Supplemental Materials

Supplemental Table S1. Data needed as input to run a simulation in Adapt-N.

| **Inputs** | **Details** |
|---|---|
| Soil inputs | Soil type or series; rooting depth; slope inclination; Soil Organic Carbon; artificial drainage. |
| Weather inputs | Daily, near-real time (one day lag): cumulative solar radiation; max-min temperature; precipitation. |
| Crop inputs | Cultivar; maturity class; population; potential yield |
| Management inputs | Tillage (time, depth, residue level); irrigation (amount, date); previous crop characteristics; manure applications ($NH_4$ and organic N levels, solids percentage, rate, timing, incorporation method). |
| N Fertilizer inputs | Multiple: Type, rate, time of application, placement depth; fertilizer price; enhance efficiency compounds. |
| Optional inputs – depending on available field-specific observations | Soil N-$NO_3$; Crop emergence date. |

Supplemental Table S2. Site characteristics and management practices for the multi-rate trials. The reported range of rates reflects the total N rate used in the experiment, including the starter application. Depth indicates the depth of sidedress incorporation.

| | | | | | | Sidedress information | | | | | | Precipitation data ¥ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Year | County | Soil series or class | OM % | Tillage† | # of rates | Range of rates (kg $ha^{-1}$) | # of reps | SD date | Form‡ | Depth (cm) | Planting to SD (mm) | Annual (mm) |
| 1 | 2011 | Cayuga | Silt Loam | 3 | ST | 3 | 28-196 | 2 | 16/6 | UAN | 8 | 51 | 1016 |
| 2 | 2012 | Cayuga | Silt Loam | 2.5 | CT(50) | 3 | 27-251 | 4 | 26/6 | UAN | 8 | 137 | 914 |
| 3 | 2012 | Cayuga | Silt Loam | 4.1 | ST | 3 | 25-235 | 2,3 | 15/6 | UAN | 8 | 104 | 1036 |
| 4 | 2012 | Cayuga | Silt Loam | 3 | ST | 3 | 25-258 | 2,3 | 22/6 | AA | 23 | 109 | 970 |
| 5 | 2012 | Cayuga | Silt Loam | 4.4 | ST | 3 | 25-260 | 2,3 | 21/6 | AA | 23 | 109 | 970 |
| 6 | 2012 | Cayuga | Silt Loam | 3.8 | ST | 3 | 25-232 | 2,3 | 16/6 | AA | 23 | 94 | 1039 |
| 7 | 2013 | Cayuga | Silt Loam | 2.4 | CT(50) | 3 | 27-251 | 2 | 7/7 | UAN | 8 | 279 | 1010 |
| 8 | 2014 | Cayuga | Williamson | 3 | ST | 6 | 61-212 | 3 | 20/6 | UAN | 8 | 160 | 983 |
| 9 | 2014 | Clinton | Hogansburg | 2.9 | ST | 5 | 38-206* | 4 | 18/7 | UAN | 8 | 150 | 1123 |
| 10 | 2014 | Clinton | Malone | 3.7 | CT(25) | 5 | 38-206* | 4 | 18/7 | UAN | 8 | 150 | 1120 |
| 11 | 2014 | Cayuga | Loam | 2.3 | ST | 5 | 75-176 | 3 | 30/6 | UAN | 8 | 79 | 1021 |
| 12 | 2014 | Delaware | Silt Loam | 3.7 | CT(50) | 6 | 40-320 | 4 | 1/7 | AS | 8 | 165 | 1123 |
| 13 | 2015 | Cayuga | Sodus | 3 | CT(25) | 6 | 10-235 | 2,3 | 10/6 | UAN | 8 | 178 | 1011 |
| 14 | 2015 | Cayuga | Honeoye | 3.4 | ST | 6 | 25-282 | 4 | 17/6 | AA | 23 | 241 | 955 |

† CT = Conservation tillage (%residue); ST = Spring Tillage; ‡UAN = Urea Ammonium Nitrate; AA = Anhydrous Ammonia; AS = Ammonium Sulfate. * These trials had a 28,062 L $ha^{-1}$ dairy manure application the fall previous to the experiment, equivalent to a loading of 34 and 17 kg $ha^{-1}$ ammonium and organic N, respectively. ¥ Precipitation data based on Adapt-N's climate database (4X4 $km^2$ grid resolution).

Supplementary Material 1

Several functions were proposed in the literature to characterize the relation between the N rate and resulting yield, including Quadratic, Quadratic–plateau, linear-plateau, Square root or exponential (Cerrato and Blackmer, 1990). In this study we used a Quadratic function in the form $y = AX^2 + BX + C$ to fit yield response to the applied N rate. The Quadratic model was chosen as it is a stable function that has performed well in an extensive comparison with 6 other response curve functions (Jaynes, 2011). To fit the Quadratic functions and calculate the EONR code was written in the R software for statistical computing (https://www.r-project.org/). Prices of \$1.098 kg$^{-1}$ and \$0.195 kg$^{-1}$ were assumed for N fertilizer and maize grain, respectively, corresponding to the mean US prices during the years 2007-to-2013 (USDA_ERS, 2015; USDA_NASS, 2015b). If a recommedation rate was lower than the EONR, the losses from the EONR were calculated using data from the response curve. If a recommendation rate was higher than the EONR, the losses from the EONR were calculated using:

$$Loss = (AONR_N - EONR_N) \times P_N - (AONR_y - EONR_y) \times P_M + (N_{rec} - AONR_N) \times P_N$$

where Loss is the profit loss (\$ ha$^{-1}$), $AONR_N$ and $AONR_y$ are the respective N rate and yield (kg ha$^{-1}$) when maximum yield is attained (also known as the Agronomic Optimum N Rate), $EONR_N$ and $EONR_y$ are the respective N rate and yield of the EONR (kg ha$^{-1}$), $P_N$ and $P_M$ are the prices of fertilizer N and maize grain (\$ kg$^{-1}$), and $N_{rec}$ is the N recommendation generated by the different tools (kg ha$^{-1}$).

In the regression procedure the Quadratic function parameters with the best fit are found by the least squared method, and are reported along with each parameter variability. To estimate the uncertainty in the EONR value, resulting from the uncertainty in the parameters fitted by the regression, we followed the methodology presented in Jaynes (2011). For each trial we generated 1000 parameter sets of the quadratic function, drawn from a multivariate normal distribution, using the CORAND function from the Simtools package for MS-Excel (Myerson, 2008). This function constructs multivariate normal random variables using a correlation array as an input. The values of the CORAND function are used as input to the NORMINV function of MS-Excel, together with the regression parameters mean and standard deviation, to generate random parameter sets of the regression coefficients. For each of the generated parameter sets we calculated the respective EONR, resulting in 1000 EONR values for each trial. Based on this EONR distribution a confidence interval of one standard deviation (68%) was calculate by dividing the inter-quartile range by 2 * 0.675 (Cressie, 1991).

References

Cerrato, M.E. and A.M. Blackmer. 1990. Comparison of models for describing Corn yield response to Nitrogen-fertilizer Agron. J. 82: 138-143.

Cressie, N.A.C. 1991. Statistics for spatial dataWiley, New York, USA.

Jaynes, D.B. 2011. Confidence bands for measured economically optimal nitrogen rates. Precis. Agric. 12: 196-213. doi:10.1007/s11119-010-9168-3.

Myerson, R. B. (2008). About SIMTOOLS and FORMLIST. Available at: http://home.uchicago.edu/rmyerson/addins.htm. Accessed 21 Sep 2016.

Myerson, R.B. 2005. Probability models for economic decisions. Thomson Brooks/Cole Belmont, CA, USA.

USDA_ERS. 2015. Fertilizer Use and Price. Retrieved from: http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx.

USDA_NASS. 2015b. Maize crop price summary. Retrieved from: http://quickstats.nass.usda.gov/#B.

Supplemental Table S3. Simulated environmental losses in each trial for the Adapt-N and CNC tools.

| Site | Year | CNC leaching losses GY† | CNC leaching losses DY‡ | Adapt-N leaching losses GY† | (A-CNC)§ Leaching GY† | (A-CNC) Leaching DY‡ | CNC gaseous losses GY† | CNC gaseous losses DY‡ | Adapt-N gaseous losses GY† | (A-CNC) Gaseous GY† | (A-CNC) Gaseous DY‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ($kg\ ha^{-1}$) | | | | | | | | | |
| 1 | 2011 | 28.9 | 27.1 | 22.9 | -6.1 (-21%) | -4.3 (-16%) | 20.2 | 18.7 | 15.7 | -4.5 (-22%) | -3.0 (-16%) |
| 2 | 2012 | 165.3 | 92.3 | 97.4 | -67.9 (-41%) | 5.2 (5%) | 14.8 | 8.3 | 9.0 | -5.8 (-39%) | 0.7 (8%) |
| 3 | 2012 | 31.9 | 13.3 | 19.2 | -12.8 (-40%) | 5.8 (30%) | 130.7 | 38.9 | 66.3 | -64.5 (-49%) | 27.4 (41%) |
| 4 | 2012 | 111.0 | 4.6 | 48.8 | -62.2 (-56%) | 44.2 (91%) | 152.5 | 2.4 | 43.2 | -109.3 (-72%) | 40.8 (94%) |
| 5 | 2012 | 94.2 | 29.8 | 47.5 | -46.6 (-49%) | 17.7 (37%) | 106.3 | 24.3 | 45.4 | -60.9 (-57%) | 21.1 (46%) |
| 6 | 2012 | 30.7 | 8.7 | 20.2 | -10.5 (-34%) | 11.4 (56%) | 115.7 | 21.3 | 58.7 | -56.9 (-49%) | 37.4 (64%) |
| 7 | 2013 | 76.9 | 7.3 | 14.2 | -62.7 (-82%) | 7.0 (49%) | 7.2 | 3.5 | 3.9 | -3.3 (-46%) | 0.4 (10%) |
| 8 | 2014 | 15.2 | 2.7 | 6.1 | -9.2 (-61%) | 3.4 (56%) | 54.6 | 5.6 | 13.2 | -41.4 (-76%) | 7.6 (58%) |
| 9 | 2014 | 4.1 | 1.7 | 4.1 | 0.0 | 2.5 (61%) | 1.2 | 1.7 | 0.7 | -0.6 (-50%) | -1.0 (-59%) |
| 10 | 2014 | 58.2 | 5.3 | 5.0 | -53.1 (-91%) | -0.2 (-4%) | 5.7 | 3.0 | 1.9 | -3.8 (-66%) | -1.1 (-37%) |
| 11 | 2014 | 19.5 | 1.5 | 1.6 | -17.9 (-92%) | 0.1 (6%) | 8.9 | 4.0 | 6.1 | -2.8 (-31%) | 2.0 (33%) |
| 12 | 2014 | 30.8 | 16.0 | 16.8 | -14.0 (-45%) | 0.8 (5%) | 49.5 | 22.6 | 30.2 | -19.4 (-39%) | 7.5 (25%) |
| 13 | 2015 | 92.6 | 5.9 | 39.5 | -53.1 (-57%) | 33.5 (85%) | 6.8 | 3.1 | 5.0 | -1.8 (-26%) | 1.9 (38%) |
| 14 | 2015 | 59.4 | 25.7 | 44.7 | -14.7 (-25%) | 19.1 (43%) | 2.5 | 1.3 | 2.1 | -0.3 (-12%) | 0.8 (38%) |
| Grand mean | | 58.5 | 17.3 | 27.7 | -30.8 (-53%) | 10.4 (40%) | 48.3 | 11.3 | 21.5 | -26.8 (-55%) | 10.2 (47%) |

†GY: based on grower potential yield

‡DY: based on default potential yield

(A-CNC): difference between Adapt-N and Cornell Nitrogen Calculator estimates