Rationale for Evaluating Sedron and DAF Manure Products in a Systems Comparison in the Dairy Soil and Water Regeneration (DSWR) Project

Dr. Bert Bock

9/25/2024

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

Why The Focus on Rationale?

- Significant emphasis in DSWR on new manure products because of the potential benefits they offer
- Questions have been raised about the rationale for this emphasis, both internally and externally
- Rationale has been communicated in pieces but perhaps not well from a comprehensive systems perspective; goal is to do that

Two Levels of Fucus in This Presentation

- Big Picture: What are the overall merits of the Sedron system that justify DSWR involvement with a piece of the Sedron system?
- Small Picture: What piece of the Big Picture was carved out in DSWR and what are the underlying hypotheses and supporting data?

Presentation Objectives

- Indicate background leading to development of DSWR
- Overview the big picture merits of the Sedron system and manure co-products
- Provide conceptual and quantitative backup for the smaller picture aspects carved out in the DSWR project

History Leading to DSWR Involvement with the Sedron Co-Products

- Pre-DSWR
  - Multidisciplinary Newtrient team analyzed potential “levers” for lowering on-farm GHG footprint of US dairy
  - Concluded enough “levers” to achieve net-zero GHG by 2050
  - Sedron process and co-products prominent in that work: Including important role for land-applied co-products vs. LDM for lowering GHG footprint, esp. w/strip- and no-till + CC
  - The multidisciplinary assessment led to the US Dairy Net Zero Initiative (NZI)
- DSWR was designed and proposed to support the NZI

DAIRY RESEARCH INSTITUTE®
NUTRITION • PRODUCTS • SUSTAINABILITY

Featured NZI programs include:

[Net Zero Initiative | U.S. Dairy (usdairy.com)](https://www.usdairy.com)

Dairy Soil & Water Regeneration

Dairy Scale for Good

Dairy Feed in Focus

The Greener Cattle Initiative

US Dairy Net-Zero Initiative (NZI) Goals

US Dairy Net-Zero Initiative (NZI) Goals

The Big Picture Hypothesis/Rationale:
Sedron Process and Co-products Combined are a Potential Game Changer for All Three NZI Goals

Big Picture Merits of Sedron System and Co-Products

- LDM ➔ Anaerobic digestion ➔ Sedron system ➔ Co-prod.
  - No long-term storage of LDM or AD digestate
- Virtually no NH_3 volatilization from land-applied manure co-products: dried solids and ammonium nitrate soln.
  - Tillage incorporation or injection not required
  - Significantly less N_2O from broadcast co-products than broadcast or injected LDM
- Nutrients substantially concentrated in co-products
  - ~10% N liquid ammonium nitrate
  - ~15% moisture solids containing all the P, K, and organic N
- What are the implications of these merits?

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

The LDM NH_3 Volatilization Challenge That Can be Solved via the Sedron Co-Products

First, The Downsides of Volatilized NH_3 from Land-Applied LDM

- Lost resource
- Atmospheric fine particulate formation (health concerns)
- Indirect N_2O: N_2O emitted when volatilized NH_3 is redeposited on land or water

  IPCC factor is 1% of volatilized $NH_3 \rightarrow N_2O$

  vs.

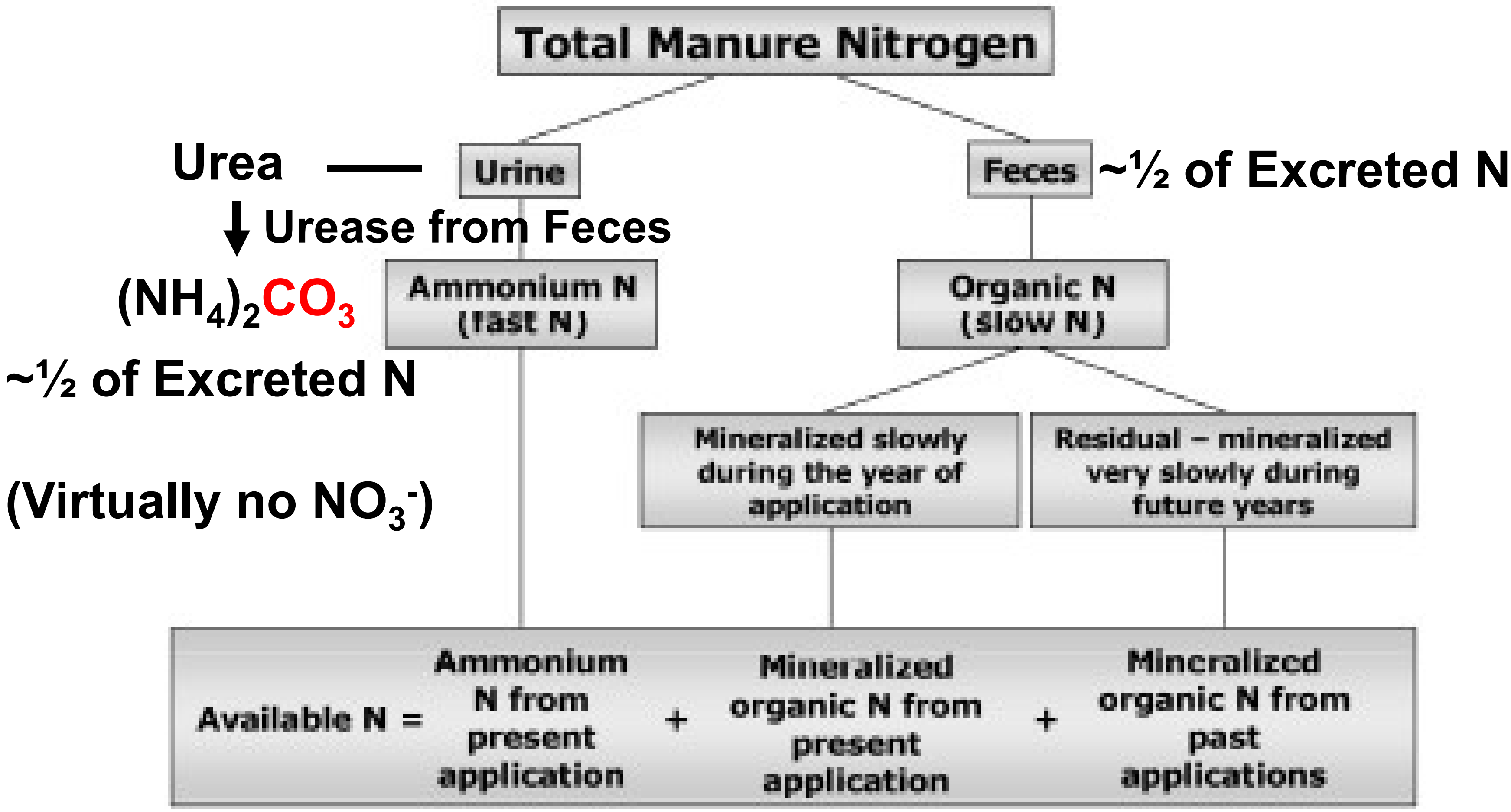
  Direct N_2O: N_2O emitted directly from where LDM is applied

  IPCC factor is 1% of applied $N \rightarrow N_2O$

- Note: N_2O from LDM generally > 1%, especially injected

The Challenge of NH_3 Volatilization from LDM

Manure N Basics: Cornell Agronomy Fact Sheet 4



DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

NH_3 Vol. Basics: Cornell Agronomy Fact Sheet 4

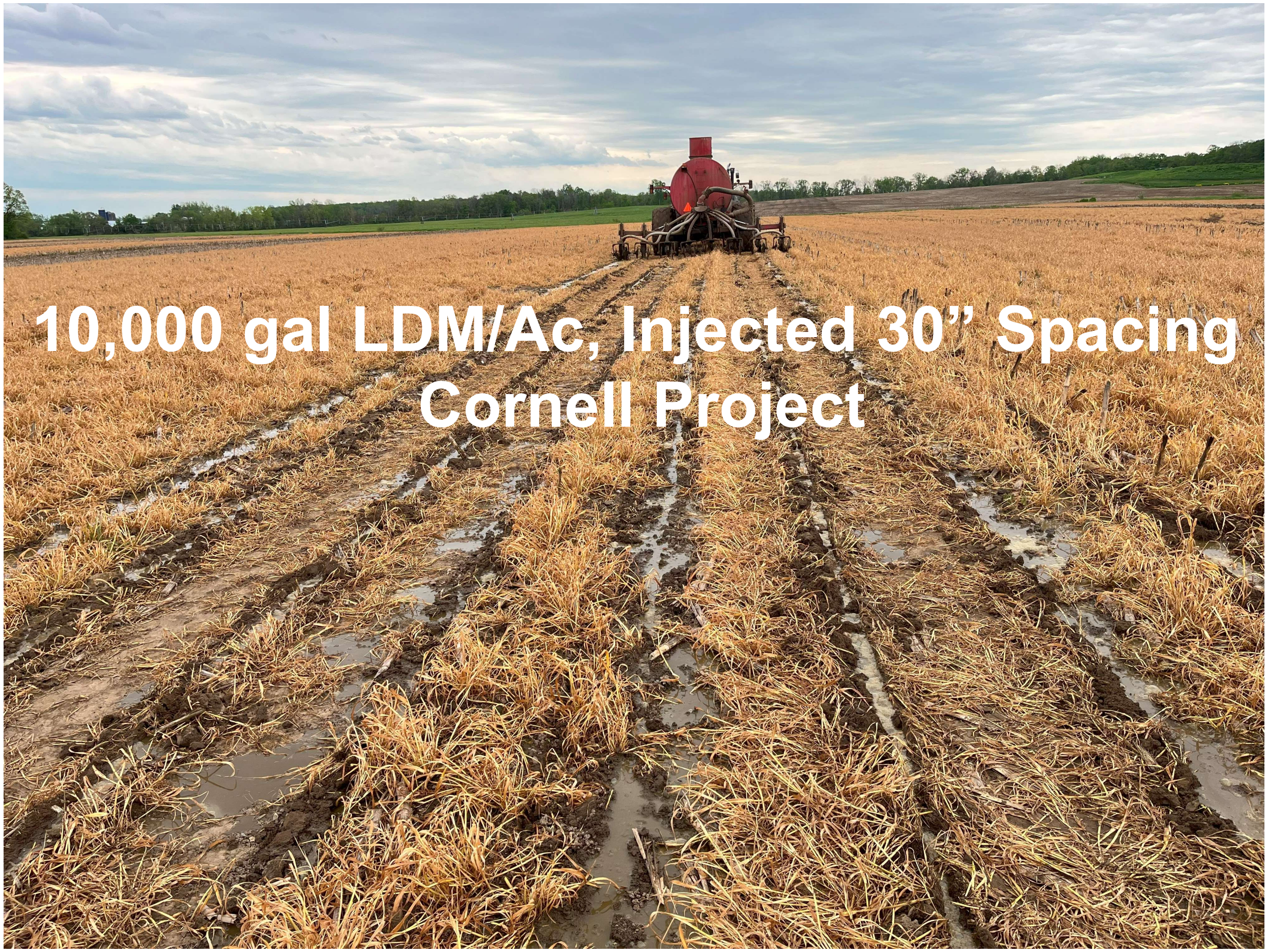
Table 1: Estimated ammonia-N losses as affected by manure application method.

Manure Application Method	% remaining
Injected during growing season	100
Incorporated within 1 day	65
Incorporated within 2 days	53
Incorporated within 3 days	41
Incorporated within 4 days	29
Incorporated within 5 days	17
No conservation or injected in fall	0

Not Always Practical to Immediately Incorporate LDM with Tillage

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

Often Still Some Ammonia Volatilization After Injection



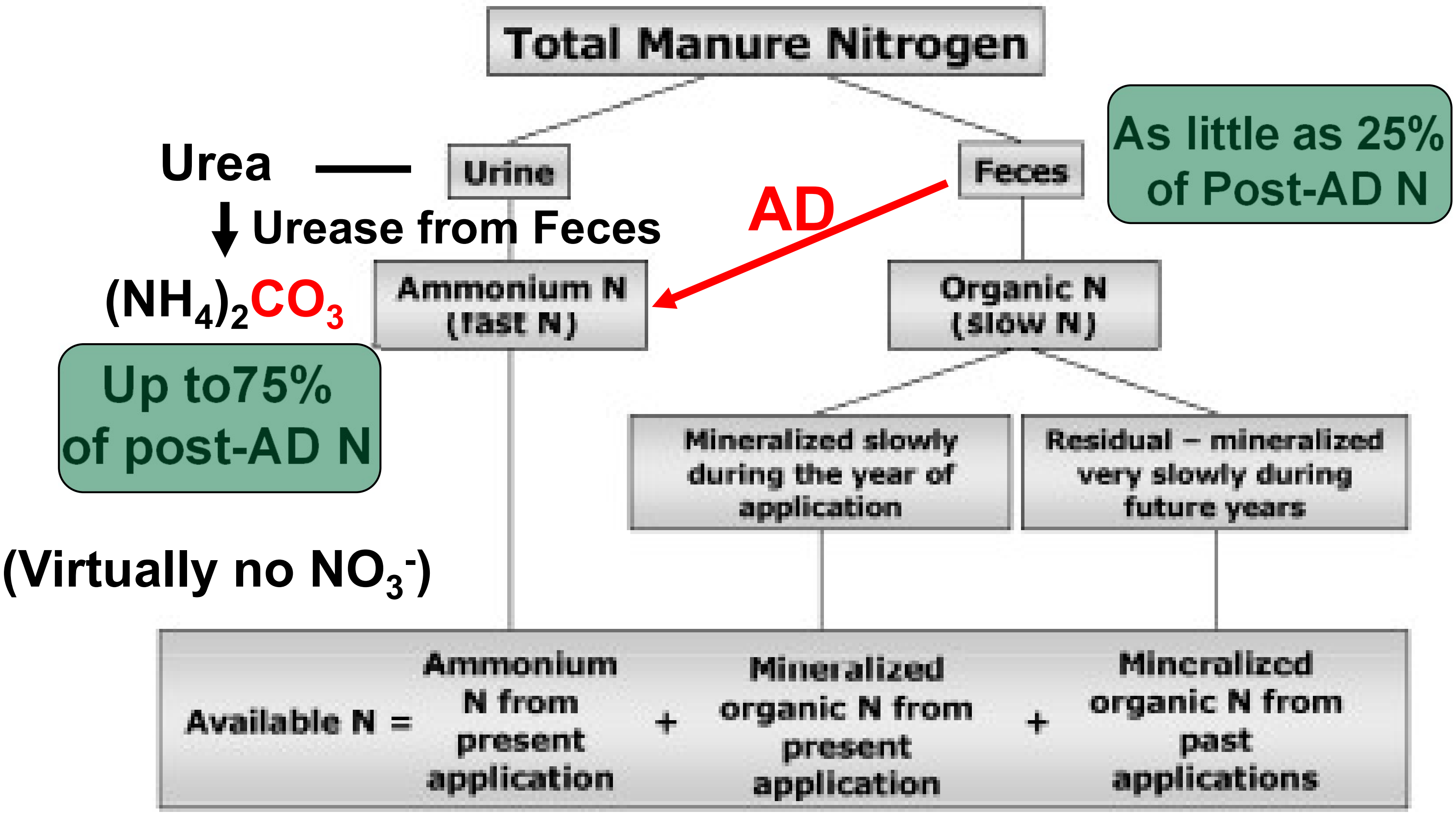
DAIRY RESEARCH INSTITUTE®
NUTRITION • PRODUCTS • SUSTAINABILITY

LDM Practicalities and Tradeoffs re NH_3 Vol. and N_2O

- High potential for Large NH_3 vol. from surface-applied LDM
- Immediate tillage incorporation often not practical
- Tillage incorporation not an option with no-till or strip-till plus cover crop (**Key "levers" for SOC sequestration**)
- **Injection reduces NH_3 loss (indirect N_2O) but increases direct N_2O substantially (widely accepted concept)**
- Need practical alternative to tillage incorporation or injection of LDM, especially for no-till or strip-till + CC
- **Smaller Picture Hypothesis**: Sedron co-products can be broadcast without tillage incorporation and provide very low NH_3 volatilization (indirect N_2O) and significantly lower direct N_2O than from broadcast or injected LDM

The Sedron System and Co-Products

Anaerobic Digestion (AD) is Precursor to Sedron System



Sedron Varcor™ System for Liquid Dairy Manure (LDM)

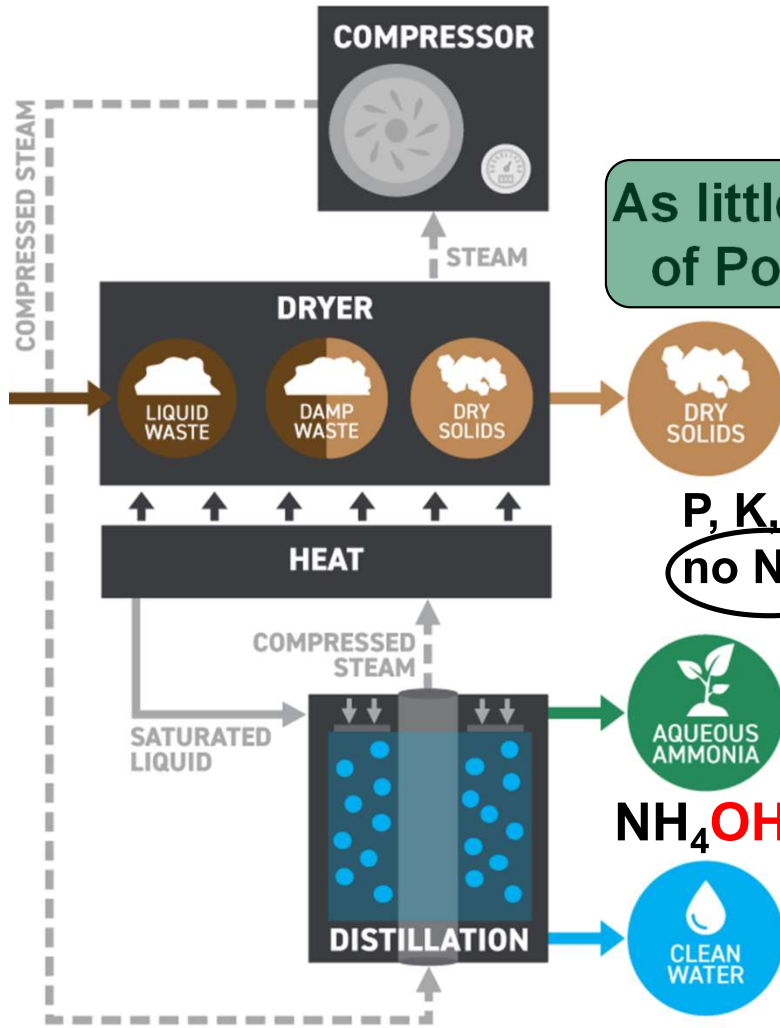
Renewable NG

↑

CH_4, CO_2

↑

LDM at barn → Coarse fiber removal → **AD** → Digestate: Solids + $(NH_4)_2CO_3$ + water



As little as 25% of Post-AD N

~15% moisture

P, K, organic N, no NH_4^+

NH_4OH

→ AN

~10% N

NH_4NO_3

Up to 75% of LDM N

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

Sedron Varcor[TM] System for Liquid Dairy Manure (LDM)

Renewable NG

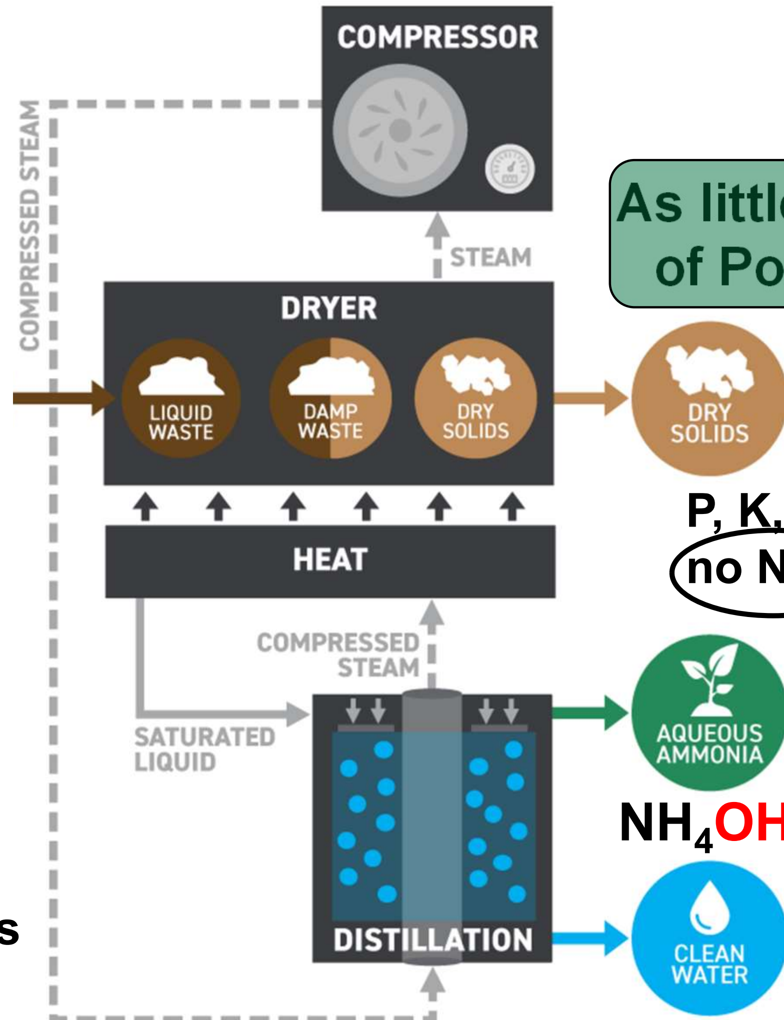
↑

CH_4, CO_2

↑

LDM at barn → Coarse fiber removal → **AD** →

Digestate: Solids + $(NH_4)_2CO_3$ + water



As little as 25% of Post-AD N

~15% moisture

P, K, organic N, no NH_4^+

NH_4OH

→ AN

~10% N

NH_4NO_3

Up to 75% of LDM N

Process energy offsets ~40% of this GHG reduction →
Net ~60% GHG reduction

No lagoon:
- No CH_4, direct N_2O, or indirect N_2O from vol. NH_3
- Avoids loss of up to 65% of NH_4^+ as vol. NH_3

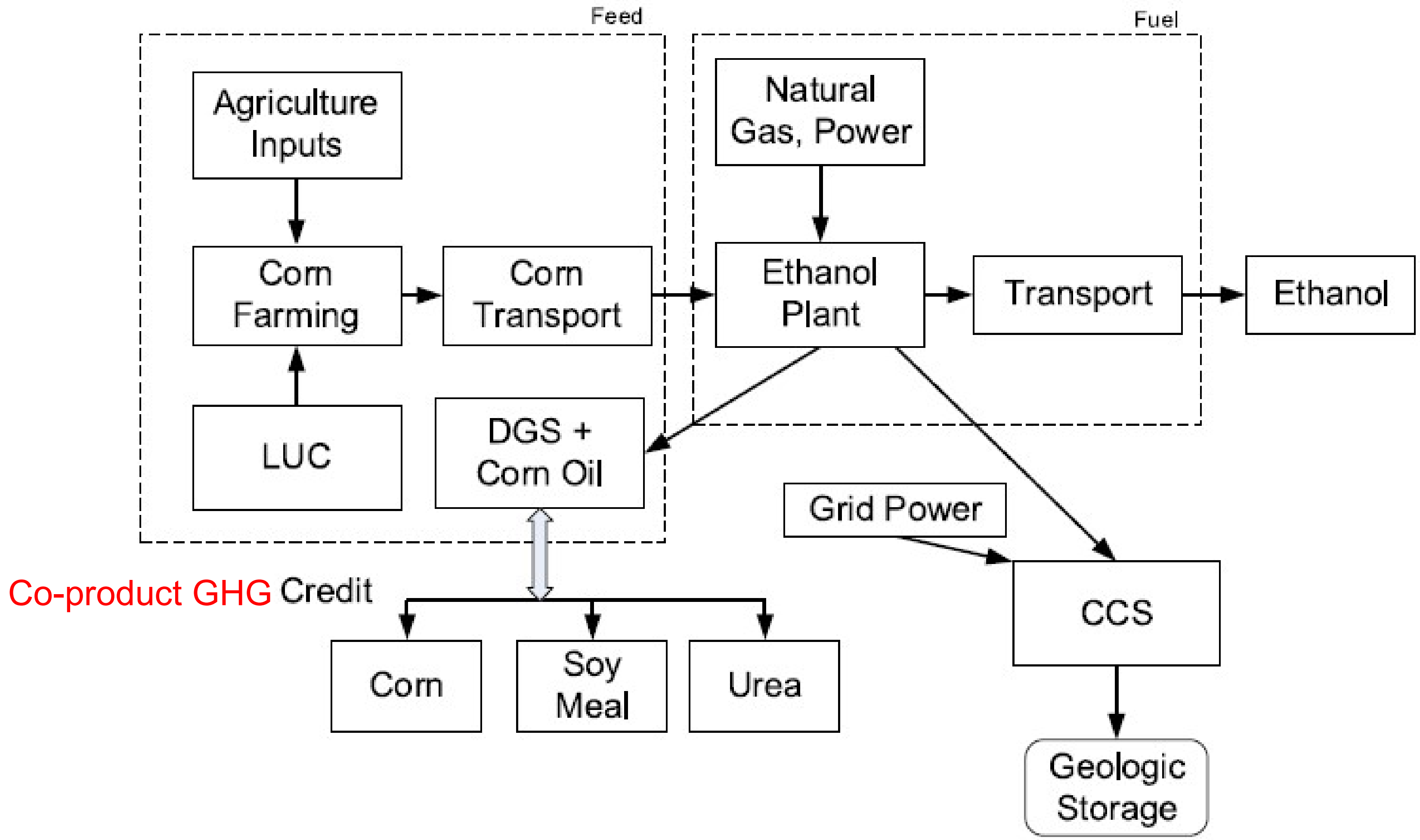
Substantial Potential for Surplus Biogenic Nutrients to Replace Higher GHG Footprint Nutrient Sources

3000 Cows, 1729 Ac Corn Silage and 1505 Ac Alfalfa	
	Surplus, %[1/]
Low N_2O, Biogenic Sedron AN	81
Low N_2O, Biogenic Sedron solids	30

[1/]P banking in silage corn/alfalfa rotation, No AD
For silage corn, replace P removed by both silage corn and subsequent alfalfa rotation
Provides all of P and most of K for both crops without wasting N on alfalfa

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

The Concept of Co-Product GHG Credits on a Replacement Basis is Well Accepted



LCA_-_45Z-EtOH-Default-FINAL.pdf (growthenergy.org)

Summary of Small and Big Picture Sedron Co-Product Value-Adds re GHG Footprint

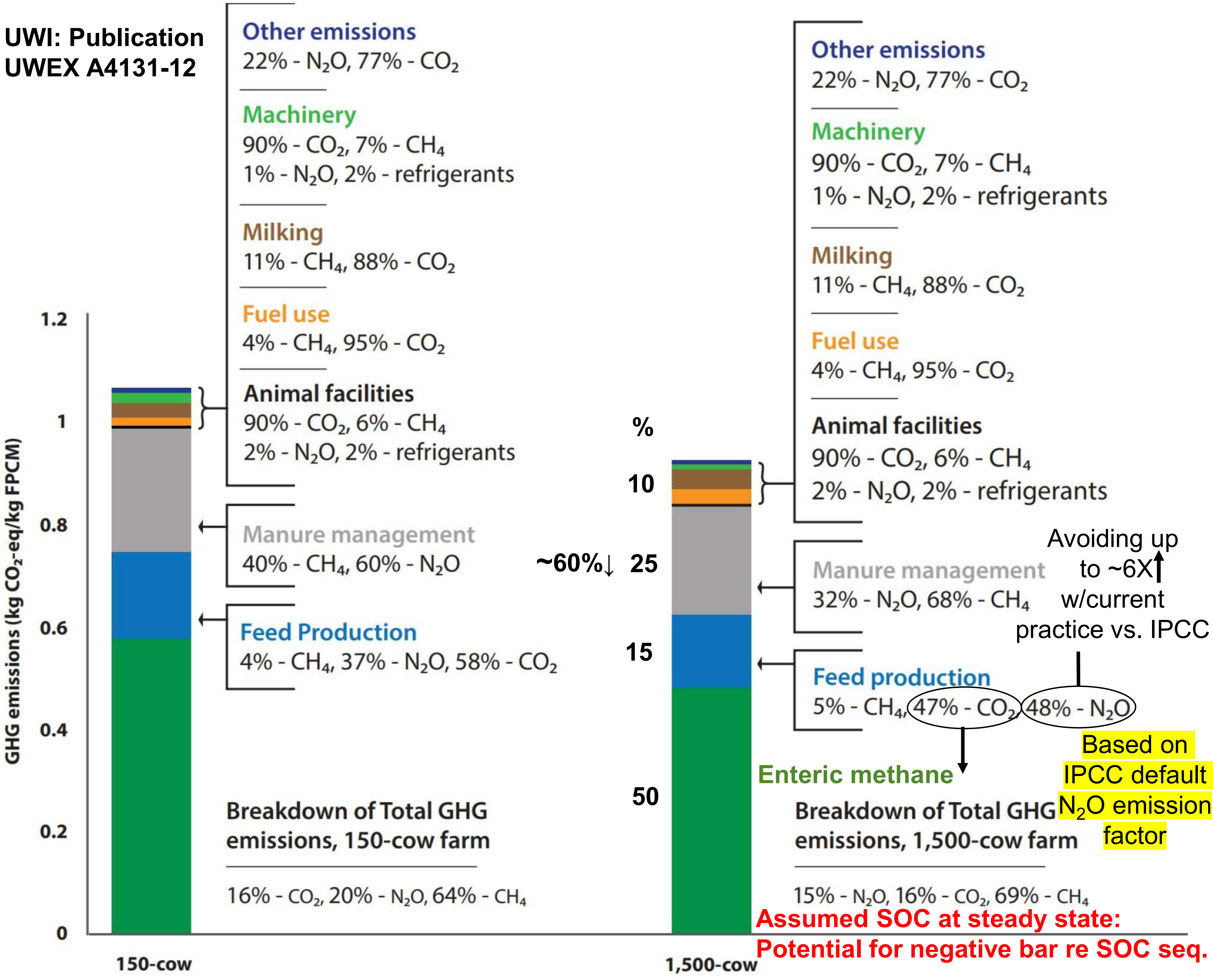
- Small Picture
  - Dried solids and AN don't have to be incorporated or injected to prevent large NH_3 volatilization losses (indirect N_2O) that occur from surface-applied LDM
  - Much less N_2O from broadcast Sedron solids and AN than b-cast or injected LDM **(need better quantification of this)**
  - Better compatibility with strip- and no-till with cover crop (**key "levers" for SOC sequestration and soil health**)
  - More practical for all tillage systems
- Big Picture
  - Lower GHG footprint for exported, low N_2O, biogenic AN and solids than replaced fossil-based nutrients
  - Less fossil energy for hauling and applying Sedron co-products vs. LDM

Sedron Process Will Replace ~ 40 Trucks at Kinnard Farms

Application of LDM is an Energy-Intensive Process

DAIRY RESEARCH INSTITUTE®
NUTRITION • PRODUCTS • SUSTAINABILITY

UWI: Publication
UWEX A4131-12

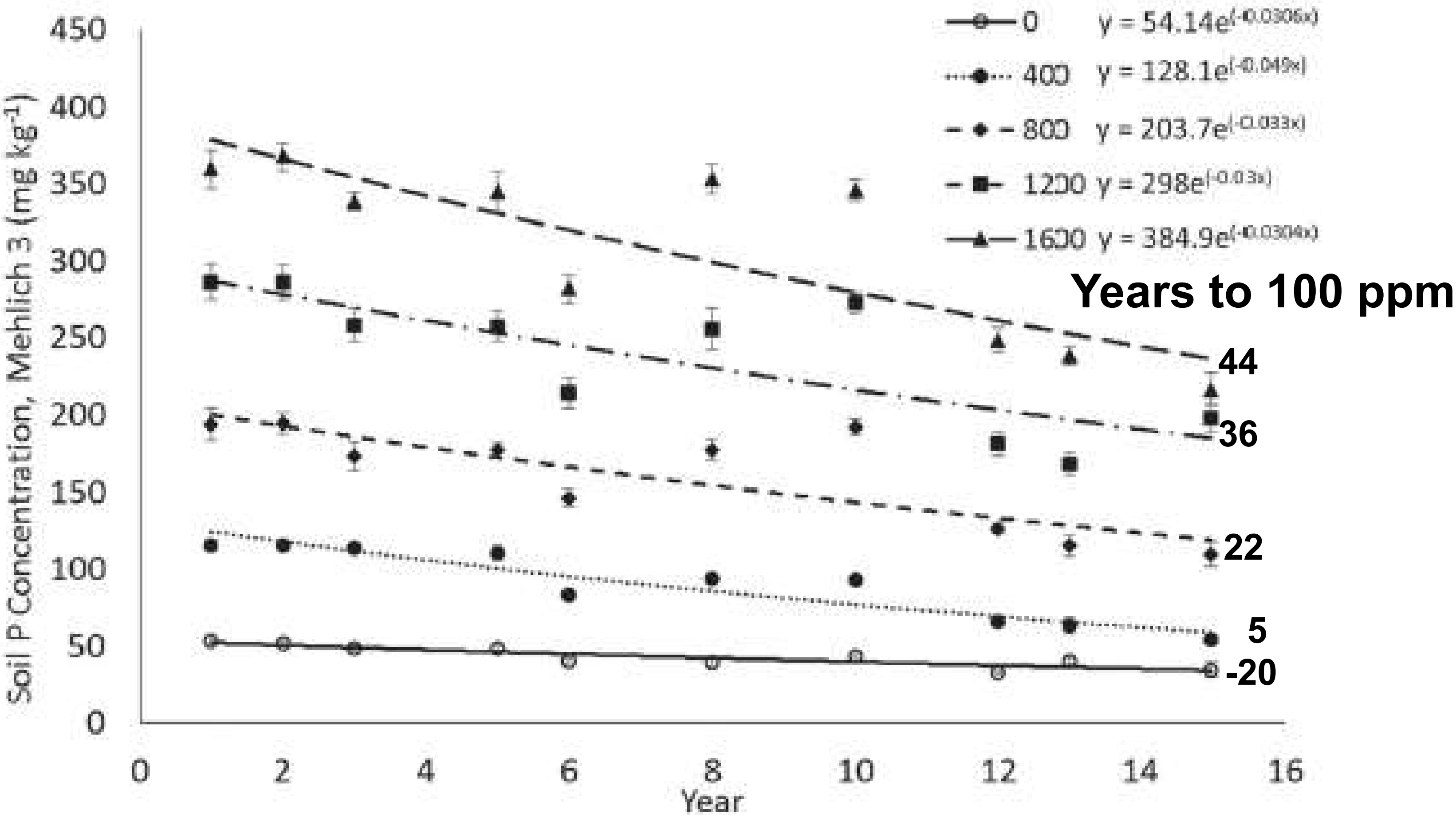


Summary of Big Picture Sedron Co-Product Value-Adds re Water Quality

- Nutrient concentration and form facilitate:
  - Practical storage of nutrients until optimum time for application
  - Practical export of surplus nutrients
- AN decoupled from P in solid co-product—facilitates applying solid co-product on P replacement or P banking basis, supplementing N with AN, and exporting excess solids and AN
- Alternatively, facilitates soil P drawdown for environmental purposes and exporting even more excess solids along with excess AN

Many Years Required to Drawdown Soil Test P to Agronomic Optimum On Soils with High Soil Test P

Cumulative manure rate over 4 years, kg P/ha



Fiorellino et al., 2017

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

What Portion of the Big Picture Did We Carve Out for the Systems Comparison in DSWR?

Little Known about How to fully Capitalize on the Sedron Co-Product Strengths vs. LDM

- 1. Compatibility with **no-till and strip-till + CC** due to hypothesized low NH_3 vol. losses (indirect N_2O) and low direct N_2O when co-products are b-cast without tillage incorp.
- 2. Greater flexibility for spring instead of fall application due to ease of manure product storage to facilitate opt. nut. timing
- 3. Greater nutrient concentration facilitating practical export of surplus nutrients, especially P, to facilitate opt. nut. rates

---

- Critical need to compare advanced sys. featuring combos. of the above strengths vs. BAU LDM and tillage practices

based on

Crop yield, N_2O, **SOC Sequestration**, and **Soil health**
Water quality at selected sites; systems comparison later

US Dairy Net-Zero Initiative (NZI) Goals

Smaller Picture Goal:

Less loss of NH_3 (i.e., indirect N_2O) and direct N_2O while using no-till or strip-till + CC to increase SOC sequestration & Soil Health

US Dairy Net-Zero Initiative (NZI) Goals

Smaller Picture Goal:
Less loss of NH_3 (i.e., indirect N_2O) and direct N_2O while using no-till or strip-till + CC to increase SOC sequestration & Soil Health

Strong dual impact:
1. **Lower GHG footprint**
2. **Improved soil health**

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

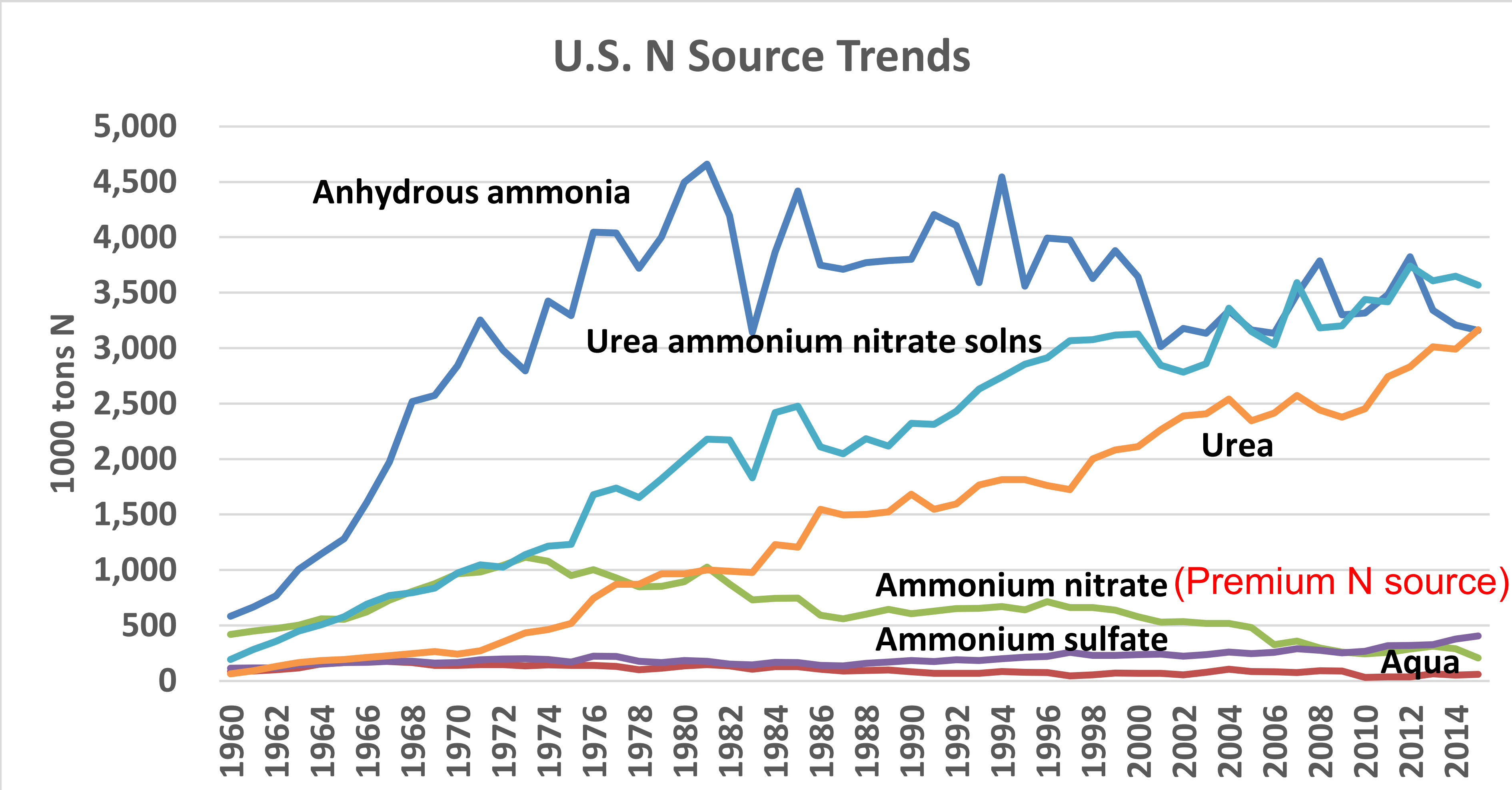
Small Picture Conceptual and Quantitative Backup

Virtually no Ammonia Volatilization from Ammonium Nitrate (NH_4NO_3)

Ammonium nitrate has relatively little effect on soil pH, and thus low volatilization, often similar to unfertilized controls. It is no longer readily available because of its potential use for making explosives. Calcium ammonium nitrate is still available in the U.S and has similarly low volatilization potential *(12)*. Common N fertilizers and their grades are in Table 1.

Urea vol factors BMP combo.pdf (montana.edu)

Reminder: AN = up to 75% of Sedron co-product N



DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

AMMONIA VOLATILIZATION FROM UREA FERTILIZERS

Bulletin Y-206

Editors: B. R. Bock
D. E. Kissel

Published by

National Fertilizer Development Center
Tennessee Valley Authority
Muscle Shoals, Alabama

1988

Hypothesis for Low NH_3 Volatilization from Broadcast Sedron Solids That Are Not Incorporated with Tillage

- Ammoniacal N has been extracted from Sedron solids
- Any volatilized NH_3 must come from organic N

-----------------Mineralization------------

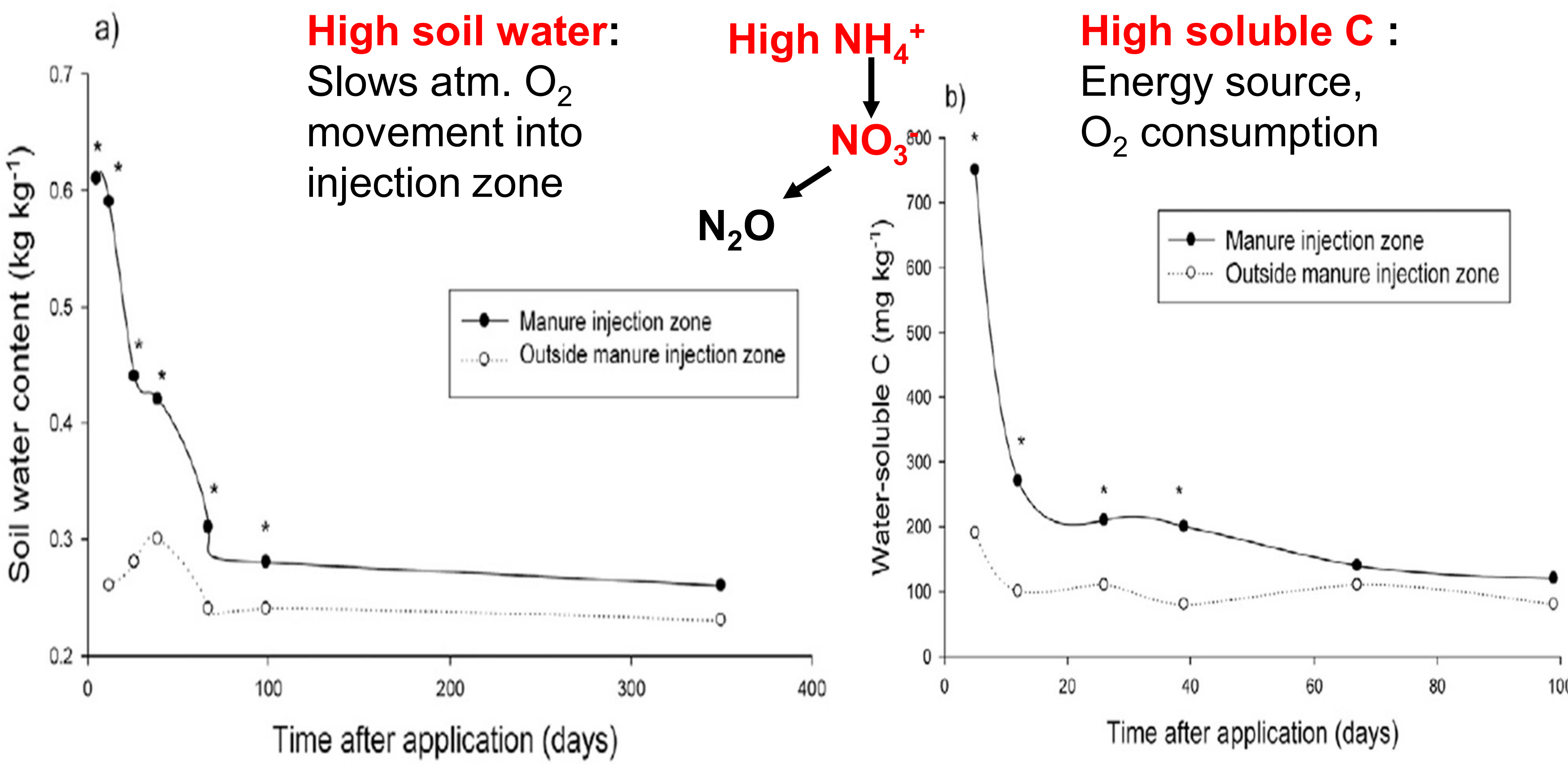
Organic N ➔ (NH_3 + H^+ ⇠ ➔ NH_4^+) ➔ NO_3^- + 2 H^+

-------Nitrification------

  - Hypothesize nitrification fast enough to neutralize any NH_3 that forms from organic N mineralization

    Need to test this hypothesis in separate study: no literature on NH_3 volatilization from NH_4-extracted manure solids

LDM Injection Zone Has “Built-In” Key Requirements for Denitrification-Based N_2O



Elevated soil water and soluble C in LDM injection zone, Dell et al. (2011) after Comfort et al., 1988); **soil not tilled after manure injection**

N_2O from Land-Applied LDM with No or Reduced Tillage (Three-year Studies)

	State	Texture	B-cast non-incorp	Injected
			Direct N_2O EF, %	
Duncan et al. (2017)	PA	Silt loam	0.8	1.8
Ponce de Leon et al. (2021)	PA	Silt loam	0.6	1.5
Dittmer et al. (2020)	VT	Silt loam	1.5	3.1
		Mean	**1.0**	**2.1**

Plus Significant indirect N_2O

Duncan, E.W., C.J. Dell, P.J.A. Kleinman, and D. B. Beegle. 2017. Nitrous oxide and ammonia emissions from injected and broadcast-applied dairy slurry. J. Environ. Qual. 46:36-44.

Maria A. Ponce de Leon, Curtis Dell, and Heather Karsten. 2021. Nitrous oxide emissions from manured, no-till corn systems. Nutr. Cycl. Agroecosyst. 119:405-421.

Dittmer, Kyle M., Heather M. Darby, Tyler Goeschel, and E. Carol Adair. 2020. Benefits and tradeoffs of reduced tillage and manure application methods in a maize silage system. J. Environ. Qual. 49:1236-1250.

Large N_2O Effects of INJ vs. B-Cast/Incorp. Cattle Slurry

Treatment	N_2O Emission [kg N_2O-N ha^{-1} yr^{-1}]			EF [% of N Applied]		
	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
CON	2.3 ^{b}	3.3 ^{c}	2.8	Unusually dry		
B-cast/INC	2.1 ^{b}	6.7 ^{b,c}	4.4	0.0	1.8	0.9
INC + DMPP&DMPSA	n.d.	5.4 ^{b,c}	5.4	n.d.	1.1	1.1
INJ	16.2 ^{a}	11.5 ^{a}	13.9	8.4	4.4	6.4
INJ + DMPP	12.8 ^{a}	5.5 ^{b,c}	9.2	6.3	1.2	3.8
INJ + DMPSA	12.4 ^{a}	8.4 ^{b}	10.4	6.1	2.7	4.4
INJ + DMPP&DMPSA	9.6 ^{a}	4.9 ^{b,c}	7.3	4.4	0.9	2.7
INJ + nitrapyrin	12.8 ^{a}	7.9 ^{b}	10.4	6.3	2.4	4.4
INJ + DCD	11.0 ^{a}	4.4 ^{b,c}	7.7	5.2	0.6	2.9
INJ + TZ&MP	13.4 ^{a}	n.d.	13.4	6.7	n.d.	6.7

n.d. not determined.

Herr et al. (2020), Germany

Silty loamy soil, 150 lb N/Ac (1st year), 170 lb N/Ac (2nd year)

Broadcast Sedron Solids vs. Injected LDM: Relative Levels of Key N_2O Factors in Application Zone

Much Lower soil water	Virtually no NH_4^+ or NO_3^- initially	Similar soluble C

------------------Imply lower N_2O------------------

Organic N ➔ NH_4^+

NH_4^+ ➔ NO_3^- ➔ N_2O

Mineralization required;
Implies delayed N_2O

Up to 75% of Sedron co-product N

Low N_2O from Sedron AN vs. LDM

- AN provides flexibility for sidedress & split applications ➔ relatively low N_2O vs. fall or spring LDM
  - Lower probability of NO_3^- exposure to excessive precipitation after sidedressing AN vs. after fall or spring LDM
  - No "built in" excessive soil moisture or soluble C to supercharge N_2O emissions
- Low N_2O during conversion of NH_4^+ to NO_3^-
  - Only half of N in AN (NH_4NO_3) is NH_4^+
  - NH_4NO_3 is not alkaline (details for another day)

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

How Does Exported Sedron AN Compare with Replaced Fossil-based Commercial N Sources re GHG Footprint?

- Generally lower GHG footprint from AN
- Details for another day: see following link for a start:

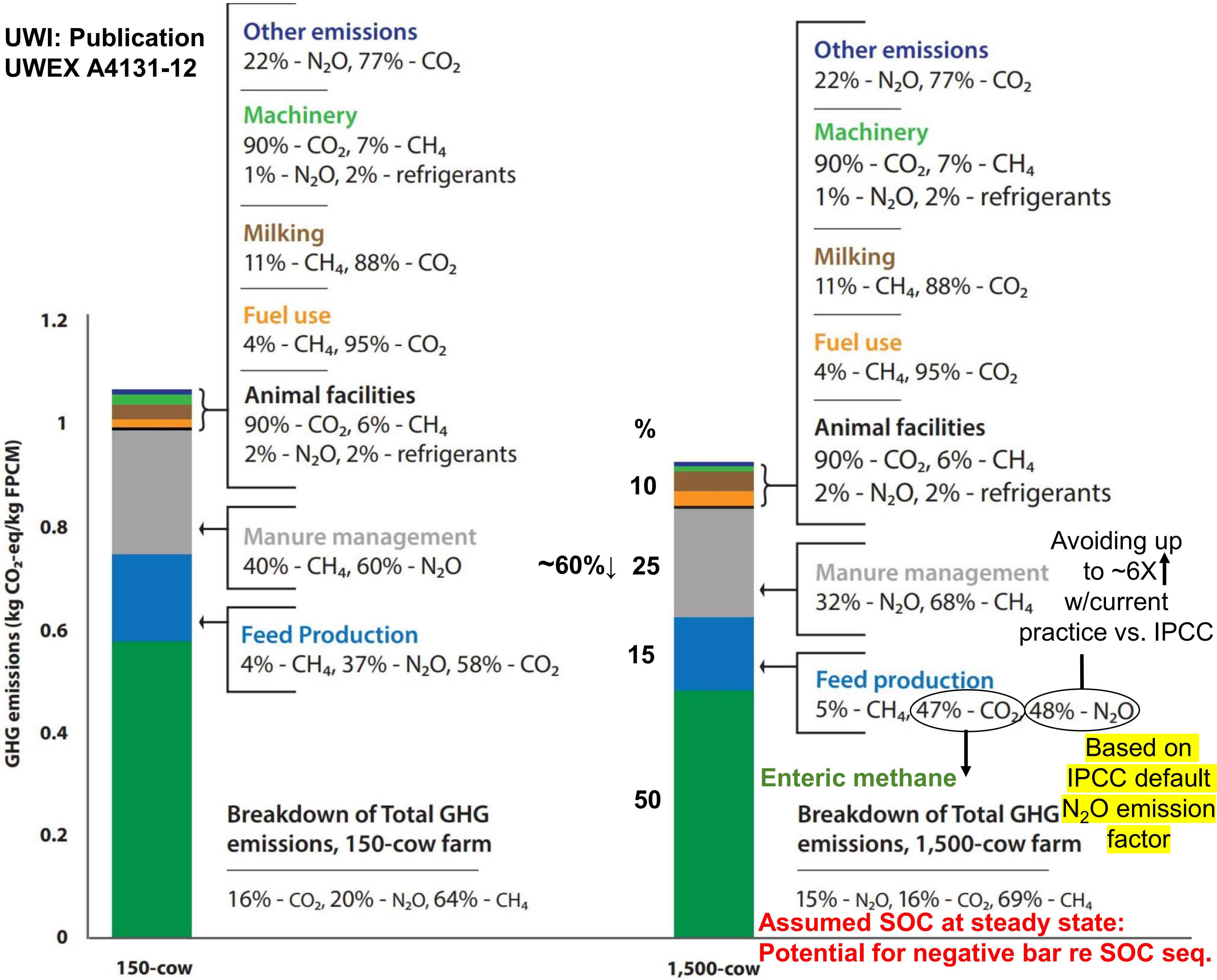
  FFF Fluid Forum 2023 – The Fluid Fertilizer Foundation

Putting N_2O Pieces Together: Placeholders for Illustration

Assuming Medium Textured Soils, "Avg." ppt.

Overall N_2O Emission Factor for Sedron Co-Products				B-cast LDM	Injected
Broadcast	% of LDM N	Direct N_2O-N	Weigthed	not incorp.	LDM
not Incorp.	in AD Digestate	EF, %[1/]	EF, %	N_2O-N EF, %[2/]	
Sedron AN	65	0.3	0.20		
Sedron soilds	35	0.7	0.25		
		Total	0.44	1.5	2.0
[1/]Doesn't account for replacement credit from exported co-products					
[2/]Direct and indirect N_2O					

UWI: Publication
UWEX A4131-12



Rel. CO_2	+	(Rel. N_2O	x	N_2O EF, %)	=	Rel. Blue Bar	
0.5	**+**	**0.5**	**x**	**1**	**=**	**1.00**	**IPCC default**
0.5	+	0.5	x	0.5	=	0.75	Sedron co-products
0.5	+	0.5	x	1.5	=	1.25	B-cast, nonincorp. LDM
0.5	+	0.5	x	2	=	1.50	Injected LDM
0.5	+	0.5	x	6	=	3.50	Injected LDM

Big Picture: Dissolved Air Flotation (DAF) Polymer-Assisted Fine Solids Separation

Table 2. 2. Distribution of nutrients and solids measured at a Trident Nutrient Recovery System Installation

Constituent	Distribution Fraction (% of input)		
	Course Solids	Fine Solids Cake	Liquid Effluent
Total N	8	38	52
Ammonia N	4	12	76
P	10	70	20
K	3	13	80
Solids	22	43	31
Notes: Source: Canter et al., (2021).	**Removed by screw press**	**DAF Fine solids**	**DAF pass through**

-------Post Screw Press-------

cbc_manure_nutrient_report.pdf (ca.gov)

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

DAF Products from LDM		
	DAF fine	DAF liquid
	solids cake	flow-through
	% of screw press effluent[1/]	
Total N	42	58
Ammonia N	14	86
P	78	22
K	14	86
Solids	58	42
[1/]Assumes coarse solids removed with		
screw press		

High pH, NH_3 loss potential → Need to Inject

Very fine solids; high in soluble carbon → high potential for denitrification with injection

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

Systems Comparison: Rationale and Description

Systems Comparison Designed to Feature Sedron and DAF Co-Product Strengths vs. LDM

- 1. Compatibility with **no-till and strip-till + CC** due to hypothesized low NH_3 vol. losses (indirect N_2O) and low direct N_2O when co-products are b-cast without tillage incorp.
- 2. Greater flexibility for spring instead of fall application due to ease of manure product storage to facilitate opt. nut. timing
- 3. Greater nutrient concentration facilitating practical export of surplus nutrients, especially P, to facilitate opt. nut. rates
- Comparing advanced systems featuring combinations of the above strengths vs. BAU LDM and tillage system practices

based on

Crop yield, N_2O, **SOC Sequestration**, and **Soil health**

Water quality: selected sites

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

DSWR Task 2 Systems (Not Single Factor) Comparison

- BAU System: Conventional till, no cover crop

vs.

- SHMS 1: Strip till, cover crop
- SHMS 2: Strip-till, cover crop
- SHMS 3: Strip-till, cover crop

- Measurements: Yield, N_2O, SOC sequestration, soil health
  Water quality: selected sites

DSWR Task 2 Systems Comparison

Manure Rate: P banking basis in all four systems; N balanced w/SD N
(For silage corn, replace P removed by silage corn and subsequent alfalfa)

- BAU System: Conventional till, no cover crop

vs.

- SHMS 1: Strip till, cover crop
- SHMS 2: Strip-till, cover crop
- SHMS 3: Strip-till, cover crop

- Measurements: Yield, N_2O, SOC sequestration, soil health
  Water quality: selected sites

DSWR Systems Comparison

- Manure Rate: P banking basis in all four systems; N balanced w/SD N
- System-specific options for manure source, placement, and timing
- All four systems designed to minimize NH_3 volatilization
- BAU System: Conventional till, no cover crop, immediate tillage incorporation of b-cast LDM in fall, supplemental SD UAN

vs.

- Advanced System 1: Strip till, cover crop, fall LDM injection, supplemental SD UAN
- Advanced System 2: Strip-till, cover crop, spring broadcast Sedron solids, supplemental SD UAN (surrogate for AN)
- Advanced System 3: Strip-till, cover crop, spring broadcast DAF solids, supplemental SD UAN
- Measurements: Yield, N_2O, SOC sequestration, soil health
  Water quality: selected sites

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

DSWR Systems Comparison

- Manure Rate: P banking basis in all four systems; N balanced w/SD N
- System-specific options for manure source, placement, and timing
- All four systems designed to minimize NH_3 volatilization
- BAU System: Conventional till, no cover crop, immediate tillage incorporation of b-cast LDM in fall, supplemental SD UAN

vs.

- Advanced System 1: Strip till, cover crop, fall LDM injection, supplemental SD UAN
  (Nut. mgt. & SH)
- Advanced System 2: Strip-till, cover crop, spring broadcast Sedron solids, supplemental SD UAN (surrogate for AN)
  (Nut. mgt. & SH)
- Advanced System 3: Strip-till, cover crop, spring broadcast DAF solids, supplemental SD UAN
  (Nut. mgt. & SH)
- Measurements: Yield, N_2O, SOC sequestration, soil health
  Water quality: selected sites

DAIRY RESEARCH INSTITUTE
NUTRITION • PRODUCTS • SUSTAINABILITY

Key Points: Rationale for Evaluating Sedron and DAF Manure Products in a Systems Comparison in DSWR

- Big Picture: Overall Sedron system is a potential game changer re GHG footprint, water quality, and water recycling; DAF system is a partial game changer
  - Co-Products facilitate: 1. export of surplus nutrients and optimal nutrient rates and 2. greater flexibility re nutrient storage and application timing
- Smaller Picture: Sedron and DAF co-products
  - Show promise for enabling low NH_3 vol. from surface/ nonincorporated application and avoiding high N_2O emissions associated with broadcast and injected LDM
  - Highly compatible with strip- and no-till systems plus cover crop, practices required for sequestering SOC and improving soil health (key DSWR objectives)

Contact Information

- Bert Bock, Ph.D.
  brbock@brbock.com
  256-627-535
  Consultant to Dairy Research Institute
  https://dairysoilwater.org/

DAIRY RESEARCH INSTITUTE®
NUTRITION • PRODUCTS • SUSTAINABILITY