Adapt-N Uses Models and Weather Data to Improve Nitrogen Management for Corn

By Bianca Moebius-Clune, Harold van Es and Jeff Melkonian

Optimal management of N for corn varies from year to year owing to differences in weather. The Adapt-N tool combines soil and crop models to predict the influence of weather on plant N demand, soil N supply, and soil N losses. On-farm validation of the tool in New York and Iowa has confirmed that its use leads to better choices for rate and time of application, improving profitability of fertilizer N use and reducing its environmental impact.

The need for precise and responsive management of N fertilizer in corn production is compelling for both economic and environmental reasons, but the optimum N rate remains an elusive notion. Economically optimal N rates (EONR) in much of North America may range from zero to 225 lb/A (Scharf et al., 2006; Sawyer et al. 2006), and may vary as the growing season progresses (van Es et al., 2007). Many factors impact soil N dynamics and crop N uptake in corn fields, and therefore should be considered in the process of determining an optimum rate recommendation. These include 1) soil texture, depth, structure, drainage, and organic matter content, 2) amount, form, placement, and timing of application of amendments like fertilizer, manure and compost, 3) crop rotational and cover crop effects, 4) tillage and crop residue management, as well as 5) weather events and 6) risk factors associated with fertilizer and grain prices. Most current recommendation systems are simple and generalized (e.g., based on yield potential or average empirical N response), while a few others incorporate some of the above attributes. Many are also static in that they give the same recommendation regardless of weather.

Seasonal temperature and precipitation, notably, influences N gains from mineralization and losses through leaching and denitrification, and are therefore highly correlated with seasonal variation in optimum fertilizer N rates (van Es et al., 2007). A meta-analysis of 51 corn N response studies in North America showed strong soil and weather effects (Tremblay et al., 2012), and fields that received high precipitation in the time period around sidedressing were found to have much greater N response than those receiving low precipitation. Early-season events appear to be the strongest determinant for optimum N rates (Tremblay et al., 2012), although mid- and late-season weather may still affect corn yields (especially in cases of drought).

Static N fertilizer recommendations based on average crop response lead to excessive fertilization in some years, and inadequate fertilization in years with high N losses. From a farmer's perspective, the uncertainty in optimum N rate poses risks for profit losses, which is exacerbated by the asymmetric profit response of corn to N rates. The associated higher cost of under-fertilization relative to over-fertilization drives farmers to apply higher rates, and use additional "insurance" fertilizer applications. This uncertainty can be addressed by providing more accurate location- and time-specific recommendations that increase accuracy and reduce uncertainty. Currently, two general approaches are pursued by scientists: canopy reflectance spectroscopy and model-database tools. This article is focused on the latter.

Abbreviations and Notes: N = nitrogen; IPNI Project # USA-NY10.

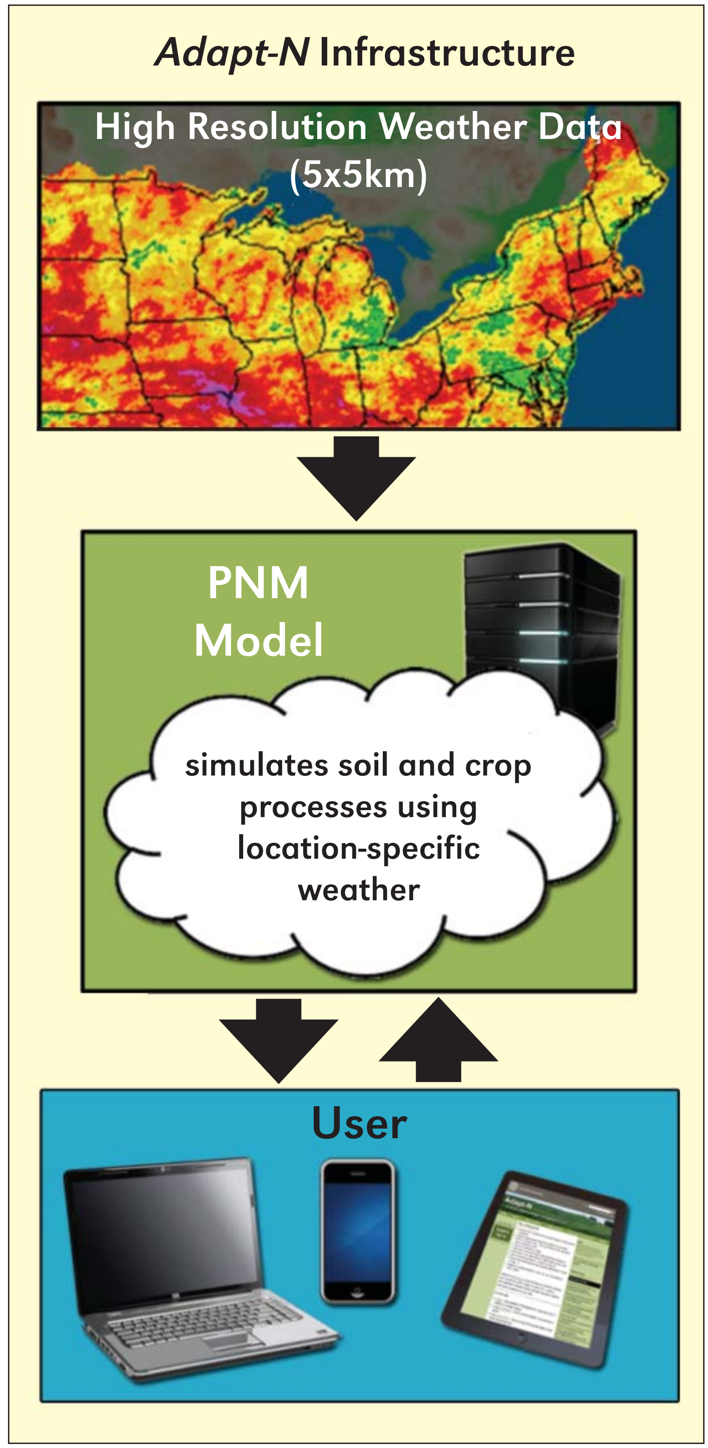

Figure 1. Users access the Adapt-N tool via web-enabled devices, automatically engaging the Precision Nitrogen Management (PNM) simulation model to obtain location-specific, weather-adjusted sidedress recommendations.

The Tool

Adapt-N is a web-based computational tool that uses a simulation model to integrate location-specific soil, crop and weather information to generate in-season N recommendations for corn (**Figure 1**). It incorporates high-resolution weather data and field-specific inputs on soil, crop, and management parameters to estimate in-season optimum N rates. It addresses most concerns with the static and generalized corn N recommendation methodologies (Stanford, 1973; Sawyer et al., 2006), which have limited ability to manage high variability in N response, especially in humid climates, and have inadequate nuance for site-specific crop management.

The Adapt-N tool is accessible (http://adapt-n.cals.cornell.edu) through any internet-connected device that supports a web browser. It is based on the Precision Nitrogen Management (PNM) model (Melkonian et al., 2005), which in turn is a re-coded and integrated combination of a corn N uptake, growth and yield model (Sinclair and Muchow, 1995), and the LEACHN soil water and N transformation model (Hutson, 2003). The crop model uses solar radiation, temperature and rainfall information to estimate the growth, development, and uptake of N and water by the crop, on a daily time step (**Figure 2**). Its version of LEACHN uses a "tipping bucket" approach and information on soil properties and weather to estimate how water from each rain event is stored in soil, lost to drainage, or evaporated over time. It also tracks the transformations and movements of N in the soil profile. Both models have been extensively tested and validated in field trials. An important feature is its dynamic access to gridded high-resolution (5 x 5 km) weather data (daily Tmax, Tmin, Precip), which allows for field-specific and timely adjustments of N recommendations. The weather database is derived from routines using National Oceanic & Atmospheric Administration's (NOAA) Rapid Update Cycle weather model (temperature) and operational Doppler radars (precipitation). For both, observed weather station data are used to correct NOAA estimates and generate spatially interpreted grids (DeGaetano and Wilks, 2009; Wilks, 2008). Soils information is derived from NRCS SSURGO datasets.

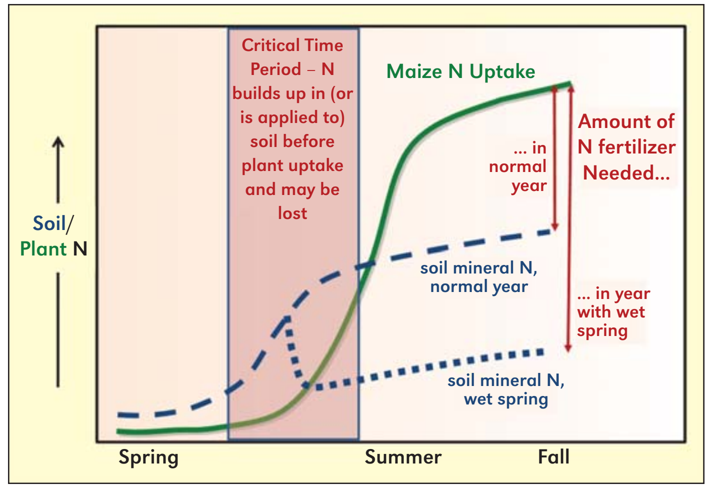

Figure 2. Adapt-N dynamically models the impact of weather on the soil N supply, soil N losses, and crop N demand.

Adapt-N uses dynamic simulations of soil and crop processes to feed into a mass balance equation that derives optimum N rates based on early season (deterministic, near-real time, currently within 1 day) and post-sidedress (stochastic, based on probability via 30-year climate data) simulation results. It provides uncertainty estimates for N rates, and also incorporates economic considerations (crop-fertilizer price ratio). It offers information on simulation results (N mineralized, N leached and denitrified, soil N levels) and allows for

Case Study: New York Farm Uses Adapt-N to Save Money and Reduce Environmental Impact

Donald and Sons Farm in Moravia, NY grows about 1,300 acres of corn and soybean annually. Until 2011, the farm used N application rates recommended by a commercial soil testing laboratory, which ranged between 195 to 260 lb N/A. The majority of their fertilizer N is applied as anhydrous ammonia at sidedress time, because early season applications run the risk of losses during wet springs. Only 22 lb/A of N is applied at planting as urea ammonium nitrate (UAN). Their large expenditures on N fertilizer were a strong incentive to seek new tools to optimize application rates and to collaborate with the Adapt-N beta-testing efforts. The web-based Adapt-N tool combines soil and crop models to predict the influence of weather on plant N demand, soil N supply and soil N losses.

After the dry 2011 spring, the Adapt-N recommendation for their trial field was only 80 lb/A. Their old recommendation was 220 lb/A, and they found no yield penalty with the substantially reduced N rate. For 2012, the farm decided to fully adopt Adapt-N and host numerous trials. They sidedressed 922 acres of corn using the tool's recommendations, employing their real-time kinetic (RTK)-GPS system to target variable rates on 90 management units distributed across 18 fields. Recommendations from Adapt-N varied from 65

to 190 lb/A, depending on local temperature, precipitation, soil texture and organic matter content (varying from 1% to 6%), as well as the date of sidedressing. In collaboration with the Cornell Adapt-N Team, on 15 fields, they left replicated comparison strips of the conventional "old" rate. Decreasing N applications by 87 lb/A reduced the simulated total N losses to the environment by 70 lb/A (by 15 December 2012), and reduced N leaching losses by 10 lb/A. Adapt-N resulted in profit gains in 83% of trials, and average savings were 42 $/A. For the farm, they saved 67,000 lb of unneeded N in 2012, with total savings of over $30,000.

By applying a science-based model of the soil and crop processes involved in the N cycle, their management of source, rate, timing and placement of N led to higher profit and reduced impact on the environment. The approach is consistent with the principles of 4R Nutrient Stewardship.

For more information, see http://adapt-n.cals.cornell.edu/

alternative management scenario analyses. A feature allows for automatic daily updates of simulation results via email or text message. Graham et al. (2010) applied the model to generate within-field site-specific N recommendations.

On-farm Testing

The main question for users is whether the tool provides recommendations that increase profits and reduce environmental impacts. We are answering this through replicated on-farm strip trials, totaling 84 in 2011 and 2012 (**Figure 3**). They involved grain and silage corn in fields with varying management history (organic amendments, crop rotation, tillage practices, etc.). Sidedress treatments involved at least two rates of N, a conventional producer-chosen "Grower-N" rate and an "Adapt-N" rate. A simulation was run for each field just prior to sidedressing to determine the Adapt-N rate.

Yields were measured by weigh wagon, yield monitor, or in a few cases by representative sampling (two 20 ft. x 2 row sections per strip). For farms harvesting silage, yields were converted to grain equivalents assuming 8.14 bu grain per ton of silage. Partial profit differences between the Adapt-N and Grower-N rates were calculated. For grain, prices of 5.50 and 6.00 $/bu were assumed for 2011 and 2012, respectively. For silage, 50 $/ton was assumed in both 2011 and 2012. A fertilizer N price of 0.60 $/lb was used for all trials.

Economic Results

Profit gains for the use of Adapt-N over the producer chosen rates were considerable, in 80% of New York trials, in 75% of Iowa trials, and 79% overall (**Table 1**). Of the 21% of cases where Adapt-N underperformed and caused lower profits, the majority was associated with either underestimated yield expectations from user inputs, or mid-season droughts following higher Adapt-N recommendations. The former concern can be corrected through better user training on yield goal estimation, and the latter relates to as yet unavoidable uncertainty about future weather events at sidedressing time.

Adapt-N recommended lower N rates for 88% of trials, in part related to generally dry growing season conditions in both years. Marginal profits were on the average 27 $/A higher ($p < 0.0001$) and N inputs 54 lb/A lower ($p < 0.0001$) when Adapt-N was used. Profit gains were also achieved in some instances where Adapt-N recommended higher N rates, and consequent yield increases were achieved. Yields decreased by only 1 bu/A on average for all 84 trials (statistically insignificant), indicating that the reduced N recommendations were generally justified. The yield decrease would have been smaller had the expected yields been estimated correctly.

Table 1. Comparison of Adapt-N and Grower-N rates from replicated on-farm strip trials.

Treatment comparison Adapt-N – Grower-N	Iowa		New York		Grand Mean
	2011	2012	2011	2012	(weighted)
Number of fields	9	19	14	42	84
N fertilizer input, lb/A	-25	-36	-66	-65	-54
Yield, bu/A †	+2	-1	-3	-1	-1
Profit, $/A	+25	+17	+26	+32	+27
Trials with greater profit, %	78%	74%	86%	79%	79%

† Yields ranged from 75 to 245 with a mean of 175 bu/A.

Figure 3. On-farm trial locations. Map courtesy of Google maps and batchgeo.com

Environmental Impacts

Lower Adapt-N recommendations resulted in substantial reductions in N losses to the environment. By the end of the growing season, simulated total N losses decreased by an average of 39 lb/A, and simulated N leaching losses declined by 8 lb/A with the use of Adapt-N. In 2012, simulated total N losses and particularly leaching losses of sidedress-applied excess N remained relatively low due to widespread dry conditions until the winter of 2012-2013. The above simulations did not include further environmental benefits achieved during the following, generally wet, spring of 2013.

Conclusions

Two consecutive growing seasons of on-farm strip trial testing demonstrated that Adapt-N resulted in profit gains in four out of five cases. The strip trial results show that using Adapt-N provides a win-win: economic advantages to growers, as well as environmental benefits. In all, Adapt-N promotes more accurate N management, and the tool's increasing precision as the growing season progresses also provides a strong incentive to shift the timing of N applications to late spring and early summer.

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