CASP: Reducing Harvest Dust Practice Adoption

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>REDUCTION</th>
<th>CASP ADOPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Orchard Floor</td>
<td>--</td>
<td>96%</td>
<td>Year-round floor management resulted in a smooth, level and clean orchard floor at harvest, to help optimize harvest efficiency and minimize dust.</td>
</tr>
<tr>
<td>Plan Route</td>
<td>--</td>
<td>94% and 99%</td>
<td>A harvest dust management plan was implemented that ensured operators of sweepers and pickup machines (including custom harvesters) and others involved in harvest activities were appropriately trained before harvest. Sweeper and pickup machine passes and travel direction directed dust into tree canopies (filter mechanism) and away from roads, homes and other sensitive locations such as schools, hospitals and day care centers.</td>
</tr>
<tr>
<td>Sweeper Height .5”</td>
<td>70%</td>
<td>94%</td>
<td>To reduce dust, the sweeper head was set at the manufacturer-recommended height (not lower).</td>
</tr>
<tr>
<td>(2012)</td>
<td>Wire Tines Only</td>
<td>--</td>
<td>41%</td>
</tr>
</tbody>
</table>
## CASP: Reducing Harvest Dust Practice Adoption

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>REDUCTION</th>
<th>CASP ADOPTION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced-pass Sweeping (2009)</td>
<td>49%</td>
<td>67%</td>
<td>Harvest sweepers designed to minimize passes and reduce dust were used (e.g., sweepers with a mounted berm brush).</td>
</tr>
<tr>
<td>Fine Tune Settings</td>
<td>--</td>
<td>99%</td>
<td>The angle of the sweeper blower spout and speed of the fan were adjusted to match orchard conditions so only nuts were moved and not soil.</td>
</tr>
<tr>
<td>Ground Speed</td>
<td>--</td>
<td>99%</td>
<td>Groundspeed and separator fan speed for conventional pickup machines were lowered to match local conditions (e.g., 1.5 mph instead of 3 mph groundspeed, and 910 instead of 1,080 rpm fan speed).</td>
</tr>
<tr>
<td>Lower Fan Speeds (2011)</td>
<td>77% MAX</td>
<td>“”</td>
<td>“”</td>
</tr>
<tr>
<td>Low-dust Harvester</td>
<td>52% AVG.</td>
<td>68%</td>
<td>Was a low dust harvester used?</td>
</tr>
</tbody>
</table>
Development of Low-Dust Harvester Incentive

- March 2017 ABC asked by San Joaquin Valley Air Pollution Control District to evaluate adoption and efficacy of low-dust harvesters, as part of “leaving no stone unturned” in development of PM2.5 plan and associated agricultural incentives
  - Harvester Survey results analysis received July
  - Harvester Dust Results (Dr. Capareda) presented to AgTech on Sep. 24

- District approves $1M for pilot low-dust harvester program on Nov. 15
Harvester Survey

Background and Purpose

• The San Joaquin Valley Air Pollution Control District, in partnership with The Almond Board of California and California Walnut Board, developed a survey on harvester practices and perceptions to inform development of an incentive program encouraging growers to utilize low-dust technology harvesters.

• Both walnut and almond harvesters were covered, as they use similar machines

Methodology

*SMS Research Advisors conducted an online survey among producers*

• **Survey Length**: Up to 20 questions (length depending on question rotation) on 2017 production

• **Database**: Almond and Walnut Boards distributed the survey to their databases of member producers
  – SMS Research assumed all records in the databases were qualified to participate (no screener questions)

• **Sponsorship**: Almond Board and Walnut Board were revealed as study sponsors

• **Incentive**: All participants received a $10 Amazon gift card for participating

• **Field Dates**: April 20, 2018 – May 18, 2018
Survey Participation

Completes by Crop Type

164 completed surveys (26 excluded from analysis due to undetermined crop-type)

- Almond exclusive: 89 completes (54%)
- Walnut exclusive: 19 completes (12%)
- Both Almond and Walnut: 30 completes (18%)

Completes by Role

- 89 owner-operator (44 custom operators, 45 non-custom operators)
- 33 land-owners, non-operators (i.e., producers who hire custom operators)
- 16 operator, non-owners (i.e., borrow equipment)

Did Survey Reflect the Industry?

- 48% respondents greater than 250 acres (12% reported 2017 Almond Almanac); 584 acres avg. almond farm size
Current Harvester Fleet

- Almond growers likely to already use a low-dust harvester (69%)
- Higher use rate than walnuts
- Majority of Almond exclusive harvesters are Flory brand, remainder Exact and Weiss-McNair
- Majority of almond harvesters less than 10 years old (61%)
- Majority of Almond exclusive harvesters are PTO (67%)
  - Significantly different than Walnut exclusive harvesters, which are majority self-driven (87%)

Harvester Share by Manufacturer
(Out of Total Number of Harvesters Used)
(n) = number of respondents

- 9% (4) Exact
- 60% (26) Flory
- 30% (13) Weiss-McNair
- Other
Incentive Awareness

Incentive Awareness (Almond exclusive)

- 45% aware of current NRCS low-dust harvester program, but still have limited participation
  - 12% received incentives through the program
  - 21% aware, but don’t qualify
  - 9% plan on enrolling in 2018

Incentive Interest

- 57% interested or somewhat interested in receiving information about new low-dust incentive
  - Those who are highly interested (9-10 rating) tend to be unaware of EQIP, or do not qualify for the program. Those who do not qualify for EQIP are still interested in additional programs
  - Those who already receive EQIP incentives are less interested in a new low-dust incentive program
  - Interest similar among both custom and non-custom operators
  - Participants who harvest both nut types show the greatest interest, followed by almond-exclusive participants

Expected Incentive

- 50% most common expected incentive level (avg. 37%)
Program Interest

- 1 in 5 (16%) almond exclusive respondents disengaged
- Those with low interest in incentive are either satisfied with current harvester, or view low-dust harvesters as financially unattainable (even with assistance)
  - Financial enticement does not strengthen program interest among 1 in 3 participants
  - The remaining moderate to low interest participants do not feel enough pressure or value to change— they are mostly satisfied with their current harvester(s)
- Producers who own land but do not personally harvest (hire custom harvesters) show potential as influencer audience
  - 1 in 4 of these participants show high interest in a low-dust program
  - Accept slightly lower discounts or incentives (avg. 28%)
Questions?
jroseman (at) almondboard.com
Project 1: Establishment of Newer PM$_{2.5}$ Emission Factors with Various Almond Harvesting Machinery

Project 2: Development of Simple Dust Measurement Techniques to Aid in Long-Term Dust Reduction Program for Almond Harvesting Operations Using Drone Technologies

Sergio C. Capareda, PhD, PE
Biological and Agricultural Engineering Department
Texas A&M University
Problem and Significance

• Project 1 Significance
  – Provide newer and updated emission factor for almond harvesting focusing on PM$_{2.5}$
  – To support the new State Implementation Plan (SIP) and incentives to owning newer harvest machines

• Project 1 Work Objectives
  – Measure significant differences in PM emissions between old and new machines and report percent reductions
  – Evaluate collection efficiencies of newer machines
  – Report on ratio between PM$_{10}$ and PM$_{2.5}$ using FRM Samplers

• Project 2 Significance
  – Evaluated simple and quick methods for visible dust measurements during harvest operations and establish correlation among methods
  – Aid in quick assessment of dust reduction strategies

• Project 2 Work Objectives
  – Quantify visible dust using total suspended particulates (TSP)
  – Evaluate various quick measurement techniques such as (a) EPA Method 9, (b) EPA Alt 082 (also called Digital Opacity Compliance System (DOCSII), (c) opacity meter and (d) laser detection system using drones

Overall goal is to reduce visible (and non visible) dust emissions during harvest by 50% by year 2025.
Machinery Tested for Project 1

- Exact 3800
- Weis McNair 9800
- Jackrabbit
- Control = Flory 480
- FRM PM$_{2.5}$/PM$_{10}$ Samplers
- EPA Approved
## % Reductions in PM Concentrations and Ratio of PM2.5/PM10

<table>
<thead>
<tr>
<th>Machine</th>
<th>% Reduction in PM$_{2.5}$ Concentrations</th>
<th>% Reduction in PM$_{10}$ Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>43.5% ± 11.9%</td>
<td>53.5% ± 9.6%</td>
</tr>
<tr>
<td>B</td>
<td>61.5% ± 14.0%</td>
<td>37.3% ± 18.4%</td>
</tr>
<tr>
<td>C</td>
<td>57.7% ± 13.8%</td>
<td>43.6% ± 12.1%</td>
</tr>
<tr>
<td>D</td>
<td>42.1% ± 32.5%</td>
<td>33.0% ± 31.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machine</th>
<th>Average from All Replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.4%</td>
</tr>
<tr>
<td>cA (Control)</td>
<td>15.7%</td>
</tr>
<tr>
<td>B</td>
<td>17.9%</td>
</tr>
<tr>
<td>cB (Control)</td>
<td>8.3%</td>
</tr>
<tr>
<td>C</td>
<td>8.4%</td>
</tr>
<tr>
<td>cC (Control)</td>
<td>10.7%</td>
</tr>
<tr>
<td>D</td>
<td>15.9%</td>
</tr>
<tr>
<td>cD (Control)</td>
<td>11.5%</td>
</tr>
<tr>
<td>Overall Average</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

Ratio of PM$_{2.5}$/PM$_{10}$ concentration ranges between 8% to 15%, with an overall average of 12.5% based from FRM PM samplers.

Harvest collection efficiencies of all machines are not significantly different from control.
## Project 1 Final Results

**Conclusion:** All New Machinery Models Quality for NRCS EQIP Incentive Program

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TSP</td>
<td>FRM PM$_{10}$</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2,153</td>
<td>492</td>
</tr>
<tr>
<td></td>
<td>9,360</td>
<td>864</td>
</tr>
<tr>
<td>Reduction</td>
<td>77%</td>
<td>43%</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1,590</td>
<td>747</td>
</tr>
<tr>
<td></td>
<td>2,820</td>
<td>1,706</td>
</tr>
<tr>
<td>Reduction</td>
<td>44%</td>
<td>56%</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2,911</td>
<td>1,360</td>
</tr>
<tr>
<td></td>
<td>9,080</td>
<td>5,200</td>
</tr>
<tr>
<td>Reduction</td>
<td>68%</td>
<td>74%</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2,643</td>
<td>1,530</td>
</tr>
<tr>
<td></td>
<td>5,748</td>
<td>4,100</td>
</tr>
<tr>
<td>Reduction</td>
<td>54%</td>
<td>63%</td>
</tr>
</tbody>
</table>
Lessons Learned

• Proper machinery adjustment is critical and newer machines had lower emissions

• Dust emissions is reduced by half from the average of all machine models

• Orchard growers and operators should begin to invest on newer machines or take advantage of government programs to acquire newer machine models

• Newer harvesters have the potential to significantly reduce PM$_{2.5}$ emission factors with proper adjustments

• We now have the ability to detect PM EF differences among harvesters using FRM PM$_{10}$ and PM$_{2.5}$ samplers including continuous FRM samplers

• While higher reductions were achieved, almond harvesting operations are still between 5-9x higher than other agricultural harvest processes (e.g. cotton and wheat).
Project 2: Four New Dust Test Protocol Evaluated

- **EPA Method 9 or Visual Emissions Evaluation (VEE)**
  - Use of EPA Certified Professionals to evaluate dust quality during harvest

- **EPA Alt 082 or DOCSII**
  - Use of digital camera and video camera to digitize captured image and determine opacity by certified professionals

- **Opacity Meter**
  - Directly measure opacity at the orchard floor during harvest

- **Laser (Diode) Attenuation Mounted on Drone Technologies**
  - Use of particulate matter (PM) measuring instruments attached to drones and follow the harvester during operations
EPA Method 9 Visual Emissions Evaluation

Rely on EPA certified professionals to rate the quality of dust generated during harvest operations
EPA Alt 082 Digital Opacity Compliance System (DOCS II)

• Use of certified professionals to capture digital images and convert into digital opacity values

Canon Powershot SXH60 for still images

Sony Handy Cam HDRCXX for continuous video recording
Method/Procedure:
1. PM laser sampler is loaded on each drone and on harvester
2. The sampler measures visible dust every second as it follows the harvester
3. Another drone takes real-time images throughout harvest episode
**Results and Discussions**

**EPA Method 9 Results**

<table>
<thead>
<tr>
<th>Control and Treatments</th>
<th>Opacity</th>
<th>% Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>23.28</td>
<td>0%</td>
</tr>
<tr>
<td>No Fan</td>
<td>7.84</td>
<td>66%</td>
</tr>
<tr>
<td>High Speed/Low Flow</td>
<td>9.68</td>
<td>58%</td>
</tr>
<tr>
<td>High Speed Standard</td>
<td>11.65</td>
<td>50%</td>
</tr>
<tr>
<td>New Machine Standard</td>
<td>13.94</td>
<td>40%</td>
</tr>
<tr>
<td>Low Speed/Height</td>
<td>17.06</td>
<td>27%</td>
</tr>
<tr>
<td>Low Speed/Low Flow</td>
<td>19.79</td>
<td>15%</td>
</tr>
</tbody>
</table>

**EPA Method 9 Works!**
Results and Discussions

EPA Alt 082 Digital Opacity Compliance System

<table>
<thead>
<tr>
<th>Treatments &amp; Control</th>
<th>Opacity</th>
<th>% Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>29.00</td>
<td>0%</td>
</tr>
<tr>
<td>No Fan</td>
<td>12.50</td>
<td>57%</td>
</tr>
<tr>
<td>New Machine Standard</td>
<td>14.09</td>
<td>51%</td>
</tr>
<tr>
<td>High Speed Standard</td>
<td>17.50</td>
<td>40%</td>
</tr>
<tr>
<td>Low Speed/Height</td>
<td>17.50</td>
<td>40%</td>
</tr>
<tr>
<td>High Speed/Low Flow</td>
<td>22.00</td>
<td>24%</td>
</tr>
<tr>
<td>Low Speed/Low Flow</td>
<td>25.00</td>
<td>14%</td>
</tr>
</tbody>
</table>

EPA Alt 082 Method Also Works!
Lessons Learned

• EPA Method 9 Works! Industry may take advantage of hundreds of Certified EPA Method 9 Professionals to help evaluate dust level generation during harvest and evaluate reductions through best management practices

• EPA Alt 082 Digital Opacity Compliance System also works but may be a little bit costly for some interested parties due to monopoly of certified analysts. Video and digital camera are quite cheap and affordable.

• Laser Sampler on drones also works but we need to develop a better protocol for consistent gathering of dust PM concentrations data

• The TAMU Group is developing a correlation software such that the EPA Method 9 data are correlated properly with digital format without having to spend for additional party analysis

Opacity meters did not provide consistent results and will not be used for future experiments
Acknowledgements

Project 1
• Harvest Contractor: Matthew Efird of Double E Farms, Inc. and Roger Isom
• Harvest Machinery: (Flory Industries, Exact Corp., Weiss McNair and Jack Rabbit)
• Funding: The San Joaquin Valley Air Pollution Control District and the Almond Board of California (ABC)
• Beta Lab Crew (Amado Maglinao, Walter Oosthuizen, and EJ Baticados)

Project 2
• Orchard Owner: Dan Visser
• Harvest Contractor: Matthew Efird of Double E Farms, Inc. and Jeff Noorigian
• Harvest Machinery: Flory Industries (c/o Mike Flora and his Engineer Operators)
• EPA Method 9 Group
  – Cameron Donnahoo (Reliable Emissions Measurements)
  – Paul Schafer and Jose Landeros (SCS Engineers)
• ALT 082 Group
  – Dr. Amado Maglinao, Jr and El Jerie Baticados
• Opacity Meter Crew
  – Dr. Butch Bataller
• Drone For Hire Group (c/o Thomas Davis)
• Funding: Almond Board of California (ABC)

QUESTIONS?
“Low-Dust” Harvesters

Ted Strauss
Air Quality Resource Conservationist
USDA Natural Resources Conservation Service

The Almond Conference
Sacramento Convention Center
December 6, 2018
Environmental Quality Incentive Program

• Authorized through the Farm Bill
• Provides eligible producers with technical and financial assistance for implementing practices through conservation planning
• The 2014 Farm Bill approved $25 million annual through Fiscal Year 2018 to address air quality resource concerns and to meet Federal, State and local regulatory requirements
• NRCS-California obligates approximately $20 million annually through the National Air Quality Initiative
• Priority projects offer creditable emissions reductions for meeting State Implementation Plan goals and Federal ambient air quality standards
Environmental Quality Incentive Program

- Use of “low-dust” harvesters for surface harvesting of nut crops
- Replacing in-use diesel powered nonroad mobile agricultural equipment
- Repowering in-use irrigation engines
- Conservation tillage and residue management
- Reduce tillage acre-passes
- Combined-tillage implements
- Proper handling and disposal of chemically-treated wood grape stakes
- Dust suppressants on unpaved roads and traffic areas
- Chipping woody debris from orchard removals and vineyard removals
- CAFO dust control, windbreaks, and manure injection
- Precision pesticide spray application through Integrated Pest Management
- Mulching with wood chips
376 – Field Operations Emissions Reductions

• The conservation practice standard (CPS) that applies to “low-dust” harvesters

• 2010-11 Texas A&M demonstration
  – Conducted under NRCS-CA Conservation Innovation Grant (CIG) 68-9104-0-1
  – Defined the 376 Specifications of 30 percent PM10 control efficiency

• NRCS list of “low-dust” harvester pick-up machines
  – NRCS-CA Air Quality Technical Note 8
  – Continue to update as new peer-reviewed information comes available (e.g. 2017 Texas A&M demonstration)
## CPS 376 “Low-Dust” Harvesters

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Drive</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exact Corporation</td>
<td>E-3600</td>
<td>Pull-behind PTO</td>
<td>Water misting and brush system at the separation fan discharge and reduced discharge air speed.</td>
</tr>
<tr>
<td></td>
<td>E-4000</td>
<td>Pull-behind PTO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E-7000 SP</td>
<td>Self-Propelled</td>
<td></td>
</tr>
<tr>
<td>Flory Industries</td>
<td>Model 860</td>
<td>Pull-behind PTO</td>
<td>Reduced fan speed, cleaning chain length, and location of dust discharge.</td>
</tr>
<tr>
<td></td>
<td>Model 8550</td>
<td>Self-Propelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 8600</td>
<td>Self-Propelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 8700</td>
<td>Self-Propelled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Model 8770</td>
<td>Self-Propelled</td>
<td></td>
</tr>
<tr>
<td>Jackrabbit</td>
<td>Harvester</td>
<td>Pull-behind PTO</td>
<td>“Constant Race” disk-based cleaning section.</td>
</tr>
<tr>
<td>Joe DiAnna</td>
<td>Clean Air Concepts</td>
<td>Retrofit</td>
<td>Cyclonic separator.</td>
</tr>
<tr>
<td>Weiss McNair</td>
<td>9800 California Special</td>
<td>Pull-behind PTO</td>
<td>Reduced fan speed, fan location, enlarged vacuum and separation chambers, and cleaning chain design.</td>
</tr>
<tr>
<td></td>
<td>Magnum X</td>
<td>Self-Propelled</td>
<td></td>
</tr>
</tbody>
</table>

This list is not in any way an endorsement by the USDA NRCS. These manufacturers have demonstrated that their designs and technologies will reduce PM10 emissions by at least 30 percent over conventional surface-harvester pick-up machines. Any modifications or changes to the equipment are discouraged, as they could adversely impact the integrity of the PM control technology. This list is subject to change as new designs, technologies, and information comes available.
Exact E-7000SP
*Photo Credit: Sonya Miller, USDA NRCS*

Weiss McNair Magnum X
*Photo Credit: Jesse Samson, USDA NRCS*

Flory Model 8700
*Photo Credit: Sonya Miller, USDA NRCS*
Clean Air Concepts
Installed on a Weiss McNair 9600 California Special
Photo by Ted Strauss, USDA NRCS

Jackrabbit Harvester
Photo by Ted Strauss, USDA NRCS
Funding Opportunities for “Low-Dust” Harvesters

- Offered statewide with priority on orchards located within PM nonattainment areas
- The air quality resource concern is excessive PM emissions from using conventional surface-harvester pick-up machines
- NRCS payments for this treatment applies only to the use of the “low-dust” technologies on the contracted acres
- CPS 376 is a management practice with a one-year project lifespan
- Through a conservation plan, EQIP contracts and annual payments may be available for up to three years
  - $36.23 per acre for contracts awarded in FY2019
- As deliverables, participating producers provide NRCS with a post-harvest report annually
“Low-Dust” Harvesters Contracted Acres (FY 2016-18)

- Represents $2,473,000 in EQIP obligations

<table>
<thead>
<tr>
<th>Harvest Season</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed Acres</td>
<td>2,751</td>
<td>10,091</td>
<td>14,263</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Planned Acres</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17,907</td>
<td>11,098</td>
<td>7,210</td>
</tr>
<tr>
<td>*PM10 Reductions (Tons/Season-Year)</td>
<td>9.74</td>
<td>35.72</td>
<td>50.49</td>
<td>63.39</td>
<td>39.29</td>
<td>25.52</td>
</tr>
</tbody>
</table>

*Notes:*
- “Pick-Up” emission factor is 23.60 pounds PM10/acre/year (California Air Resources Board 2013)
- “Low-Dust” Harvester minimum control efficiency is 30 percent (CPS 372 Specifications)
Please visit your nearest USDA Service Center for more information

https://offices.sc.egov.usda.gov/locator/app?state=CA

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Off-ground Harvest of Almonds: Preliminary Technoeconomic Cost and Benefit Analysis with Analysis of Barriers to Adoption

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Goals

Understand the economic opportunities and risks associated with potential off-ground harvesting approaches compared to conventional methods.
Goals

- Inform **decision making** on off-ground harvest strategy

- Highlight **technological aspects** of off-ground harvest that are cost drivers and warrant **research to reduce cost**

- Identify **goods and services** that are **cost drivers** for off-ground harvest to gauge effect of price volatility

- Identify **cost drivers** for off-ground harvest that could be targets for **new policies and incentives**
Conventional harvesting
Conventional harvesting
Conventional harvesting
Conventional harvesting
Conventional harvesting
Off-ground harvesting
Off-ground harvesting
Drying scenario 1
Drying scenario 2
Drying scenario 2
Drying scenario 2
Drying scenario 2
Drying scenario 3
Drying scenario 3
Drying scenario 3
Drying scenario 3
Scenarios

Off-ground harvesting

- In-orchard windrow drying
- Lot drying
- Mechanical drying
Scenarios

In-orchard windrow drying

- Conventional vs low-dust pickup
- Soil stabilization vs bare soil

Off-ground harvesting

Lot drying

Mechanical drying
Scenarios

Off-ground harvesting

In-orchard windrow drying

Lot drying
- Land availability and cost
- Lot size
- Soil stabilization vs bare soil
- Possibility of turning almonds

Mechanical drying
Scenarios

Off-ground harvesting

In-orchard windrow drying

Lot drying

Mechanical drying

Dryer format and cost

Drying losses
Economic metrics

Change in net return above total costs

- Change in total costs
  - Change in operating costs
  - Change in capital recovery costs
- Change in gross returns
Expected effects

- Losses due to windfall; may be affected by
  - Region
  - Variety
  - Harvest schedule

+ Harvesters; effect currently unknown; rental cost will be affected by
  - Capital cost
  - Fuel/labor demand/cost
  - Lifespan/depreciation
  - Maintenance cost

Cultural practices
- Fewer pest control measures needed
- Less stringent leveling needed

Harvest operations
- Blowing/sweeping are avoided
- Pickup may be avoided

Change in net return per acre above total costs relative to conventional practices ($/acre)

(undesirable)

? (desired)
Prior cost study by UC Davis and UC Cooperative Extension
Sources

Experts from

...along with cost data from additional vendors and service providers
Assumptions

Model developed for a hypothetical orchard

- 100 acre orchard
- >4 years old
- 2200 lb/acre yield
- $2.50/lb selling price
- 1% windfall
- Conventional sanitation, fertilization, irrigation, pest management, pruning, pollination etc. agree with existing cost study
Assumptions

Off-ground harvesters

- Off-ground harvesters can be utilized at a cost similar to conventional harvesters
- Off-ground harvesters have no loss
Assumptions

Drying lot scenario

- Drying lot sized 5-7 acres
- Land not currently used for production
- Land either owned by grower or leased near orchard
- Hand raking is required
Assumptions

Mechanical drying scenario

- Mechanical drying of almonds can scale to accommodate all off-ground harvesting
Results - Overview

Predicted ranges

Conventional harvesting baseline

- $23 per acre

Conventional harvesting with low-dust pickup

$107 per acre

Scenario 1: Off-ground harvest + in-orchard drying

$92 per acre

Scenario 2: Off-ground harvest + lot drying

$43 per acre

Scenario 3: Off-ground harvest + mechanical drying

$75 per acre

-$140 per acre

-$137 per acre

Change in profit ($/acre)

-160 - 80 0 +80 +160
Results - Detailed

- In-orchard windrow drying
- Lot drying
- Mechanical drying
Results

In-orchard windrow drying

- No soil stabilization
  - Conventional pick-up: +$75 per acre
  - Low-dust pick-up: +$53 per acre
- Soil stabilization
  - Conventional pick-up: -$115 per acre
  - Low-dust pick-up: -$137 per acre

OFF-GROUND HARVESTING

- Lot drying
- Mechanical drying
Results

In-orchard windrow drying

Mechanical drying

Lot drying

- 5-acre lot
  - Tarped soil: +$77 per acre
  - Soil stabilization: +$91 per acre
- 6-acre lot
  - Tarped soil: -$27 per acre
  - Soil stabilization: -$17 per acre
- 7-acre lot
  - Tarped soil: -$140 per acre
  - Soil stabilization: -$124 per acre

Change in profit

- Conventional pick-up: +$115 per acre
- Low-dust pick-up: +$137 per acre

No soil stabilization

Soil stabilization

Change in profit

+$75 per acre
+$53 per acre
-$115 per acre
-$137 per acre
OFF-GROUND HARVESTING

In-orchard windrow drying

Lot drying

- 5-acre lot
  - Tarped soil
    - Change in profit: +$77 per acre
  - Soil stabilization
    - Change in profit: +$91 per acre

- 6-acre lot
  - Tarped soil
    - Change in profit: -$27 per acre
  - Soil stabilization
    - Change in profit: -$17 per acre

- 7-acre lot
  - Tarped soil
    - Change in profit: -$140 per acre
  - Soil stabilization
    - Change in profit: -$124 per acre

Change in profit:

- Conventional pick-up
  - No soil stabilization: +$75 per acre
  - Low-dust pick-up: +$53 per acre
  - Conventional pick-up: -$115 per acre
  - Low-dust pick-up: -$137 per acre

Mechanical drying

+10% price adjustment

- 1% over-drying loss
  - Change in profit: +$43 per acre
- No over-drying
  - Change in profit: +$98 per acre
- 1% over-drying loss
  - Change in profit: +$53 per acre
- No over-drying
  - Change in profit: +$107 per acre

No price adjustment

- No over-drying
  - Change in profit: +$98 per acre
Results

**Off-ground harvesting**

- **Lot drying**
  - 5-acre lot: Tarped soil + $77 per acre
  - 6-acre lot: Tarped soil + $91 per acre
  - 7-acre lot: Tarped soil + $140 per acre

- **Soil stabilization**
  - 5-acre lot: -$27 per acre
  - 6-acre lot: -$17 per acre
  - 7-acre lot: -$124 per acre

- **Conventional pick-up**
  - 5-acre lot: -$115 per acre
  - 6-acre lot: -$137 per acre
  - 7-acre lot: -$137 per acre

- **Low-dust pick-up**
  - 5-acre lot: +$53 per acre
  - 6-acre lot: +$53 per acre
  - 7-acre lot: +$53 per acre

**In-orchard windrow drying**

- **Conventional pick-up**
  - No soil stabilization: +$75 per acre
  - Low-dust pick-up: +$53 per acre

- **Low-dust pick-up**
  - No soil stabilization: -$115 per acre
  - Low-dust pick-up: -$137 per acre

**Mechanical drying**

- **Change in profit**
  - +10% price adjustment: +$43 per acre
  - No price adjustment: +$98 per acre

- **1% over-drying loss**
  - +10% price adjustment: +$53 per acre
  - No price adjustment: +$107 per acre

- **No over-drying**
  - +10% price adjustment: +$107 per acre
  - No price adjustment: +$107 per acre
## Results

### Dust Mitigation Strategies

<table>
<thead>
<tr>
<th>More Dust Control</th>
<th>Less Dust Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional harvest</td>
<td>Conventional harvest</td>
</tr>
<tr>
<td>Conventional harvest + low-dust pickup</td>
<td>Conventional harvest + low-dust pickup</td>
</tr>
<tr>
<td>Conventional harvest + soil stabilization</td>
<td>Conventional harvest + soil stabilization</td>
</tr>
<tr>
<td>Off-ground harvest + in-orchard windrow drying + low dust pickup</td>
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</tr>
<tr>
<td>Off-ground harvest + lot drying with soil stabilization</td>
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</tr>
</tbody>
</table>

### Predicted Change in Profit ($/acre)

- Off-ground harvest + mechanical drying: +$107
- Off-ground harvest + lot drying with tarping: +$77
- Off-ground harvest + lot drying with soil stabilization: +$91
- Off-ground harvest + soil stabilization + in-orchard windrow drying + low dust pickup: -$137
- Off-ground harvest + in-orchard windrow drying + low dust pickup: +$53
- Off-ground harvest + soil stabilization + in-orchard windrow drying: -$115
- Off-ground harvest + in-orchard windrow drying: +$77
- Conventional harvest + soil stabilization: -$190
- Conventional harvest + low-dust pickup: -$23
- Conventional harvest: -$0
Research targets

- How much windfall occurs? What is the quality of windfall almonds?
- Can drying on tarped soil reduce dust during pickup? Can tarps withstand pickup machines?
- Can soil stabilizers reduce dust during almond pickup? Do such stabilizers affect almond quality?
- What are the optimal drying conditions for almonds in various mechanical dryer formats?
- What are appropriate drying lot conditions (layer thickness, turning, duration)?
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