Improving Alfalfa-Based Livestock Forage Production Systems Using Life Cycle Analysis

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Presenter: Joel Tallaksen (University of Minnesota)

Project Team: John Grabber, Josh Gamble (USDA-ARS)

Jared Goplen, Bill Lazarus, Brad Heins, Craig Sheaffer, and Robin Sehler (Univ. of MN)

Consumer Expectation Are Changing

- Increasingly want to see environmentally sustainable food systems
  - Growing sales for “buy local”, “sustainable food”, organic
  - Survey data shows more people want sustainable options
  - Increased media discussions on sustainable foods
- Consumers often consider carbon footprint (greenhouse gases), water use, and energy use as part of sustainability

Alfalfa Can Be Part of the Solution

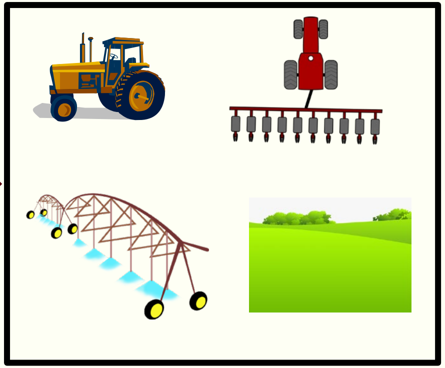
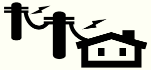
- Both Dairy and Beef Industry are actively involved in improving the environmental footprints of their products
  - Manufactures improving processes and transport efficiencies
  - Establishing environmental benchmarks for farmers
- The single largest input to these systems is <u>FEED</u>.
- Alfalfa can be part of healthy forage production

Sustainable Alfalfa Production

- A positive environmental footprint is only one part of sustainable alfalfa production
  - Need to include economics
  - Needs to work with the farmers complete operation
    - Other crops in the rotation, size and type livestock
- These other areas of sustainability are being examined by the project team

What is Life Cycle Assessment?

An accounting system that evaluates a systems inputs and outputs to calculate the systems impacts

Background information	Inputs	On Farm Activities	Outputs	Impacts
Fuel: 5 lbs. carbon/gal				Carbon Footprint: 800 lbs. CO_2 Equiv./ton alfalfa
Water: 20 lbs. carbon/acre inch			Alfalfa Yield: 3.2 tons/acre	
Electricity : 2.5 lbs. carbon/kWh				

Ideal Topics for Life Cycle Assessment

- Environmental concerns with good numerical data
  - Greenhouse Gases
  - Energy
  - Water Use
  - Land Use

Limitations of Life Cycle Assessment

- LCA is not appropriate for some environmental questions
- Qualitative data is difficult to model
  - Biodiversity, social issues
- Overly complex numerical data
  - Some interactions with other crops rotation
  - Limited soil carbon and soil health

LCA Objectives for This Project

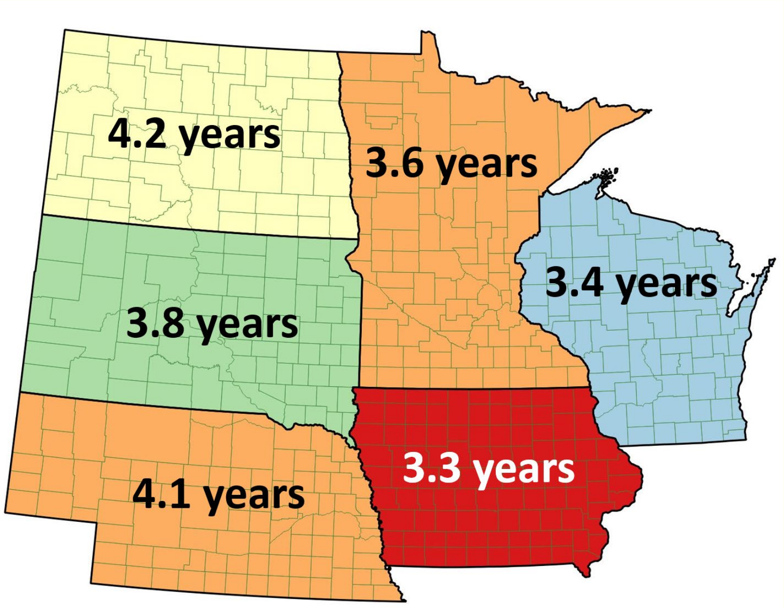
- Environmental Impacts for Midwestern Alfalfa
  - Greenhouse Gases
  - Fossil Energy
  - Land Use
  - Water Use (in irrigated regions)
- How alfalfa production system variations affect impacts
  - Subregions, changing inputs, irrigation,

Defining ‘Typical’ Alfalfa Production

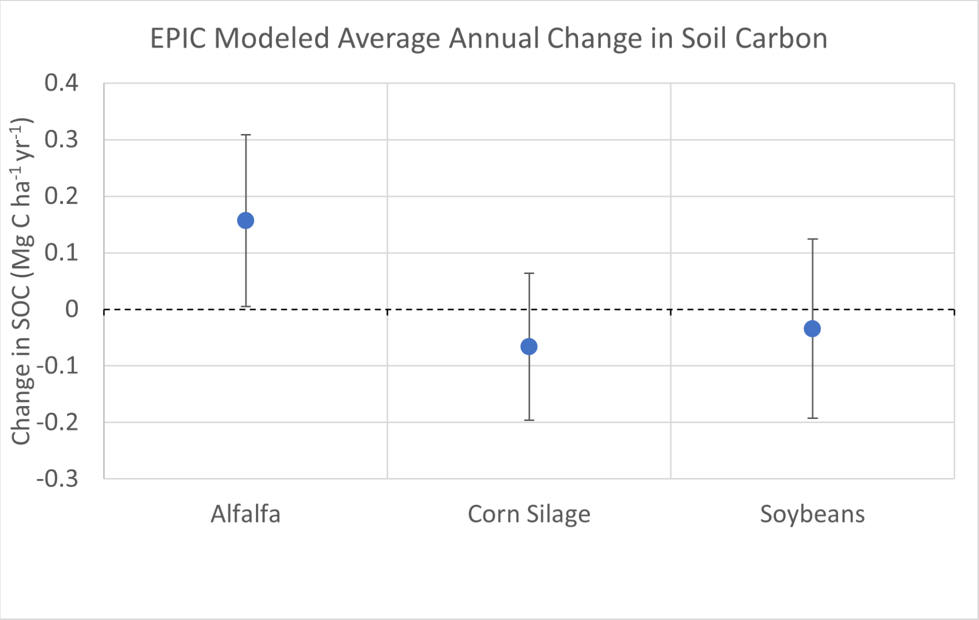
- Most other crops are standardized
- Alfalfa production has many variations
  - Planting with companion crops or cover crops
  - Different stand lengths
  - Different forms harvested (hay vs haylage, baled vs loose)
- Our choice was to evaluate pure alfalfa stands
  - Best available data
  - ‘typical’ midwestern setting

Developing A Data Set for Modeling

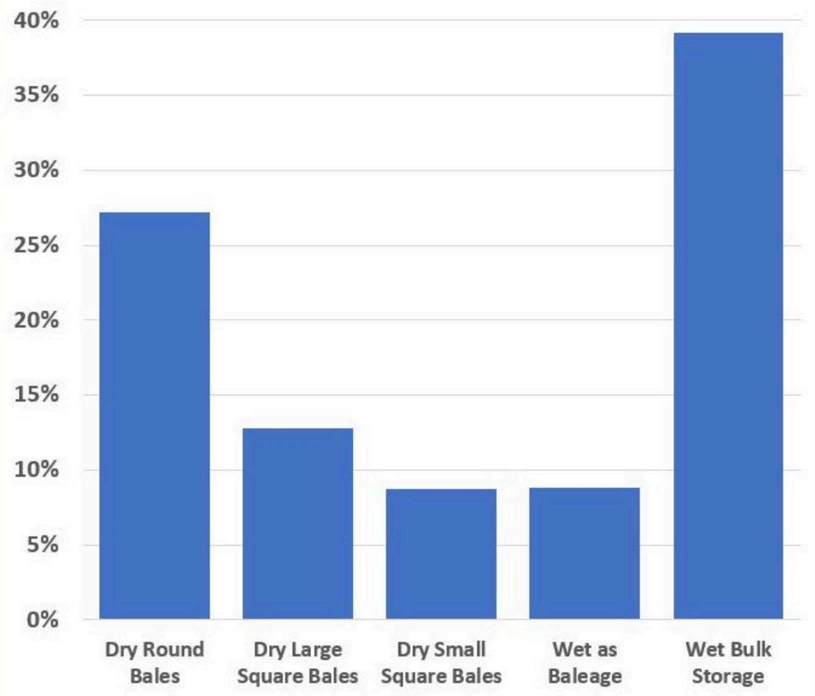
Satellite image based stand lengths



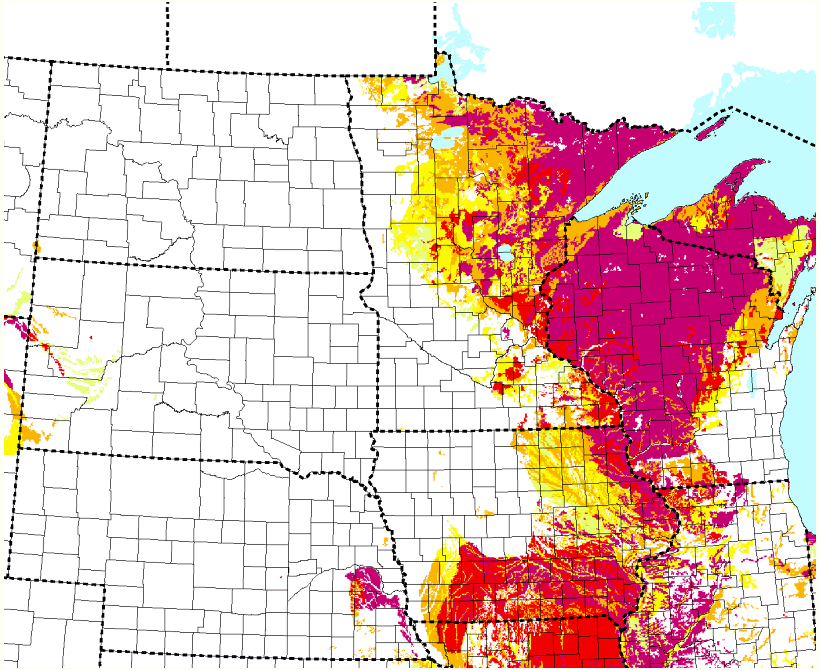
Alfalfa influences on soil organic carbon



Surveys of On Farm Methods



Need for Application of Lime



Life Cycle Models

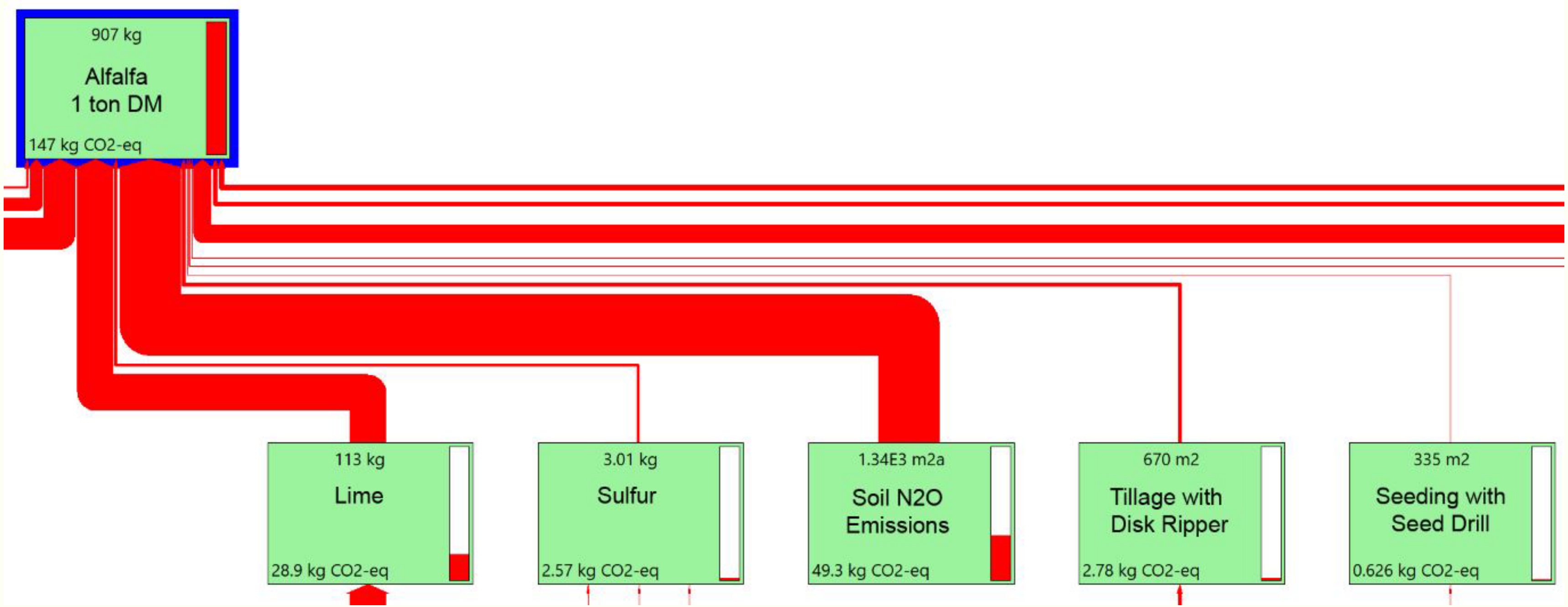
- Brining together all input and output data
- Inputs/output linked to background data to quantify potential impacts
- Expresses impacts in terms of functional units:

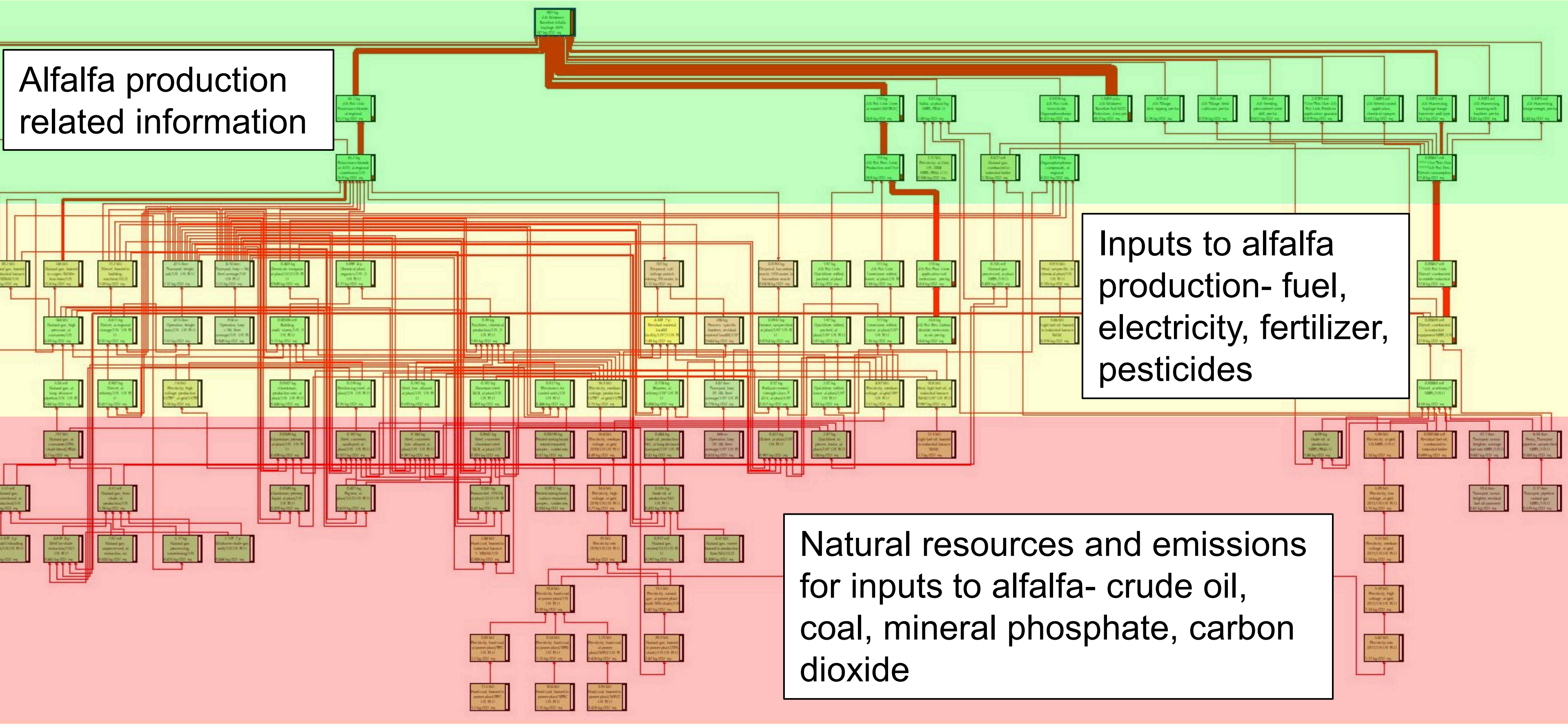
Impacts per ton DM of alfalfa

Outputs	Amount	Unit
Alfalfa haylage, 65% moisture, at field	27060	kg
Inputs		
Tillage, disk-ripping	2	ha
Weed control application, chemical sprayer	5	ha
Seeding, presswheel seed drill	1	ha
Alfalfa seed	16.81	kg
Monoammonium phosphate	457.5	kg
Potatsium chloride	1793.4	kg
Lime	3363	kg
Herbicides & Pesticides	2.5	kg
Harvesting, haylage forage harvester	10	ha
Harvesting, mowing with haybine	10	ha
Harvesting, forage merger	10	ha
Land occupation, annual crop	4	Ha_a
Soil N2O Emissions	4	ha a

Visualizing the Alfalfa Production

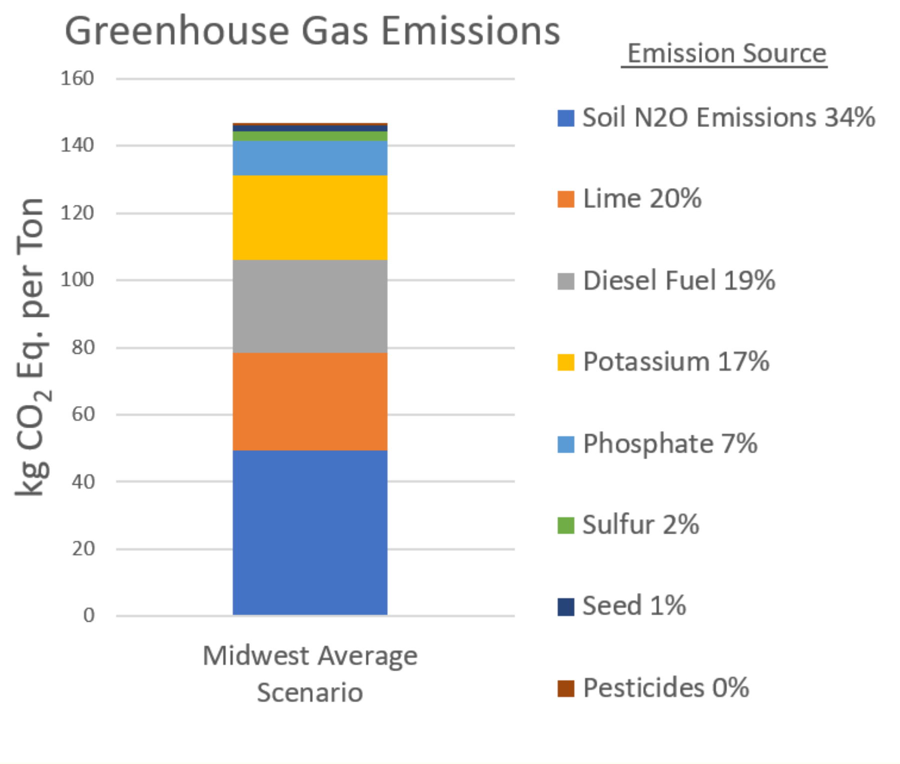
- Software modeling make maps to track individual activities




Alfalfa production related information
Inputs to alfalfa production- fuel, electricity, fertilizer, pesticides
Natural resources and emissions for inputs to alfalfa- crude oil, coal, mineral phosphate, carbon dioxide

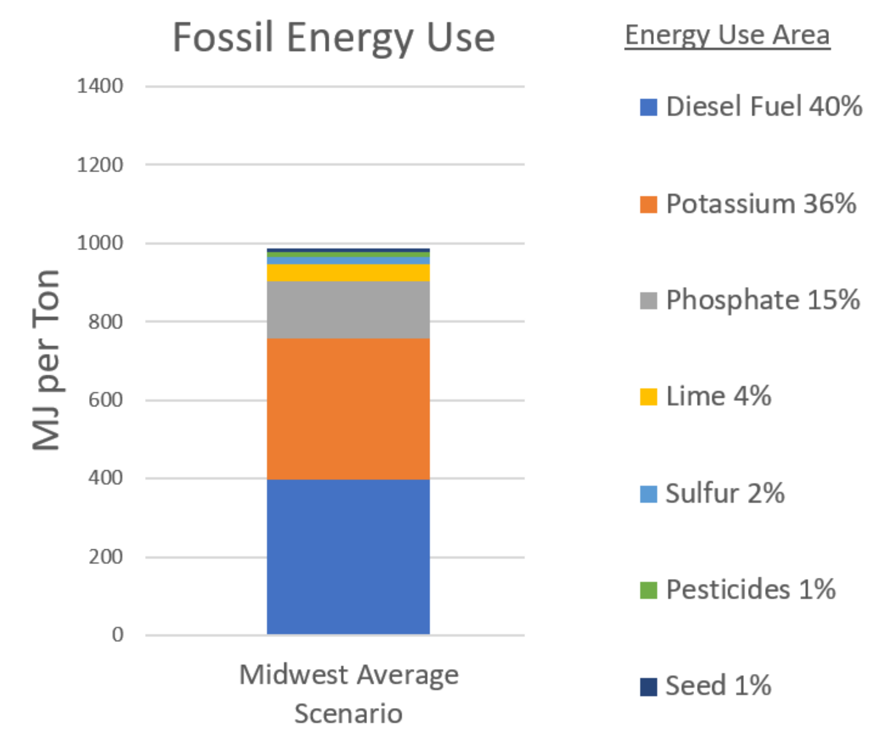
Greenhouse Gases

- Includes chemical outputs that impact climate change- CO_2, N_2O, CFC's
- N_2O is around 275 times more impactful than CO_2
- N_2O from nitrogen



Fossil Energy

- The largest use of diesel fuel is for harvest.
- The production of potassium chloride (the base of several potassium fertilizers)
- Phosphate fertilizers that have a nitrogen component have an energy impact.



How Can We Use the LCA Model

- An LCA model is a predictive tool that can evaluate environmental impacts of changes to a system
  - Inputs
  - Outputs
  - Production technologies

Output Sensitivity Analysis

- Variations in yield often greatly influence the final environmental impacts per unit output
- Low yields in particular can quickly increase impacts per unit output as impacts

Yield Tons per Acre*yr	2.00	2.25	2.50	2.75	3.02	3.25	3.50	3.75	4.00
kg CO_2 Eq. per Ton DM	221	197	177	161	146	136	126	118	110
% Difference	+51%	+34%	+21%	+10%		-7%	-14%	-20%	-25%

Midwest Average

Input Sensitivity Analysis

- Lime (1 ton per acre)

  ± 19.2 kg CO_2 Eq. per ton DM

- Irrigation (1 inch per acre)

  ± 3.38 kg CO_2 Eq. per ton DM

- Diesel (per liter per acre)

  ± 0.11 kg CO_2 Eq. per ton DM

- Potassium (10 Lbs./acre)

  ± 1.40 kg CO_2 Eq. per ton DM

Greenhouse Gas Impacts for Lime Application

Tons/Acre	kg CO2-eq per ton DM
0	0.0
1	19.2
Baseline (1.5)	28.8
2	38.4
3	57.6
4	76.7
5	95.9
6	115.2
7	134.3

Background Impacts Differences

Phosphorus Fertilizer (per kg)	kg CO_2-eq
Monoammonium phosphate	0.69
Ammonium nitrate phosphate	1.80
Diammonium phosphate	1.47
Single superphosphate	0.45

Energy Source (per MW)	kg CO_2-eq
Midwest Grid 2018	680.1
Minnesota Grid 2018	562.9
US annual Mix 2016	620.5
Wind Power (with infrastructure)	0.1774
Solar (with infrastructure)	0.0019

Final phase of this work

- As we refine LCA, soil, and economic models:
  - Evaluating alfalfa in crop rotations
  - Examining alfalfa in dairy production
  - Provide LCA models to National Agriculture Library
    - This information will be public
    - Will include background discussions on LCA variables

Long Term Goal for This Project Leveraging LCA for Alfalfa Improvement

- Provide a general frame work for researchers to compare alfalfa production systems
- Improve alfalfa’s environmental footprint with input reductions or yield increases
- Assist the industry goals of meeting consumer desire for environmentally sustainable food.

Acknowledgements

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- Thanks to the producers for all the surveys they have completed over the years to provide data