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Nitrogen application decision-making under climate risk in the U.S. Corn Belt

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ABSTRACT

Nitrogen fertilizer is one of the most important inputs to corn production and farmers manage their crop by deciding how much to apply, when to apply it and how to apply it to maximize their yields and resulting profit. There is risk inherent in crop fertility management because once nitrogen is applied to the soil it is no longer immobile and cropland is subject to loss of this costly input under different weather conditions. Days suitable for field work, a farm's machinery set, and weather conditions determine when field preparation and planting activities are completed each year. This paper documents the methods and data used to evaluate the economic costs and benefits of the agronomic practice of "splitting" nitrogen fertilizer—applying some at or just before planting and a second application after the plant has already emerged and is in greatest need of nutrients. An example of how to use the free online decision support tool Corn Split N_{DST} (splitn.agclimate4u.org) to evaluate the climate risk and economics of post-planting N applications is developed to illustrate the application of methods described.

1. Introduction

Risk from adverse or extreme weather events is a persistent condition for agriculture that has a strong impact on crop yields. The risk of yield losses from different types of weather events differs by climate and cropping system. Yield and revenue risk are the focus of crop insurance and forward pricing strategies regularly employed to manage the financial risk of farming. The weather experienced in a given year combined with farm management and soil characteristics are what determine the harvested yield on a given farm, and optimizing planting and fertilization is essential to achieve the best economic results possible. The focus of this paper is on decision-making about nitrogen (N) fertilizer application timing for corn production in the Corn Belt region of the Midwestern U.S. Fertilizer is one of the most expensive inputs to corn and it is also one of the most important to ensure that corn crop growth is not N limited and achieves the highest yield possible.

There are two main sources of climate risk that are most relevant for fertility management: nitrogen loss from soil and days suitable for fieldwork (DSFW). Weather—as the occurrence of climate at a given point in time—interacts with soil and farm management to determine the number of days that are suitable to perform field work (e.g., the number of days that soils are not too wet to prevent tillage, fertilizer application or planting activities) which constrains the number of days available to complete spring field preparation and planting in a timely fashion. Delayed planting because soils are too saturated

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and/or cold will affect yields at harvest (Myers and Wiebold, 2013). Weather between the time that N fertilizer is applied and when it is needed by plants for growth or grain production also determines the risk of N loss via leaching, runoff and denitrification (Scharf, 2015).

The prior literature on DSFW has focused mainly on a basic understanding of the usefulness of these data for farm management and planning (Griffin, 2009), or the applied use of historical DSFW data to support farm machinery sizing (Rotz et al., 1983; Rotz and Harrigan, 2005) and more general farm management optimization (Doster et al., 1983; Dillon et al., 1989; Etyang et al., 1998) in different production systems and locations. The practical importance of DSFW is evidenced by extension publications (e.g. Parsons and Doster (1980), Massey et al. (2007), Edwards (2015)), and regional (Griffin, 2016) and national (USDA-NASS, 2016) online data resources devoted to farm management decision support.

Farmers traditionally apply N to the soil in a single pass across the field, either post-harvest in the fall or in the spring before planting. Nitrogen, applied in various forms, may not be immediately available for uptake by plants, but once it is in nitrate form it can be taken up by growing plants or it may be lost to the environment. Early nitrogen application—before plants need it to grow—can result in significant losses due to weather factors (e.g. warm, moist soils between the time N is applied and plant uptake occurs). For this reason, agronomic recommendations from university Extension services generally encourage nitrogen fertilizer shortly before maximum crop uptake (Scharf, 2015; Vitosh et al., 1995). Research has shown that splitting the application of N with one application before or around the time of planting and a second application after planting when there is greater demand for N from the crop can reduce total nitrogen use resulting in economic savings for the farmer and/or reduce nitrogen loss to the environment resulting in reduced negative externalities to society (Curran and Lingenfelter, 2015; Bundy, 2006).

A second application of nitrogen to growing crops can be done using high clearance ground equipment or aerial applications. Using ground equipment allows for greater management flexibility but a shorter application window than aerial applications. Aerial applications are limited to dry nitrogen sources, to reduce foliar burn (Mengel, 1996), and the use of a nitrogen stabilizer is recommended (Emmert, 2016), making the product more expensive. Availability and price may also be higher for aerial application depending on location.

There are some risks involved with a split N application strategy. The economic risk of greater costs being incurred if two passes through the field with machinery are required. The climate risk of the second application (if conducted using ground application equipment) being hindered by soils that are too wet resulting in insufficient N when a second application is needed that may result in lower yields. The objective of this work is to develop a decision support tool (DST) that helps farmers evaluate the economics and risk of split N application, using ground application equipment, based on historical data on DSFW and temperature that determines crop development rates. To this end, we developed the Corn Split N DST that combines experimental data on crop fertility management with a farmer's yield goal, N application rate and timing, and N and corn prices to estimate the economic costs and benefits of post-planting N application. This work was done as part of the Useful-to-Usable project (www.agclimate4u.org) to develop decision tools for farmers and their advisors to help them manage for climate risks to maize based cropping systems. A survey conducted at the outset of the project identified a strong demand among farmers and their advisors for a decision support tool for N management.

The Split N tool developed and documented in this paper has its origins in the Probable Fieldwork Days spreadsheet model developed by Gerlt et al. (2016) at the University of Missouri (http://fapri.missouri.edu/farmers_corner/tools/index.asp) to manage the risk of not completing cropping operations in an acceptable amount of time due to fieldwork and time constraints with a given machinery complement. The Split N tool builds upon the use of historical DSFW data to evaluate the probability of completing fieldwork for a specified number of acres over a specified range of dates by incorporating growing degree day based crop development, economic costs and benefits, agronomic information on yield penalties, and user customization of yield goal and initial N application amounts.

2. Data and methods

Two main categories of data sources underlie the Split N tool—user-provided inputs and data contained within the tool for historical fieldwork days, growing degree days (GDDs) and yield penalties for not completing the post-planting N application. After selecting the farm location, the most critical user inputs are the planting date, farmer's yield goal they manage for in bushels per acre, and the amount of N initially applied at or before planting in pounds per acre. These and related inputs are shown in Fig. 1. The default values that appear in the tool after a user selects their location from a map come from different sources; a summary of the main variables and sources is contained in Table 1 and the text that follows.

The default value for the yield goal is the county average yield in the user-selected county for the most recent year data are available from the USDA National Agricultural Statistics Service (NASS). The GDD calculations are based on gridded daily temperature data contained in the Applied Climate Information System maintained by the NOAA Regional Climate Centers based on the user-selected location. Growing degree days are calculated following the 86/50 method for ceiling and floor temperatures (Farenheit) to determine the corn growth stage as a proxy for plant height in the field. The 86/50 method is based on the principle that biological growth is primarily controlled by temperature, with temperatures above 50°F contributing to crop growth up to the ceiling temperature 86°F, above which the growth rate declines. The height of the corn in the field is important because our model is for ground application of in-season nitrogen. Other metrics, in addition to or instead of GDDs, could be used to model crop development but this is not the focus of the current research.