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AE487

Agricultural Management Options for Climate Variability and Change: Sensor-Based, Variable-Rate Nitrogen Management[1]

Wesley Porter, Ahmad Khalilian, Daniel Dourte, and Clyde Fraisse[2]

This series of EDIS publications provides information about different agricultural management options available to improve resource-use efficiency and adapt to climate variability and change. To see the complete series of publications, visit http://edis.ifas.ufl.edu/topic_series_agricultural_management_options.

Introduction

Adapting to climate variability and change can be achieved through a broad range of management alternatives and technological advances. While decision making in agriculture involves many aspects beyond climate, including economics, social factors, and policy considerations, climate-related risks are a primary source of yield and income variability. Existing strategies can help producers minimize the risks associated with climate variability and change as well as improve their resource-use efficiency. This series of EDIS publications gives information on these existing technologies, and this publication focuses on the use of sensor-based variable-rate nitrogen management in crop production systems.

What is sensor-based, variable-rate nitrogen management?

High production costs make it increasingly important for producers to reduce crop inputs and maximize yields to stay competitive in the global market. The price of nitrogen is closely correlated with the price of crude oil, which can be highly variable. Nitrogen fertilizer cost represents about 10%–15% of total farm costs for corn, cotton, and wheat in the Southeastern United States (USDA ERS 2012a; USDA ERS 2012b). The efficiency of nitrogen use can be highly variable for producers because of differences in topography and soil properties within a field. Therefore, a sensor-based, variable-rate nitrogen application (SVNA) system has been developed for irrigated and dryland row crops to reduce production costs (Khalilian et al. 2008). The SVNA system captures the within-field variability and adjusts the nitrogen (N) side-dressing rates, meaning N applications at some time after planting.

To properly implement SVNA, producers should establish a High Nitrogen Calibration Strip or HNCS. The HNCS enables producers to determine the nitrogen status of plants in comparison to a non-limited reference strip. It serves as a guide or benchmark for mid-season nitrogen fertilization. For convenience, the width of the HNCS area may be

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2. Wesley Porter, Extension associate engineer, Biosystems and Agricultural Engineering, Oklahoma State University; Ahmad Khalilian, professor, Agricultural and Biological Engineering, Clemson University; Daniel Dourte, research associate, Department of Agricultural and Biological Engineering; and Clyde Fraisse, assistant professor, Department of Agricultural and Biological Engineering; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611.

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equivalent to the width of the nitrogen applicator and about 50–100 feet long. Alternatively, the area can be multiple passes wide. The HNCS is specific to the crop being produced, region where it is produced, and the specific management zone of a field. Separate HNCS may be established in different zones of a field; this is optional, but is recommended in fields having high variability in yields or soil properties such as texture or organic matter levels. Zones of a field can be distinguished based on producer knowledge of yields, automated yield mapping, or a soil-based mapping technique. An index called normalized difference vegetation index (NDVI) is used to help estimate plant N status. NDVI can be measured with optical sensors, and is a proxy for greenness and canopy cover.

The SVNA system works as follows:

1. Typical pre-plant N rate of 30 lbs/ac is applied to the crop across all management zones.

2. HNCS is established in each part of the field management zone, where the producer wants to manage nitrogen separately. Management zones can be developed from the farmer's knowledge of the field, aerial photos of the field available from online sources, maps showing the variability of soil electrical conductivity or yield, topography, soil water monitoring, and other relevant information.

3. At the time of nitrogen side-dress, optical sensors first measure the (NDVI) of the HNCS in each management zone and then measure the NDVI of the plants from the corresponding zones for comparison.

4. Using the NDVI readings, a mathematical formula within the control system calculates N requirements based on an in-season estimate of potential yield as predicted by the N algorithm. The N algorithm also calculates the yield response to additional nitrogen fertilizer and the required nitrogen rate for obtaining the calculated yield. Depending on the type of equipment the producer uses, the N application rate may be calculated in real-time and the SVNA controller would apply N at the same time. If producers do not have a controller linked with the NDVI system, then they would collect NDVI data in a separate operation, process it to obtain the required nitrogen rate, and import an application map to their SVNA.

Affordable, GPS-based equipment can be retrofitted onto producers' existing fertilizer applicators for controlling the rates of nitrogen to match crop needs based on NDVI of the crop (Figure 1), NDVI of the crop in the HNCS area, and the N-application prescriptions of the SVNA (Porter et al. 2010). Clemson University researchers developed an SVNA system that uses GreenSeeker® optical sensors to calculate side-dress nitrogen requirements for cotton and corn (Figure 1; Porter 2010).

How does using sensor-based, variable-rate nitrogen management reduce climate-related risks?

- The nitrogen application is specifically adjusted to the recent weather conditions. This is because the HNCS is established at planting, and temperature and rainfall between planting and N side-dress are considered in the N application equations that determine application rates.

- Economic losses from droughts and dry spells may be reduced. Lower N applications can make systems more

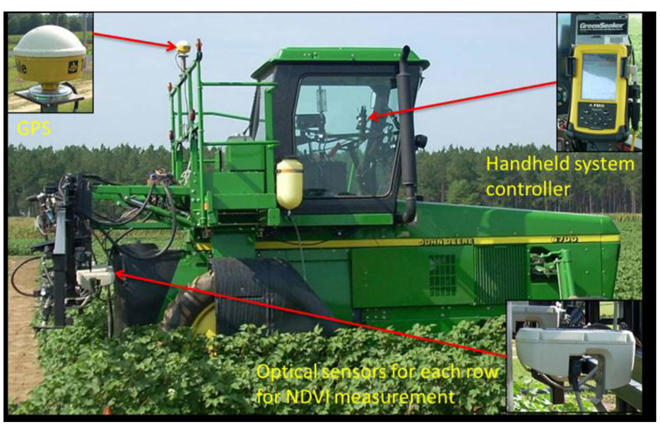

Figure 1. GreenSeeker® RT-200 integrated sensing and variable application system (left) and Clemson-designed variable-rate nitrogen applicator that does not have onboard sensors; NDVI data were collected in a previous trip across the field (right). Credits: Wesley Porter

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profitable when yields are reduced as a result of dry conditions.

- There may be less adverse impacts on ground and surface water quality by reducing the potential for N runoff and deep drainage – in areas where the system has reduced N applications – resulting from unusually intense or prolonged rain events.

- The SVNA system considers the residual N from previous crops for calculating N rates.

What are the agronomic benefits?

- The main benefit of using a SVNA system is improved nitrogen-use efficiency. Studies at Clemson University have shown 40%–50% reductions in nitrogen applications. The amount of N reduction will vary depending on soil type, within-field variability, and production year. Experiments with SVNA systems have shown N-application reductions with very small yield changes (Figure 2). In regions and crops where 90 lb/acre of N would be a typical side-dressing amount, the SVNA could save producers 35-45 lb of N in a season.

What are the impacts on production costs?

- A Clemson University study conducted on Coastal Plain Soils showed approximately $20/acre savings in fertilizer application without a significant reduction in yield.

- Assuming N cost savings of $10/acre and a $25,000 investment cost for a complete SVNA system (6-row), about 5 years would be required for the system to recover the investment cost (Table 1).

- U.S. producers apply over 9 million tons of N to cotton, corn, and wheat every year. If sensor-based application rates were applied in all acreage for these three crops, the assumed minimum 20% reduction in nitrogen use could save over $1.8 billion annually.

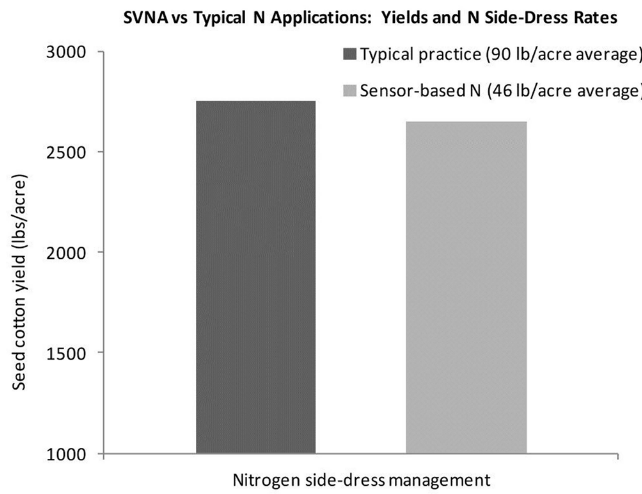

Figure 2. Seed cotton yields are very similar between sensor-based and typical N applications across a field experiment at Clemson University. Sensor-based N application reduced the amount of applied N by nearly 50%. All treatments received 30 lb/acre at planting; additional N rates at side-dress are shown in the figure. Credits: Ahmad Khalilian and Wesley Porter

What is the investment cost?

Investment costs range from $4,000 for a one-row optical sensor that can only be used to make NDVI maps to $25,000 for a fully automated 6-row SVNA system that will make NDVI maps and N application rate calculations, and regulate the application of nitrogen.

What are the impacts on greenhouse gas emissions?

Depending on the form of nitrogen fertilizer, a range of 1–2 pounds of CO_2 emissions is associated with the production of 1 pound of nitrogen fertilizer (Wood and Cowie 2004). Using sensor-based N application, there is a minimum 20%

Table 1. Estimated annual savings from reduced nitrogen application rates for N cost savings of $5 to $30 per acre and field sizes from 500 to 3000 acres.The N cost savings cover a range of N reductions from about 7 to 45 lb/acre, assuming N cost of $0.65/lb N.

Approximate annual cost savings for different farm size and acreage N savings						
N cost savings	Farm size, acres					
$/acre	500	1000	1500	2000	2500	3000
5	$2,500	$5,000	$7,500	$10,000	$12,500	$15,000
10	$5,000	$10,000	$15,000	$20,000	$25,000	$30,000
15	$7,500	$15,000	$22,500	$30,000	$37,500	$45,000
20	$10,000	$20,000	$30,000	$40,000	$50,000	$60,000
25	$12,500	$25,000	$37,500	$50,000	$62,500	$75,000
30	$15,000	$30,000	$45,000	$60,000	$75,000	$90,000

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reduction in N usage. If that rate reduction were applied to all the cotton, corn, and wheat grown in the United States, CO_2 emissions from N fertilizer production would be decreased by 2.7 million tons.

What are the barriers and incentives for implementation?

Barriers

- Equipment costs and complexity; may require services of a crop consultant or technology expert
- Lack of confidence in the equipment and automated N application calculations

Incentives

- Lower production costs
- Increased farm profits
- Eligible for Natural Resources Conservation Service Environmental Quality Incentives Program (NRCS EQIP Program; for more information, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip.)
- Potential for increase in yield, especially in good rainfall years in dryland systems

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