Recognizing Fertilizer Practices that Mitigate Greenhouse Gas Emissions

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Recognizing Fertilizer Practices that Mitigate Greenhouse Gas Emissions

The federal government's 2020 announcement of a target to reduce greenhouse emissions arising from fertilizer use by 30 percent by 2030 sparked has sparked considerable discussion and debate about the means by which it could be achieved, recognized, and verified. Several 4R practices for fertilizer application have been shown to effectively reduce nitrous oxide emissions. The use of nitrification inhibitors, for example, has been shown in a second-order global meta-analysis to reduce emissions by 44 to 49 percent. In addition, several indicators related to nitrogen use efficiency have been linked to emission reduction. Since 4R practices influence and seek to optimize nitrogen use efficiency, and may also show effects on emissions that are independent of use efficiency, disagreements have arisen between government and industry as to the specific practices that may become eligible for cost-share in mitigation programs. This presentation will review the evidence base for the efficacy of 4R practices in reducing emissions and improving nitrogen use efficiency, and discuss options for recognizing farm practices in national inventories and protocols for greenhouse gas emission reporting. Newly aligned principles of 4R plant nutrition apply to the challenge of mitigating emissions while continuing to improve both the net primary productivity and economic yields of managed cropping systems. Important components include climate-smart fertilizers, more dynamically determined rates and timing, along with more effective placement. Climate-smart fertilizers are of particular interest as industry shifts attention and investment to manufacturing nitrogen products with low or zero carbon footprint, products with reduced post-application emissions of greenhouse gases, and products with “smart” release characteristics relevant to improving nitrogen use efficiency.

Outline – fertilizer practices mitigating GHG emissions

- Context: trends in NUE in Canadian agriculture (vs US, World)
  - Production increasing, NUE improvement slight, fertilizer the main input
  - Trends in fertilizer form: urea, UAN, anhydrous, AN/CAN, DAP/MAP, other
  - Many moving pieces toward a net zero future
- 4R practices with specific effect on N_2O:
  - Inhibitors (PCU, urease, nitrification) [evidence base]
  - Climate-smart fertilizers
  - More dynamic rate adjustment through timing
- Options for recognizing 4R:
  - surveys, census, baseline

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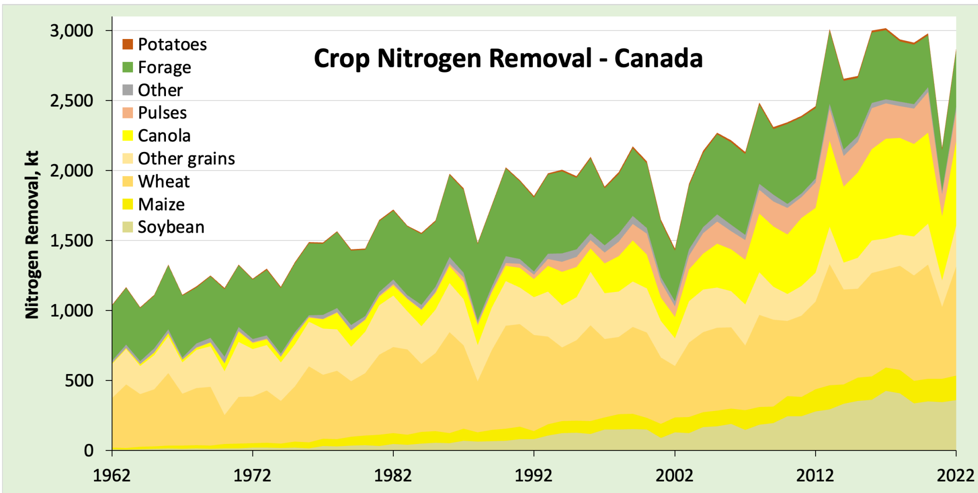
Canadian Crop output – increasing trend for past six decades



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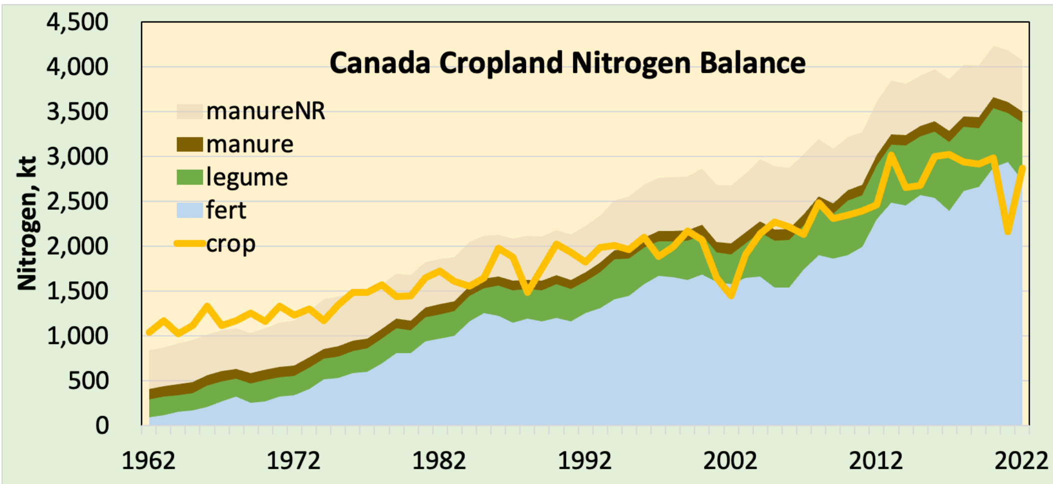
Crop production is not static – it has increased tremendously, mostly owing to increased yields

Concomitantly, N inputs also trending higher



Crop removal includes all crops and harvested forage. Data sources: Statistics Canada fertilizer shipments, livestock inventories, crop production.

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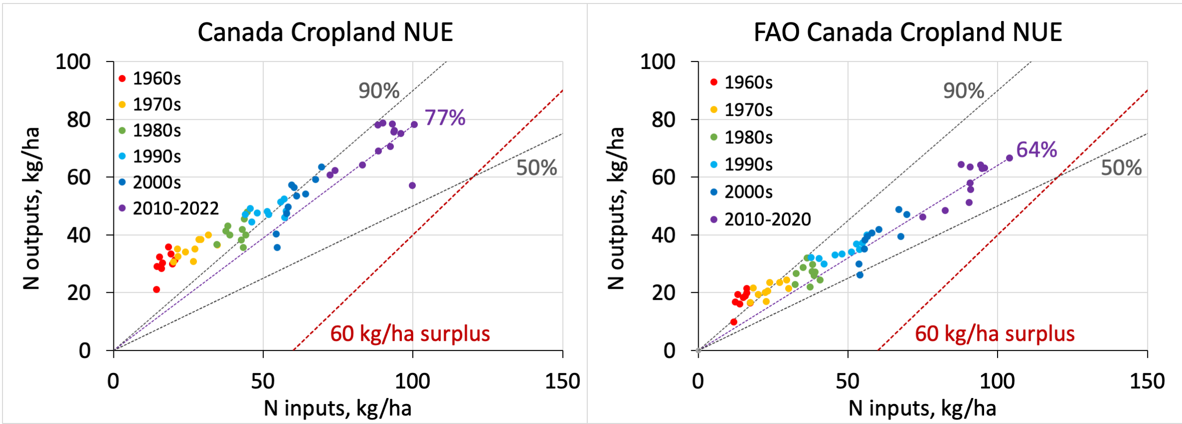
Nitrogen use efficiency has not increased, though we mine less from the soil than in the far past

Cropland NUE values increase when forages are included



NUE = outputs/inputs

Outputs: Crop removal. FAO does not include harvested forages.

Inputs: Fertilizer + manure applied + biological fixation + atmospheric deposition

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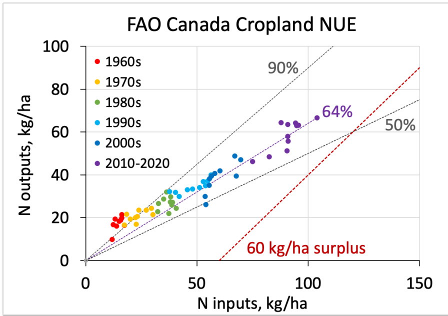
The balance on the left side also assumes less manure N is applied than in the FAO dataset.

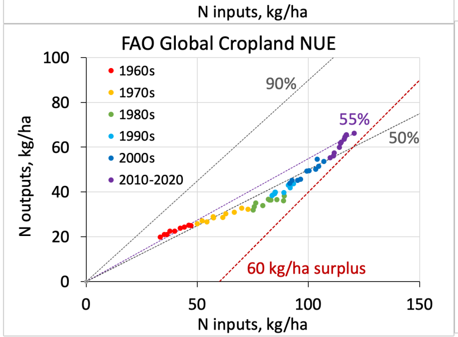


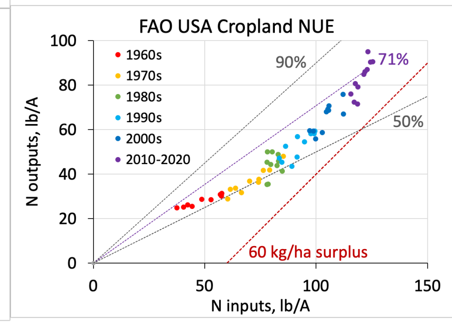
Canada's NUE exceeds global average

NUE = outputs/inputs

Outputs: Crop removal. FAO does not include harvested forages.

Inputs: Fertilizer + manure applied + biological fixation + atmospheric deposition





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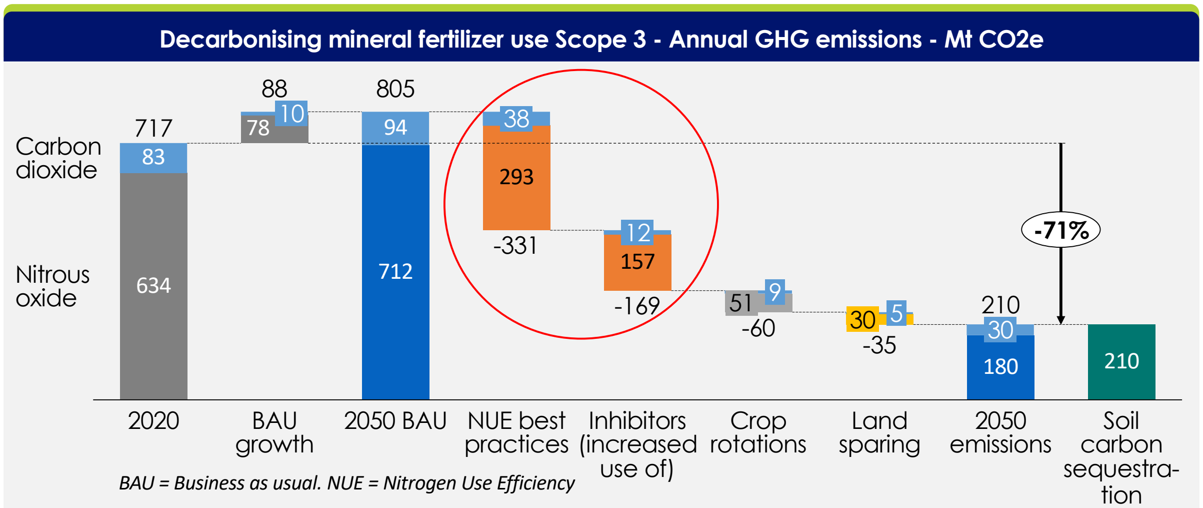
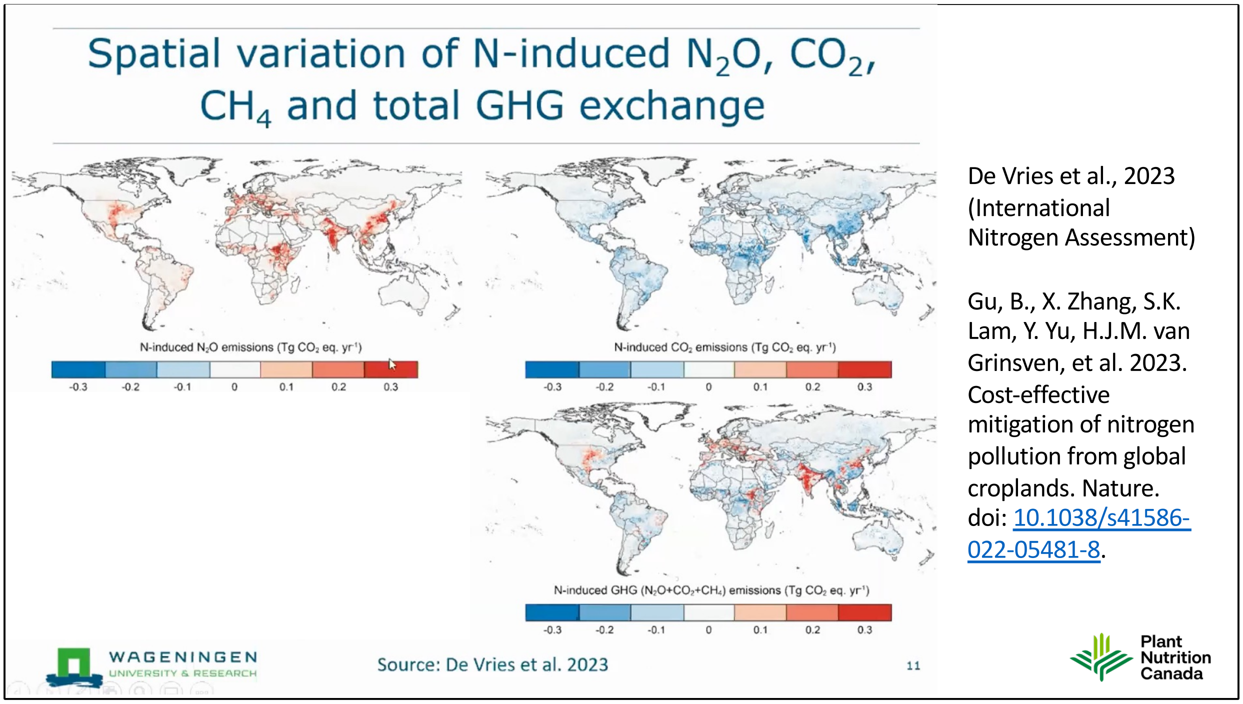
Cropland in the USA has higher NUE. One of the main differences is the large proportion of N removal represented by soybeans, a high NUE crop.

'Scope 3 Emissions' from the use of fertilizer can be more than halved by 2050 through increasing N use efficiency (50%→70%)



ifa INTERNATIONAL FERTILIZER ASSOCIATION SYSTEMIQ

https://www.fertilizer.org/Reducing-Emissions

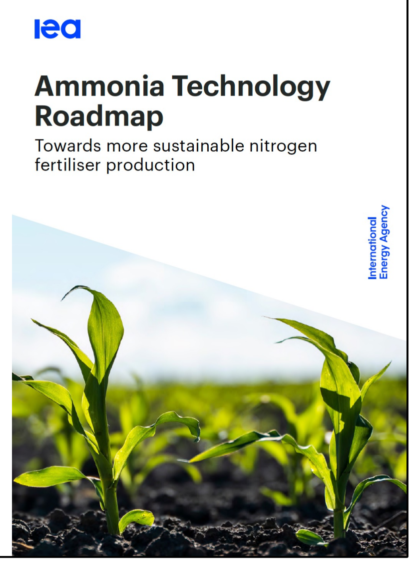


De Vries et al., 2023 (International Nitrogen Assessment) is to be published in the coming year.

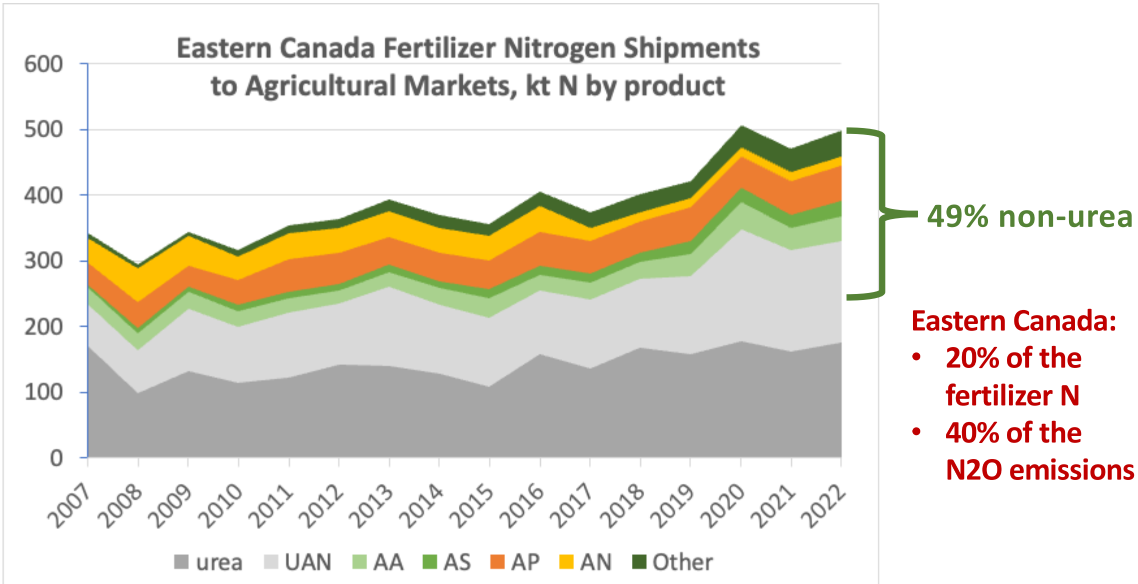
The GHG impact of the nitrous oxide emissions arising from reactive N inputs into the environment are balanced by the increase in carbon dioxide uptake in nitrogen-limited natural terrestrial and marine ecosystems. Thus, improving NUE has little net effect on total greenhouse gas emissions.

Net-zero future has many moving pieces

- Green ammonia: IFA projects 3.5 Mt by 2027, almost 85 Mt after 2027.
- Urea: CO_2 release = 1.6 tonnes per tonne of N (IPCC)
- "In the Sustainable Development Scenario the use of urea-based fertilisers declines by 28% by 2050 compared to today, replaced by ammonium nitrate and calcium ammonium nitrate."
- "In both scenarios (SD and NZ) some of the CO_2 required for urea has to be obtained from sources other than the process CO_2 emission streams of ammonia plants."
- "if all ammonia were produced via either electrolysis or methane pyrolysis … neither route would generate CO_2 for use in urea production." (IEA, 2021)



The future of the dominant form of nitrogen fertilizer, urea, is questioned in roadmaps charting options for net-zero fertilizer manufacturing.



Data Source: Statistics Canada – Fertilizer Shipments to Canadian Agricultural Markets

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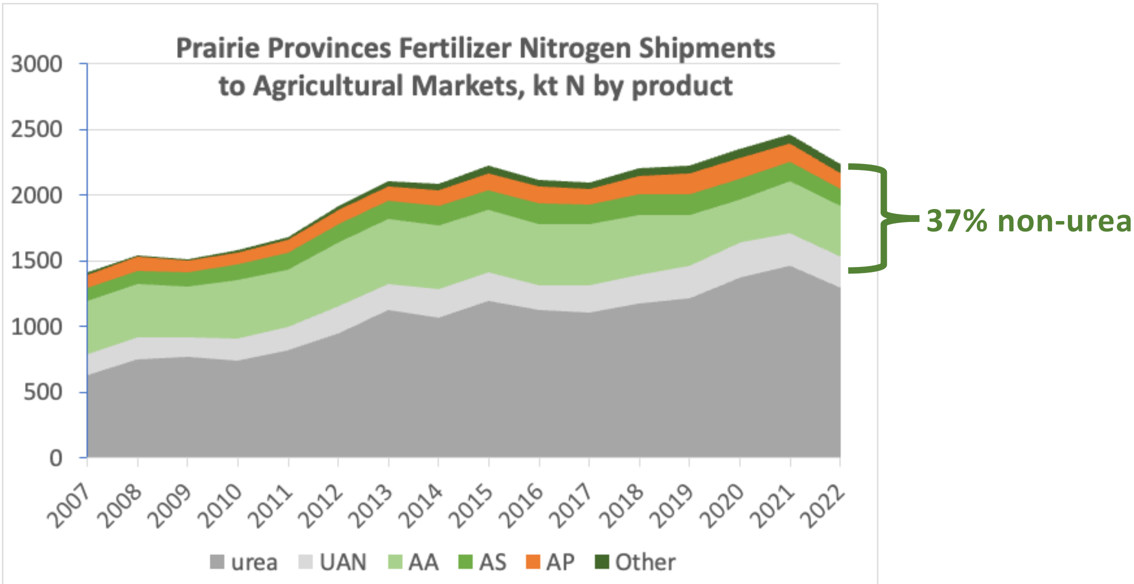
Non-urea forms of nitrogen fertilizer play a considerable role in Canadian crop production currently. Options for mitigation of nitrous oxide loss need to be provided for all forms, in accordance with the principle of specific practices to suit the wide array of soil and crop management systems in use on today's farms.



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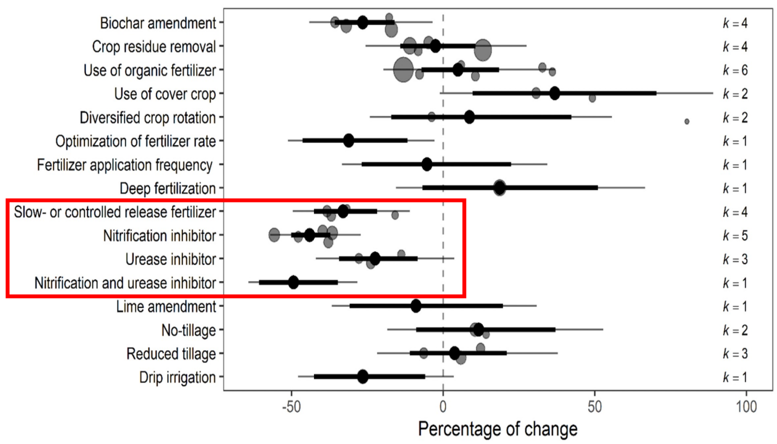
Evidence base: inhibitors

Inhibitors and polymer coatings

- 0-7% yield gain
- 0-15% NUE gain
- 20-50% less N_2O

Thapa et al. (2016) Effect of enhanced efficiency fertilizers on nitrous oxide emissions and crop yields: a meta-analysis. Soil Sci Soc Am J 80:1121–1134

Abalos et al. (2014) Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. Agric Ecosystems & Environment 189: 136–144



Grados, et al. (2022). Synthesizing the evidence of nitrous oxide mitigation practices in agroecosystems. *Environmental Research Letters*. https://doi.org/10.1088/1748-9326/AC9B50

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In the meta-analysis of Thapa et al 2016, nitrification inhibitors DCD and nitrapyrin were found to reduce emissions on average by over 40 percent. Polymer coated urea by 20 percent.
The effects on yield were small, and another meta-analysis by Diego Abalos found similar effects on yield and nutrient use efficiency—SMALLER than the nitrous oxide reduction.
The important point here is that the use of these products is less beneficial to the farmer than to society. Farmers are paid for yield, and nitrogen use efficiency makes fertilizer use more profitable, but they are not paid for the larger benefit of reduced emissions.
Thus payments to farmers to increase adoption is well-justified, as a GHG emission reduction strategy.

Evidence base: inhibitors

Table 3. Mean annual N_2O emissions and estimated marginal means (EMMEAN) …

General soil texture	Fertilizer Type	Mean N_2O emissions (kg ha^{-1})	EMMEANS (± 1 SE)
Fine	Control	1.253 ± 0.239	0.0774 ± 0.328
	Enhanced efficiency	0.769 ± 0.093	0.2098 ± 0.330
	Regular synthetic	3.871 ± 0.780	0.9016 ± 0.327
	Organic	0.704 ± 0.596	− 0.1370 ± 0.437
Medium	Control	0.835 ± 0.089	− 0.3688 ± 0.316
	Enhanced efficiency	1.176 ± 0.224	− 0.2365 ± 0.326
	Regular synthetic	1.695 ± 0.162	0.4553 ± 0.314
	Manure	3.153 ± 0.309	0.6897 ± 0.332
	Organic	0.351 ± 0.069	− 0.5833 ± 0.419

ANNUAL EF reduced by 84%

"We used Google Scholar and Scopus to find papers that had measured N_2O emissions from agricultural lands in Canada throughout the whole year (annual emissions)."

Pelster, D.E., A. Thiagarajan, C. Liang, M.H. Chantigny, C. Wagner-Riddle, et al. 2023. Ratio of non-growing season to growing season N2O emissions in Canadian croplands: an update to national inventory methodology. Can. J. Soil. Sci. 103(2): 344–352. doi: 10.1139/cjss-2022-0101.

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This very recent meta-analysis found enhanced efficiency fertilizers were as effective in reduced annual mean emissions as those during the growing season.

Climate-smart Fertilizers

Climate-smart fertilizers reduce greenhouse gas emissions.

Three attributes:

1. Lower manufacturing CO_2 emissions
   - "green" and "blue" ammonia
2. Inhibit loss of nitrous oxide (N_2O)
   - nitrification inhibitors and polymer coated urea
3. Improve nitrogen use efficiency (NUE)
   - controlled-release, stabilized, "smart fertilizers"

Research Article | Open Access | Published: 04 June 2023

Nitrous oxide emissions after struvite application in relation to soil P status

Zhongchen Yang, Laura M. E. Ferron, Gerwin F. Koopmans, Angela Sievernich & Jan Willem van Groenigen

Plant and Soil (2023) | Cite this article

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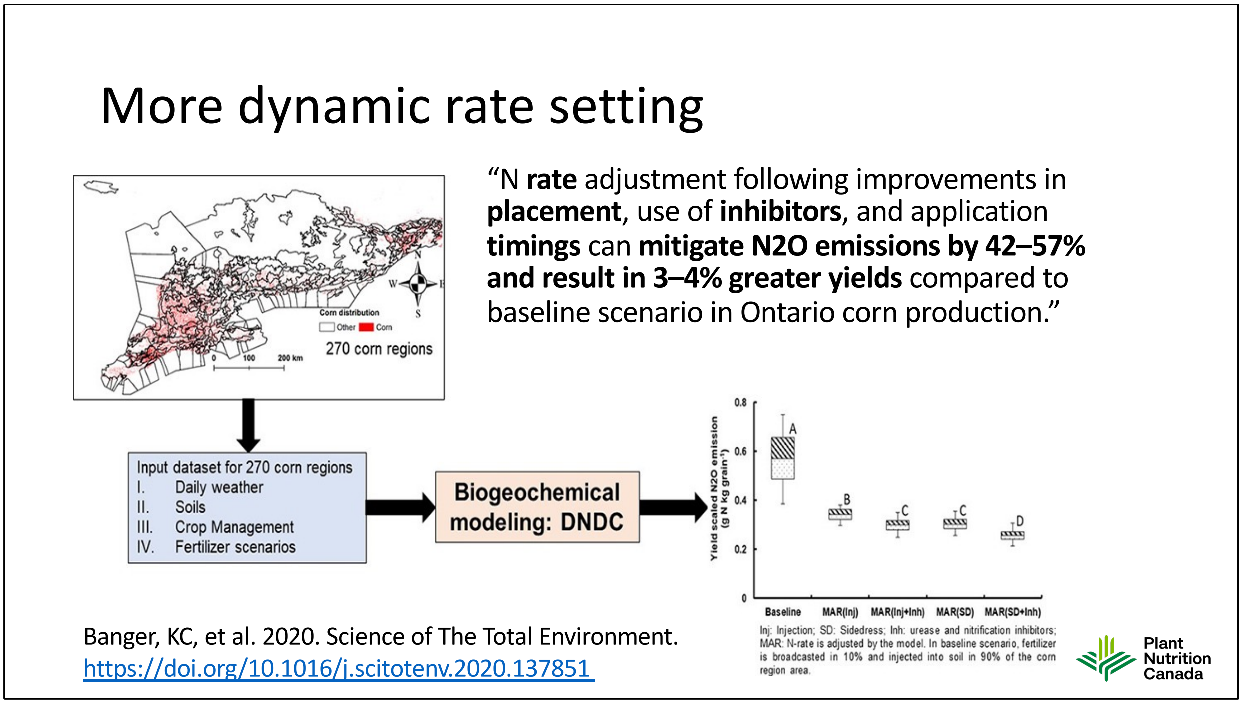
The nitrogen supplied in struvite emits less nitrous oxide than that in other sources.

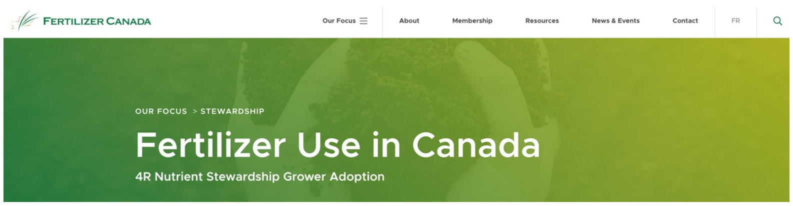


The DNDC model result identifies the potential benefits that could be attained if optimum rates could be predicted by the time of nitrogen application. This is still a quest that is being undertaken in many different ways by practitioners.

Recognizing 4R practices

- Regulatory reporting of fertilizer shipments to agricultural markets
- Census – amounts spent on fertilizer and lime
- Fertilizer Use Survey – industry supported

https://fertilizercanada.ca/our-focus/stewardship/fertilizer-use-survey/



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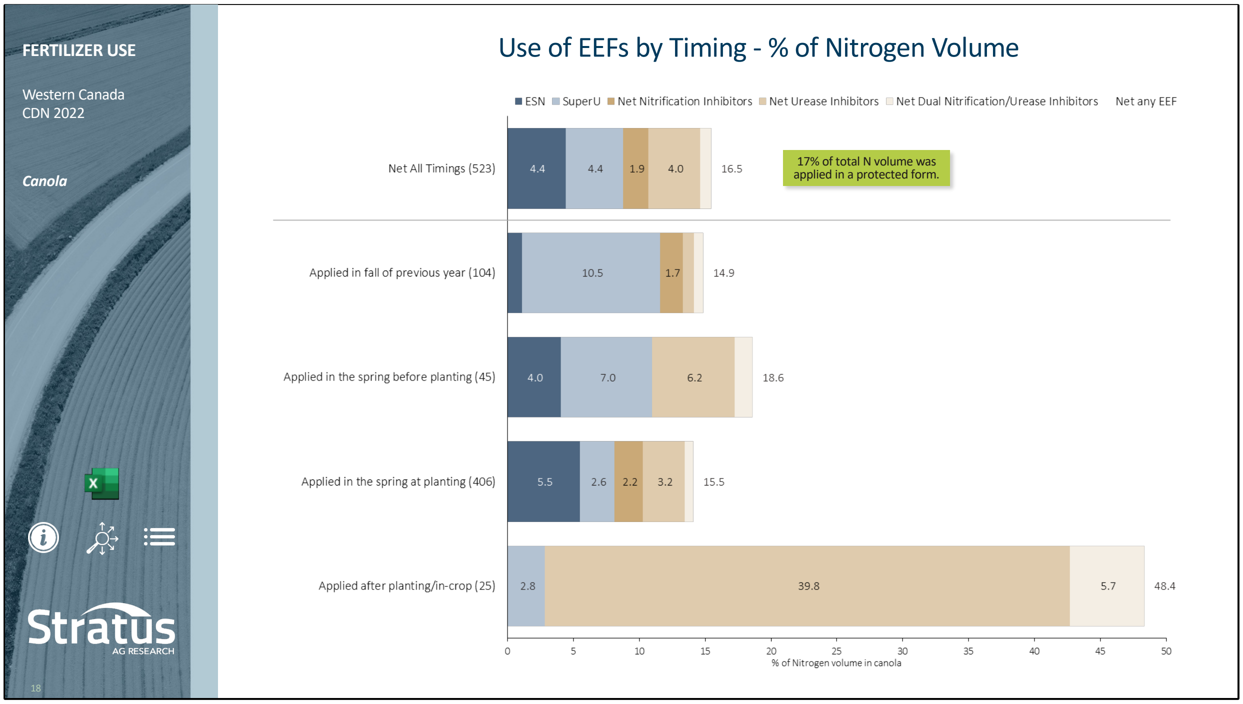
The Fertilizer Use Survey provides detailed insight into current 4R practices for nutrient application.

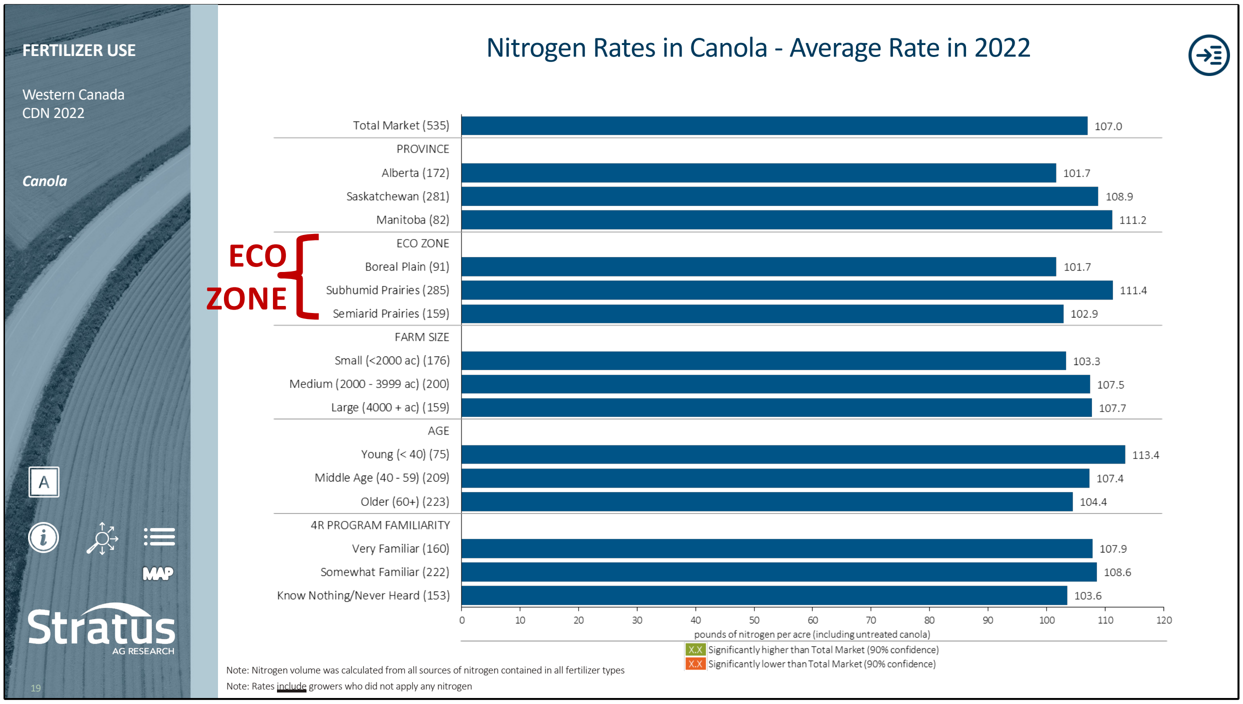


All respondents were asked: "Which of the following fertilizer types did you apply (the list included ESN and SuperU)?"

Respondents who used any other primary Nitrogen fertilizer (excluding ESN and SuperU) were asked: "Which of the following nitrogen stabilizers did you use?"

Separately for each application timing, the chart illustrates the % of primary Nitrogen fertilizer volume that was treated with each type of EEF.

Statistics on us … be used to estimate their contribution t…



FERTILIZER TYPES

NITROGEN
Ammonium Nitrate (34-0-0)
Anhydrous ammonia (82-0-0)
Calcium Ammonium Nitrate (27-0-0)
Calcium Nitrate
ESN (44-0-0)
Last N (25-0-0)
Sodium Nitrate (15-0-0)
Super U (46-0-0)
SRN (28-0-0)
Urea (46-0-0)
Urea-ammonium-nitrate (UAN) 28% (li
Urea-ammonium-nitrate (UAN) 32% (li

PHOSPHORUS
40 Rock (12-40-0-6.5 +1% Zinc)
Ammonium Polyphosphate (liquid) (10
Croplex: (12-40-0-10)
Diammonium Phosphate (DAP) (18-46
MESZ (12-40-0-12 + 1% Zn)
MicroEssentials S10 (12-40-0-10)
MicroEssentials S15 (13-33-0-15)
MicroEssentials SZ (12-40-0-10)
Monoammonium Phosphate (MAP) (1
Nitrate Phosphoric Acid (52-60% P_2O_5)
OCP: (12-45-5 +1% Zinc)
Organomineral fertilizers (Hyper P) (11
Other In-furrow Liquid Starter
PhosAgro: (12-40-0-10)
Rock Phosphate
Simple Super Phosphate (SSP) (0-20-0-
Smart Nutrition MAP + MST: (9-43-0-1
Struvite (Crystal Green) (5-28-0 +10% M
Super Phosphoric Acid (SPA) (69-76% P
Symtrx 10S: (14-24-0-10)
Triple Superphosphate (0-46-0)

POTASSIUM
K Mag (0-0-22-22)
K Mag Premium (0-0-21.5-21 + 10% M
Potash (dry) (0-0-60)
Potash (caustic) (0-0-45)
Potash (liquid) (0-0-12)
Potassium Nitrate (14-0-46)
Potassium sulphate (0-0-50-17)

SULPHUR
Alpine K Thio (0-0-6.6-4.5)
Amidas (40-0-0-5.5)
Ammonium Sulphate (21-0-0-24)
Ammonium Sulphate fines (21-0-0-24)
Ammonium Thiosulphate (liquid) (15-0
Bio-Sul Premium Plus (0-0-0-70)
Elemental Sulphur (S) (0-0-0-90)
Magnesium sulphate (0-0-0-14, 10.5%
NutraSul90 (Keg River) (0-0-0-90)
Symtrx 20S: (16-1-0-20)
Super S (11-0-0-75)
Tiger 50 (12-0-0-50)
Tiger 90 (0-0-0-90)
Vitasul G (Sulvaris) (0-0-0-90)
Other elemental sulphur (0-0-0-90)

For each fertilizer type used in either a custom blend or applied as an unblended product, respondents were asked: a) how many acres they applied, and b) the application rate in pounds of actual nutrient/ac. Volumes of each nutrient were calculated by multiplying acres treated times the application rate.

Separately by province, eco zone, farm size, age and 4R familiarity, the graph illustrates the average nitrogen application rate in pounds of nitrogen per acre (including untreated canola acres).

Fertilizer practices to mitigate GHG emissions

- Canadian cropland yields are increasing while maintaining NUE
  - While most fertilizer N is in the form of urea, other forms are important
  - As we move toward a net zero future, fertilizer forms will change
  - Improving NUE may contribute little to net reduction of GHG emissions
- 4R practices can reduce nitrous oxide emission:
  - A strong evidence base supports the efficacy of inhibitors (PCU, urease, nitrification) in reducing nitrous oxide emissions
  - Climate-smart fertilizers and more dynamic rate adjustment through timing are likely to improve NUE
- Monitoring 4R practices can contribute to the reporting and verification of emission reductions from fertilizer use.
  - Industry continuing to refine the Fertilizer Use Survey

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