Environmental impact of the California dairy industry over 50 years

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How has the environmental impact of the California dairy industry changed in the last 50 years?

A cradle-to-farm gate Life Cycle Assessment (LCA) of California milk production in 1964 and 2014 was conducted considering greenhouse gases (GHGs), water, and land use, to assess the changes that occurred over 50 years.

Background

Life Cycle Assessment (LCA)

- A tool for characterizing and quantifying the environmental impact of a product or system
- Allow us to look at the system as a whole
- Compare similar products
- Identify hotspots within systems investigated

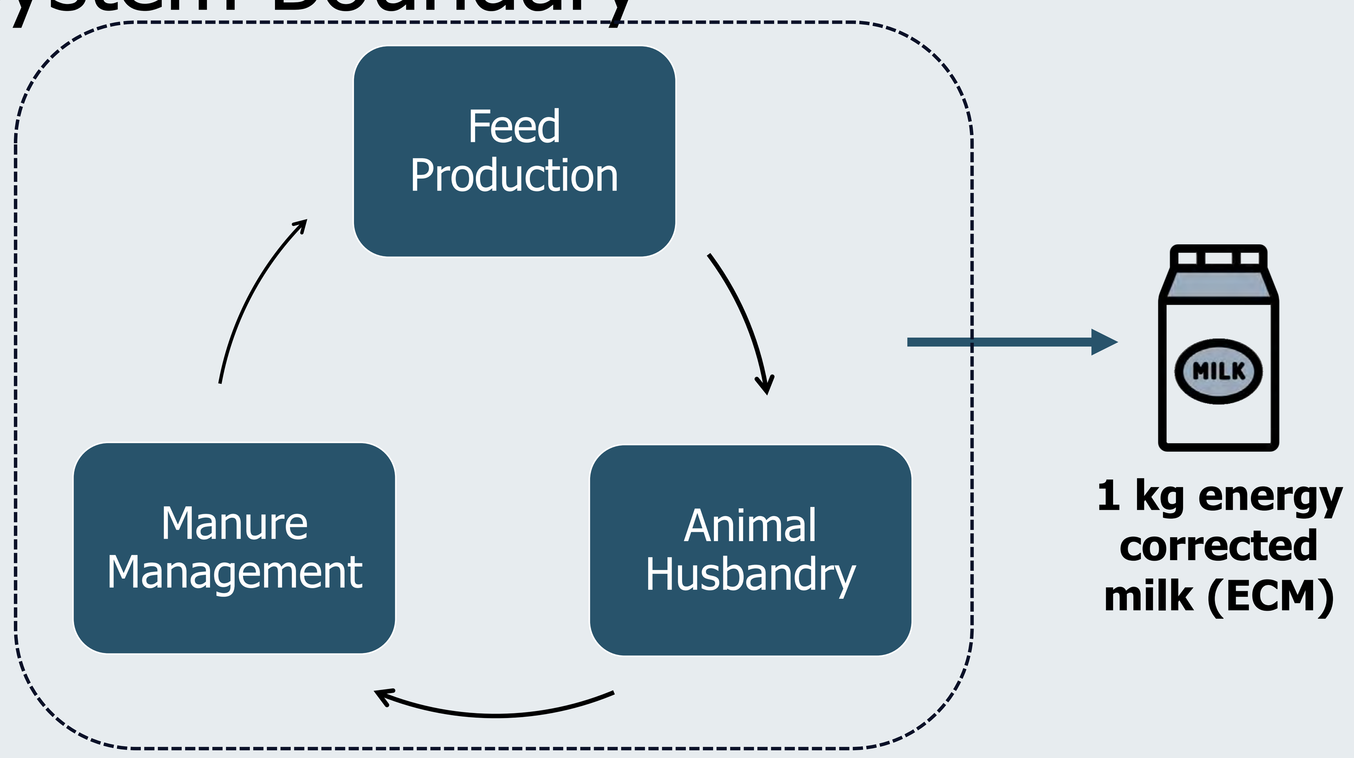
Raw Material Extraction → Manufacture → Use & Maintenance → Treatment & Disposal

Methodology

Guidelines

- International Organization for Standardization (ISO) 14040 and 14044
- Livestock Environmental Assessment and Performance Partnership (LEAP) from Food and Agriculture Organization of the United Nations
- Recommendations of the Intergovernmental Panel on Climate Change (IPCC) for GHGs. This study used IPCC Assessment Report 5 values for global warming potential (over 100 years):
  - 1 kg CH_4 = 28 kg CO_2 equivalents
  - 1 kg N_2O = 265 kg CO_2 equivalents

System Boundary



Model Characteristics

	1964	2014 Model 1	2014 Model 2
Energy Corrected Milk (kg/day)	15.9	39.8	36.4
Milk Fat (%)	3.85	4	4
Milk Protein (%)	3.4	3.3	3.3
Milk data source	CDFA and USDA	primary data from 5 commercial dairies	CDFA
Time in Life Cycle (days)	2080	2049	2049
Ration Information	Literature review in the 60's	Primary data	Cost of milk production reports
Byproduct (%)	3	49	37.6
Final Body Weight (kg)	600	650	650
Milk-Meat Allocation Factor	81:19	92:8	91:9

Data Collection

- Government Reports (USDA, CDFA, NASS, EPA, CARB)
- Published Peer-Reviewed Literature
- UC Extension Reports
- GaBi (PE International) for Emissions Factors

Model Selection

Feed Production

$$= kg\ of\ Crop\ x\ EF\ to\ produce\ 1\ kg\ of\ crop\ (\frac{kg\ Co_2e}{kg\ crop})$$

Animal Husbandry

Free Water Intake (L/d)

Calves	2.28 + 0.569 Age + 9.58Milk Replacer Presence + 0.037 DM of Milk Replacer + 0.0184 Age^2	communication with J.A.D.R.N. Appuhamy
Heifers and dry cows	1.16 DMI + 0.23 DM% + 0.44 TMP + 0.061 $TMPC^2$	Appuhamy et al. (2016b)
Lactating cows	–91.1 + 2.93 DMI + 0.61 DM% + 0.062 NaK + 2.49 CP + 0.76 TMP	Appuhamy et al. (2016b)

Energy Use

$$Energy\ Use\ Emissions = EF\ for\ energy\ source\ x\ \frac{Energy\ Use\ per\ Cow/day}{ECM\ per\ cow\ /day}$$

Enteric Methane

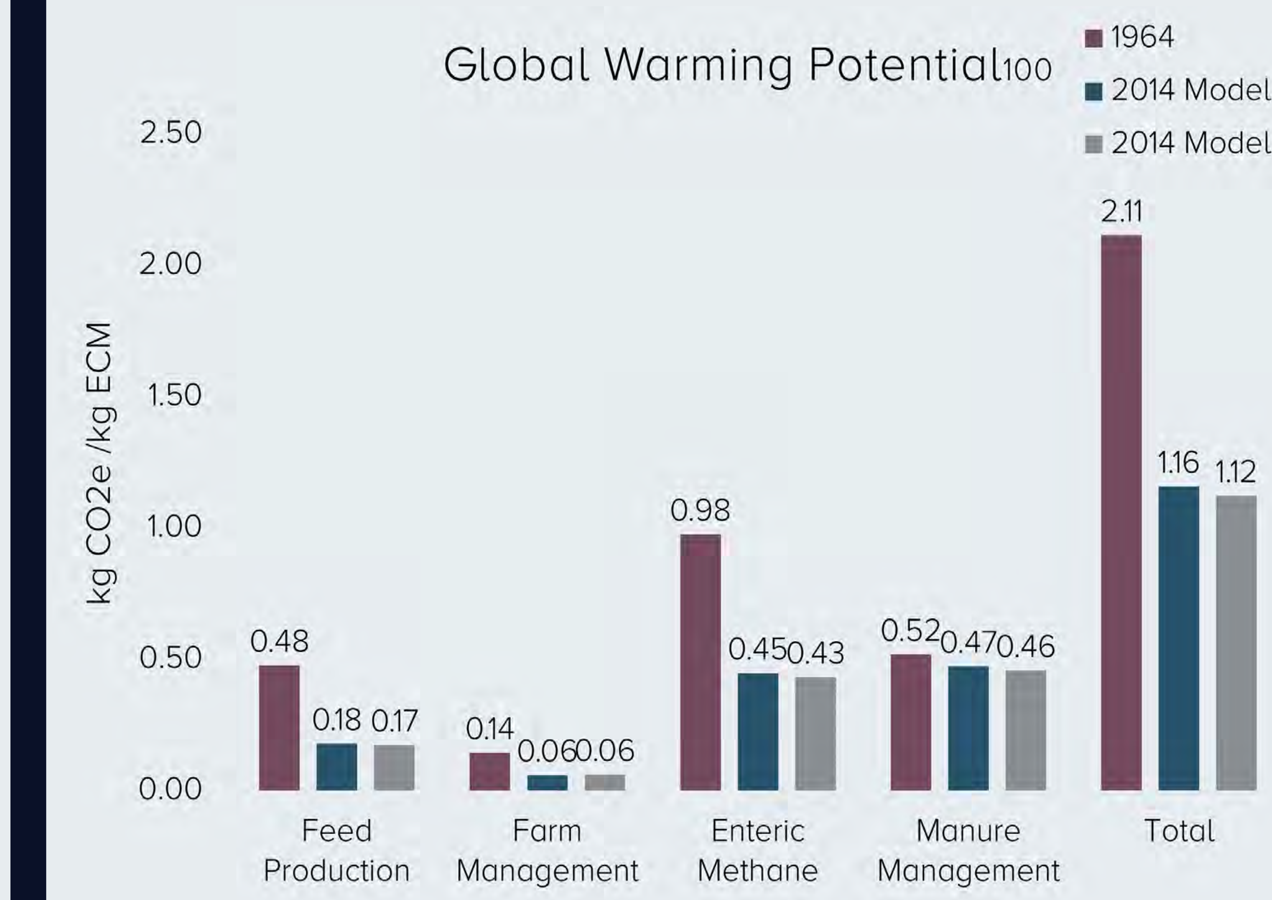
$$grams\ CH_4 = \frac{1.23\ DMI\ +\ 1.45\ FA\ +\ 0.120\ NDF}{0.05565}$$

Nielson et al. 2013

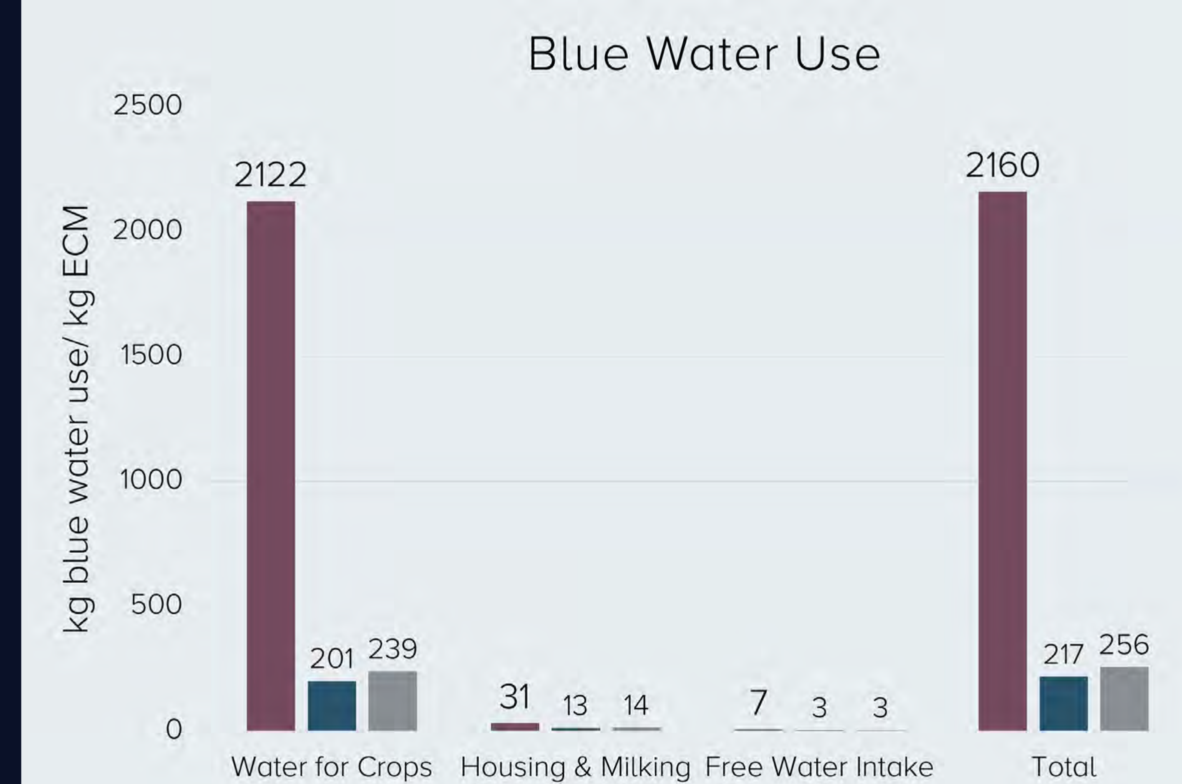
Manure Management

Volatile solids (g/d)	0.354 DMI - 0.084 CP + 0.027 NDF	Appuhamy et al. (2016c)
Total manure nitrogen (g/d)		
Lactating cows	20.3 + 0.654 NI	Johnson et al. (2016)
Heifers & non-lactating cows	15.1 + 0.828 NI	Johnson et al. (2016)

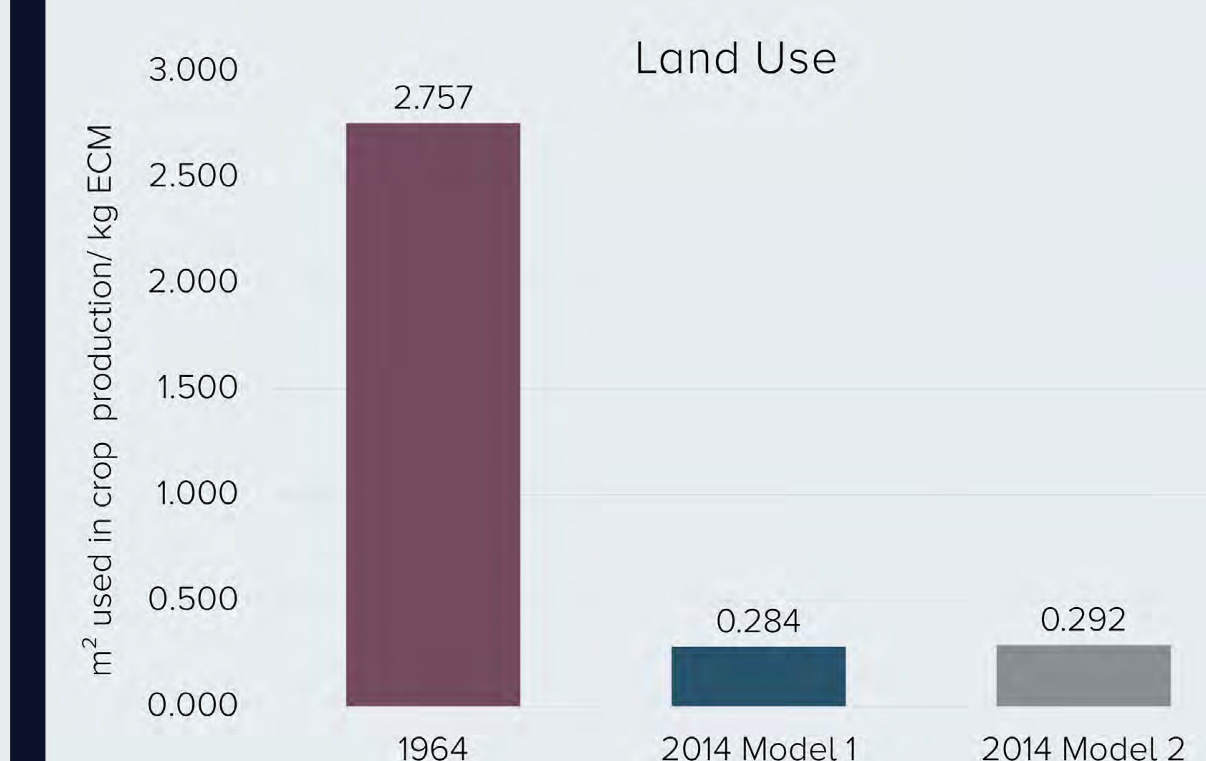
Results



- Total GHGs reduced by 41-45%
- Emissions from crop production reduced by 62.6 - 63.9%
  - Less feed is required to produce 1kg ECM
- Enteric methane reduced by 54.1 – 55.7%
- Manure management emissions reduced by 8.7 -11.9%
  - Reductions are low because of a switch from dry storage to lagoon storage in 2014 data



- Total water use reduction was 88.1-89.9%
- Majority of reductions were due to improvements from crop production
  - Improved fertilizer application; plant genetics; biotechnology
- Due to lack of data for 1964, housing & milking water use reduction was due to the improvements of daily milk per cow entirely



- Total land use reduced by 89.4-89.7%
- Total land saved equivalent to state of Connecticut
- Majority of reductions due to improvements from crop production and production efficiency
- Continued improvements in crop production will reduce land use

Conclusions

- Per unit of milk production, GHGs, land, and water use decreased considerably in the last 50 years
- The values were lower compared to national LCA models for dairy (1.23 kg CO_2e/kg ECM)
- Manure and enteric methane present opportunities to mitigate emissions through innovation