Understanding Nitrogen Overapplication through Farmers' Perceived Yield Responses

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1. Introduction

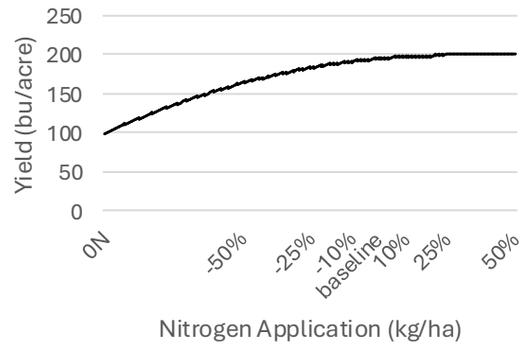
Canada's 2030 Emissions Reduction Plan aims to reduce agriculture's GHG emissions, including nitrous oxide, by 30% below 2020 level by 2030. To make farmers reduce their application of nitrogen, we should have an idea of their perception of nitrogen effectiveness to their yield.
This study attempts to investigate how farmers assume the nitrogen-yield relationship is and then compare it with what agronomy studies found out using field trials.

2. Objective Response Function

Given the unpredictable factors like weather and pest outbreaks, there is no unique objective response function; however, agronomic field trials on corn mostly have consensus on the functional form, i.e., Quadratic-Plateau Model (Lyons et al, 2018).

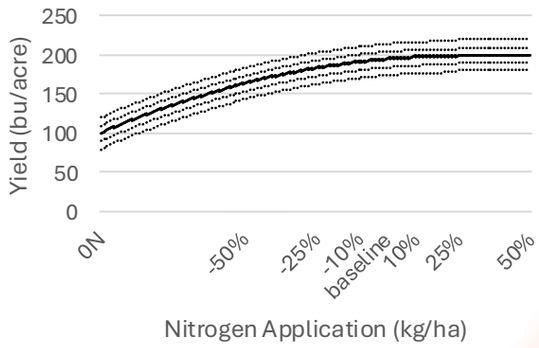
2.1. Quadratic-Plateau Model

It reflects a more realistic agronomic scenario in which yield increases at a diminishing rate and then levels off. The flat segment reflects the agronomic reality that once nitrogen is no longer limiting, other factors, like genetics or environmental constraints, cap yield potential (Bullock & Bullock, 1994).



2.2. Quadratic Response Stochastic Plateau Model

To address the unpredictability of quadratic-plateau model, Quadratic Response Stochastic Plateau model introduces a random component to the plateau yield, allowing it to vary stochastically across observations (Dhakal & Lange, 2021).



3. Data and Method

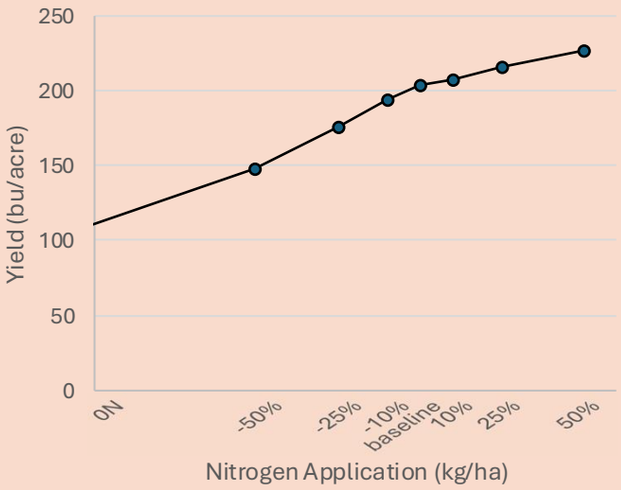
We use data from 437 Ontario corn farmers from the 2024 Fertilizer Use Survey. Farmers reported their target yield and nitrogen application. They evaluated yield under 7 nitrogen scenarios: without nitrogen, 10%, 25%, 50% less, and 10%, 25%, 50% more than their current application. This gives 8 nitrogen-yield scenarios per farmer, revealing subjective beliefs beyond average expectations and showing perceived marginal returns at different levels.

4. Subjective Response Function

The figure below presents the average subjective yield response curve, which diverge from objective response curve in terms of its functional form.

5. Remarkable points

- Farmers see the first 50% of nitrogen as less productive than the second 50% of what they applied.
- They expect only a small yield increase from 10% more nitrogen, but moderate gains from 25% and 50% more.
- They do not believe nitrogen effectiveness plateaus, even up to 50% more.
- While objective curves show diminishing returns, meaning a constant decrease in slope until the plateau, subjective curves show increasing slopes at some points.



6. Discussion and Implication

- Avoiding the potential danger: Not believing in plateau after their current application rate might lead them to apply even more from what they applying currently. It is of crucial importance to assure farmers that applying excess nitrogen would not lead to higher yield to prevent the exacerbation nitrogen emission in agriculture sector.
- A barrier to nitrogen reduction: Rather than believing in diminishing marginal returns, where the first unit of reduction has the least impact on yield reduction, farmers belief is closer to "things can't get much worse beyond a certain amount of reduction," implying the opposite. Thus, they mistakenly overvalue the first amount of reduction in nitrogen. Any policy aimed at cutting the nitrogen fertilizer should priorities be adjusting this distorted mental model of the nitrogen–yield relationship. Having fixed that, there will be lower resistance on the part of farmers in reducing the amount of nitrogen application.

7. References

- Bullock, D.G. & Bullock, D.S. (1994) Quadratic and quadratic-plus-plateau models for predicting optimal nitrogen rate of corn: A comparison. *Agronomy Journal. 86*(1):181-195
- Dhakal, C. & Lange, K. (2021) Crop yield response functions in nutrient application: A review. *Agronomy Journal. 113:*5222–5234.
- Lyons, S.E., Tang, Z., Booth, J., Ketterings, Q.M. (2018) Nitrogen response model for winter cereals grown for forage. *Journal of Agronomy and Crop Science. 205*(2):248-261