Costs and Benefits of Alternative Manure Management Practices

California Livestock Methane Measurement, Mitigation and Thriving Environments Research Program (CLIM3ATE-RP)
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About the CLIM3ATE Research Program

The California Livestock Methane Measurement, Mitigation, and Thriving Environments Research Program (CLIM3ATE-RP) is a research funding initiative administered by the California Department of Food and Agriculture's Office of Agricultural Resilience and Sustainability (OARS).

CLIM3ATE-RP was launched with funds from the Budget Act of 2021 (SB 170, Chapter 240) to support applied research that advances California's climate goals and strengthens the long-term environmental and economic sustainability of the state's livestock sector.

Research Program Focus Areas

CLIM3ATE-RP funded research in three critical areas related to methane emissions and manure management in livestock operations. The three impact areas of the CLIM3ATE Program are:

1. Verification of Methane Reduction Strategies,
2. Alternative Methane Reduction Strategies and
3. Manure Recycling and Innovative Product Development.

In the 2022 funding cycle, CDFA awarded six research projects totaling $4.7 million in funding.

How UCANR's Project "Costs and Benefits of Alternative Manure Management Practices" Accomplishes CLIM3ATE-RP Goals

This project received $60,000 in funding to support goal 1 of the CLIM3ATE-RP to verify methane reduction strategies by supporting work to improve and validate greenhouse gas estimates for projects funded under CDFA's Alternative Manure Management Program (AMMP) and the Dairy Digester Research and Development Program (DDRDP). This includes evaluating methane reductions resulting from AMMP practices and enhancing quantification tools used in California's climate-smart agriculture programs.

The voluntary adoption of climate smart agricultural practices for dairy farms through the Alternative Manure Management Program (AMMP) is a strategy toward meeting California's aggressive greenhouse gas reduction goals. With funding from AMMP and other sources, dairy producers in California have installed manure separation systems and compost bedded pack barns as methods to reduce methane emissions, but with little information about the long-term costs of running and maintaining the systems. The long-term investment in these technologies needs additional research to quantify the actual costs and benefits as installed and operated on California dairies to encourage adoption of sustainable practices to permanently reduce GHG emissions from dairies.

The project had three main objectives:

1. Quantify complete costs of annual operation and maintenance of actual compost bedded pack and mechanical separator systems operating in California.
2. Quantify separation efficiency of total and volatile solids in mechanical manure separator systems installed on California dairies in the past 1-5 years.
3. Quantify moisture levels and composting efficiency in compost bedded pack barns installed on California dairies in the past 1-5 years.

The following report will evaluate each objective and its findings.

Objective 1: Quantify complete costs of annual operation and maintenance of actual compost bedded pack and mechanical separator systems operating in California.

Key Take-Aways:

1. Costs and management practices were highly variable by dairy.
2. Pressure washing screens daily was a common practice that was perceived to improve the operating efficiency of slope screen separators.
3. Estimated annual service costs for separators ranged from $1,000 to $20,000. The average estimated annual service cost was $9,600.
4. Electricity costs were perceived to increase significantly after separator installation, for those that did not previously have a separator at their site. Precise estimates were not available in most cases due to changes to the electrical system when the new separator was installed.
5. Separators run for 3 to 20 hours daily on the sampled dairies. Most run for longer periods of time during the winter.
6. The total cost of running the separator was estimated to be $7,700 to $28,000 per year.
7. Sale of manure solids was a new source of revenue for some dairies.

Cost and management data for mechanical manure separators and compost-bedded pack barns were collected through structured interviews with participating California dairy producers. General herd information included number of milking cows, total dairy animals, breed(s), and housing type. For mechanical separators, producers reported system type (slope screen, conveyor, or screw press), duration of use, daily runtime, maintenance schedule and protocol, whether service was in-house or contracted, annual service costs, and electricity usage before and after installation. Additional data included seasonal cost variations, lagoon and solids management, and any revenue from separated solids. For compost-bedded pack barns, producers provided details on stirring frequency and equipment, bedding type, amount and frequency of addition, bedding cost, and seasonal adjustments. Information on other sustainability practices (e.g., biodigesters, solar panels) and funding sources was also documented.

Objective 1 Results

Complete questionnaires were obtained from 17 participating dairies. Precise costs were difficult to obtain and varied widely.

On dairies with mechanical manure separators, the most common maintenance practices included pressure washing the screen and greasing the separator components. Pressure washing was most often completed at least once daily but ranged from two times per day to once every other day. Greasing of the separators ranged from three times per week to three times per year. Pump maintenance was typically performed annually. Participants estimated annual service costs to range from $1,000 to $20,000. Higher estimates included labor costs while lower estimates typically only described supply costs. Of the respondents who answered the service cost question, ten completed general maintenance activities using existing farm employees (“in house”) and six contracted with a third-party.

We were unable to quantify electrical costs to operate the separator with the current study design. Responses to questionnaires indicated that producers who did not previously operate a separator noticed a significant increase in electrical costs, while those who replaced an older separator did not.

Costs were perceived to vary based on seasonal rates (higher in the summer) and separator use (longer run times in the wet season).

Some producers indicated that cost savings or additional sources of revenue were realized. Benefits realized after the installation of the manure separator included less frequency of cleaning solids from manure storage lagoons and increased manure solids available for fertilizer, bedding, and sale to non-dairy crop producers.

Overall operation, maintenance, and repair costs were estimated to range from $7,700 to $28,000 annually for the mechanical manure separator systems evaluated in this study.

Objective 2: Quantify separation efficiency of total and volatile solids in mechanical manure separator systems installed on California dairies in the past 1-5 years.

Key Take-Aways

1. Regional manure management on dairies likely plays a key role in differences in manure separation effectiveness and is an area for future investigation.
2. Seasonal variation did not affect manure separation effectiveness
3. The estimates that the California Air Resources Board uses in the AMMP calculator are consistent with the data in this study and accurately predict potential methane emission reductions from using mechanical manure separators on California dairies.

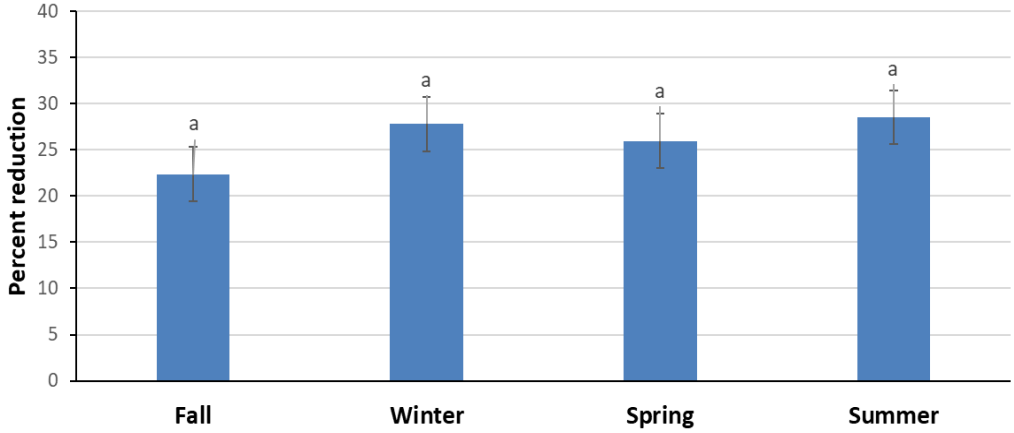
Liquid influent and both liquid and solid effluent from 19 mechanical manure separators, including sloped screen (n = 11), conveyor (n = 5), and screw press (n = 3), were sampled. Sampling occurred across four seasons (Fall 2023, Winter 2024, Spring 2024, and Summer 2024) and in three geographic regions of California: North Coast (NC, n = 6), North Valley (NV, n = 5), and South Valley (SV, n = 8). Liquid samples were analyzed for total solids (**TS**) and volatile solids (**VS**), and solid samples for dry matter content. Each dairy farm completed a questionnaire on manure management and separator usage. Data were analyzed using a mixed linear model in SAS.

Objective 2 Results:

Complete data over four seasons was obtained for 19 dairies. Incomplete data sets were obtained for two dairies, which were excluded from the analysis.

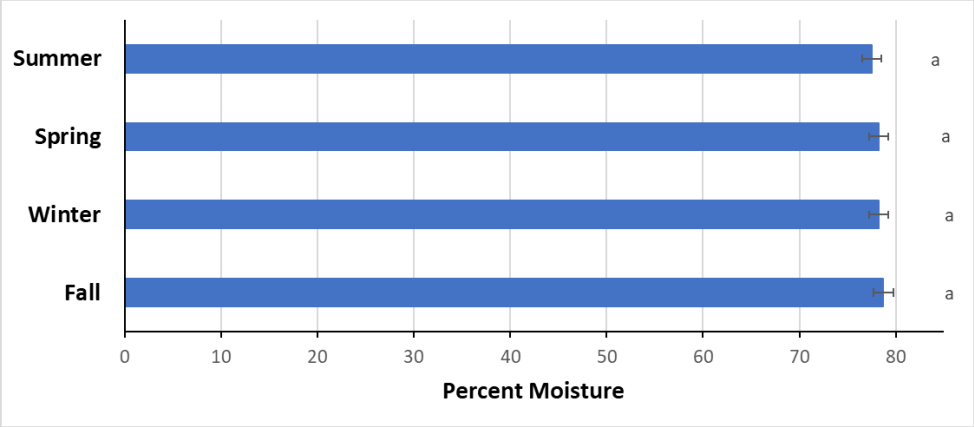
Reduction of volatile solids (Fig 1) did not differ by season. Across all separator systems evaluated, reduction of volatile solids was 22.37% ± 2.95, 27.83% ± 2.95, 25.95% ± 2.95, and 28.58% ± 2.90 (p > 0.05) for Fall, Winter, Spring, and Summer seasons respectively.

Figure 1: Volatile Solids Reduction by Season



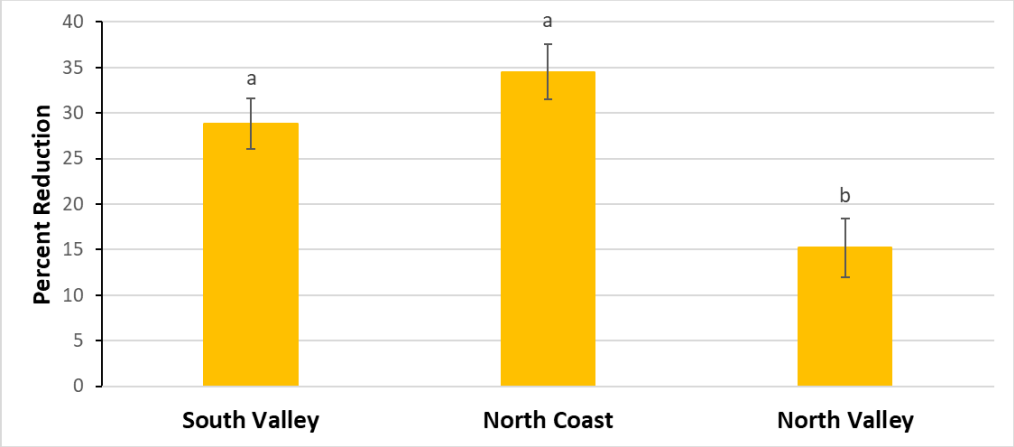
Moisture content of the separated solids (Fig 2) was also similar across seasons. Moisture was 78.71% ± 1.16, 78.21% ± 1.16, 78.23% ± 1.16, and 77.53% ± 1.16 ($p > 0.05$) for Fall, Winter, Spring, and Summer seasons respectively.

Figure 2: Solids Moisture by Season



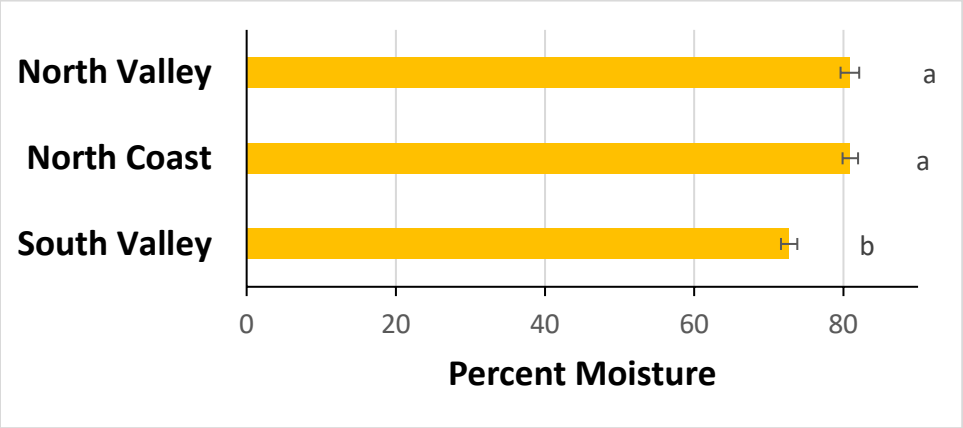
Regional differences in volatile solids reduction were observed. The percentage reduction of volatile solids in the North Valley region across all seasons and separator types (15.20% ± 3.20) was lower than the South Valley (28.83% ± 2.78; $p = 0.0005$) and North Coast (34.52% ± 3.04; $p = 0.0006$) regions. Volatile solids reductions between the South Valley and North Coast regions did not differ ($p = 0.43$).

Figure 3: Volatile Solids Reduction by Region



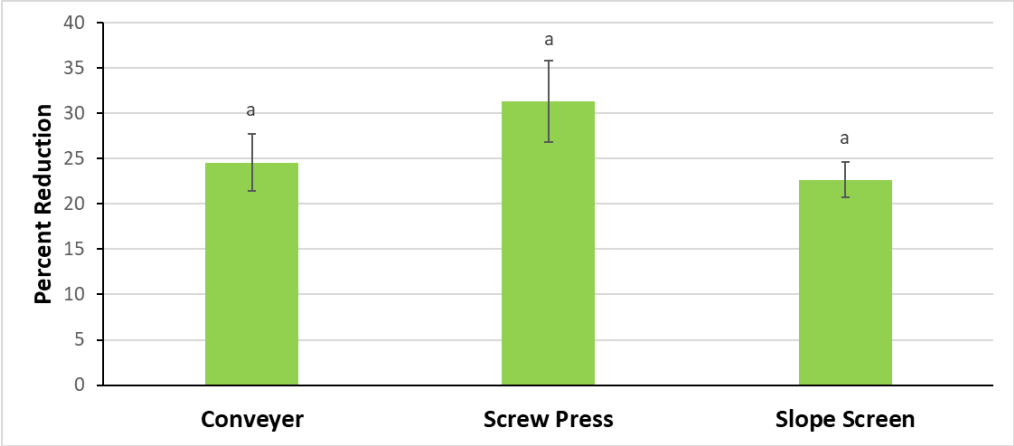
Moisture content of the separated solids (Fig 4) was lower in the South Valley (72.72% ± 1.10) compared to the North Valley (80.86% ± 1.25; $p < 0.0001$) and the North Coast (80.92% ± 0.77; $p < 0.0001$) regions.

Figure 4: Solids Moisture by Region



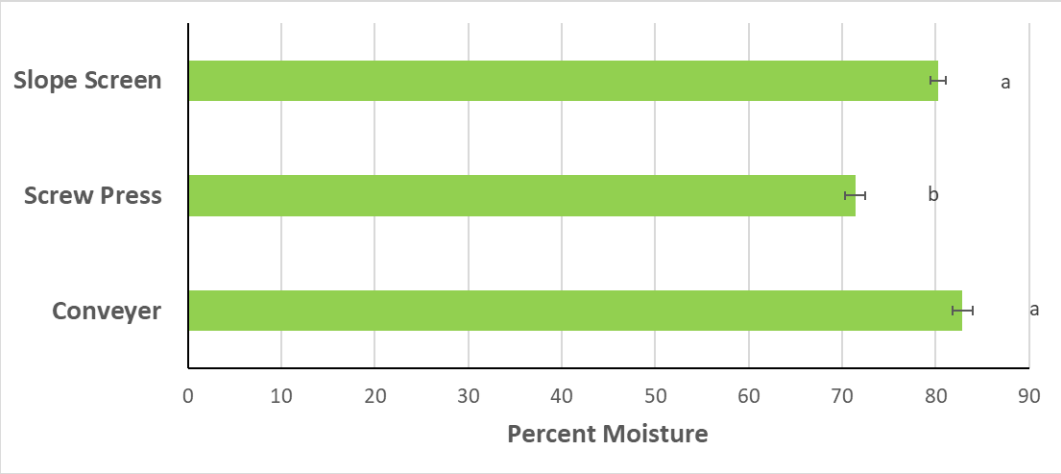
Separator type was not associated with any differences in volatile solids reduction in this study (Fig 5). Conveyer, screw press, and slope screen separators were estimated to remove 24.56% ± 3.15, 31.34% ± 4.53, and 22.66% ± 1.96 of volatile solids respectively in this study ($p > 0.1$).

Figure 5: Volatile Solids Reduction by Separator Type



The moisture content of separated solids (Fig 6) from screw press separators (71.39% ± 1.72) was lower than the moisture content of manure solids from conveyer (82.85% ± 1.09; $p < 0.0001$) and slope screen (80.27% ± 0.77; $p < 0.0001$) separators in this study.

Figure 6: Solids Moisture by Separator Type



Objective 3: Quantify moisture levels and composting efficiency in compost bedded pack barns installed on California dairies in the past 1-5 years.

Key Take-Aways:

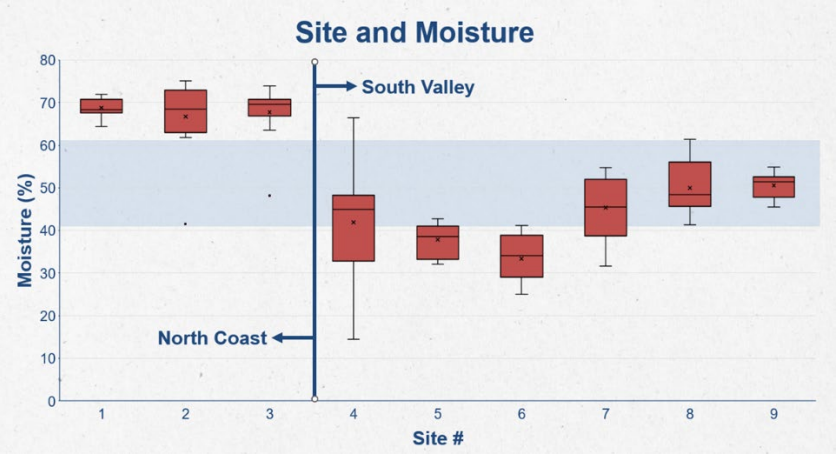
1. Compost bedded pack barns in the South Vally region demonstrated greater composting efficacy, indicated by lower carbon to nitrogen ratios (C:N) and moisture levels, likely due to management differences.
2. South Valley barns were stirred at least monthly, whereas North Coast barns were not. These findings highlight the importance of management practices, such as regular stirring, in optimizing composting efficacy in compost bedded pack barns.
3. The lower moisture and C:N ratio observed in the South Valley region suggest that active management can enhance aerobic decomposition and reduce anaerobic emissions.
4. Implementing the best practices for compost bedded pack barn management can improve manure storage efficiency and contribute to California's greenhouse gas reduction efforts.

Sampling occurred across four seasons (Fall 2023, Winter 2024, Spring 2024, and Summer 2024) and in two geographic regions of California: North Coast (NC, n = 3) and South Valley (SV, n = 6). Compost bedded pack barns were sampled at three depths (surface, 15 cm, and 30 cm) across nine locations per compost bedded pack barn to create one composite sample for each depth, with samples analyzed for carbon to nitrogen (C:N) ratio and moisture. Data were analyzed using a mixed linear model in SAS.

Objective 2 Results:

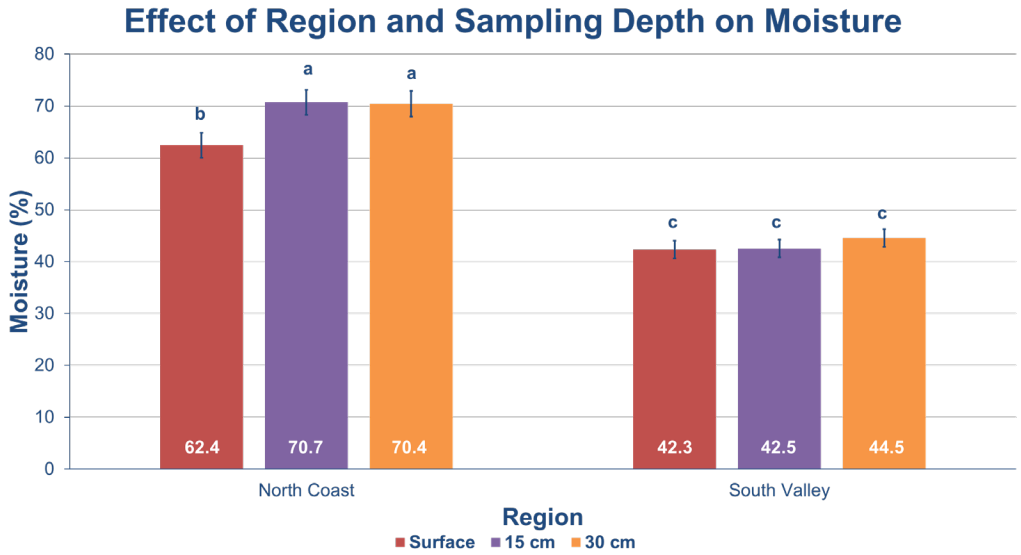
The moisture content of compost bedded pack barns was variable by location (Fig 7). Compost bedded pack barns in the North Coast region were wetter (67.82% ± 1.93) than South Valley sites (43.11% ± 1.36; $p < 0.0001$). No differences in moisture content were observed across seasons.

Figure 7



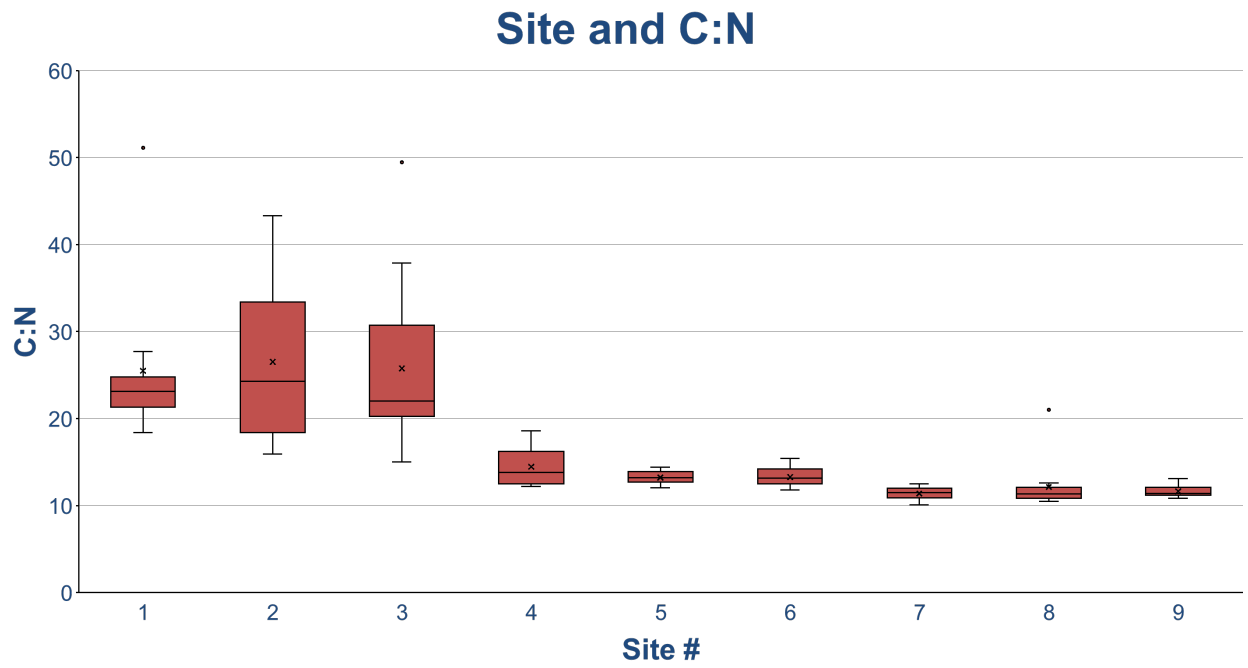
Moisture content of the compost bedded pack at different sampling depths (0, 15, 30 cm; Fig 8) was variable in the North Coast region but not significantly different in the South Valley region. Across all sites, moisture content was higher at 30 cm (57.24% ± 1.48) than at the surface of the pack (53.12% ± 1.46; $p = 0.022$). Moisture content at 15 cm was 56.04% ± 1.46 and not significantly different from the surface ($p = 0.135$) or 30 cm ($p = 0.707$) depths.

Figure 8



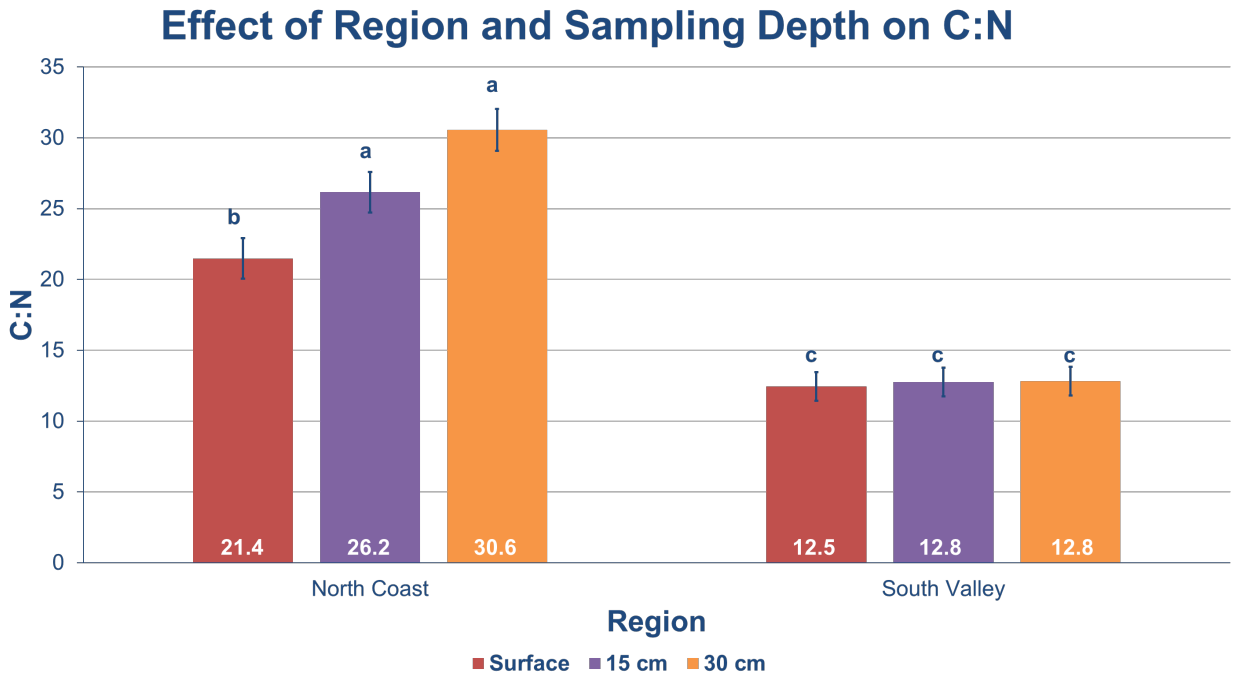
The C:N ratio was also variable across sites (Fig 9). North Coast region sites had higher C:N ratios (25.97 ± 1.14) that sites in the South Valley region (12.68 ± 0.80; $p < 0.0001$). No differences were observed across seasons.

Figure 9



The C:N ratio varied by sampling depth and region (Fig 10). Across all samples, C:N was higher at the 30 cm depth (20.85 ± 0.91) compared to the surface of the pack (17.68 ± 0.90; $p = 0.0069$). C:N at 15 cm was 19.44 ± 0.90 and not significantly different from the surface ($p = 0.1902$) or 30 cm ($p = 0.3482$) depths.

Figure 10


Effect of Region and Sampling Depth on C:N
C:N
35
30
25
20
15
10
5
0
b
a
a
c
c
c
21.4
26.2
30.6
12.5
12.8
12.8
North Coast
South Valley
Region
Surface
15 cm
30 cm

Discussion

This study assessed the operational costs, reduction of volatile solids, and composting performance of alternative manure management systems implemented on California dairies within the past five years. Data were collected via structured interviews and seasonal sampling across multiple regions and analyzed using mixed linear models to evaluate system performance and regional variability.

Operational costs varied widely depending on system type, herd size, and management practices. Annual service costs for mechanical separators ranged from $1,000 to $20,000, with an average of $9,600. Total operating costs, including electricity and maintenance, were estimated to be between $7,700 and $28,000 per year. Electricity usage increased notably for dairies installing separators for the first time, although precise estimates were limited due to concurrent electrical upgrades. Separators operate between 3 and 20 hours daily, with longer running times during winter months. Several dairies reported new revenue from the sale of separated manure solids, indicating potential economic co-benefits.

Mechanical separators demonstrated consistent separation efficiency across seasons and regions. Sampling of sloped screen, conveyor, and screw press systems showed that seasonal variation did not significantly affect performance. Volatile solids reduction and moisture content varied by separator type, with screw press systems generally showing higher efficiency. Regional differences in manure handling practices may influence separator effectiveness and warrant further investigation. Importantly, the study's data aligned with estimates used in the California Air Resources Board's AMMP calculator, supporting its continued use for methane reduction quantification.

Composting performance in compost bedded pack barns was strongly influenced by management practices. South Valley dairies, which stirred packs at least monthly, exhibited lower moisture levels and carbon-to-nitrogen (C:N) ratios, indicating more effective aerobic decomposition. In contrast, North Coast dairies that did not stir regularly showed higher moisture and C:N ratios, suggesting less efficient composting. Seasonal sampling confirmed that active management, rather than climate alone, was the primary driver of composting efficacy.

Overall, the findings highlight the importance of site-specific management and technical support in optimizing the performance and cost-effectiveness of AMMP-funded systems. Adoption of best practices—such as regular stirring in compost bedded pack barns and routine maintenance of separators—can enhance environmental outcomes and contribute to California's greenhouse gas reduction goals.

This study provides critical insights into the operational costs, performance, and management practices of alternative manure management systems implemented in California dairies. Mechanical manure separators and compost bedded pack barns demonstrate measurable benefits in reducing methane emissions and improving manure handling efficiency. However, their effectiveness is highly dependent on site-specific factors and management intensity. Results of this study provide helpful insights to manure management in California but should still be interpreted with caution to due differences amongst sites, variable management practices, and sample size.

Findings confirm that mechanical separators operate reliably across seasons and regions, with performance consistent with current methane reduction estimates used by CARB. Compost bedded pack

barns show enhanced composting efficiency when actively managed, particularly through regular stirring and bedding adjustments. These results underscore the importance of technical assistance and producer education to ensure optimal system performance and long-term sustainability.

Continued investment in applied research, producer outreach, and refinement of quantification tools will support California's climate-smart agriculture goals and encourage broader adoption of practices that reduce greenhouse gas emissions from the livestock sector.