# Unfolding the Bias in Farm Nitrogen Management

## Abstract

Nutrient pollution from farming has been linked to hypoxia - with negative ecological and economic consequences - in water bodies around the world. Better nitrogen management decisions through improved design of nutrient management plans at the farm level has potential to address water quality problems. The 2008 Action Plan of the EPA presents a national strategy to reduce, mitigate, and control hypoxia in the Northern Gulf of Mexico and improve water quality in the Mississippi River Basin. Iowa and other states have come under intense pressure to reduce nitrogen runoff from agricultural fields. Efforts to date, however, have centered on programs that rely on voluntary participation by farmers through encouragement of best management practices. The effectiveness of such efforts for achieving water quality improvements has been questioned.

Agronomists and agricultural economists have studied fertilizer decision-making, and provided recommendations and policy advice. Despite these efforts, almost nothing is known about the underlying decision processes used by farmers when making nutrient management decisions. Most studies observe nutrient application outcomes but do not know how farmers came to their application decision, nor do they know why two observationally identical farmers make different choices about fertilizer use.

This research exploits insights from the psychology and behavioral economics literature to measure and characterize the subjective beliefs of farmers about the uncertainty over crop yields, and importantly, their beliefs about the role of nitrogen in plant growth. We measure and integrate actual subjective beliefs, specifically the perceived crop response to nitrogen application, into models of agri-ecosystem services provision. Subjective beliefs are measured with a web-based survey of farmer's from Central Iowa. The survey elicits beliefs about the perceived fertilizer to crop transformation relationship for each farmer.

Literature in behavioral economics supports absolute optimism and over-precision in individual subjective beliefs about uncertain events. To test for this formally we measure farmer's potential over-optimism and over-precision regarding the nitrogen-crop yields response function. We also characterize the belief function of farmers and the important factors that shape their beliefs about crop yield. Survey data about subjective beliefs of Expected Yield – Nitrogen mapping are fit to a 3-level Hierarchical Linear model (Mixed Model). Random effects specific to farmer are predicted along with the fixed effects in the model. The explanatory variables at all levels are centered which allows us to facilitate contextual analysis and hence separately identify the within and between estimates. The within estimates provide us with the farmer specific estimates of marginal productivity of nitrogen on expected corn yields. For the purpose of comparison, we use an objective benchmark that is modeled as nitrogen conditional yields from the ISU research farm experimental nitrogen trial data. The objective data is fit to a Generalized Linear Model with beta distribution, which predicts the moments of the conditional yield density. The marginal productivity of nitrogen from both the subjective belief model and the objective

model are compared.

Our findings support the heterogeneity of farmer's beliefs about the shape of yield distributions and about the growth response to nitrogen. There is evidence of positive skewness in the expected crop yield distribution, which we compare with an estimated, objective benchmark. We find bias in farmers' perceptions about the marginal productivity of nitrogen. For almost more than 50% of surveyed farmers, the expected marginal product of N is biased upwards when compared to an objective benchmark. Farmers' believe that the marginal productivity of nitrogen is higher in the event of late planting. Such a belief points to the fact that farmer's perceive nitrogen as a substitute for yield loss that might accrue due to delayed planting. The beliefs are also evident of lower marginal productivity of nitrogen if the expected pollination date is later. We also find signs of higher marginal productivity of nitrogen for farmers who reported to have consulted others for their nitrogen management decision on their fields. The beliefs of farmers' support diminishing marginal productivity of nitrogen that is slightly higher (i.e. slower diminishing returns) for educated or experienced farmers.

Our results reveal stark differences between farmers' subjective beliefs about nitrogen and its effects on yields, and the presumed decision processes that underlie current nitrogen-reducing policy designs. The presence of an upward bias in the marginal productivity of nitrogen is an indication of how over-valued the perception of farmers about the productivity of nitrogen is than it actually is. We quantify the bias in nitrogen management in agricultural fields which is integral to their decision of how much nitrogen to apply. This suggests room for evidence based policymaking taking into account the subjective bias of farmers in nutrient decision making rather than adhoc policy based on the assumption of a rational decision making farmer that have disappointing or unintended consequences for water quality. The discovery of the upward bias in productivity of nitrogen can also have a story to tell possibly linking the nitrogen usage and crop insurance purchased, but it is beyond the scope of this study but a direction for future work.

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