Agricultural Mitigation Strategies for Animal Management Systems in California

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Overview

• Introduction
• Mitigation potential to reduce GHG
• Objective of the current analysis
• Methodology
  – Data collection
  – Statistical analysis
• Results
• Further work
Introduction

• GHG from agriculture
  – Methane
  – Nitrous Oxide
  – Carbon Dioxide

• Sources of emission in animal agriculture
  – Enteric fermentation
  – Manure storage
  – Manure application
## Dairy sector in CA

### Cattle by Class as of January 1, 2001-2012

<table>
<thead>
<tr>
<th>Year</th>
<th>Beef</th>
<th>Dairy</th>
<th>All</th>
<th>Cow Replacements</th>
<th>Heifers 500+ Lbs.</th>
<th>Other Heifers</th>
<th>Calves Under 500 Lbs</th>
<th>Other Cattle</th>
<th>All Cattle and Calves</th>
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<td></td>
<td></td>
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California Department of Food and Agriculture
Mitigation Potential

Potential Reductions in Methane per unit of Milk

- Rumen function
- Feed efficiency
- Genetic selection
- Management practices
- Herd structure
Dietary Manipulations

- Various dietary mitigation strategies
  - Lipids/fat
  - Starch vs fiber
  - Ionophores (monensin)

- ETAAC (2008) report
  - 16% NRC recommendations
  - 11% specific agents
  - 3% long-term management and breeding
Objective

• Quantify potential reduction in methane emissions from dairy cattle in CA by formulating diets based on:
  – Current practices (1)
  – NRC recommendation
    • Unrestricted (2)
    • Restricted (3)
  – Minimized methane (4)
# Methodology

- Data from 40 dairies in CA collected

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<td>0</td>
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<td>0</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

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- Feed ingredients converted to chemical composition (according to NRC)
Methane Emission Estimation

• IPCC Tier 2 equation most common
• Not preferred because
  – It does not account for nutrient differences
  – Less precise
  – Assessment of mitigation limited to reduction in cow numbers and feed consumption
• Developed our own model using over 1,000 energy balance records
Methane model

\[ y = X\beta + Z_1\alpha + Z_2\xi + \varepsilon, \]

where \( y \) is the vector of \( n \) methane records \( X, Z_1 \) and \( Z_2 \) are design matrices relating element of \( y \) to elements of \( \beta, \alpha \) and \( \xi \) which represent vectors of regression coefficients, animal random regression coefficients, and study random regression coefficients. \( \varepsilon \) is the vector of errors.

Methane (GE/d) = -0.32 (0.318) + 0.19 (0.008) DMI (kg/d) – 0.05 (0.046) EE (%) + 0.038 (0.007) NDF (%)
Investigated changes in methane emissions for all scenarios

\[ \text{min}(c^T x), \text{ subject to } A x \{ \leq, =, \geq \} b, \]

where \( c \) is the vector of objective function coefficients (e.g. cost), \( x \) is the vector of decision variables (feed), \( A \) is the matrix of constraints coefficients and \( b \) is the vector of constraints right hand sides (requirements).
Objective

- Quantify potential reduction in methane emissions from dairy cattle in CA by formulating diets based on:
  - Current practices (least cost formulation)
  - NRC recommendation (least cost)
    - Unrestricted
    - Restricted (practical)
  - Minimized methane (least emission)
Results – Scenario 1

Distribution of Methane Emissions in CA Dairies

Methane (Mcal / d)

Dairy

Methane Emissions in CA Dairies

Methane (Mcal / d)

Dairy
• Using the NRC recommendations with no restrictions caused an increase in total methane emissions of 9.23%
• diets were not practical. E.g. (% DM) 11% soybean meal, 34% tomatoes, 50% grass silage, and 5% whey.
Results – Scenario 1 vs 2

Comparison of predicted current emissions in 40 CA dairies (red dotted line) compared to NRC based diets (black solid line)
Results—Scenario 2 (costs)

Distribution of Diet Costs

Diet Costs - using NRC Model

Diet Cost ($/d)

Dairy

Density

3.00 3.50 4.00 4.50 5.00 5.50

1 5 9 14 19 24 29 34 39
Results – Scenario 3

- Using the NRC recommendations with restrictions caused an increase in total methane emissions of 1.24% compared to current.
- Diets were practical. E.g. (% DM) 20% corn silage, 10% DDG, 40% grass silage, 3% molasses, 3% rice bran, 12% soybean meal, 10% tomatoes, 1% whey, 1% mineral supplement.
Results – Scenario 2 vs 3 (costs)

- Using the NRC recommendations with restrictions caused an increase in diet costs of about 16% compared to no restrictions.
Methane Emissions of the three Scenarios

- Scenario 1
- Scenario 2
- Scenario 3

Dairy Methane (Mcal / d)

- Scenarios 1: 4.50
- Scenarios 2: 5.25
- Scenarios 3: 6.00, 6.75

R-NRC

Current

NRC
• Using the minimized methane model with restrictions caused an 
decrease in total methane emissions of 24% compared to current
• Diets were practical. E.g. (% DM) 40 % alfalfa silage, 8% bakery 
waste, 9% canola, 26% ground flaked corn, 15% soybean meal, 1% 
whey, 1% mineral supplement
Results– Scenario 1 vs 3 vs 4

Methane Emissions of the three Scenarios

Methane (Mcal / d)

Min CH4
Current
NRC-R

Dairy

MODELING SUSTAINABLE AGRICULTURE at UC DAVIS
Results—Scenario 3 vs 4 (costs)

- Diets formulated to minimize methane emissions increased costs by an average of 49%
Further Work

- Multi-criteria LP to reduce methane AND cost
  - Cap and trade?
  - Shadow prices
- Specific agents (monensin)
  - Include recent work (in press, JDS)
- Estimate costs of current diets
- Suggestions welcome