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Wheat Nitrogen Response Conditional on Past Yield and Weather: A Step in Making Use of Big Data

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Selected Poster prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1

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Introduction

Uncertainty about nitrogen needs results in an optimal solution where producers apply nitrogen that is not needed in most years. Precision nitrogen application has sought to apply just the right amount of nitrogen in a given year. The extra nitrogen usually applied not only results in decreased profits for farmers, it can also lead to externalities such as leaching of nitrogen into groundwater and runoff into lakes and rivers.

Research has shown these precision farming techniques are not typically profitable, such as in precision sampling of the soil (Hurley et al. 2001; Swinton and Lowenberg-DeBoer 1998) and precision sensing of the plant (Biermacher et al. 2009). These precision techniques can also be costly to adopt.

We propose using yield data from yield monitors as well as local weather to make recommendations about nitrogen response. Note that we are letting the response to nitrogen be a function of weather rather than just the yield being a function of weather. Yield monitor data and weather data are available at relatively little cost since they are already being collected. The question is how to use this data and how much will it help predict how much nitrogen to apply?

Objectives

The objective of this paper is to use cheaper information to predict wheat yield response to nitrogen. For this paper the information used was weather and yield data from a research station in Lahoma, Oklahoma.

Data

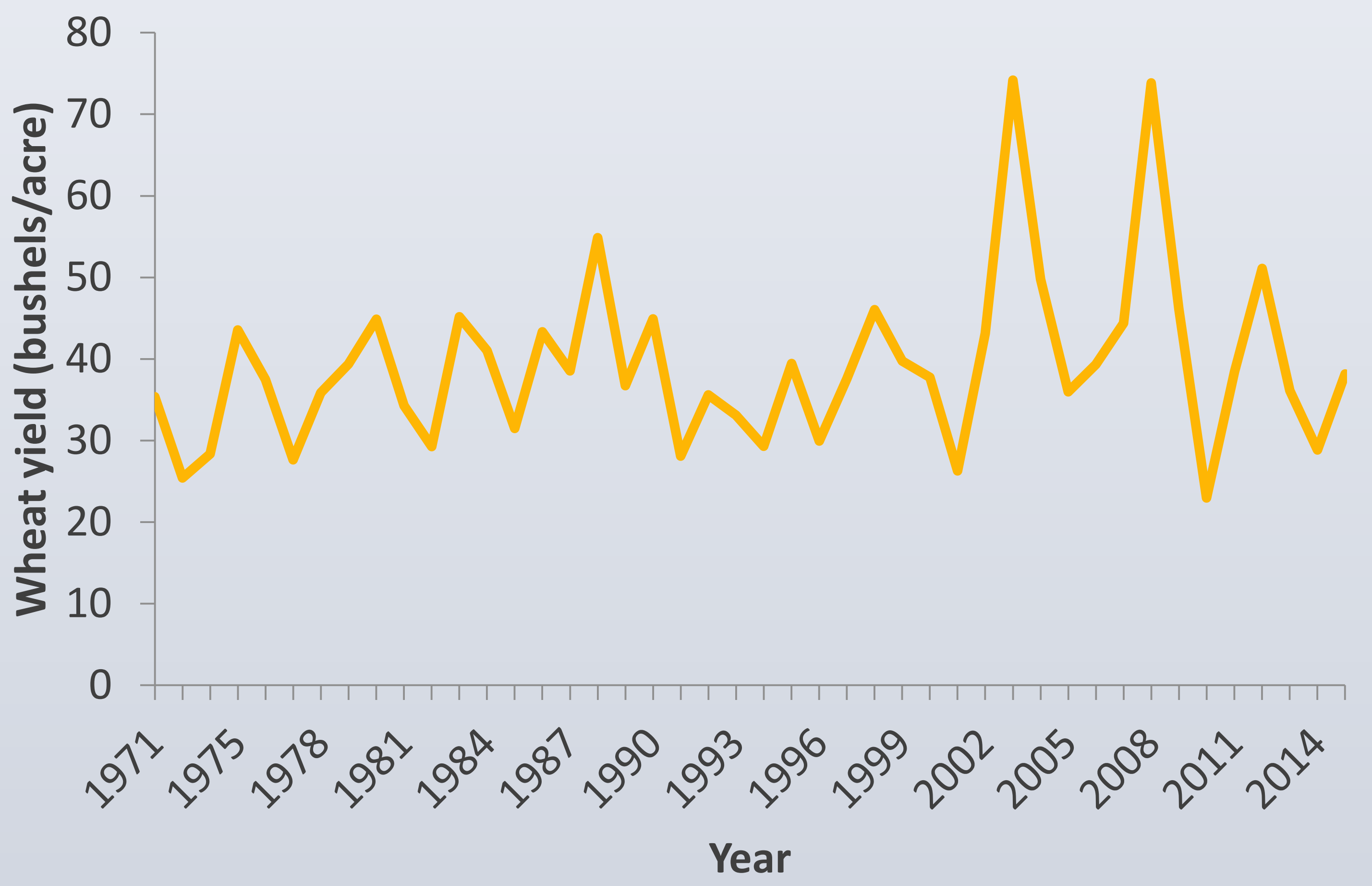
The data are from a long-term experiment conducted on winter wheat's response to fertilizer. In total 43 years are used dating from 1971 to 2015. The experiment conducted using a random block design. Rainfall data was obtained from the University of Oklahoma weather center. The rainfall data are the cumulative rainfall in inches between October and January of each year.

Figure 1. Wheat fertility experiment 502 nutrient application rates

TRT	Pre-plant N rate (lb N / ac)	Pre-plant P rate (lb P_2O_5 / ac)	Pre-plant K rate (lb K_2O / ac)
1.*	0	0	0
2.*	0	40	60
3.*	20	40	60
4.*	40	40	60
5.*	60	40	60
6.*	80	40	60
7.*	100	40	60
8.	60	0	60
9.	60	20	60
10.	60	60	60
11.	60	80	60
12.	60	60	0
13.	100	80	60
14.	60	40	60 (Sul-Po-Mag)

N applied as 46-0-0 (Urea)
P applied as 0-46-0 (Triple Super Phosphate)
K applied as 0-0-60 (Potash)
* - YP plot

Figure 2. Average wheat yield for Lahoma experiments



Method

We estimated the following linear stochastic plateau yield model:

$$(1)\ Y_{it} = \min(\beta_0 + \beta_1 * N_i + \beta_2 * Y_{it-1} + \beta_3 * R_t + \beta_4 * N_i R_t + \beta_5 * N_i Y_{it-1}, P + \rho_2 * Y_{it-1} + \rho_3 * R_t + \lambda_t) + \varepsilon_{it}$$

$$\lambda_t \sim N(0, \sigma_\lambda^2)$$

$$\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$$

where Y_{it} is the yield in year t om the ith plot ,N_i is the nitrogen applied, Y_{it-1} is the yield of the previous year, R_t is the rainfall from October to January of year t,$N_i R_t$ is the interaction between nitrogen and rainfall in year t, $N_i Y_{it-1}$ is the interaction between nitrogen applied and the previous year's yield, P is the plateau intercept, λ_t is a normally distributed error term for the plateau in year t, and ε_{it} is a normally distributed error term.

Results

Table 2. Parameter Estimates for Wheat Yield (bushels/acre Response

Parameter	Mean
Intercept	22.4375
	(3.2459)
Nitrogen (lbs/acre)	0.0911
	(0.0347)
Lag of Yield	0.111
	(0.0444)
Rainfall (inches)	0.0686
	(0.4079)
Rainfall-Nitrogen Interaction	0.0511
	(0.00573)
Lag Yield-Nitrogen Interaction	0.00096
	(0.00066)
Plateau	34.173
	(4.2885)
Lag of Yield Plateau Shifter	0.2292
	(0.0245)
Rainfall Plateau Shifter	0.0383
	(0.5743)

Note: Standard errors are in parenthesis

Conclusions

The interaction term for rainfall and nitrogen is positive, which indicates that higher amounts of winter rainfall would require more nitrogen to be applied.

The interaction term for previous year's yield and nitrogen is also positive, meaning that more nitrogen is needed when the previous year had high yields.

Rainfall and yield data can be a cheap way of predicting nitrogen application rates. Even though predictability may be lower than other methods, this could potentially be a way to utilize big data as the costs of obtaining rainfall and yield data are relatively low.

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