An Assessment of Nitrogen Use and N_2O Emissions from Semidwarf Wheat

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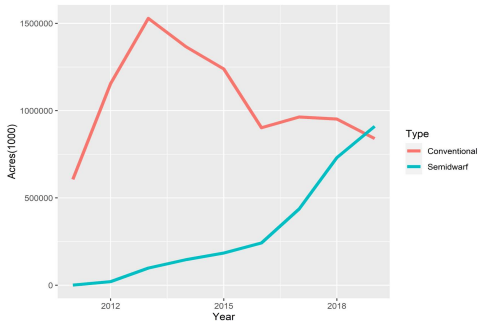
Background and Motivation

- Semidwarf wheat is becoming increasingly popular among Canadian wheat farmers.
- For example, in recent years, the acreage of farmland in Saskatchewan (SK) seeded with semidwarf wheat started to exceed that of conventional wheat (see Figure 1).
- Semidwarf wheat has higher nitrogen responsiveness and tolerance compared to conventional varieties, which allows farmers to apply more nitrogen (N) fertilizer to increase production.
- Nevertheless, the additional N_2O emissions produced from N fertilizer application are often ignored in the benefit & cost analysis of semidwarf wheat (e.g., Brennan 2007; Morris et al. 1994; Loddo and Gooding 2012).

Figure 1: Acres of semidwarf and conventional wheat seeded in SK between 2011 and 2019



Research question: Does adopting semidwarf wheat affect farmers' use of N fertilizer, and if so, how does this sequentially affect the N_2O emissions from wheat farming?

Study area: Saskatchewan (SK), Canada.

- The fact that SK wheat farmers are transitioning from conventional to semidwarf wheat makes the province ideal for this type of study.

Objectives:

1. Estimating the change in N application rate when SK farmers grow semidwarf wheat instead of conventional wheat;
2. Predicting the subsequent change in direct N_2O emissions and the associated environmental damage caused by changes in N use.

Data (2011-2019)

- Main source of data: Saskatchewan Crop Insurance Corporation (SCIC):
- A Field-level panel data on crop and variety selections, farm input uses, and crop insurance.
- Combined with regional weather data from the Government of Canada (2021) and variety attributes from SK crop guide (2019).
- 54,243 fields between 2011 and 2019 in SK were selected for analysis, making a total of 95,556 observations.

Empirical Specification

Estimating effect on N use :

- We use a control function (CF) approach to account for the simultaneity bias between the decisions of wheat varieties and nitrogen use.

Table 1: Structure of a CF specification

	Dependent variables	Instrumental variables	Other variables of control
1st stage (probit)	Choosing semidwarf varieties (0/1)	Stem rust resistance rating(1-5), Leaf rust resistance rating(1-5)	Soil zone, Previous year precipitation, and temperature, Previous crop, Wheat grain price, N fertilizer price, Expected yield, Total farm insurance liability
2nd stage (OLS)	N application rate (lbs/ac)		

Estimating N2O Emission from Semidwarf Wheat:

- Idea: use N_2O emissions from wheat in SK in 2019 as the status quo, and predict growth in N_2O emissions as the remaining conventional wheat in the province switches to semidwarf wheat.
- We adopt the a N_2O emission equation used by ECCC (2021) and emission factors of synthetic N fertilizer provided by Rochette et al (2018).

Results—Estimating the Effect on N application rate

Finding: SK farmers apply 5.9% more nitrogen fertilizer on semidwarf wheat compared to conventional wheat.

Table 2: Marginal effect estimates from the CF regression. Standard errors are in parentheses.

	Dependent variable	
	Semidwarf [0/1]	ln(Nitrogen) [lbs/ac]
	1st stage (Probit)	2nd stage (OLS)
Stem rust resistance rating [1-5]	0.091*** (0.011)	
Leaf rust resistance rating [1-5]	0.26*** (0.022)	
Semidwarf		0.059*** (0.004)
Control for farm, weather, and market variables	Yes	Yes
Observations	95,556	95,556

Statistical significance is denoted by: *p < 0.1; **p < 0.05; ***p < 0.01.

Results—N_2O Emissions from Semidwarf Wheat

- Only soil direct N_2O emissions from synthetic N are considered.
- At the status quo for SK (2019), the value of damage from N_2O from semidwarf wheat is $10.95 million higher than conventional wheat.
- When all remaining conventional wheat in SK switches to semidwarf wheat, the direct N_2O emissions will increase by 5,711.75 tonnes CO_2eq^* (CO_2 equivalent), translating to $0.29 million CAD worth of environmental damage given a social cost of carbon† of $50 CAD/tonne CO_2eq (ECCC 2021).

Table 3: Estimated total direct N_2O emissions (tonnes CO_2eq) from N fertilizer applied to wheat as the remaining conventional wheat in SK in 2019 switches to semidwarf wheat

	Percentage of remaining conventional wheat acres switching to semidwarf wheat				
Wheat	0	20	50	80	100
Conventional	103,840.02	83,072.02	51920.01	20768	0
Semidwarf	322,816.05	344,726.40	377,591.94	410,457.47	432,367.82
Total	426,656.07	427,798.42	429,511.95	431,225.47	432,367.82

Table 4: Estimated total value of environmental damage (million CAD) from direct N2O emissions induced by N fertilizer applied to wheat as the remaining conventional wheat in SK switches to semidwarf wheat.

	Percentage of remaining conventional wheat acres switching to semidwarf wheat				
Wheat	0	20	50	80	100
Conventional	5.19	4.15	2.6	1.04	0
Semidwarf	16.14	17.24	18.88	20.52	21.62
Total	21.33	21.39	21.48	21.56	21.62

* 1 tonne N2O = 298 tonnes CO2eq.
† Social cost of carbon is the value of damage caused by each unit of greenhouse gases.

Conclusions

- SK farmers use more N fertilizer when they adopt semidwarf wheat.
- The N_2O emissions from N fertilizer used in wheat production has already increase in SK because of the transition from conventional to semidwarf wheat.
- By the time all remaining conventional wheat in SK are replaced by semidwarf wheat, the damage induced by N_2O emissions is expected to increase by $0.29 million CAD.
- The results suggest that previous benefit & cost analyses have overlooked a significant amount of environmental side-effects from the growing popularity of semidwarf wheat.
- We recommend future agricultural & environmental policies to start considering the environmental implications of genetically improved crops.

Acknowledgements

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