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Fertilizer Canada Consultation Response:

Reducing emissions arising from the application of fertilizer in Canada's agriculture sector.

Global Food Security: Supporting agricultural intensification so Canada can remain competitive.

While we are fortunate in Canada to not face the same food insecurity concerns as other countries, we have seen our grocery bills rise. The world's population is estimated to grow by approximately 2 billion people by 2050. Global agriculture production will need to increase by 50% from 2005 to feed all these people. Geopolitical turmoil, most recently with the war in Ukraine, adds to the strain on food supply. Fertilizer plays an important role in fighting food insecurity around the world and providing Canadians and our trading partners with affordable, nutritious food. Canada, and Canadian fertilizer, is uniquely positioned to step up to the challenge. Based on a recent poll conducted by Abacus Data, 75% of Canadians agree that Canada plays a critical role in maintaining global food security and 64% of Canadians say that Canada should be focusing more on food production, even if it means we can't reach a 30 % reduction in fertilizer emissions.

Fertilizer is one of the most important inputs for crops grown around the world. Farmers rely on nitrogen-based fertilizers to increase the amount of food they grow, putting food on tables across Canada and beyond. Fertilizer consumption in Canada has increased over the past two decades as farmers have utilized fertilizer to increase yields and take advantage of the increased genetic potential for higher yields. These higher yields have been obtained while maintaining high levels of nutrient use efficiency. Higher yields are necessary to meet the growing global demand for Canadian crops, which has been endorsed by the federal government's target of $75 billion in agri-food exports by 2025. To meet this target while making continued progress on emissions reductions, accelerating adoption of 4R Nutrient Stewardship is critical.

Currently, Canada has an opportunity to increase its contribution to feeding the world using a food production system which is already a world leader in sustainable practices. Canadian growers have set targets to meet export needs, including the Canola Council's target to increase yields to 52 bu/ac by 2025. Canada also has the potential to increase high quality wheat production, which can help meet world needs given the war in Ukraine is causing large cuts in wheat available for the global export market.[1]

[1] https://downloads.usda.library.cornell.edu/usda-esmis/files/zs25x844t/4t64ht03b/kd17f006c/grain.pdf

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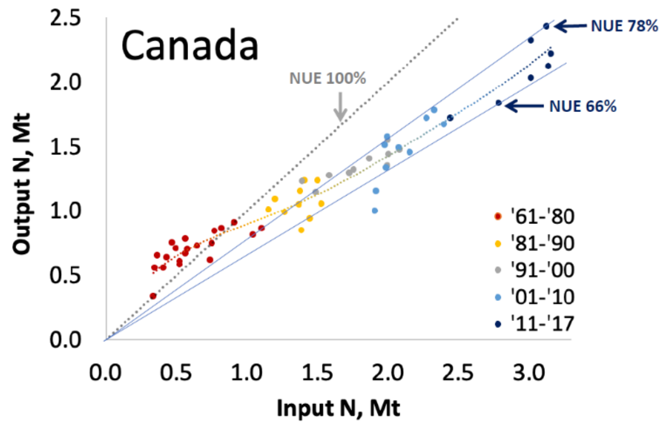
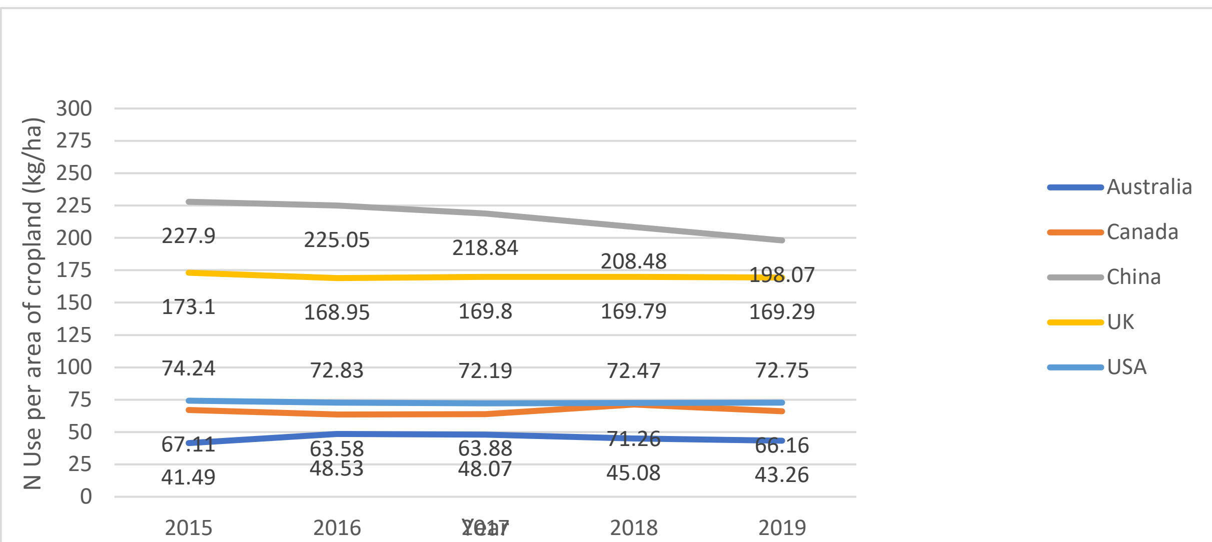
Crops grown in Canada are already the gold standard when it comes to sustainability. Nitrogen use efficiency (NUE), a measurement of how well crops utilize nutrient inputs, currently sits at 72% in Canada exceeding the world average. Over the past 10 years, we have seen a large increase in efficiency as production levels rose and Canadian farmers and their crop advisors have continued to adopt new technologies and apply 4R principles to their fertilizer N management. Canada has less opportunity for further improvement compared to Western European countries with a NUE of 61%. However, further improvement is possible and the industry is actively engaged in the development and adoption of advanced fertilizer management practices under the 4R framework. Compared to other large crop producing countries, Canada also utilizes a smaller amount of N fertilizer per acre of cropland.[2]



IFA, 2020- Nutrient Use Efficiency Database. Input= fertilizer + fixation + manure; Output = harvest



FAO, 2021- N use per area of cropland https://www.fao.org/faostat/en/#data/EF

Within the discussion document Figure 4, taken from the FAO, shows Canadian cereal crops emissions as some of the highest in the world. However, Canada's cereal production is mainly hard red spring wheat,

[2] https://www.fao.org/faostat/en/#data/EF

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a product which has a high protein content and so directly requires increased uptake of nitrogen versus the same bushel of low protein wheat. Countries like the USA and France produce soft wheats and maize, products which require less N inputs due to their lower protein contents. Additionally, the emission intensity values in Figure 4 were calculated using the IPCC Tier 1 approach, which assumes that 1% of fertilizer applied is emitted as N_2O. With the current Tier 2 methodology used in National Inventory Report (NIR), Canada is actually a leader in emissions intensity compared to our competitors. Per hectare of cropland, Canada's N_2O emissions from fertilizer N (direct + indirect) amount to 0.4 tCO_2e, compared to 0.8 tCO_2e for the USA. Total direct plus indirect N_2O emissions from fertilizer amounts to no more than 4.5 tCO_2e per metric ton of fertilizer N in Canada compared to 7.1 tCO_2e in the USA. Per metric ton of crop N removal, Canada's N_2O emissions from fertilizer amount to no more than 4.1 tCO_2e, compared to 4.8 for the USA.[3]

Throughout the discussion paper the attempt at utilizing a rate-based approach is continuously noted as not the objective of the government; however, given current modeling for measurement and practices listed in Annex B of the discussion paper which cite timing and placement practices accompanied by a reduced rate, we have concerns that the emissions reduction target may only be achievable with implementation of a rate reduction approach. Fertilizer Canada and its members endorse a 4R approach to the issue of managing nitrous oxide with rate optimization embedded within a framework of BMPs based on source, time and place practices with proven efficacy for reducing nitrous oxide emissions and improving nitrogen use efficiency while maintaining or improving yields. We should not be promoting practices that result in poor agronomic outcomes.

Rate reductions have been implemented in other jurisdictions and are often accompanied with consequences to food production. The European Union's current *Field to Fork* strategy includes targets such as a reduction of pesticide use by 50%, reduction of fertilizer use by 20%, and removal of 10% of existing farmland from agricultural use. It is expected that under this *Field to Fork* model, overall agriculture production in Europe will decrease by 12%, there will be a 20% drop in exports, and that food prices will increase.[4]

While there are many things we can do differently to cut emissions, one thing we cannot do is give up food. Significant emission reductions are possible, but we must be realistic and not jeopardize food security. This is an existential challenge for the global human family and an economic challenge for Canada. Agriculture and Agri-Food Canada (AAFC) has acknowledged in the discussion paper that reducing absolute greenhouse gas emissions, and ultimately reaching net-zero emissions by 2050, while finding ways to increase yields and economic growth is a major challenge. This initiative should not be about ruthlessly cutting absolute emissions in agriculture, but rather about recognizing the climate challenge is a global one. If Canada can produce greater yields and better-quality grain without drastically increasing overall emissions, that is a competitive advantage for the Canadian economy and a global benefit in the efforts to limit global warming. There is an opportunity to encourage further innovation, apply fertilizer more efficiently, and thereby protect and support the agriculture industry. As

[3] Data calculated from the National Inventory Reports for each country for 2016-2020.
[4] https://www.ers.usda.gov/webdocs/publications/99741/eb-30.pdf?v=6109.2

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Canadian leaders and innovators we can drive change to improve economics, reduce emissions and contribute more to global food security.

Focusing on absolute emissions from the sector will have severe consequences to the competitiveness of farmers and the fertilizer industry. Policies that discourage fertilizer use can actually increase GHG emissions. A reduction in grain production in Canada through less fertilizer use, would not only have a significant negative impact on soil organic carbon and potentially reverse the current trend of sequestration, but would lead to carbon leakage as crop production and the N fertilizer to support increased production moves offshore.

Investments aimed at sustainable agricultural intensification to improve crop yields per unit of existing land area are at the forefront globally. The concept of sustainable intensification has been endorsed by the United Nations through FAO's Climate-Smart Agriculture Strategy as well as sustainable supply chains that are looking for low carbon intensity supply. Additionally, a carbon footprint per tonne intensity-based approach would better align with an output-based pricing system and emerging trade policies on carbon border adjustments. An absolute emission reduction is out of step with this global direction.

Recommendation:

Given the current need to increase food production, and that Canada's food system is already among top in the world for nitrogen management, the government needs to adopt an intensity-based approach and ensure that the approach used does not limit the continuation of crop yield improvement and production growth. A voluntary emissions reduction will not be achieved under the current proposed absolute emission target.

On-Farm Practices that Reduce N_20 Emissions: 4R Nutrient Stewardship.

We are an industry that values and invests in sustainable solutions. 4R Nutrient Stewardship does just that - balancing farmer, industry, and government goals to improve on-farm economics, crop productivity, and fertilizer efficiency while benefiting the environment. We have been working with partners in industry, academia, and government; educating, promoting, and helping farmers implement the 4R program for over 15 years. As of 2022, over six million acres have been verified under 4R management in Canada, with millions more following 4R best management practices.

We were pleased to see formal recognition of 4R Nutrient Stewardship by AAFC as an innovative solution to support greenhouse gas emission reductions and enhanced food production within the discussion paper. Further exploration of the specific BMPs put forward within the discussion paper are provided in Appendix A of this response which looks at the concepts behind the BMPs, why they are expected to reduce N_2O emissions, as well as expected benefits from and barriers to implementation.

With only eight growing seasons left until the 2030 harvest is complete, we must now work together to accelerate uptake in the program among Canadian farmers. Making progress towards emissions

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reductions requires the government to work closely and urgently with the agriculture community to increase the adoption of a growing suite of 4R best management practices. With 4R Nutrient Stewardship at the centre of the federal fertilizer emissions reduction strategy, farmers can continue to grow more food, increase exports, raise farm incomes, and improve food security at home and abroad.

We believe that the Canadian agricultural industry can achieve significant emissions reductions with the use of 4R Nutrient Stewardship BMPs. Peer-reviewed research has shown that implementing 4R BMPs can reduce on-farm emissions without reducing crop production.[5][6][7][8][9][10] The recent study on Natural Climate Solutions for Canada, published by Nature United and others in Science Advances, suggests that adoption of intermediate-level practices as defined in the 4R Climate Smart Protocol could substantially reduce annual emissions by 2030 up to 6.27 Tg CO_2e/year.[11]

This Protocol specifically addresses opportunities to substantially reduce nitrous oxide, but practices required under the Protocol including utilization of controlled-release products (source), sub-surface application of nitrogen in bands (place), and varying application rates at a sub-field level using variable rate technology (rate) are not currently supported under the On-Farm Climate Action Fund – a fund meant to initiate action towards the government's 30% target – nor has the development of the 4R Climate Smart Protocol within the federal carbon offset framework been prioritized.

Fertilizer Canada has commissioned a study which utilizes a series of scenarios for major Canadian cropping systems across Canada and builds out a path forward to 2030 based on broader implementation of selected 4R practices. This study models the impact of BMP adoption and nitrous oxide emissions from fertilizer for major cropping systems in five regions and compares the effects of different 4R BMP adoption rates on the regional crop production economy and nitrous oxide emissions from fertilizer. The study found that a 30% absolute emission reduction is not realistically achievable even when flattening yields and threatening Canada's contribution to global food security.

However, Canada can raise production levels with aggressive but realistic adoption rates of 4R N management practices and substantially reduce fertilizer N_2O emissions by 1.6 MtCO_2e or 14%. This substantial reduction can be realized with growth in production of key grains and oilseeds, maintenance or improvement of the crop-based economy, and reduction in carbon intensity.

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[5] Maaz, T.M., T.B. Sapkota, A.J. Eagle, M.B. Kantar, T.W. Bruulsema, et al. 2021. Meta-analysis of yield and nitrous oxide outcomes for nitrogen management in agriculture. Glob. Chang. Biol. n/a(n/a). doi: https://doi.org/10.1111/gcb.15588
[6] Venterea, R.T., J.A. Coulter, and M.S. Dolan. 2016. Evaluation of Intensive 4R Strategies for Decreasing Nitrous Oxide Emissions and Nitrogen Surplus in Rainfed Corn. J. Environ. Qual. 45(4): 1186–1195. https://doi.org/10.2134/jeq2016.01.0024
[7] Snyder, C.S. 2017. Enhanced nitrogen fertiliser technologies support the "4R" concept to optimise crop production and minimise environmental losses. Soil Res. 55(5–6): 463–472. doi: 10.1071/SR16335. https://www.publish.csiro.au/sr/SR16335
[8] Eagle, A.J., L.P. Olander, K.L. Locklier, J.B. Heffernan, and E.S. Bernhardt. 2017. Fertilizer Management and Environmental Factors Drive N_2O and NO3 Losses in Corn: A Meta-Analysis. Soil Sci. Soc. Am. J. 81: 1191–1202. doi: 10.2136/sssaj2016.09.0281. https://acsess.onlinelibrary.wiley.com/doi/full/10.2136/sssaj2016.09.0281
[9] Banger, K., C. Wagner-Riddle, B.B. Grant, W.N. Smith, C. Drury, et al. 2020. Modifying fertilizer rate and application method reduces environmental nitrogen losses and increases corn yield in Ontario. Sci. Total Environ. 722: 137851. doi: https://doi.org/10.1016/j.scitotenv.2020.137851 .
[10] Gao, X., S. Parsonage, M. Tenuta, K. Baron, K. Hanis-Gervais, et al. 2017. Nitrogen Fertilizer Management Practices to Reduce N_2O Emissions from Irrigated Processing Potato in Manitoba. Am. J. Potato Res. 94(4): 390–402. doi: 10.1007/s12230-017-9574-4. http://link.springer.com/10.1007/s12230-017-9574-4
[11] Drever, C., R., Cook-Patton, S., C., Akhter, F., Badiou, P., H., et al. 2021. Natural Climate Solutions for Canada. Sci Adv. 7:23. doi: 10.1126/sciadv.abd6034. https://www.science.org/doi/10.1126/sciadv.abd6034#T2

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Key findings from the three scenarios explored are outlined below:

1. No Yield Increase: Even when yields were held constant (no yield increase) at 2020 levels and aggressive, but realistic 4R BMP adoption out to 2030 were assumed, a 30% absolute emission reduction could not be met resulting in a 2.5 $MtCO_2e$ reduction in GHG emissions and a cost of $495 million per year. While the cost of BMPs were offset by savings in fertilizer cost most regions experienced a negative net income by 2030. While the study focused on the average costs based on the adoption rates, the cost for an individual farm to fully implement the BMPs would cost approximately $34 per acre in 2022 and rise to $43 per acre by 2030. Without an increase in yields, contribution margins in 2030 would fall by $109 million below 2020 levels due to the net cost of implementing the BMPs.
2. Yield Increase: Yields were increased, including a moderate increase in N rate to support this, and aggressive, but realistic increases in 4R BMP adoption out to 2030 were explored resulting in a 1.6 $MtCO_2e$ reduction in GHG emissions – or 14%. The cost to remove CO_2 increased from $44 to $113 per tCO_2e from the no yield increase scenario to the increased yield scenario. Contribution margins increased across all regions between $48 and $83 per acre higher than the no increased yield scenario, which for all regions equals a $4.3 billion increase in contribution margins.
3. Getting to 30%: Yields were increased, including a moderate increase in N rate to support this, and 4R BMP adoption rates were increased until the 30% absolute reduction target was reached. To reach this target, adoption of multiple advanced 4R BMPs were required on every acre of N fertilized crop. Ontario and Quebec would require an adoption rate of 100% and Western regions would require an adoption rate between 60-70% (adoption rates in Ontario and Quebec are higher than Western Canada, but magnitude of change needed in each region is similar). The cost to achieve these higher adoption rates would be an investment of $4.6 billion for BMPs over the 10-year timeframe. This is $3.1 billion above the 2020 baseline and would be an additional $1.2 billion more than the costs for adoption in the other scenarios. This scenario resulted in a $4.4 billion increase in contribution margins. While there is potential for savings in this scenario that are significant, individual farmers will have to weigh the risk of increased spending on BMPs with the potential of experiencing below average yields or prices due to weather or markets in some years.

Recommendation:

Canada will have to balance the goal of reducing greenhouse gas emissions from fertilizer application against farm profitability, economic growth, and global food security. There is no free lunch in food production. Rather than focusing on a single source, government goals and the policies and programs that support those goals should be focussed on a comprehensive cropping systems approach to carbon accounting and emission reduction aimed at sustainable intensification and reducing the carbon intensity of Canadian crops.

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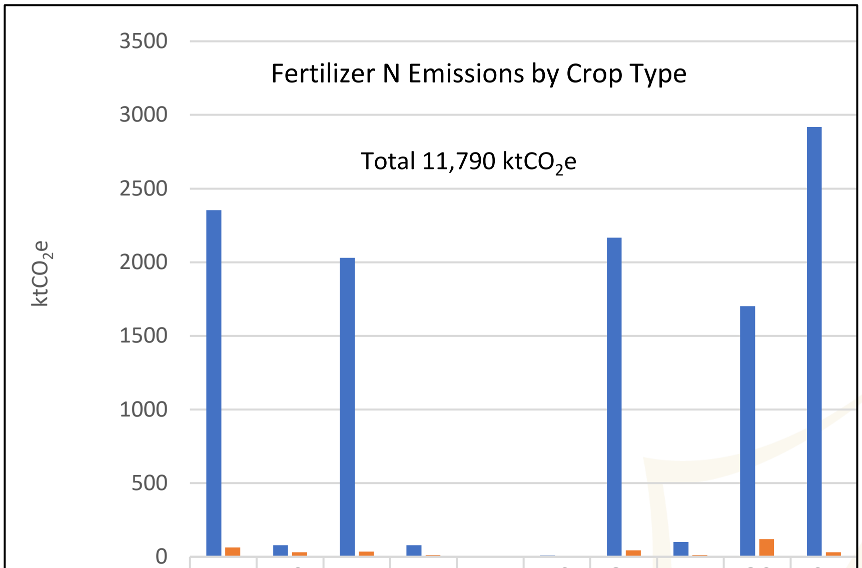
Canada has an opportunity to build on the recognized 4R approach to lowering agricultural emissions. Many Canadian farmers already use some 4R practices and are familiar with the concept. Major crop-producing provinces have formally recognized 4R Nutrient Stewardship. AAFC has taken an important step by formally recognizing 4R Nutrient Stewardship within the discussion paper. We invite AAFC's collaboration to work with farmers, the provinces and the fertilizer industry to quickly scale up 4R adoption to support Canada's ambitious climate goals and put words into action by fully integrating the 4Rs into programs, policies and international climate diplomacy.

Recognize Canadian Growers: Improved Data Collection & Modelling

Although the 30% emission reduction target was announced in late 2020, April 2022 was the first time the target was available in absolute (tCO_2e) terms. The release of the 2022 National Inventory Report (NIR) estimates the N_2O emissions from fertilizer at 11.79 MtCO2e (or 11.79 GgCO2e) and the reduction target at 3.54 $MtCO_2e$.

N_2O Emissions Fertilizer

- 97% of fertilizer emissions are from annual crops
- 63% of fertilizer emissions are from the Prairies
- 34% of fertilizer emissions are from Ontario and Quebec
- 3% of fertilizer emissions are from other provinces
- Total 11.79 $MtCO_2e$
- 30% reduction: 3.54 $MtCO_2e$



	AB	BC	MB	NB	NL	NS	ON	PE	QC	SK
Annual	2354	78	2030	80	0	10	2166	101	1702	2918
Perennial	63	32	36	11	1	4	44	11	120	32

Although the new NIR methodology reduced estimated emissions from fertilizer, it did not change the relative ranking of provinces substantially. Saskatchewan, despite a generally dry climate and low emissions per unit of N, has the highest aggregated emissions as a result of its extensive cropped acreage. Emissions from fertilizer applied to perennial crops, like tame hay or forage seed crops, account for just 3% of emissions nationally.

Ontario and Quebec have higher emissions per unit of applied N, which combined with more intensive N use on crops like corn results in aggregated emissions in a similar range as the Prairie Provinces.

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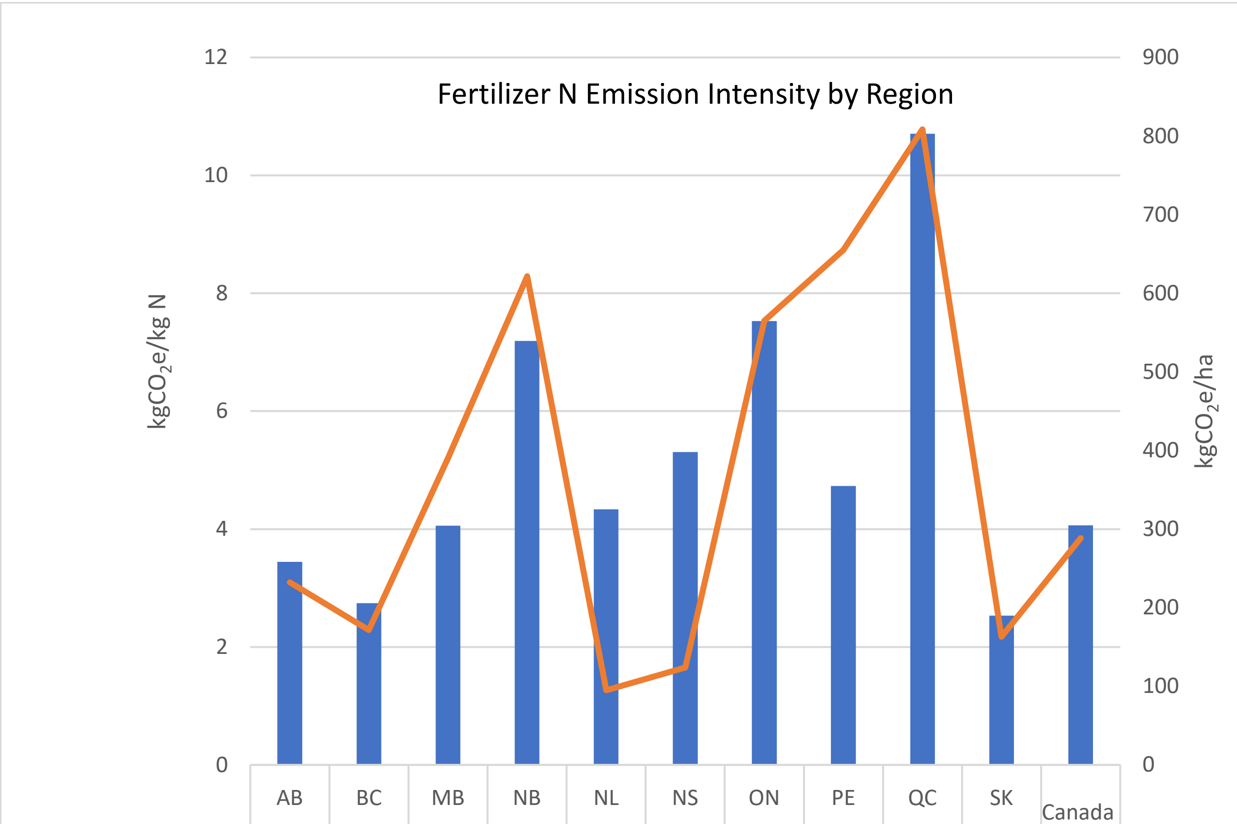
Emissions from Atlantic Canada and British Columbia are two orders of magnitude lower due to small area of arable land and except for Prince Edward Island (due to heavy potato rotations), low average fertilizer rates. On an intensity basis, emissions are highest in Quebec and lowest in Saskatchewan on both a per unit of N applied and per hectare basis.



	AB	BC	MB	NB	NL	NS	ON	PE	QC	SK	Canada
Per Unit N	3.4	2.7	4.1	7.2	4.3	5.3	7.5	4.7	10.7	2.5	4.1
Per Unit Area	232.2	171.4	389.8	621.6	94.9	123.7	564.8	654.8	808.5	162.8	288.6

While the updated methodology of the 2022 NIR better addresses differences in precipitation, topography, soil texture, irrigation and tillage across Canada, it still does not account for most on-farm practices that are known to mitigate emissions, such as the use of nitrification inhibitors and polymer coatings and other practices that fall under the 4R Nutrient Stewardship framework. The current adoption levels of 4R practices, which are substantial, are not accounted for within current modeling. Environment and Climate Change Canada (ECCC) has indicated that this is largely due to a lack of available on-farm nutrient management data. Currently, the Stats Canada shipments survey only captures volume and type of fertilizer shipped across different provinces to agricultural markets. Fertilizer Canada's Annual Fertilizer Use Survey can be utilized to support a joint effort to improve the capture of on-farm activity data.

Since 2014, Fertilizer Canada has proactively worked with grower organizations, governments, and technical experts to survey and collect on-farm nutrient management data. In 2021, the survey found that 60% of spring wheat growers, 55% of canola growers, and 70% of corn growers self assessed their

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farming practices as being consistent with a basic level of 4R Nutrient Stewardship.[12] Less than 6% of growers reported having a 4R Nutrient Management plan from a qualified advisor.

The NIR 2022 Part 1 suggests that there will be changes to incorporate the emission reduction potential of BMPs into nitrous oxide estimates within the next three to five years. This would require a significant improvement in farm activity data in order to accurately estimate BMP adoption rates as well as developing a methodology to generate appropriate emission factors for individual and combinations of BMPs.

AAFC has also confirmed that the carbon dioxide emissions coming from urea are included in the emissions associated with fertilizer use. However, we cannot mitigate carbon dioxide coming out of urea, we can only mitigate nitrous oxide. That's 0.2 tonnes of carbon per tonne of urea; 1.6 t CO_2e per tonne of urea-N. The only option is to use a substitute for urea and, in many cases, there is not a good substitute for urea and would require investment into expanding use at the farm, retail, distribution and manufacturing level. Examples include anhydrous ammonia, which has storage and handling safety risks, and cannot always be used to meet "right time" and "right place" requirements, and calcium ammonium nitrate, which has higher manufacturing, transport, and application costs.

Recommendations:

1. AAFC and ECCC should work collaboratively with growers and the fertilizer industry to identify pathways to overcome challenges with procuring the farm management activity data required to update inventory estimates. Additional government investment over the next 8 years is required to move Canada towards a Tier 3 approach to emissions inventory. Federal financial support to continue and expand Fertilizer Canada's Grower Fertilizer Use Survey is required to inform modeling. This needs to be a joint effort with support from the government to ensure that the data is robust enough to meet the needs of Canada's UNFCCC commitments to reporting a national inventory of greenhouse gas emissions.
2. Parallel to improving data collection, AAFC must undertake a science assessment and work with the research community, both public and private, to update emission factors from management practices and new products that are not considered in the NIR methodology or in current programs like OFCAF. We propose that over the next year, government, growers, and industry develop a strategy to identify BMPs where we have enough research to justify emission reduction factors and areas where more research is needed. This collaborative strategy can then help target investment to improve the measurement, reporting and verification of BMPs. There also needs to be a sizable investment into research on new technologies here in Canada to validate their associated impact on emissions.
3. The NIR is not a static document and ongoing changes may change the target for emission reductions if the 2020 baseline is recalculated. A rational and achievable intensity-based target should be set that focuses on reducing the emissions it takes to produce a bushel of crop such as tonnes CO2e per tonne of cereal production.
4. Emission intensities vary regionally, rate optimization approaches that reduce fertilizer N applied to corn in Quebec would have approximately 4 times the impact on N_2O emissions of an

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

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equivalent reduction to canola in Saskatchewan. Source, time, and place BMPs will likely have a significantly larger impact in the regions with higher emission intensity.

5. The cost of BMP adoption is just one barrier faced by farmers aiming to reduce their nitrous oxide emissions. There are also agronomic, market access, and environmental constraints that must be overcome. Programs and policies must be based on a comprehensive assessment of impacts to avoid unintended consequences that may undercut the economic, social and environmental sustainability of Canadian crop production.

Support Canadian Growers: Sustainable Incentive Programs for Reduced Emissions

The discussion paper highlights that AAFC has made preliminary scientific assessments confirming the emissions reduction models developed under a 4R Climate Smart Protocol and its potential to bring forward large scale emission reductions. These practices/emission reduction models are based on a protocol but there is no mention of offset protocol opportunities in the discussion paper as a potential tool.

A major challenge noted was accurate record keeping at the farm level. However, acquiring data for a purpose and producing value to the farm - through a carbon market – can provide the incentive needed to acquire this data. The federal government needs to support carbon markets (both regulatory and voluntary) if we are going to realize the emission reduction potential in Canadian crop production. The cost of conversion to a low carbon crop production sector is an order of magnitude higher than government programs provided, so being able to stack revenue streams will increase mobilization and incentivize the targeted practices.

Government funds to support farmer adoption of new BMPs should act as an instrument to build long-term revenue benefits for farms by building capacity for farmers to access the carbon offset, inset, and low carbon intensity markets which are developing globally. There has been accelerated interest in carbon markets because the price on carbon is increasing. For voluntary markets, large corporates (including food and beverage companies and crop input and agronomic service companies) are developing projects through their value chain to reduce Scope 3 emissions and meet their global decarbonization commitments. This can provide opportunities for early adopters to be paid for verified carbon outcomes or reduce overhead costs of practice change by partaking in pilot studies or voluntary programs happening across the country.

By limiting the sustainability of payments to farmers in the long-term, we risk losing the permanency of these transformational changes when government funding comes to an end. Changes in production need to be sustained and continued or else we will have gained no benefit long term. If Canada doesn't enable farms to participate in carbon markets for nitrogen management, Canada will be left behind and investments will go elsewhere. Based on production levels, Canadian farmers can be leaders in this space.

There is an opportunity for government to co-invest with private sector and create an on-ramp for participating in carbon markets which have a higher burden of data and evidence for creation of offsets as compared to the data requirements of other government programs.

Moving growers towards more effective, but expensive BMPs may require significant intervention by governments and/or the marketplace in the form of incentives. For example, developing carbon markets that more fully compensate growers for the costs of emission reductions or premiums for low carbon

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grains may be viable market-driven approaches. Other policy initiatives such as tax credits or direct payments to farmers that initiate N_2O reducing strategies may be required to more fully compensate growers.

Recommendations:

1. AAFC should focus future investments on 4R Nutrient Stewardship. Support for research, measurement, and farmer adoption need to go well beyond the current OFCAF funds. AAFC needs to expand its future programs to fully explore a wide range of emerging technologies and programs needed to utilize the talent, skills and dedication of Certified Crop Advisors, Professional Agrologists, and field agronomists who are the trusted advisors of Canadian farmers.
2. Environment and Climate Change Canada should facilitate continued development and implementation of the 4R Climate-Smart Protocol in collaboration with the fertilizer and grains industries. Integrating on-farm measuring and reporting of emission reductions into its offset program will help Canada reach targets and incentivize farmers with saleable carbon credits.
3. Other policy instruments for accelerating adoption should be considered including Crop Insurance programs and Environmental Farm Plans.

Federal and Provincial Government Alignment

Fertilizer Canada, provincial grower groups, and provincial governments have supported 4R Nutrient Stewardship practices for years through MOU and MOC agreements. These agreements are longstanding and provide a regional focus on implementation of 4Rs under each province. The government should align their objectives with the current provincial governments and look for opportunities to leverage already established programs.

Throughout the entire consultation process, there has often appeared to be disconnect between the two federal organizations ECCC and AAFC. Given that this is emissions reduction target was established by ECCC to meet Paris Agreement targets and has since been passed on to AAFC, it will be important for the two departments to ensure collaboration and similar messaging across both ministries.

We look forward to continuing to collaborate with farmers, governments and industry stakeholders to achieve shared goals of accelerating national scale adoption of 4R best management practices that maximize emissions reduction potential while ensuring our continued contribution to global food security.

APPENDIX A

BMPs Put Forward in the AAFC Discussion Paper

Below, Fertilizer Canada explores the concepts behind the BMPs, why they are expected to reduce N_2O emissions, as well as expected benefits from and barriers to implementation.

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Annual Nitrogen Soil Testing – Right Rate BMP

The standard for determining soil test nitrogen (STN) is the nitrate-N test. Ammonium, the other plant available form, tends not to accumulate in soil and is generally not included in STN. Time of sampling needs to be considered in the interpretation of results. Post-harvest fall testing after the soil has cooled is the standard approach used on the semi-arid prairies, where there is generally reasonable correlation between fall and spring soil test nitrogen. Fall or spring testing is not a good predictor of available N for the growing season outside the prairies. In humid environments, where soils may be saturated and unfrozen through the winter, nitrate measured in the fall may be lost through denitrification and leaching. Sampling depth is also important; nitrate is mobile in soil and can accumulate in the lower reaches of the rooting zone. This N may not be available in the earlier part of the season but can be accessed as the roots extend downward. Deeper sampling is generally recommended for nitrogen (as compared to sampling for phosphorus and other nutrients) with separate 0-15 cm (0-6 in) and 15-60 cm (6-24 in) depths as the most common configuration.

Fall soil testing for N in semi-arid regions indicates if there is residual available N in the soil following harvest and is useful in determining if the crop was over fertilized. It is less useful for this purpose in Eastern Canada, since loss mechanisms can be active during the period before and after harvest. Spring soil testing as close to seeding as possible is the best time for using soil test N in developing rate recommendations in Western Canada. In-season, the pre-sidedress nitrogen test or PSNT can be useful in setting split fertilizer N application rates in corn.

AAFC suggests in their discussion paper that nitrogen soil testing can contribute to reduced nitrous oxide emissions from fertilizer by 5-15%. Soil nitrogen testing is supported as a 4R Right Rate BMP under the OFCAF program. The underlying assumption is that increased soil testing would lead growers that are currently over applying to reduce their rates to optimum levels. While some growers may be overapplying, there is no compelling evidence that there is currently significant overapplication of nitrogen to Western Canadian crops. In Eastern Canada, overapplication is limited to covering uncertainties in predicting year-specific crop N requirements, and in predicting the availability of nitrogen in applied manures. The discussion paper suggests that an additional 5.7 Mha/year or roughly 15% of arable crop land could be tested on an annual basis. This increase when combined with current annual soil test volumes would bring annually tested fields in the range of 45-55% of total fields.

<u>Considerations</u>

1. Soil testing for nitrogen has been widely available in Canada for over 50 years. Soil testing is largely performed by private laboratories and total test volumes are close to that reported in the industry's Soil Test Summary (https://soiltest.tfi.org/). Annual sample volumes have roughly doubled in the past two decades, from 165 thousand in 2001 to 325 thousand in 2020. Keep in mind that this system does not track N tests and the numbers above are for P tests. An N test is typically done on the Prairies as part of standard test packages but not in the rest of Canada. Nitrogen test volumes are in the range of 125 to 175 thousand per year. Fertilizer Canada's Fertilizer Use Survey suggests that there has been some increase in uptake over the past decade but less than a third of growers surveyed tested their fields for N on an annual basis.
2. The available windows for sampling fields are after the soil cools in the fall and before freeze-up and after the soil thaws in the spring and before planting. Fall sampling can be delayed by late

harvest and poor weather and is not useful for developing N recommendations outside the Prairies. In much of Canada, the time between the spring thaw and optimal seeding date is typically less than a month leaving little time for sampling fields, analysis, and recommendation building. The pre-sidedress soil nitrate test requires sampling in June (a busy month for farmers) and requires rapid turnaround to inform the in-season application rate decision.

3. While spring samples may be preferred for making recommendations, growers are typically looking for recommendations well ahead of planting. Recommendations using fall sample results are used for setting fall application rates and to pre-order or purchase fertilizer N for spring application to take advantage of lower fall prices.
4. Sampling and analytical capacity would need to increase in-order-to provide rapid turn-around time on samples. New technologies capable of making in-field determinations may provide more immediate results and artificial intelligence approaches that predict the soil test values based on a multitude of variables are starting to be used to reduce the extent of actual sampling.
5. Soil test N on its own is not a good predictor of yield response and is only one variable in more comprehensive N recommendation systems. These systems need data on a wider array of soil properties including soil organic matter and soil texture as well as tillage systems. More advanced systems also utilize past and forecasted weather and/or crop sensing information.
6. There is currently no methodology for explicitly linking soil testing as a BMP to reductions in N_2O emissions from fertilizer, although most of its benefits could be assumed to be directly proportional to improvement in nitrogen use efficiency. The emission reduction is therefore per unit of crop produced, not per unit of fertilizer used, and not necessarily per unit area of cropland. The value will be in using soil testing as an indicator of residual N following harvest where high residual N would be an indicator of unused fertilizer N and overapplication. On the prairies, high residual N values are generally associated with low yields in drought years.
7. There are several logistical barriers to increasing soil testing - in particular spring testing. There are several emerging analytical technologies that are shortening the turn-around time but the results from these novel methods need to be calibrated and understood before they are useful in recommendations.

Accounting for N in Previous Legume Crops – Right Rate

Crop residues from legumes tend to have higher N content and lower C:N ratios compared to cereals and oilseeds. Current thinking is that the lower C:N ratio results in higher net mineralization primarily due to reduced immobilization and potentially more available N for the crop that follows. The idea behind this BMP is that a cereal or oilseed following a legume requires less N fertilizer. There is also an assumption that the effects of legumes on N availability (the N credit) is not widely accounted for in N recommendations. Work on the Northern Great Plains has found that a) not all pulses produce N credits, b) contributions of N to the subsequent crop were highly variable and generally in the range of 10-20 lb N/acre, c) annual legumes were best treated as a longer-term rotational strategy d) some of this N credit is in the form of nitrate which can be prone to denitrification the following spring. Adding pulses to cereal and oilseed rotation on the prairies tends to have benefits such as disrupting cereal and canola disease cycles. However, pulse crops have their own set of diseases - many that are shared among the different pulse crops and other rotational crops as well as agronomic problems related to seeding and

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harvest. Faba beans, peas and lentils will under normal conditions provide a N credit to the crop that follows while chickpeas and field beans typically do not. Warm moist post-harvest conditions can result in rapid mineralization and the N credit showing up in soil test N results. This can lead to underapplication and conditions that favor denitrification and leaching over winter N loss. Growers in Western Canada often seed wheat on pulse stubble without a significant reduction in N rate and rely on the pulse credit to achieve high protein wheat.

Corn grown in corn-soybean rotations or following forage legumes tends to outperform continuous corn. In Ontario it is common to reduce fertilizer N rates 20-30 lb N/acre following soybean and by at least 100 lb N/acre following alfalfa. This doesn't seem to apply to corn or other crops following soybean in Manitoba where the net N benefit following soybean is approximately 6 lb N/acre.

<u>Considerations</u>

1. In the 2020 crop year data used for the 2022 NIR, the area of annual legumes is 2 Mha for soybean and 3.7 Mha for pulses. There is an additional 3.3 Mha of alfalfa, but alfalfa is not turned over every year. The discussion paper suggests that accounting for N credits following legumes could reduce emissions on an additional 4.9 Mha and that adoption of this practice is already medium to high. The additional hectare estimate is in our opinion more in the range of 2-3 Mha as the practice already has high adoption.
2. Updating and publishing regional estimates of N credits by legume crop and across a range of growing season conditions would assist agronomists in more realistically accounting for N credits and facilitate further adoption.
3. Assigning a N credit is not a stand-alone issue and is tied to greater use of nitrogen soil testing and better techniques for predicting net mineralization rates as part of an integrated fertilizer recommendation system. Alberta's AFFIRM is an example of one such system. There needs to be a considerable research and development investment in developing the data required by expert recommendations systems for all the major cropping systems and soil types in Canada.
4. Warm moist post-harvest conditions can result in rapid mineralization and the N credit showing up as soil test N results. This can lead to underapplication causing an increase in N_2O as the credit is in effect counted twice.
5. Growers in Western Canada often seed wheat on pulse stubble without a significant reduction in N rate and rely on the pulse credit to achieve high protein wheat.

Applying N in Spring Compared to Fall – Right Time
Applying N fertilizer as close as possible to the time of maximum crop uptake can reduce risk of N loss and increase nitrogen use efficiency. Research on the prairies has shown that spring application tends to result in higher yields than fall application. This is particularly true when fall broadcast is used with non-stabilized nitrogen. Limited farm activity data makes it difficult to assess how much N goes down in fall on the prairies and pinpointing where it is a more common practice. Wet falls and/or early freeze-up, late harvests and high N prices tend to reduce fall-applied acres while the opposite conditions lead to increased fall N. In the 2019 Fertilizer Use Survey, canola growers reported that ≈20% of N is fall applied on the Prairies and the practice is more common (44% of growers) in Manitoba.[13] Quarterly shipment

[13] 2019 Fertilizer Use Survey, Fertilizer Canada. https://fertilizercanada.ca/our-focus/stewardship/fertilizer-use-survey/

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data[14] suggests sufficient anhydrous ammonia is available for fall-application on 4-6 million acres and also points to the practice being most common as a percent of total acres in Manitoba and least common in Alberta. However, the split between storage over winter at retail and on-farm and actual fall-application cannot be accurately assessed from shipment data. Farmers purchase granular N in fall, primarily urea, for spring application to take advantage of lower prices. This makes it difficult to assess how much urea or urea containing blends are fall applied.

In humid environments, for example Southern Ontario, where soils may not freeze and profiles are often fully recharged with moisture, overwinter N losses through leaching and denitrification can be substantial. Other than applications of ammoniated phosphorus sources, very little N fertilizer (<3% in corn and ≈15% in winter wheat[15]) is applied as a primary N source in fall. The fall application to winter wheat is agronomically justified, since the crop actively absorbs N in the fall up to freeze-up, and in the spring immediately following the thaw. The opportunity for conversion from fall to spring timing is therefore largely confined to the prairies. Best practice for fall application is deep banding after the soil has cooled below 10 °C, using anhydrous ammonia with a nitrification inhibitor as well as other N sources and urease inhibitors.

Switching from fall to spring may not always result in lower N_2O emissions. Research in Manitoba has shown that emissions can be lower from anhydrous ammonia applied in late fall compared to pre-plant in spring.[16] Overwinter losses of fall-applied N tend to be higher with earlier application and in depressional area of fields.

Considerations

1. Fall application reduces spring workload. Switching from fall to spring may also involve a switch in placement from banding to broadcasting potentially reducing nitrogen use efficiency. The desired conversion is from fall application of non-stabilized N whether banded or broadcast to spring banding which tends to result in higher NUE.
2. Conversion from fall to spring N application may involve equipment changes particularly if the change to application is from fall to time of seeding and will significantly impact the supply chain for availability of spring nitrogen.
3. Fall-banding after the soil has cooled below 10°C is considered a 4R Climate Smart BMP on the Prairies. Moving to late fall-timing with a urease and/or nitrification inhibitor may be a more achievable transition than conversion from fall to spring.
4. Targeting finer-textured soils on the moist Prairies will result in greater reductions per unit of N applied.

Fertigation (Injection of Fertilizers with Irrigation) – Right Time

Fertigation provides an opportunity to move N applications closer to time of maximum crop uptake. Fertigation carries applied N into the rooting zone, which is an advantage compared to other in-season

[14] Statistics Canada. Table 32-10-0038-01 Fertilizer shipments to Canadian agriculture and export markets, by product type and fertilizer year, cumulative data (x 1,000) **DOI:** https://doi.org/10.25318/3210003801-eng

[15] 2020 Fertilizer Use Survey, Fertilizer Canada. https://fertilizercanada.ca/our-focus/stewardship/fertilizer-use-survey/

[16] Tenuta, M., X. Gao, D.N. Flaten, and B.D. Amiro. 2016. Lower Nitrous Oxide Emissions from Anhydrous Ammonia Application Prior to Soil Freezing in Late Fall Than Spring Pre-Plant Application. J. Environ. Qual. 45(4): 1133–1143. doi: 10.2134/jeq2015.03.0159.

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surface application techniques, improving NUE. Fertigation works well with crops with a longer uptake period such as potatoes. With cereals and oilseeds grown under irrigation, the window for supplemental N can be quite narrow and depending on rainfall, irrigation may not be required. A large proportion of irrigated land grows legume-based hay or is annual silage grown on manured land and does not receive N fertilizer. The discussion paper suggests that the practice could be expanded to an additional 0.3 Mha, 40% of Canada's irrigated land base of 0.7 Mha. This may be optimistic in terms of area, but expansion of the practice should be encouraged particularly on high value irrigated crops in both Eastern and Western Canada.

Considerations

1. Conversion to fertigation requires equipment that meters liquid fertilizer into the irrigation water stream. This will require investment as irrigation farmers will need to purchase injection equipment and potentially equipment for storing and hauling liquid N sources such as UAN.
2. Irrigation timing and optimal fertilizer application timing may not coincide.
3. Irrigation is applied on less than 2% of Canada's cropland. Even though the NIR methodology ascribes higher direct and indirect emissions to irrigated soils, converting half the irrigated acres to fertigation as suggested in the discussion paper would provide less than 1% of the required N_2O reduction.

Split Application/Sidedress with Rate Adjustment Based on Sensors – Right Time

Split-application offers advantages by allowing growers to adjust N rates based on growing season conditions. The practice is most feasible with row crops like corn where UAN can be side dressed through coulters or surface applied with Y-drops using a high clearance sprayer. Corn grower survey data from Ontario suggests that up to 40% of the total N applied to corn is applied in-season. Given that most growers applying in-season are also applying at or before seeding, the survey data suggests that the practice is already widely adopted in Ontario's corn growing regions.

For cereal and oilseed crops, UAN or liquid urea can be applied using a high clearance sprayer fitted with streamer nozzles. Urea, ammonium nitrate, calcium nitrate and other granular products can also be broadcast. Surface applications are dependent on timely rain or irrigation to carry the N into the rooting zone. Surface application of urea-based products can result in significant volatilization loss. Use of a urease inhibitor or a controlled release product can reduce volatilization losses. The windows for application can be quite narrow for cereals, no later than stem elongation for yield response, and optimal timing can be interrupted if poor weather makes fields untrafficable.

Equipment-mounted sensors that adjust rates in real time across the field are one approach. Used in isolation they require a grower to commit to the split application/sidedress operation as the rates are not known in advance. Hand-held sensors, satellite imagery, and/or drone-based imagery can also be used to provide a pre-operational assessment of N status of a crop. Currently available sensing techniques do not directly sense N in the plant but detect indicators such as greenness or use normalized difference vegetative index calculations (NDVI) as a proxy for N status. Mechanistic models are also available that predict N uptake and losses and provide growers insight into the N status of the crop and whether it needs to be supplemented as the season progresses. Artificial intelligence (AI) methods are also being developed that predict N status based on a range of available weather and

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agronomic data. A lower tech approach is the Pre-side dress Nitrate Test, basically an in-season soil test prior to making an application.

Considerations

1. Split application may not lead to rate reductions when early season N losses are high. There is in fact a tendency for the final rates to be higher in years with greater rainfall, since more rain generally increases potential crop yield as well as potential N losses.
2. Provides growers with an N saving option when spring soil moisture is low at seeding. Additional N can be applied if conditions improve.
3. Equipment mounted sensors require considerable investment in hardware. Other techniques are available and may be lower cost or allow growers to trial split applications with minimum investment in hardware.
4. Split-application increases the complexity and timing of field operations and an extra pass across the field adds to operational costs that may not be recovered through reduced total N rates, increased yields, or improved crop quality.
5. Increased potential of volatilization losses in semi-arid conditions if rainfall does not occur post application soon enough.
6. Already a relatively high level of adoption in Ontario and limited opportunity on the Prairies.

Apply in Bands/Injection Accompanied by Reduced Rate – Right Rate

Banding of granular or liquid fertilizers containing urea generally increases NUE compared to surface broadcasting. Banding reduces contact with soil and creates a fertilizer reaction zone that limits soil microbial activity. This slows nitrification and potentially reduces the nitrate available for denitrification and leaching should soil become saturated after fertilizer application. Placing N below the surface can also reduce volatilization provided bands are sufficiently deep and there is good closure over the band. Shallow banding can reduce the benefits of banding with respect to volatilization under dry condition and in coarser textured soils. Banding away from the seed, side-banding or midrow banding, avoids the seedling damage that can occur from placing N in the seedrow.

Yields tend to be 10-20% higher in Prairie cropping systems where N is banded rather than broadcast. Just over 90% of N applied by canola growers on the Prairies was applied in bands and numbers are expected to be similar for cereals. There is limited opportunity to increase banding on the Prairies. Farmers know that banding reduces N losses, increases NUE and leads to higher yields; N is broadcast to save time. In Ontario, split application appears to be growing and surface banding (using Y-drops for example) may be reducing the volume of N applied through sub-surface banding in corn.

Considerations

1. Although 90% of N fertilizer on the Prairies is banded, recent trends to broadcasting N on the Prairies are typically driven by time and equipment constraints. There is an opportunity to increase the use of stabilized nitrogen when utilizing surface applied broadcast practices. Banding tends to be dominantly shallow banding, which does not significantly reduce losses in Western Canada.

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2. Growers switching to sub-surface banding will need to invest in banding equipment.
3. Opportunities for conversion from broadcasting to banding are likely highest in regions of Eastern Canada where broadcasting N is still common practice. However, in Eastern Canada broadcast/incorporated urea are considered equal in efficacy to banded urea, and general recommendations do not reduce N rates for banding relative to broadcast/incorporated.[17]

Enhanced Efficiency Fertilizers, Inhibitors, or Slow Release – Right Source

Nitrogen based Enhanced Efficiency Fertilizers (EEF) affect processes in the N cycle in ways that prevent N loss and increase NUE. Depending on the mode of operation they may also reduce N_2O emissions. The most effective at reducing N_2O emissions are nitrification inhibitors (NI). These products typically reduce N_2O emissions by 25-49%.[18] Urease inhibitors (UI) tend to be less effective at reducing nitrous oxide emissions generally in the 5-15% range. There are NI products available for use with anhydrous ammonia, urea, and UAN and UI products for urea and UAN. Double inhibitor products containing both an NI and a UI are available for urea and UAN and have been shown to provide reductions in total nitrogen losses[19]. Controlled release products such as polymer coated urea (PCU) typically reduces N_2O by 10-28%[20]. A global meta-analysis with the largest number of comparisons of polymer-coated urea to urea, including 20 from Canada, found an average 19% reduction in nitrous oxide emissions.

The yield response to EEFs is not as obvious as the GHG emission reduction potential – and active rates in products also play a big factor into yield and nitrogen loss performance. A yield response will only occur if crops are N limited and the EEF results in more N available to the crop compared to a conventional N product, or environmental conditions arise resulting in significant nitrogen losses. Replacing conventional N with an EEF on a pound for pound basis will increase costs without an increase in revenue, if N rates were already adequate to meet crop demand. By switching to an EEF, farmers can potentially increase efficiency and therefore potentially increase production or improve operational efficiencies.

Consideration

1. Some EEFs are effective at reducing N_2O, however, the yield effect for inhibitors and controlled release products are less obvious than the emission reduction when available nitrogen is greater than crop demands. The economic benefit is smaller than the environmental benefit and farmers are not being paid for that environmental benefit. A mechanism at the national level

[17] Woodley, A.L., C.F. Drury, X.Y. Yang, L.A. Phillips, D.W. Reynolds, et al. 2020. Ammonia volatilization, nitrous oxide emissions, and corn yields as influenced by nitrogen placement and enhanced efficiency fertilizers. Soil Sci. Soc. Am. J. n/a(n/a). doi: 10.1002/saj2.20079.

[18] Fan, D., W. He, W.N. Smith, C.F. Drury, R. Jiang, et al. 2022. Global evaluation of inhibitor impacts on ammonia and nitrous oxide emissions from agricultural soils: A meta-analysis. Glob. Chang. Biol. n/a(n/a). doi: https://doi.org/10.1111/gcb.16294.

[19] Fan, D., W. He, W.N. Smith, C.F. Drury, R. Jiang, et al. 2022. Global evaluation of inhibitor impacts on ammonia and nitrous oxide emissions from agricultural soils: A meta-analysis. Glob. Chang. Biol. n/a(n/a). doi: https://doi.org/10.1111/gcb.16294.

[20] Thapa, R., A. Chatterjee, R. Awale, D.A. McGranahan, and A. Daigh. 2016. Effect of Enhanced Efficiency Fertilizers on Nitrous Oxide Emissions and Crop Yields: A Meta-analysis. Soil Sci. Soc. Am. J. 80(5): 1121–1134. doi: 10.2136/sssaj2016.06.0179.

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(carbon credits, for example) is required to reward farmers for the societal benefits they provide.

2. EEFs can be applied like conventional sources, few logistic barriers to application, and can provide operational efficiencies.
3. Current use of EEFs is 10-15% of N fertilizer volume in the Prairie provinces, and 6-24% in Ontario. A significant increase in use may require expansion of manufacturing capabilities and output, and/or imports.

Replace Inorganic Fertilizer with Manures, Composts, or Digestate

A significant portion of the N contained in manure is in the organic form. This organic-N is released into the available pool as manure and breaks down. Manure acts as a slow-release fertilizer and as such may produce lower direct N_2O emissions per unit of N applied. The NIR methodology estimates direct emissions per kg of manure N applied to annual crops are approximately 16% lower than a kg of fertilizer N. However, the benefit of lower direct emissions is partially clawed back by higher volatilization losses compared to inorganic fertilizer resulting in indirect emissions. The 2022 NIR estimates total annual manure N production in Canada at 670 kt N. Of this 42% is directly deposited by animals on pastures, ranges, and paddocks and is largely unrecoverable for application to crop land. The remaining manure N (approximately 390 kt N) is applied predominantly to annual crops (290 kt N), perennial crops (68 kt N) and improved pasture (31 kt N). Application of manure N to annual and perennial crops is approximately 14% of applied fertilizer N. An additional quantity of N_2O emissions, however, is also assigned to “manure management” and represents approximately double the N_2O emissions associated with manure application. These emissions represent N losses from livestock operations between excretion and land application. Technologies capturing this large volume of lost nitrogen from manure in forms suitable for land application could potentially displace fertilizer N and reduce net N_2O emissions.

While manure could be used more effectively, recoverable manure volumes are too low to replace significant quantities of fertilizer N. More efficient application methods that reduce ammonia volatilization could make a small but significant reduction in N_2O emissions. For example, reducing estimated volatilization losses by half for manure applied to crops and improved pastures would reduce N_2O emissions by approximately 175 ktCO_2e or 5% of the total targeted reduction.

Biosolid N is estimated at < 1% of all N applied to agricultural lands. Land application of biosolids from sewage treatment is regulated at the provincial level and typically requires immediate incorporation.

The discussion paper suggests that manure and other organics could replace inorganic fertilizer on 1.4 Mha. At average fertilizer rates (67 kg N/ha) this would require redirecting approximately 24% of the recoverable manure to new fields. This may reduce N_2O emissions attributable to fertilizer by 4-6% but will have little impact on overall emissions from agricultural soils.

Considerations

1. Manure application is regulated at the provincial level with controls on rate, time, and place practices for field application.

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2. Efficient use of manure requires incorporation to prevent ammonia loss and solid manure application is incompatible with zero tillage systems.
3. Nitrification inhibitors are available for use with liquid manures.
4. Increased hauling distances significantly increase manure application costs.
5. Technologies to increase nutrient captured from manure during the stages from excretion to land application could have substantial impact on emissions.

Conservation Tillage

Conservation tillage typically slows turnover of soil organic carbon and leads to carbon sequestration. Conservation tillage also affects the N cycle and can result in an increase in N_2O emissions relative to conventional tillage. Conservation tillage prevents erosion, increases water holding capacity, and generally improves soil health. During transition from conventional to conservation tillage, higher N rates may be required to maintain yield as N is immobilized with the sequestered carbon. As the system matures, mineralization increases and the N supplying power of the soil increases. Direct seeding has been widely adopted on the Prairies. Forms of reduced tillage such as strip till have become more common in the last decade. Currently carbon sequestered in agricultural soils is reported under the Land Use Land Use Change and Forestry (LULUCF) section of the NIR following IPCC directives. Agriculture receives no credit for sequestered carbon in cropland but the N_2O from soil organic carbon turnover is part of the agricultural soils assertion in the NIR.

The discussion paper suggests that conservation tillage could be expanded to an additional 1.6 Mha and may reduce emissions by 5-15% but does not specify if the reduction is net of carbon sequestered.

<u>Considerations</u>

1. Rather than focussing on reductions from fertilizer, the focus should be on net in-field emissions from cropland with the aim of bringing them as close to net zero as possible. This would include the positive effects of carbon sequestration on reducing emissions and eventually could expand to other nature-based and technical solutions on the farm.
2. For the purposes above, carbon sequestration should be calculated conservatively but not discounted for permanence as it is in offsetting protocols.

Improved Drainage

Installing tile drainage can reduce the length of time that the soil is saturated and reduce denitrification losses. Nitrate-N can be lost in drainage waters and contribute to indirect emissions. Installing drainage is expensive and routing water from fields can contribute to flooding and eutrophication of surface waters. Drainage is regulated by provinces.

<u>Considerations</u>

1. Drainage of wetlands including ephemeral wetlands may disqualify growers from participation in various regulatory and voluntary carbon and/ecosystem service markets that have biodiversity criteria. For example, the Canadian Clean Fuel Standard contains biodiversity criteria that must be met.

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2. Some provinces have setbacks from drainage ditches or waterways that are constructed or used for carrying drainage waters. Application of manure or fertilizer may not be allowed in the set-back zones.

3. New technology is making drainage easier to install and systems are emerging the store drainage water in spring and then recycle it as the crops water demand increases through the growing season.

Increasing Legumes in Rotation

As discussed earlier, annual and perennial legumes that produce an N benefit can reduce the fertilizer required for subsequent cereal and oilseed crops. These can include pulse crops (field peas, lentils, faba beans, chickpeas), oilseed legumes like soybean, and perennial forage crops like alfalfa and clovers. A more important aspect is the reduction in N_2O emissions from not adding N fertilizer in the legume year(s). For example, going from a wheat, canola rotation to a wheat, canola, pulse may reduce N fertilizer use by up to a third. Switching from continuous corn to a corn-soybean rotation could cut fertilizer N use and associated emissions in half, but at the same time might reduce potential soil organic carbon storage. Adding legumes to rotation helps break disease cycles and typically yields of non-legume crops are higher in rotations that include legumes.

There are several barriers to increasing grain and oilseed legumes in rotations. While pulse crops break the disease cycle of cereals and oilseeds, they have diseases of their own several of which are shared among all the pulse species. Herbicide options are limited in pulse crops and growers adding pulse crops to their rotation may need to rethink their herbicide rotations to insure they are not increasing selection pressure for herbicide resistance. Production costs can be high and yields low and specialized equipment such as land rollers and draper headers may be required for seeding and harvesting. Finally, market and/or market access can be an issue. On the Prairies lentil acreage expanded, largely at the expense of wheat acres, in the 2010's. Soybean acreage has steadily expanded in Manitoba, but field pea acreage has declined throughout the Prairies. In Ontario and Quebec, soybean acreage already exceeds corn acres suggesting that there is little room for further expansion of soy acres in the rotation and expansion would likely have detrimental effects to soil health and soil carbon storage.

<u>Considerations</u>

1. Long-term increases in pulse acreage will require both improvements in disease management through crop breeding and market development.

2. Current N management protocols such as 4R Climate Smart, VM 22, or NMPP do not use a rotational approach that credits an increase in legumes in rotation and the overall reduction in N_2O through the rotational cycle. This needs to be rectified so voluntary and regulatory carbon markets reward growers who increase legume acreage and frequency in their rotations.

3. Legume crops provide nitrogen back into the soil in multiple forms, including nitrate, and are therefore not net zero in N_2O emissions. Crop type does influence the amount of N_2O loss that can be observed after legume crops, with some having more limited emissions while others can produce more.
4. While legume acreage has expanded, there are limitations both from a lack of market need/demand perspective and a regionality perspective – there are limited acres that are suitable to grow legumes depending on climate, soil conditions, etc.