WHAT IS THE OPTIMAL RATE AND N_2O MITIGATION POLICY FOR NITROGEN APPLICATION IN SASKATCHEWAN CANOLA?

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INTRODUCTION

- The Canadian agricultural industry accounts for 10% of national annual GHG emissions with a major contributor being N_2O from N fertilizer application[1].
- The Government of Canada has set a national target to reduce absolute levels of GHG emissions from fertilizer application by 30% from 2020 levels by the year 2030[1].
- Over the years 2005-2019, fertilizer use has increased by 71% which has been driven by increased N fertilizer use in Western Canada[1].

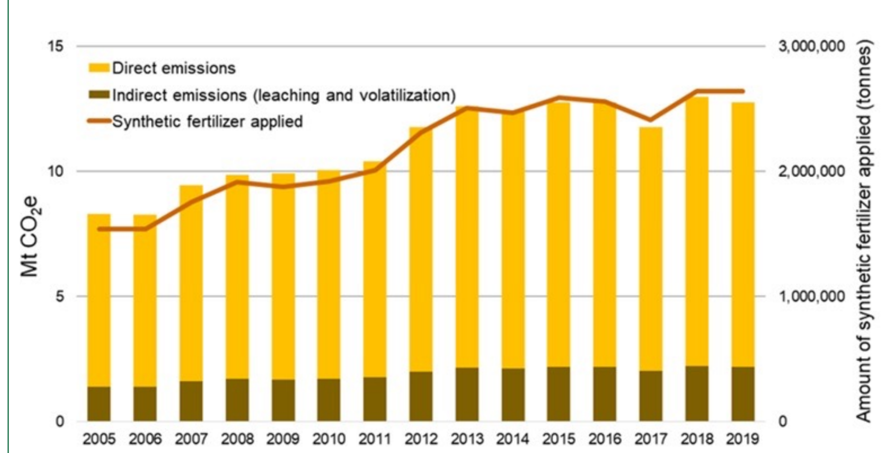


Figure 1 *Canada's Direct and indirect N_2O emissions from synthetic fertilizer application from 2005 to 2019*[1][2].

- Increased N fertilizer use has contributed to record crop production but has also resulted in N_2O emissions increasing by 54% over the years 2005-2019[2] (see Figure 1).
- Canola is a high N use crop with growing demand for edible oil, seed, meal and biodiesel products[3] posing a challenge to reducing fertilizer application emissions.

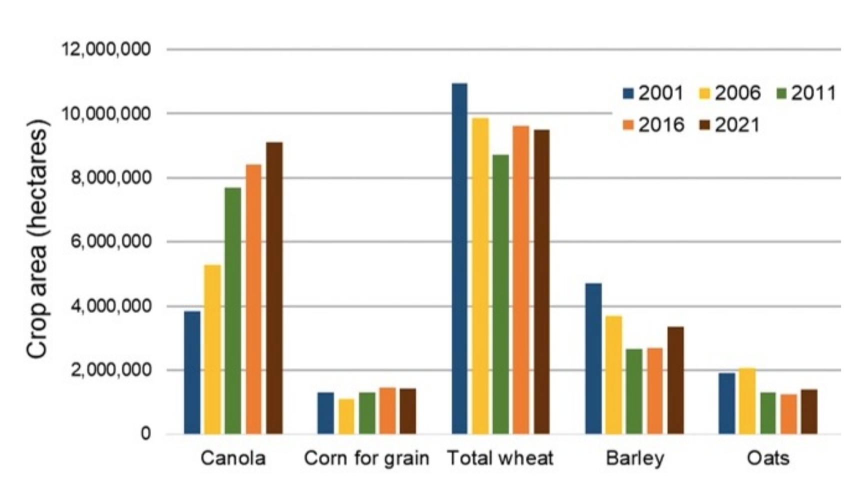


Figure 2 *Changes in field crop area between 2001 and 2021 in Canada* [1].

- Canola production has risen rapidly in Canada since 2001 (see Figure 2) and Saskatchewan alone accounts for over half of national canola production[4].
- Optimizing N fertilizer application is crucial, not only to increase canola yields[5] and improve nitrogen use efficiency[6], but to reduce the carbon footprint of canola[7].
- The study of the optimal N application rate in canola, and potential policies to reduce N_2O emissions from nitrogen fertilizer are needed to meet Canada's emission targets.

OBJECTIVES

1. Estimate the economic private optimum rate of applied N for Saskatchewan Canola using a large, producer reported field-scale data set.
2. Estimate the marginal abatement cost for direct N_2O emissions from N fertilizer application in Saskatchewan.
1. Compare an optimal Pigouvian tax on N fertilizer use to a regulated 30% reduction in N fertilizer use for Saskatchewan.

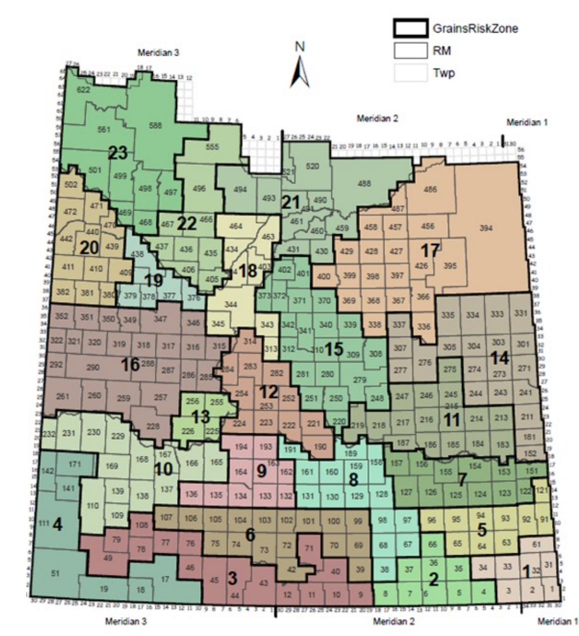
METHODS

- The types of data used in the canola production function, estimation of the private optimal N rate and N_2O abatement cost include:

Management[8] | Weather[9] | Variety[10] | Price[11][12] | Emission [13]

- The management data set is producer reported field level data (2011-2019) from Saskatchewan Crop Insurance Corporation (SCIC) with over 47,059 observations across 23 grain cropping risk zones of Saskatchewan (see Figure 3).

Figure 3 *Grain risk zone regions of Saskatchewan as classified by SCIC*[14].



- A quadratic canola production function with fixed effects was estimated where yield is a function of variable inputs, management and agro-ecological factors (see Table 1).

Table 1: *Independent variables in canola production model.*

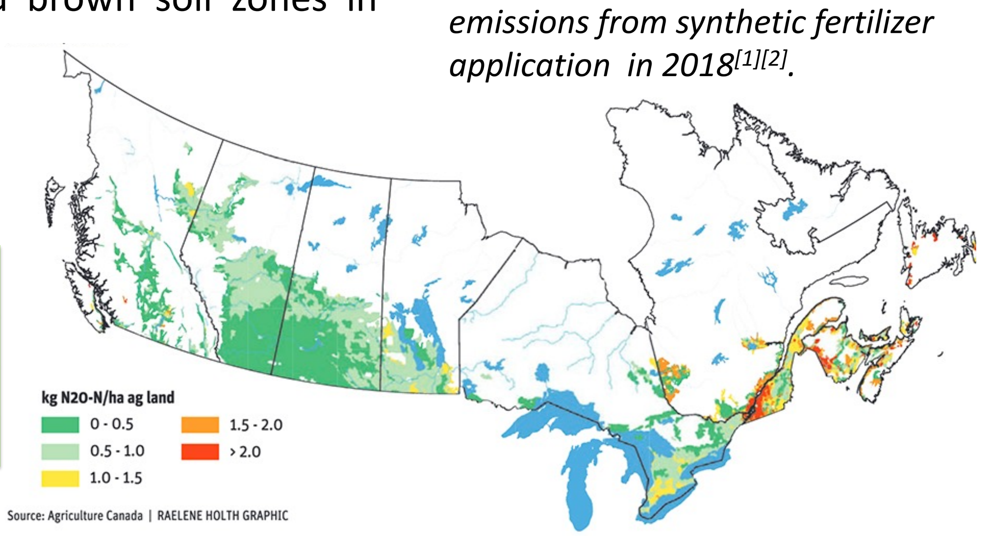
Variable Inputs	Management Factors	Agro-Ecological Factors
Nitrogen	Previous Crop	Growing Season Precipitation
Phosphorous	Variety	3yr Avg Precipitation
Potassium	Manager	Risk Zone
Sulphur		Soil Class
Fungicide		Year

- The N_2O Abatement cost from N application was calculated using direct emission estimates for the black and brown soil zones in Saskatchewan (see Table 2 and Figure 4).

Figure 4 *Indirect and direct N_2O emissions from synthetic fertilizer application in 2018*[1][2].

Table 2: *Canada's direct GHG emission factors per tonne of applied N fertilizer*[13].

Ecoregion	N_2O-N (kg)	CO_2 eq. (t)
Black soil zone	3.3	1.545
Brown soil zone	1.60	0.749
Eastern Canada	21.1	9.88

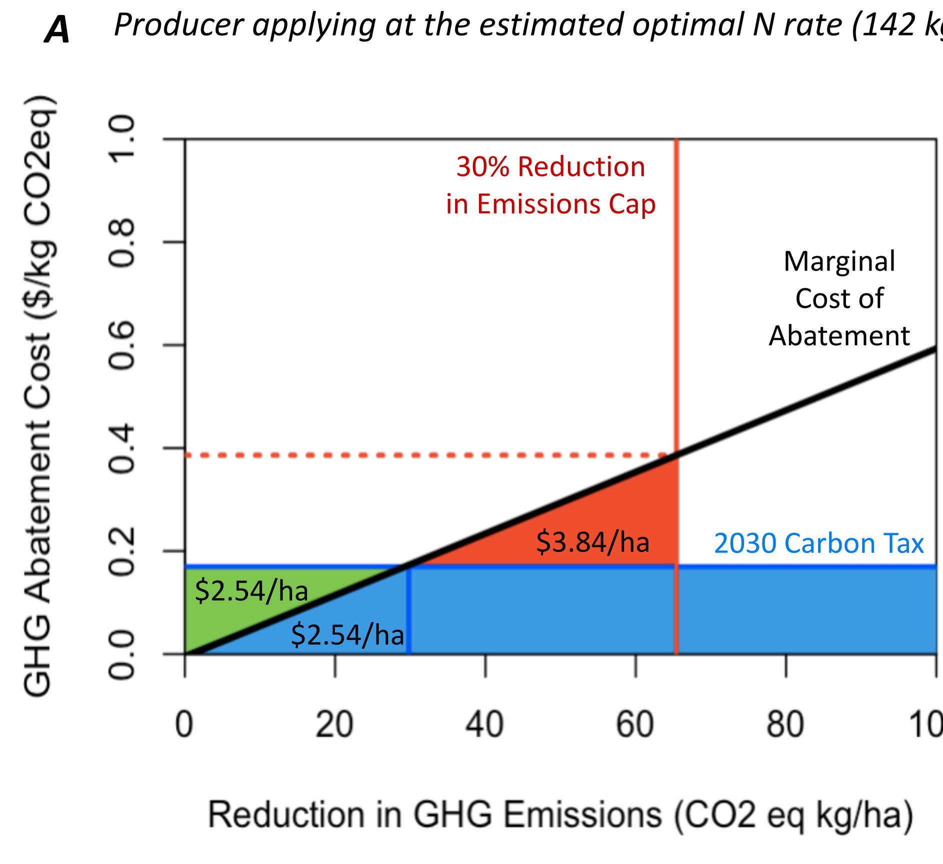


RESULTS

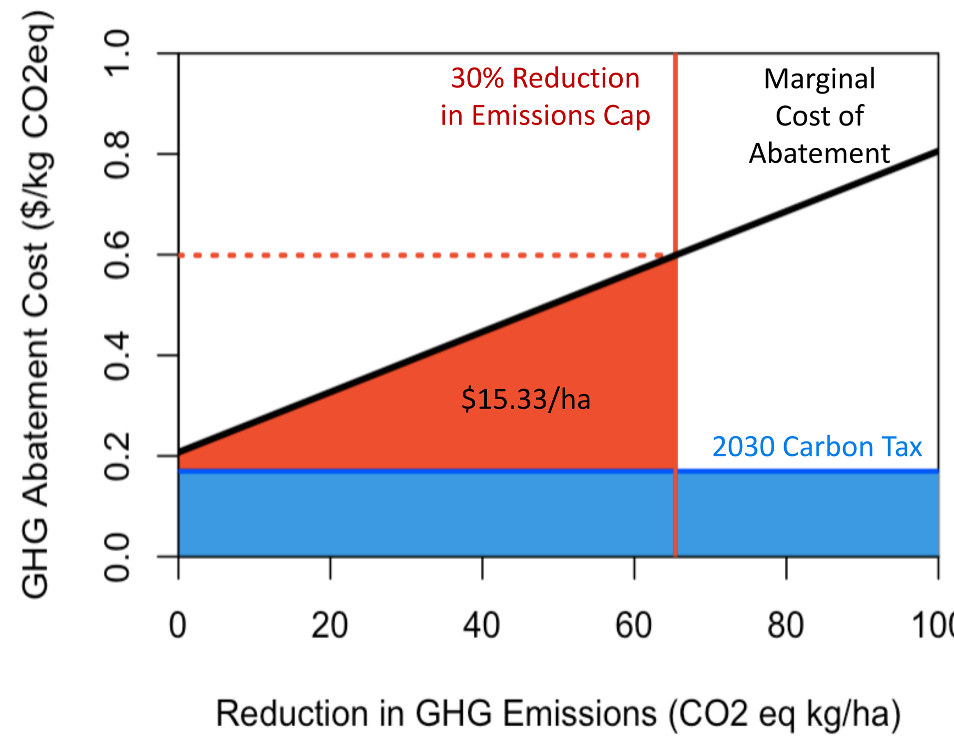
- The estimated privately optimal N application rate increased with higher canola variety yield index.
- The estimated privately optimal N rates were significantly higher following cereal or oilseed crops versus pulse crops.
- On average, producers reported applying N near or below the estimated private optimal N rate.
- A direct N_2O tax using the 2030 social cost of carbon of \$0.17/kg CO_2eq is estimated to reduce N rate applied by 19kg/ha from the estimated private optimal N rate which corresponds to a reduction in emissions by 29.8 CO_2eq kg /ha (see Figure 5A).
- In the absence of a regulation or tax, the negative externality of direct N_2O emissions is equal to \$2.54/ha when producers are applying at the private optimal N rate (see Figure 5A).
- A regulated 30% reduction in direct N_2O emissions results in a DWL of \$3.84/ha with a marginal cost of abatement of \$0.386/kg (Figure 5A).
- When a producer is applying N at the observed rate in 2019 (underapplying by 23 kg ha[-1] relative to the private optimal N rate) the DWL of a regulated 30% reduction in emissions is \$15.33/ha (see Figure 5B).
- Due to lower direct emissions associated with N application in the brown soil zone, the N_2O abatement costs in the brown soil zone are greater relative to the black soil zone

Figure 5 *Marginal abatement cost for direct N_2O emissions through reduced N use in the black soil zone. Estimated using 2019 prices, 2019 average variety index and following a cereal crop. The case of a producer applying at the estimated private optimal N rate (142kg/ha) is depicted in* ***A*** *while the case of a producer applying at the average observed rate in 2019 (119 kg/ha) is shown in* ***B***.

A *Producer applying at the estimated optimal N rate (142 kg/ha).*



B *Producer applying at the average rate in 2019 (119kg/ha).*



POLICY IMPLICATIONS

- There are vastly different N_2O emissions factors within Canada (see Table 2) which suggests very different rates of Pigouvian taxation per unit of N applied across ecoregions.
- Regulation to reduce N fertilizer rates by 30% would result in net social welfare losses for canola cropping systems in Saskatchewan (see Figure 4B).
- Given the heterogeneity in farming practices and emissions factors, focusing on the 4R's of Nutrient Stewardship, agronomic research and extension to improve nitrogen management and optimize fertilizer use are opportunities to reduce emissions.

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FUNDING

WGRF
Advancing Agriculture through Research