Pelletization and Application of Composted Dairy Manure and Almond Woody Biomass

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Sponsors and Collaborators

Sponsors

- Almond Board of California
- The California Dairy Research Foundation
- CDFA Healthy Soils Program
- CDFA Alternative Manure Management Program

Collaborating Farms

- Wickstrom Dairies L.P.
- Van Ruler Orchards

Other Collaborators

- JPT Composting & Spreading
- Nichols Custom Ag Services
- Silva & Sons Custom Spreading

Other Collaborators

- G & F Ag Service, Inc
- Cortez Grower's Association
- Almond Tree Huller
- Kamps Hulling
- RDO Equipment Co

The California Dairy and Almond Industries

Some facts about these industries:

Dairy Industry

- #1 commodity at $6.4B in sales
- ~19% US milk/cheese production
- #3 Agricultural Export: $1.7B
- 2.5M (1.7M milking) of 5.2M cattle

Almond Industry

- #3 commodity at $5.5B in sales
- 100% US & 78% World production
- #1 Agricultural Export: $4.5B
- 1.4 out of 24.3M acres farmed

CA Agricultural Statistics Review, 2018-2019

The California Dairy and Almond Industries

Some challenges these industries face:

Dairy Industry

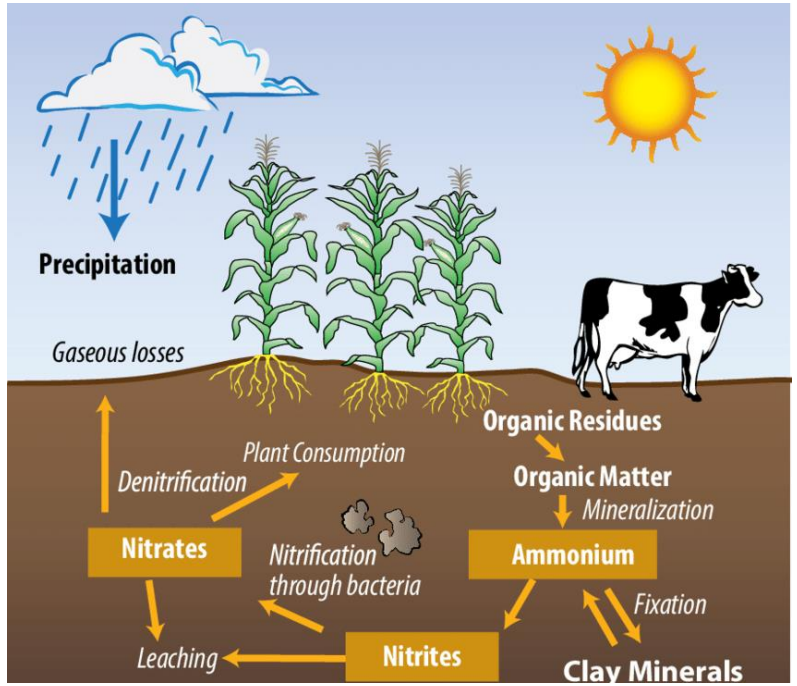
- Increased herd concentration
- Generate tons of manure
- Impact our air and water quality
- Tough regulatory/business environment

Almond Industry

- Water used to grow almonds
- Waste and residues generated in orchards
- Use of chemicals for pest management
- Dust generated from orchards

CA Agricultural Statistics Review, 2018-2019

Illustration by Susie Cagle



The Nitrogen Cycle *(Verhulst, 2014)*

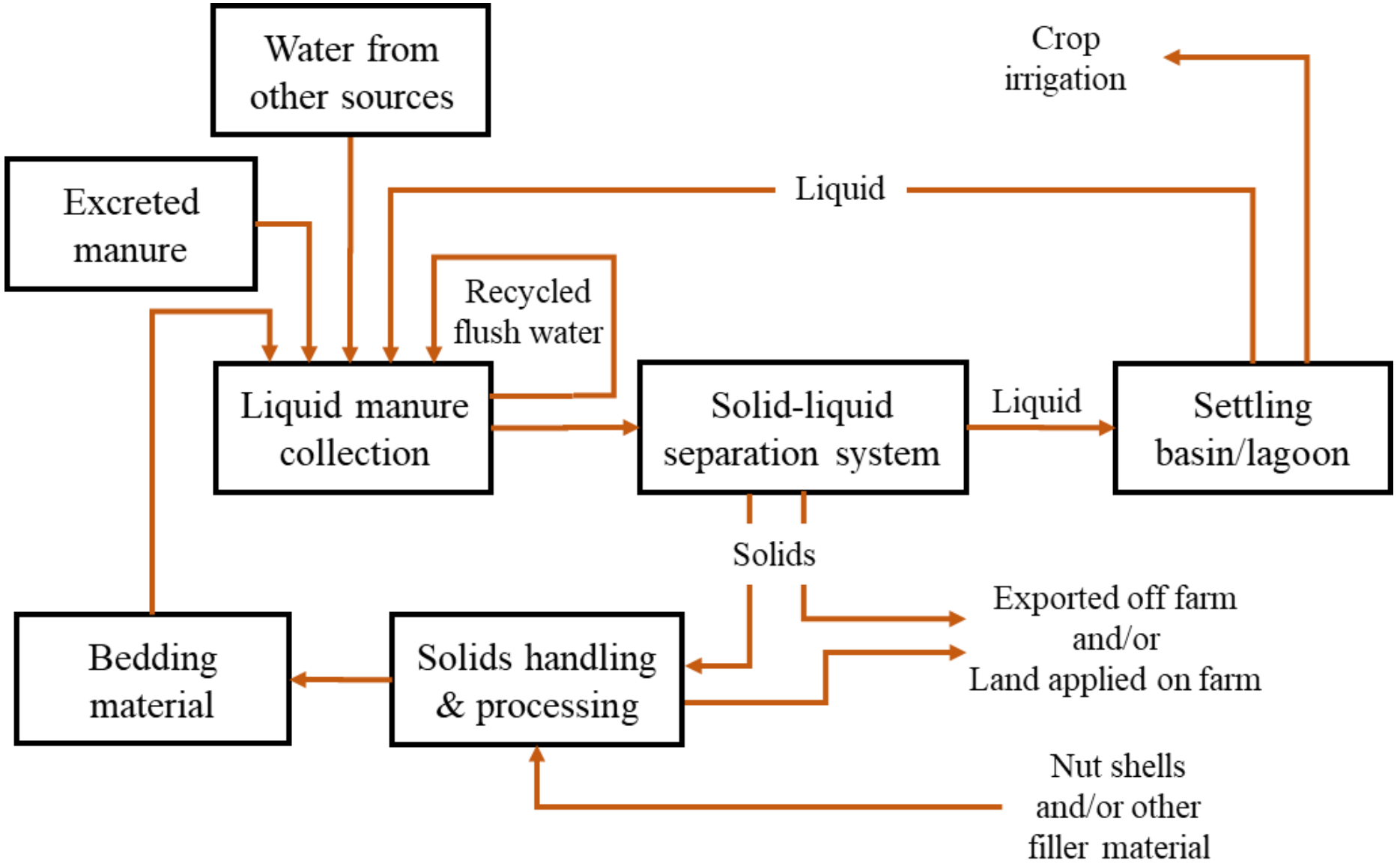
Waste Streams on Dairies and in the Almond Industry

Dairy Manure

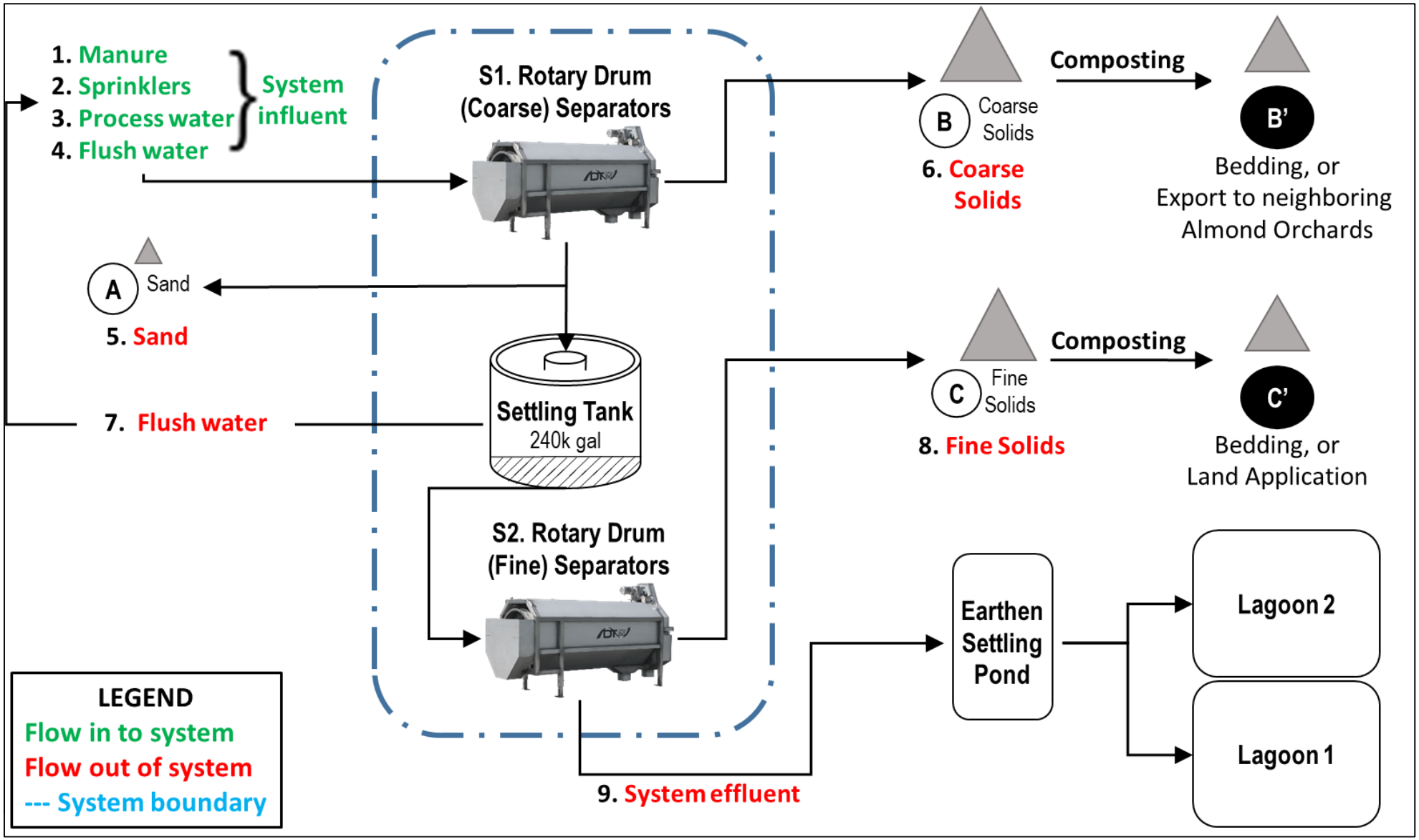
Stick/Twig waste from almond processors

Where is it generated and how can we use this “waste” beneficially?

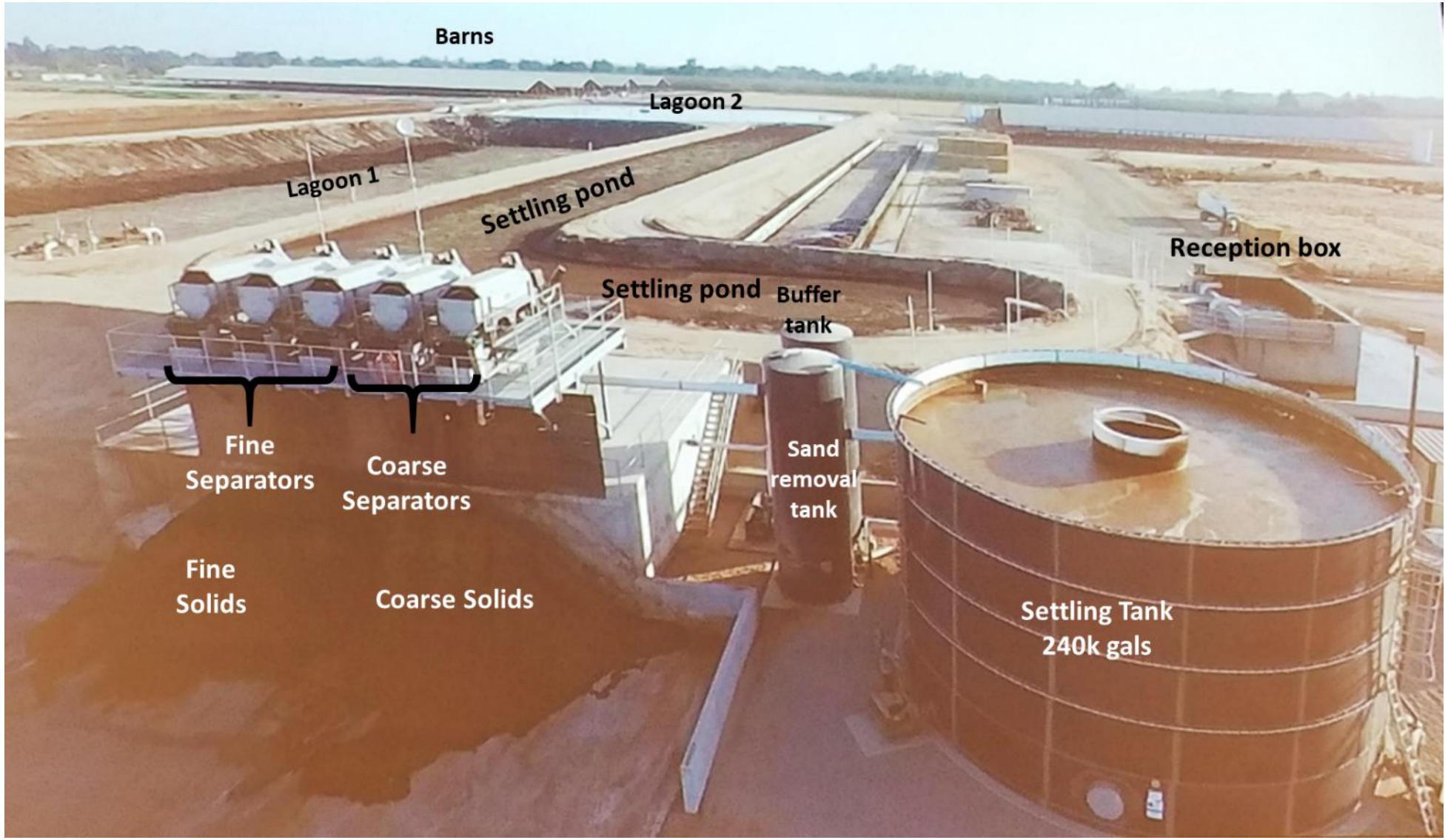
Manure Management System on a California Dairy



Manure Management System on a California Dairy



Dairy Manure from Wickstrom Dairy



Agricultural Waste: Dairy Manure from Wickstrom Dairy

Coarse Solids > 3.175 mm

- Composted or
- Subjected to advance solar drying
- Used for bedding
- Fall 2017 (1 day):
  - ~60,000 lb wet (~MC 75%)

Fine Solids > 0.533 mm

- Composted or
- Subjected to advance solar drying
- Some used for bedding
- Also land applied
- Fall 2017 (1 day):
  - 105,000 lb wet (~MC 75%)

Almond Processor Waste: Sticks/Twigs from Processors

- Orchard debris is on average 13% (10-25%) of the field weight of material brought to the processor
- The debris is not “clean” and consists of dirt, pebbles and rocks, twigs and sticks, and trash such as drip tape.
- It has little to no value and is given away for free at best. At worst, it can take up space for years, can be a fire hazard, and takes $ to process and have hauled away.
- We visited several huller/sheller facilities to see the problem for ourselves.

Average Field Weight Yield

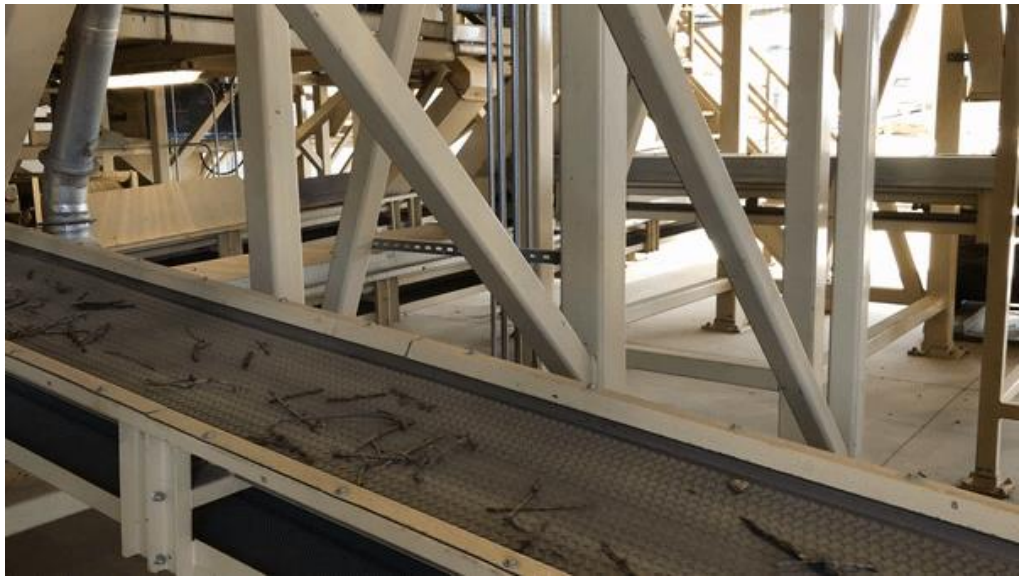
Almond Fraction	Average % Field Weight
Debris	13%
Hulls	50%
Shells	14%
Meat	23%
Total	100%

Note: This can vary significantly farm to farm.

“9.10.2.1/Almond Processing.” Compilation of Air Pollutant Emission Factors, vol. 1, US EPA, 1995.

Sticks and Twigs from Almond Processors

- Some facilities have extensive pre-cleaning processes and can produce relatively “clean” piles of sticks and twigs.
- Many do not and the result is stick and twig piles riddled with orchard trash (rope, drip tape, gloves, etc.) and rocks from pebbles to small boulders.
- The amount of impurity depends on field (farming practices, field soil characteristics, age of the orchard) and manufacturing factors (degree of pre-cleaner processing).
- Sticks and twigs are removed during several stages in the process.



Separated Sticks traveling on a conveyor belt early at a processor after pre cleaning

“9.10.2.1/Almond Processing.” Compilation of Air Pollutant Emission Factors, vol. 1, US EPA, 1995.

Sticks and Twigs from Almond Processors

- **Equipment separating sticks and twigs from rocks.**
- **There are multiple unit operations like this, removing impurities throughout the process (pre-cleaning, de-hulling, de-shelling, etc.)**

Sticks and Twigs from Almond Processors

Stick/twig pile from a processor in Ripon, CA

Sticks and Twigs from Almond Processors

Ground sticks/twigs from a processor in Chowchilla, CA; which we used in the project

Idea: Let's produce amendments from this "waste"

Orchards need Organic Matter Amendment (OMAs) and nutrients

- Increase water holding capacity
- Resilience to drought
- Increase crop yields
- Decrease sediment erosion

Why is this a good idea?

- Dairy farms and almond orchards/ processors are co-localized in CA.
- Dairies have a history of using almond hulls as feed and shells for bedding.
- Many dairies already practice limited composting for bedding production.

Dairy Cows in California
http://grist.org/

Almond Cultivation in CA
http://grist.org/

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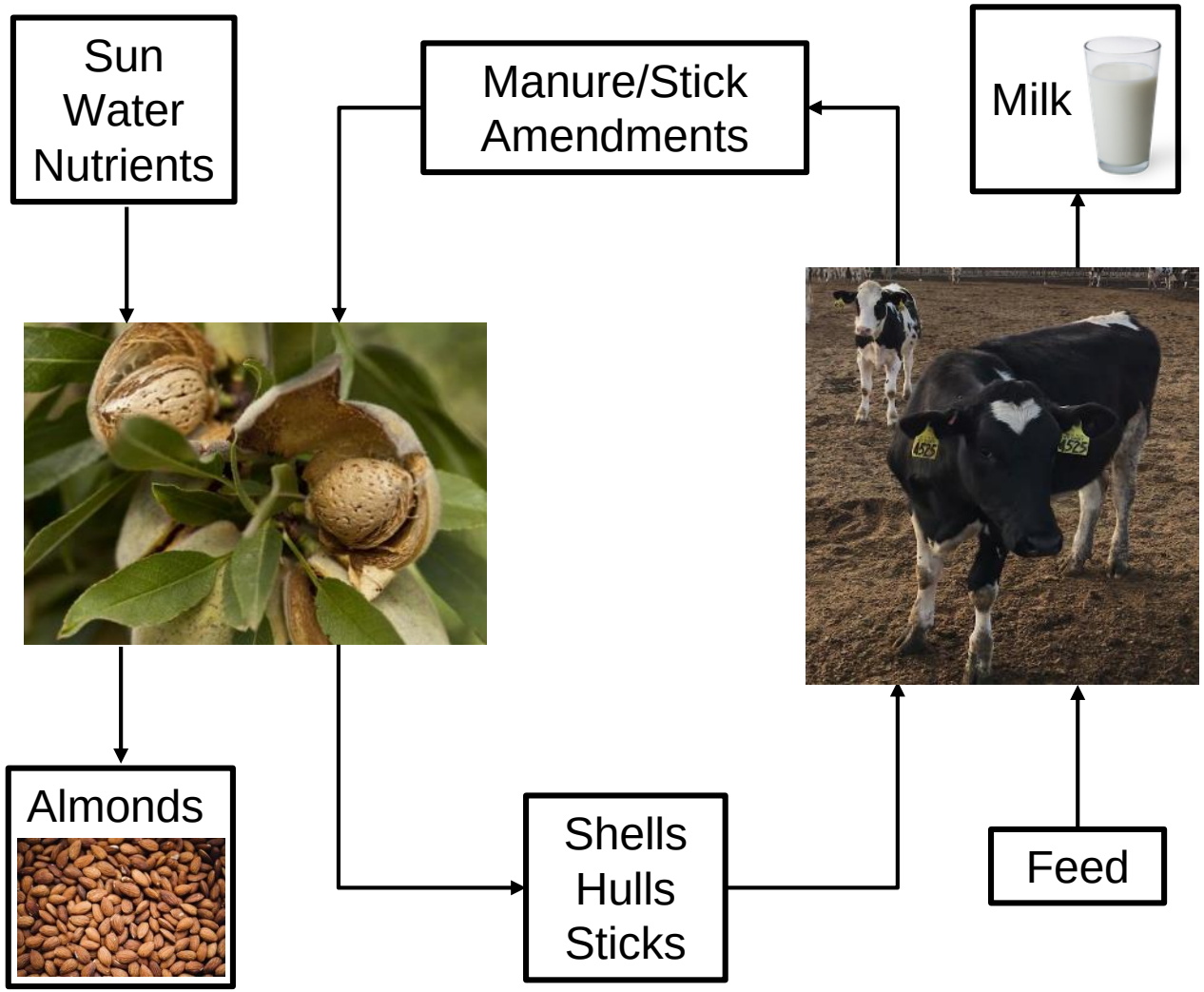


Almond Dairy Loop *(Courtesy of Yike Chen)*

Project Goal and Objectives

Goal

Recycle dairy manure and almond stick-twig waste on almond orchards as nutrient rich, safe, organic amendments, which sequester carbon and provide economical and sustainable benefits to the soil, crop, and environment.

Objectives:

1. Investigate the on-farm composting of dairy manure and dairy manure co-composted with almond stick-twig waste and produce pelletized amendments from the compost.
2. Apply the loose and pelletized amendments using a conventional orchard applicator, and study/compare pelletized manure and manure-sticks compost
3. Study the affect of these organic amendments on the soil and the trees as it relates to: carbon sequestration, soil physicochemical properties, pathogens, and soil GHG emissions; and tree health, almond yield, and consumer safety.

Process Overview

COMPOSTING

Sticks and Twigs

~20% by volume

Dairy Manure

~80% by volume

100%

Manure-Stick Compost

Manure Only Compost

Active composting 8-10 weeks

PELLETIZATION

Pelletizer

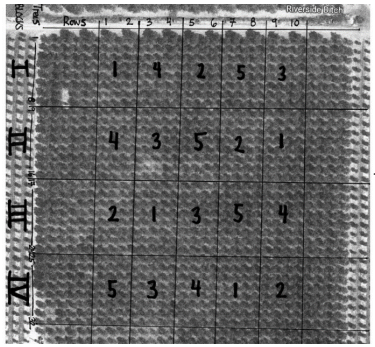
Treatment 1. Manure Compost

Treatment 2. Manure-Stick Compost

Treatment 3. Pelletized Manure Compost

Treatment 4. Pelletized Manure-Stick Compost

APPLICATION



Experimental Plot

Applicator

Orchard Application: Experimental Design

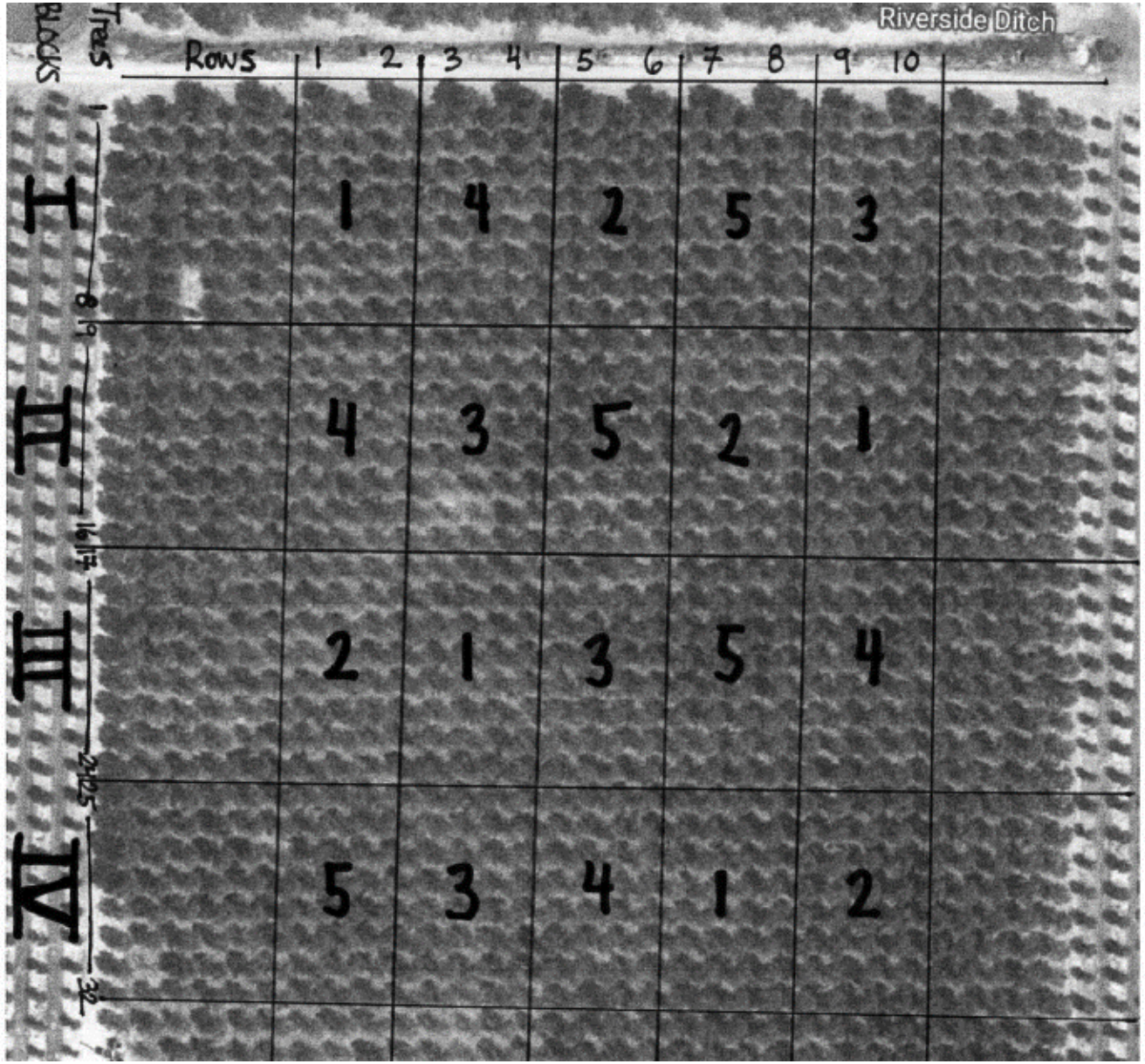
Design: Randomized
Complete Block Design
-16 experimental trees/block

Treatments:

1. Dairy Manure Compost
2. Dairy Manure + Almond Sticks/Twigs Compost
3. Pelletized DMC
4. Pelletized DMCS

Tree Variety: Independence

Application Rate: 4 dry tons/acre



Experimental Layout

Composting of Dairy Manure and Almond Sticks/Twigs

- What is composting?
  - A biological process
  - Produces fertilizer that is stable, free of pathogens and plant seeds
- Why composting?
  - Reduces Organic Waste
  - Mitigates Methane Emissions
  - Improves Soil Health
  - Conserves Water

- Carbon to Nitrogen (C:N) Ratio
  Ideally 25:1-35:1 by weight
  If C:N is too low ammonia gas is emitted
  If C:N is too high microbial growth is stunted
- Moisture: 40 to 60%
- Temperature: above 55°C
- pH = 6-8

Composting: Setting Up Piles

1. Loading raw materials into side dump and weighing on a scale

Composting: Setting Up Piles

2. Creating piles with a side dump

Composting: Setting Up Piles

3. (Optional) Adding water to the wood-sticks pile to bring up the moisture

Compost Pile & Raw Material Moisture Content

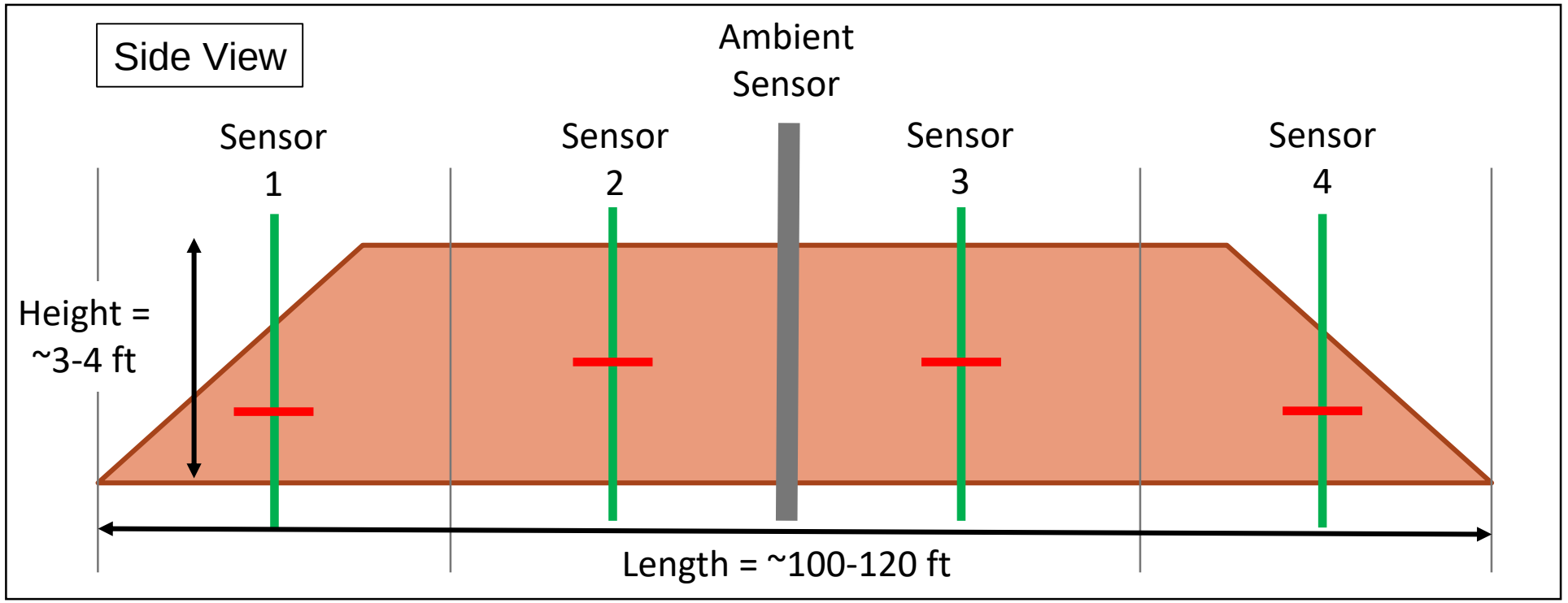
Material	MC
Manure only	77.4%
Sticks only	6.7%
Manure-Stick, prewater	55.2%
Manure-Stick, post water	71.2%

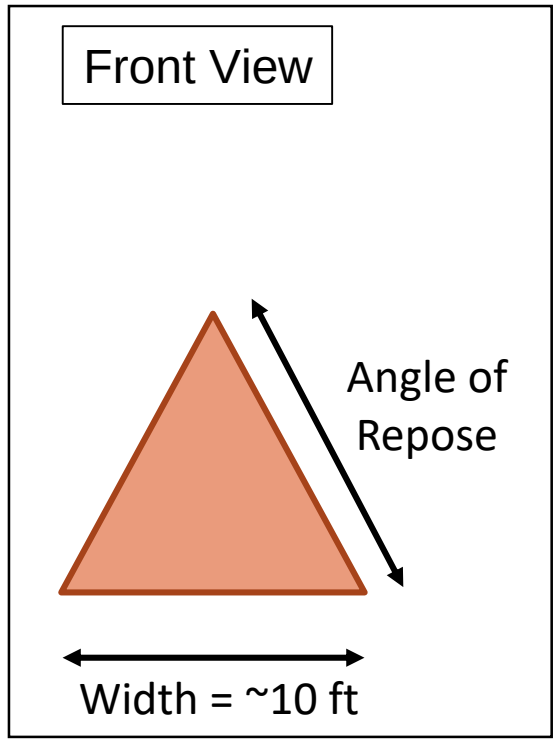
Composting: Setting Up Piles

4. Turning compost piles to shape, aerate, and mix them

5. Return weekly to turn piles, take measurements, and samples

On Farm Measurements





- Compost pile divided into 4 sections. Green lines are the midpoint of each section.
- Temp sensors inserted halfway into the piles at the intersection of the red-green lines.
- Ambient sensor mounted on pole just above the compost pile
- Weekly measurements: length, width, height, angle of repose, and bulk density as well as sampling for laboratory analysis after the windrows were turned

Temperature Measurements

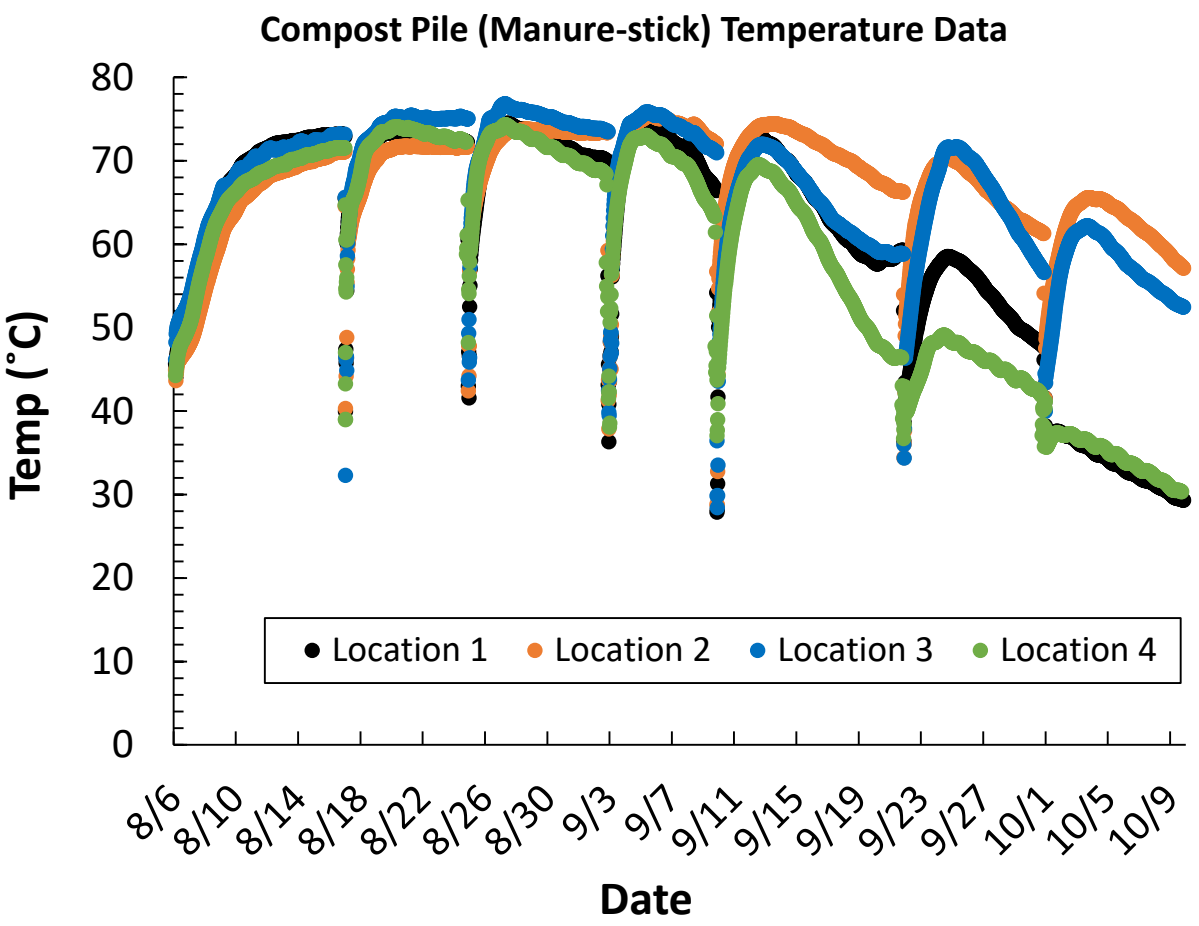
We monitored compost temperature, ambient and pile internal temperatures during active composting

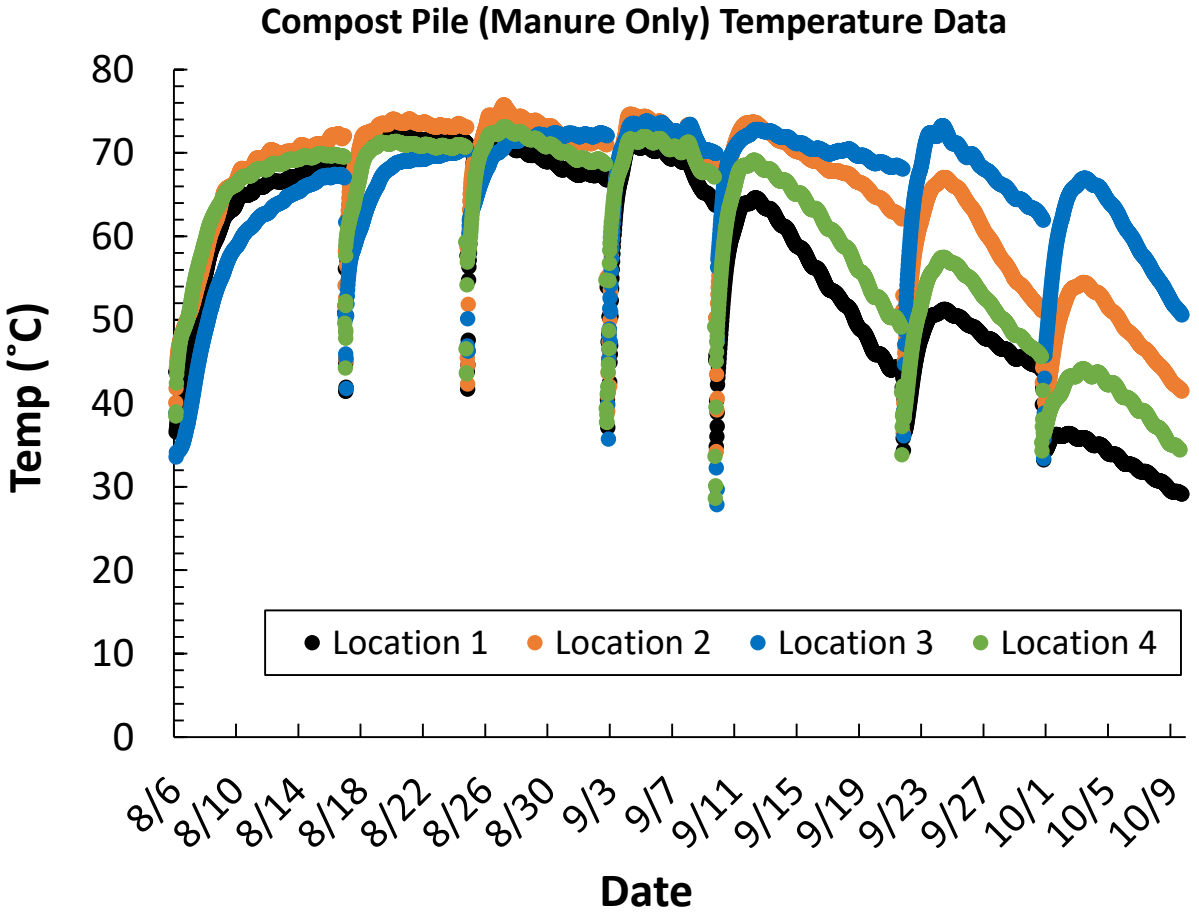
HOBO® Temperature Sensor (Onset®, MA)

Ambient Temp sensor

Internal temperature sensor

2020 Composting Temperature Data

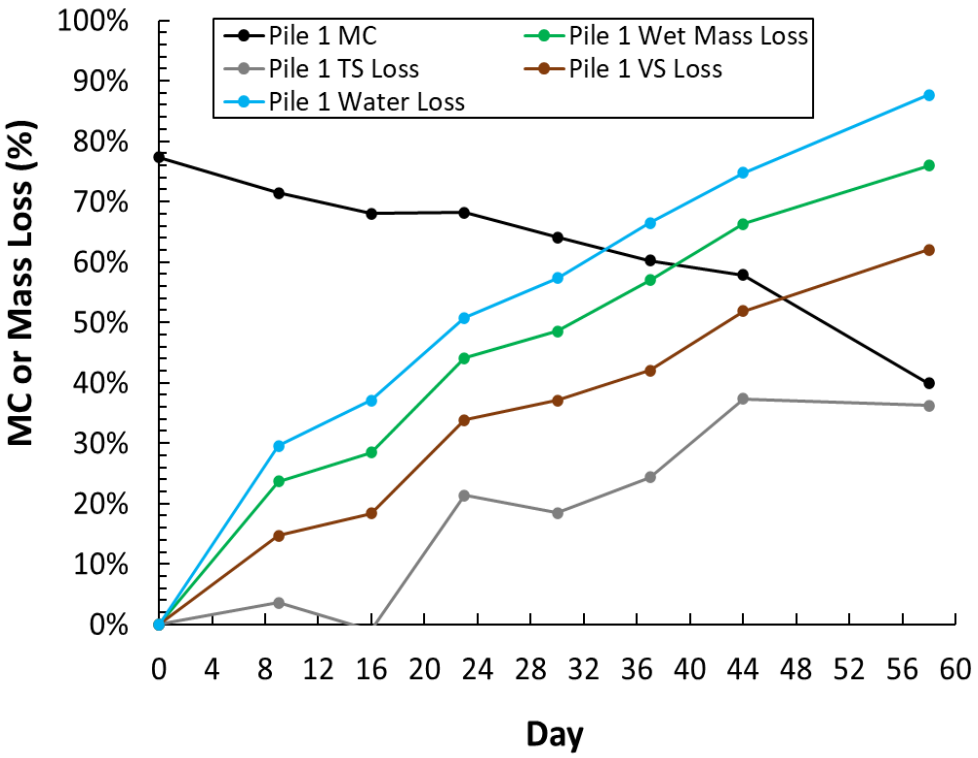




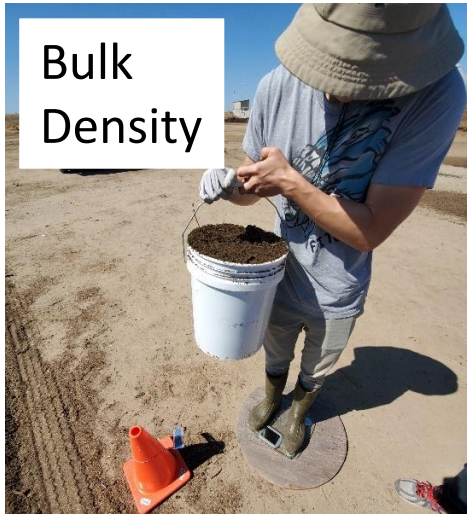
- Windrows achieved temperatures between 60°C and 75°C in the first 4 weeks
- Temperatures at both edges decreased significantly in week 5
- Drops in temp occurred at turning events

Mass Balance Measurements

We measured compost windrow dimensions and bulk density to determine mass and moisture changes during active composting.

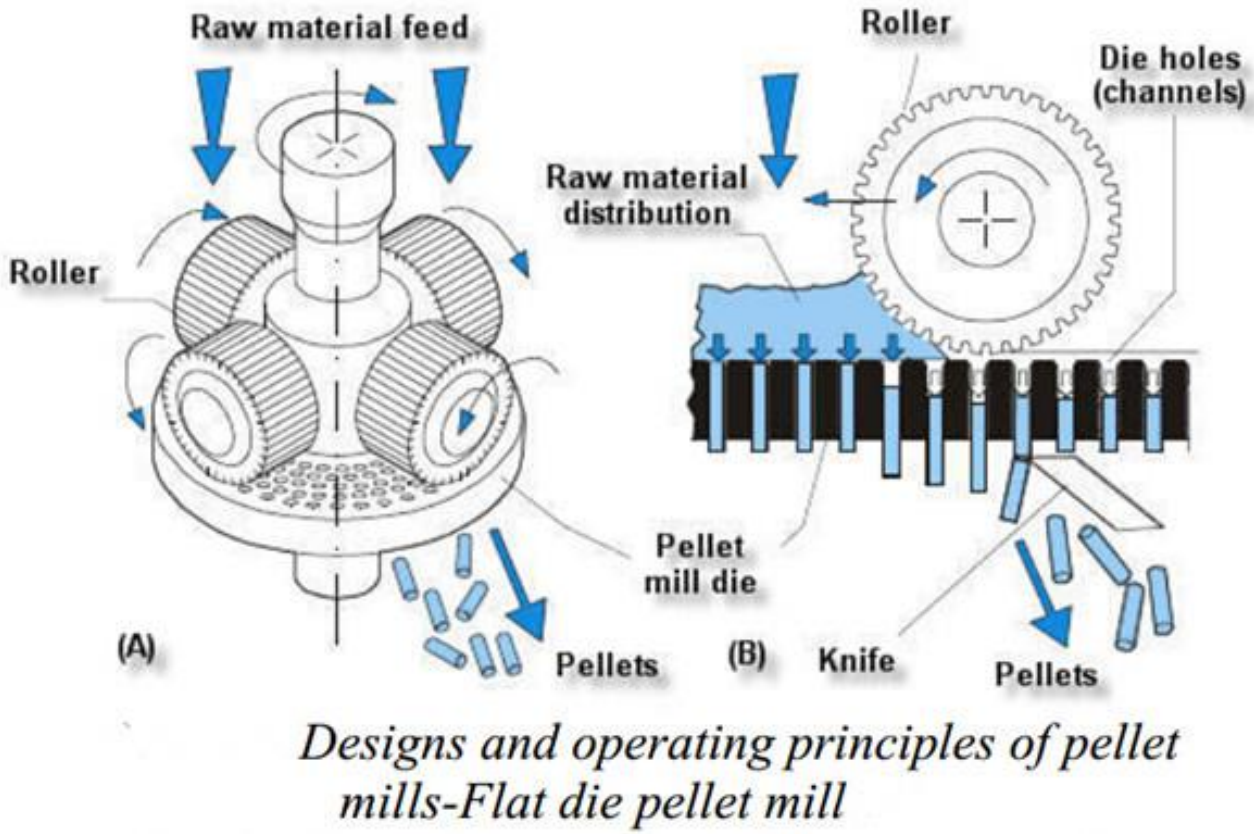


Compost Pile 1: Manure Only (2019)



Pelletization and Application of Dairy Manure and Almond Processing By-products

- What is pelletization/pelleting?
  - A process where smaller particles are formed into larger pellets
  - Accomplished by various methods – flat die pellet mill used in this work
- Why pelletize?
  - Increases bulk density
  - Improves storage, handling, and application
  - Reduces dust generation
  - Attractive to higher value markets



Designs and operating principles of pellet mills-Flat die pellet mill

Image: http://www.biofuelmachines.com/

Pelletization: Pellet Mill Specs, Setup, and Operation

- Used a Buskirk PM605 Laboratory Scale Pelletizer
- Driven by 5 HP motor
- Processes 100-150 lb/hr
- Recommend input material be between 10-15% MC
- Operating temperature depends on input material:
  - 90-220℃

Pelletization: Pellet Mill Specs, Setup, and Operation

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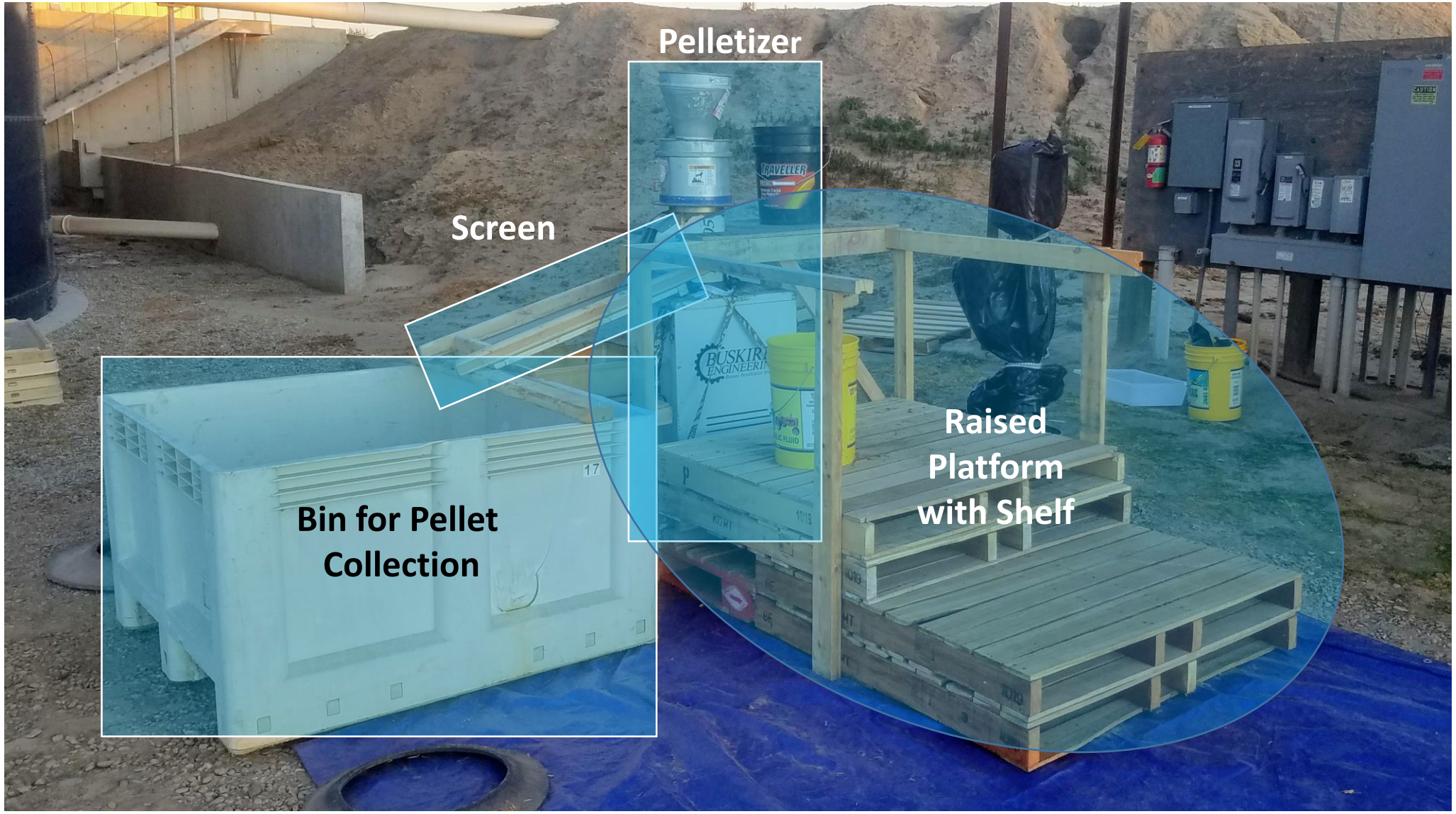

Pellet Mill in Action

Manure-Stick Compost Pelletization

Video link: https://photos.app.goo.gl/LKmex2aKYBo1F86W8

Observations from Manure and Manure-Stick Compost Pelletization

- Pelletization of compost at different moisture content
  - MC < 20% (Too dry) → plugged the pellet mill die.
    - Dry compost plugged up the pellet mill die with hardened compost
    - Believed to be due to high amount of sand in the compost
  - MC > 35% (Too wet)→ pellets less durable, easily break apart.
- Manure vs manure-stick pelletization
  - Manure compost fairly homogenous in particle size
  - Manure-stick compost is not homogenous
    - Large wood particles:
      - Negatively affect pellet durability and
      - Cause more wear and tear on the mill
    - A hammer mill needed for material conditioning preceding pelletization

Compost/Pellets Bulk Density and Composition

- Amendments abbreviations
  - MC: Manure Compost
  - MSC: Manure-Stick Compost
  - PMC: Pelletized MC
  - PMSC: Pelletized MSC
- Bulk Density
  - Pelletizing MC ↑ BD by 1.9x
  - Pelletizing MSC ↑ BD by 1.5x
- C:N Ratio
  - MC (17:1) → MSC (24:1)
  - PMC (17:1) → PMSC (20:1)
- Electrical Conductivity
  - Adding wood ↓ EC by 0.5x
  - Pelletizing ↑ EC by 1.3-1.4x

Amendment Composition

Parameter	Units	MC	MSC	PMC	PMSC
Bulk Density	lb/cu ft	26	32	50	48
Moisture (H_2O)	%	31.9	21.1	23.8	23.5
pH	pH units	7.0	7.3	7.2	7.4
Electrical Conductivity	mmhos/cm	6.15	3.36	8.43	4.40
Total Nitrogen (TN)	% db	1.20	1.03	1.33	1.10
Total Phosphorus (TP)	% db	0.310	0.210	0.390	0.260
Potassium (K)	% db	0.760	0.610	1.00	0.870
Organic Matter (OM)	% db	36.3	42.4	39.2	38.2
C:N Ratio (C:N)	Ratio	17:1	24:1	17:1	20:1
Sodium (Na)	% db	0.250	0.190	0.290	0.240
Sulfur (S)	% db	0.350	0.250	0.320	0.350
Calcium (Ca)	% db	1.50	1.30	1.70	1.50
Magnesium (Mg)	% db	0.440	0.350	0.480	0.420
Zinc (Zn)	mg/L	103	81.0	112	108
Boron (B)	mg/L	26.0	22.0	31.0	31.0
Manganese (Mn)	mg/L	142	112	165	152
Iron (Fe)	mg/L	4,910	3,860	5,420	5,440
Copper (Cu)	mg/L	31.0	29.0	32.0	37.0

Compost/Pellets Nitrogen-Phosphorus-Potassium

- Amendments abbreviations
  - MC: Manure Compost
  - MSC: Manure-Stick Compost
  - PMC: Pelletized MC
  - PMSC: Pelletized MSC
- NPK (%)
  - MC/PMC : 1.25-0.35-0.90
  - MSC/PMSC: 1.05-0.23-0.75
  - NPK of MSC products < MC
- NPK (per acre at 4 dry tons/acre)
  - MC/PMC : 100-28-72
  - MSC/PMSC: 84-18-60

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Pathogen Study (2020): Method and Results

- **Method:**
- 1: qPCR by the Veterinary Diagnostic Lab at Kansas State Univ.
- 2: Culture method (XLD agar plates) at Pandey Lab at UC Davis

- **Tested:** 4 amendments (MC, MSC, PMC, PMSC) for *E. coli* + *Salmonella*

***Salmonella and pathogenic E. coli* test results for 4 Amendments**

OMA	*Salmonella*[2]	*E. coli O26*[1]	*E. coli O45*[1]	*E. coli O103*[1]	*E. coli O111*[1]	*E. coli O121*[1]	*E. coli O145*[1]	*E. coli O157*[1]
MC	-	-	-	-	-	-	-	-
MSC	-	-	-	-	-	-	-	-
PMC	-	-	-	-	-	-	-	-
PMSC	-	-	-	-	-	-	-	-

Pelletization: Pellet Mill Specs, Setup, and Operation

(Top) Fresh pellets
(Bottom) Pellets in the applicator

Pellets up close

Orchard Application: Applicator Calibration

Orchard Application: February 2021 Compost and Pellet application

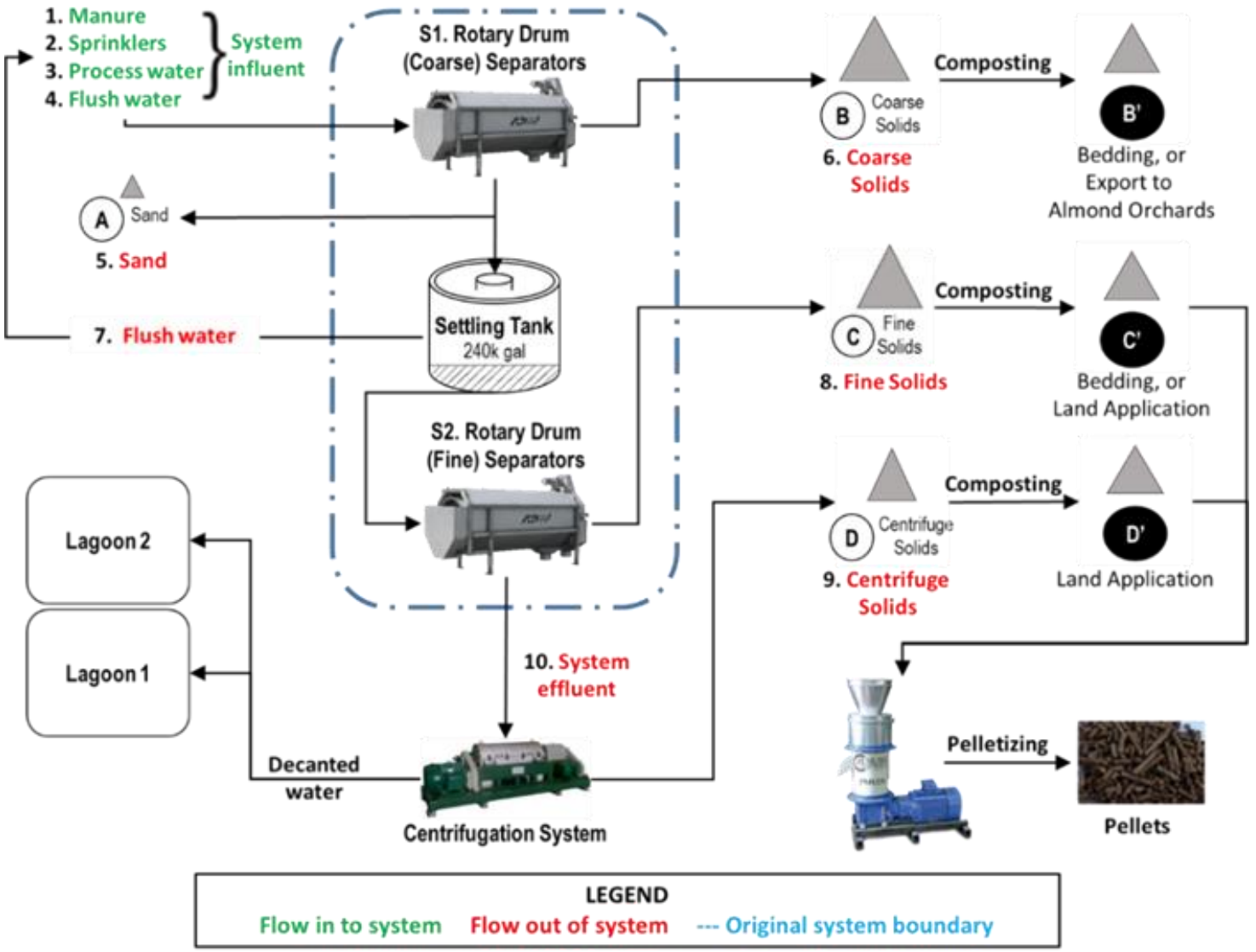
Composted Manure Application

Pelletized Composted Manure Application

Next Steps

- For 2.5 years we have been:
  - Studying the orchard soil, taking samples for physicochemical and pathogen analysis
  - Measuring soil GHG emissions between different treatments
  - Studying the almonds tree health by measuring harvest yield, tree circumference, and testing almonds for consumer safety (pathogens)
- We are submitting samples for analysis and analyzing data
  - In the process of drawing conclusions and writing up data
  - Submitting final project report and having a final field day to disseminate results
- In the meantime, Wickstrom Dairy is in the process of putting in a centrifuge on their separation system and a 1 ton per hour pellet mill as part of a CDFA funded demonstration project.

Next Steps: 1 ton per hour demonstration system at Wickstrom Dairy



Acknowledgements

Project Sponsors

- California Dept. of Food and Agriculture
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- California Dairy Research Foundation
- University of California, Davis

Research Collaborators

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The Farm Personnel
Dr. Guangwei Huang, Almond Board CA
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Kyle Nichols, Nichols Custom Ag Services
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Thank You