Re-Analysis of the NutrientStar Dataset

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Executive Summary

NutrientStar is a technology evaluation program initiated by Environmental Defense Fund that recently became a division of Brookside Laboratories. It aims at evaluating nutrient management tools and, among others, evaluated the Adapt-N tool for the 2016 and 2017 growing seasons based on multi-N rate trials conducted on commercial farms in the US Midwest. The Adapt-N evaluation was published on the NutrientStar web site, but results were generally out of line with earlier research conducted by our team. NutrientStar agreed to share the trial data with us for re-analysis, which is the focus of this report.

The re-analysis involved two approaches to evaluating model performance: (i) assessment of the correctness of Adapt-N use and inputs as part of the NutrientStar analysis and the changed outcomes from adjustments, and (ii) an evaluation of the choice of N response function on analysis outcomes. Several concerns with the NutrientStar trial implementation could not be addressed through a re-analysis, notably unusual but unknown soil inputs, and a large fraction of trials conducted with sidedress timing outside the optimum window (mostly very early). Corrections related to the common underestimation of potential yield and the use of differential fertilizer:grain price ratios were addressed in the re-analysis. In addition, comparisons were made on Adapt-N performance relative to EONR and Grower management using estimates with quadratic vs. quadratic-plateau models.

Overall, average losses from the EONR using the quadratic function were: 1) $55/ac in the published NutrientStar analysis; 2) $35/ac in the trials that we were able to reconstruct; and 3) $26/ac after correction of input errors (where possible). With input corrections only, Adapt-N recommendations were $10/ac less economical than Grower N management for all reconstructed trials, but this was achieved with an average 23 lbs/ac lower N rate. Moreover, use of the more appropriate quadratic-plateau function for fitting N response data considerably improved Adapt-N performance: average recommendations within 9 lbs/ac of the

EONR, and a near-identical profit loss to the Grower for all reconstructed trials[1] ($3/ac relative loss with 23 lbs/ac lower N rate). We conclude that (i) input data and N response functions had a large impact on the conclusions around Adapt-N's economic value, and (ii) Adapt-N overall performed well through good economic and environmental outcomes, especially considering trial implementations that were not optimum for the tool.

Potential conflict of interest statement:

Shai Sela acknowledges funding from Yara ATC for this analysis through a private consulting agreement. Harold van Es is the lead inventor of Adapt-N, receives modest royalty payments through the Cornell University exclusive use license to Yara, and performs modest consulting efforts for Yara. His conflicts of interest are managed per Cornell University guidelines.

[1] Based on the NutrientStar data, additional model adjustments were made to account for low N use efficiency in poor-yielding fields. Accounting for these changes and the QP function lead to $3/ac higher profit for Adapt-N over the Grower, achieved with 16 lbs/ac lower N inputs.

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1. Background and research gaps

NutrientStar is a program initiated by Environmental Defense Fund which is now a division of Brookside Laboratories. It aims at evaluating nutrient management tools and, among others, evaluated the Adapt-N tool for the 2016 and 2017 growing seasons based on 80+ multi-N rate trials conducted on commercial farms in different states in the US Midwest. The Adapt-N evaluation was published on their web site.

The multi-N rate trials allowed for the determination of the Economic Optimum N Rate (EONR) through curve fitting of the N response data. The EONR is a retrospective (*post-hoc*) evaluator of the optimum rate and allows for performance assessment of predictive recommendation tools (which by definition will show some profit loss). The review found Adapt-N recommendations to lead to higher profit losses than Grower rates: $34/ac lower revenue in 2016 and $58/ac lower revenue in 2017 for trials where the EONR could be statistically estimated, and $16/ac and $49/ac considering all trials. In most cases, Grower rates were higher than Adapt-N rates and losses were associated with reduced estimated yields. These results contradicted our own extensive research efforts published previously (Sela et al 2016; 2017; 2018a; 2018b), which showed Adapt-N rates to be more efficient agronomically (higher NUE), environmentally (reduction of 30-40% in N losses) and economically (average profit *gain* of $26/ac over Grower rates). It also disagrees with a previous NutrientStar evaluation of Cornell on-farm trials -- conducted by Dr. Jim Schepers – that showed relatively precise Adapt-N estimates for lower vs. higher nitrogen needs relative to Grower practice. In 83% of cases the tool recommended less N than Grower, generally without yield losses; in 17% of cases it recommended more N than Grower which was generally justified by significant yield benefits (Sela et al 2016.) Overall, use of Adapt-N resulted in reduced N inputs at higher returns.

The NutrientStar program strives to make science-based evaluations of different N management tools, but for Adapt-N this did not involve the optimal use of the tool for a substantial number of trials. For example, there were many trials where sidedress N was applied either very early (V3-4) or late (V16-18). This suboptimal application timing might be practiced by some farmers concerned with weather, equipment and labors constraints, but this is not optimal use for an in-season tool like Adapt-N. Also, concerns existed with the use of Adapt-N input data and the use of the quadratic N response function. NutrientStar agreed to make the experimental data available to Cornell and ATC-Yara, which formed the basis of this re-analysis.

2. Objective

To evaluate, examine and re-analyze Adapt-N performance in the NutrientStar field trials.

3. Methods

a. Data organization procedures and description

A spreadsheet with the raw experimental data of the 2016 and 2017 seasons was supplied by NutrientStar. The respective fields and zones created in the Adapt-N system were located and copied. Forty five and 41 trials in the Adapt-N database out of 47 and 45 trials in the NutrientStar spreadsheet were identified for the 2016 and 2017 seasons, respectively, for a total of 86 trials (we were unable to identify several trials in the Adapt-N software). Each trial setup in Adapt-N was subsequently carefully examined to ensure that all necessary data to run N recommendations were present. The experimental data spreadsheet supplied by NutrientStar included for 2016 a column with the breakdown of the application details (preplant N, Starter, sidedress etc.). For 15 of the trials (33%) discrepancies were found between application data in the spreadsheet and N applications found in the respective Adapt-N fields (summary presented in Appendix A). In cases of discrepancies, the field set up in Adapt-N was corrected based on the spreadsheet data. For the 2017 season no such information was available, and the field set ups were used as copied from the Adapt-N database. For one trial in 2017 the spreadsheet suggested the lowest N rate to be zero, while in Adapt-N there were 3 N applications prior to sidedress date, for a total of 94 lbs/ac. Since we were unable to reconcile this large discrepancy, we excluded this trial from further analysis. Descriptive data for the 2016 and 2017 seasons can be found in Tables 1 and 2, respectively.

b. N response functions, parameter fitting, and calculation of the EONR

All evaluations of optimum N rates and resulting profits were based on curve fitting of the trial results (yield response at different N rates), which then retroactively allows for determination of the Economic Optimum N Rate (EONR) and subsequent evaluation of the relative performance of Adapt-N and Grower recommendations. Note that in this approach neither N rate recommendation was actually implemented in the field trial but retroactively estimated in the context of a yield response curve using an assumed mathematical function (quadratic). To be compatible with the NutrientStar analysis, the same quadratic function was used to fit the N response data (Tables 3 and 4). This assumes an increase in yield with increase in fertilizer rate that reaches a maximum value,

$$\text{Yield} = a+bX-cX^2$$

where a is the intercept with the ordinate axis, X is fertilizer rate, and b and c are positive fitting parameters. The respective EONR was calculated by finding the maximum value of the following equation:

$$\text{EONR} = a+bX-cX^2-dX$$

where d is the price ratio of fertilizer to yield (0.1 bu/lb in this analysis, identical to the value used by NutrientStar). All statistical analyses were performed using the R programming language with various plug-in modules.

It is well established that the use of quadratic N response curves results in relatively high estimates of the EONR and that the quadratic-plateau model is more appropriate for N response data (Sela et al., 2018; Cerrato and Blackmer, 1990). This disadvantages tools that provide conservative N recommendations and balance profits and environmental impacts, like Adapt-N. An analysis was performed to evaluate the impacts of the functional choice on the relative performance of Adapt-N to EONR and Grower management, which is separately discussed in section e. Finally, an analysis was performed on the effects of early-season sidedress N applications with subsequent field monitoring, which is discussed in section f.

Table 1. Field trials description – 2016 season. Trials marked in yellow had underestimated expected yield (EY).

ID in this report	ID in program	ZSID in adapt-N	State	Soil type	SOM%	Max yield (bu/ac)	Original EY (bu/ac)	Adjusted EY (bu/ac)	comments
1	NST-01BCS00293	27235088	IL	SiLo	3.9	243	200	240	
2	NST-01BCS00294	27235089	IL	SiClLo	4.8	235	220	240	
3	NST-01BCS00295	27235090	IL	SiLo	4.0	240	220	240	
4	NST-01BCS00296	27235091	IL	SiLo	4.5	227	220	230	
5	NST-01BCS00297	27235092	IL	ClLo	4.6	234	220	230	
6	NST-01BCS00298	27235093	IL	SiClLo	4.4	214	200	210	
7	NST-01BCS00299	27235094	IL	SiLo	4.1	254	220	250	100 lbs/ac fall preplant without starter.
8	NST-01BCS00300	27235095	IL	SiClLo	4.5	252	250	250	
9	NST-02MOF00002	27235096	IN	SiLo	2.0	190	200	200	
10	NST-03ATA00007	27235098	IN	ClLo	3.5	173	190	190	
11	NST-03ATA00008	27235099	IN	SiLo	3.0	205	180	200	
12	NST-03ATA00009	27235100	OH	Lo > 2.5	3.1	180	160	180	
13	NST-03ATA00010	27235101	OH	SiLO>2.5	3.2	169	160	170	
14	NST-03ATA00128	27235102	IN	ClLo	2.0	192	170	190	
15	NST-04PAS00003	27235103	OH	SiCl	4.0	141	200	200	Manure, mid-season drought
16	NST-04PAS00004	27235104	OH	SiLo > 2.5	3.5	144	220	220	Manure, mid-season drought
17	NST-05GRN00014	27235105	IN	SiLo	1.5	210	200	210	Relatively low SOM% for medium soil texture.
18	NST-05GRN00015	27235106	IN	Lo	1.6	237	210	240	Relatively low SOM for medium soil texture, very shallow rooting depth assigned, 12".
19	NST-05GRN00016	27235107	IN	SiLo	1.8	211	200	210	Very shallow rooting depth assigned, 12"
20	NST-05GRN00017	27235108	IN	SiLo	1.6	213	200	210	Mismatch between fall preplant assigned in Adapt-N and spreadsheet comments. Very shallow rooting depth assigned, 12".
21	NST-05GRN00018	27235109	IN	SiLo	1.9	220	200	220	
22	NST-07NAG00013	27235132	OH	Cl	4.6	182	200	200	Manure
23	NST-07NAG00014	27235133	OH	ClLo	3.5	193	200	200	
24	NST-09OTE00001	27235111	OH	SiLo > 2.5	3.4	160	180	180	Very shallow rooting depth assigned, 12".
25	NST-09OTE00003	27235112	OH	SiLo > 2.5	3.4	209	200	210	Very shallow rooting depth assigned, 12". Fall manure
26	NST-09OTE00004	27235113	IN	SiClLo	2.7	181	180	180	Very shallow rooting depth assigned, 12".
27	NST-09OTE00005	27235114	OH	SiLo > 2.5	2.9	245	200	240	Fall manure
28	NST-10MCN00011	27235115	IL	Si	1.5	215	190	220	Relatively low SOM% for a heavy soil, very shallow rooting depth assigned, 12".
29	NST-10MCN00012	27235116	IL	SiClLo	1.0	162	200	200	Very low SOM% for a heavy soil.
30	NST-10MCN00013	27235117	IL	SiLo	2.0	180	200	200	
31	NST-12DAL00003	27235118	OH	SiLo > 2.5	2.6	137	160	160	Very shallow rooting depth assigned, 12".
32	NST-13DAR00013	27235119	MI	Lo > 2.5	3.5	182	220	220	Spring manure
33	NST-13DAR00120	27235120	MI	SaLo	2.5	156	220	220	
34	NST-14GKC00013	27235121	IN	SiLo	2.0	164	170	170	
35	NST-14GKC00016	27235122	OH	SiLo > 2.5	3.5	195	170	200	
36	NST-14GKC00017	27235135	IN	SiLo	2.7	139	180	180	Spring manure
37	NST-14GKC00018	27235123	IN	SiLo	3.0	222	210	220	
38	NST-16HAS00006	27235124	OH	Cl	3.0	161	170	170	
39	NST-16HAS00016	27235125	OH	SiClLo	2.8	204	220	220	
40	NST-16HAS00017	27235126	OH	Cl	3.5	198	200	200	
41	NST-16HAS00018	27235127	OH	ClLo	3.5	143	170	170	
42	NST-16HAS00019	27235128	OH	Cl	3.5	167	170	170	
43	NST-16HAS00020	27235129	OH	SaLo	3.5	219	220	220	
44	NST-18ANZ00001	27235130	MN	ClLo	3.5	236	240	240	Fall manure
45	NST-19EXT00001	27235131	MN	SiCl	5.1	216	220	220	

Table 2. Field trials description – 2017 season. Trials marked in yellow had the expected yield (EY) underestimated.

ID in this report	ID in program	ZSID in adapt-N	State	Soil type	SOM%	Max yield (bu/ac)	Original EY (bu/ac)	Adjusted EY (bu/ac)	comments
1	NST2017ILLB001	27234987	IL	SiClLo	3.3	278	240	280	Two zones with two different soil types
2	NST2017ILLB002	27235201	IL	SiClLo	4.4	253	240	250	
3	NST201702MO001	27235206	IN	Lo	2.0	244	220	240	
4	NST201704PA001	27235137	OH	SiClLo	3.5	191	200	200	Two zones, two different soil types
5	NST201704PA002	27232187	OH	SiCl	3.5	206	200	210	Two zones with two different soil types
6	NST201705GR002	27235191	IN	SiClLo	4.3	230	200	230	Default SOM value was assigned
7	NST201705GR003	27235190	IN	SiLo	2.4	236	190	240	
8	NST201707NA001	27235195	OH	SiCl	3.2	163	180	180	
9	NST201707NA002	27235194	OH	ClLo	4.0	183	190	190	
10	NST201708MA001	27235181	MI	SiLo	3.0	195	200	200	
11	NST201709OT001	27235152	IN	SiCl	3.0	200	200	200	
12	NST201709OT002	27235151	OH	SiClLo	3.6	165	200	200	Fall manure
13	NST201710MC001	27235178	IL	SiClLo	1.8	229	180	230	Relatively low SOM% for a heavy soil, very shallow rooting depth assigned, 12”.
14	NST201710MC002	27235179	IL	SiLo	2.0	177	210	210	
15	NST201710MC003	27235180	IL	SiLo	1.8	170	170	170	
16	NST201713DA001	27235208	MI	SiLo	2.4	217	180	220	
17	NST201714GK003	27235186	IN	ClLo	2.6	238	180	240	Fall manure.
18	NST201714GK005	27235189	IN	SaLo	2.0	213	250	250	Spring manure.
19	NST201714GK006	27235187	IN	ClLo	3.0	237	200	240	Two zones with two different soil types
20	NST201716HA001	27235087	OH	ClLo	3.5	171	180	180	
21	NST201716HA002	27235203	OH	ClLo	4.4	153	180	180	Default SOM value was assigned
22	NST201716HA003	27235204	OH	SaLo	2.0	224	200	220	Default SOM value was assigned
23	NST201716HA004	27235086	OH	ClLo	3.5	167	180	180	
24	NST201716HA005	27235205	OH	ClLo	4.4	208	200	210	Default SOM value was assigned
25	NST201719EX001	27235172	MN	SiClLo	5.9	244	210	240	
26	NST201719EX003	27235154	MN	SiLo	4.7	219	200	220	Two zones with two different soil types.
27	NST201721CN002	27235144	IA	SiClLo	3.4	252	240	250	
28	NST201721CN003	27235146	IA	SiClLo	4.4	255	230	260	
29	NST201721CN001	27235145	IA	SiClLo	4.0	227	260	260	Spring manure. Spreadsheet states lowest N rate in trial is zero, but there are 94 lbs of N applied through 2 pre plants and a starter. Trial excluded from further analysis
30	NST201723CB004	27235198	IA	Lo	4.8	260	240	260	
31	NST201723CB005	27235199	IA	SiLo	3.0	201	230	230	
32	NST201723CB006	27235200	IA	SiClLo	5.0	198	240	240	
33	NST201723CB007	27235196	IA	Lo	5.0	273	260	270	
34	NST201723CB008	27235197	IA	LO	4.0	184	240	240	
35	NST201724SS001	27235176	WI	SiLo	4.3	235	220	230	
36	NST201724SS002	27235175	WI	SiClLo	4.2	222	220	220	
37	NST201726FF002	27235183	IN	SiClLo	2.3	196	180	200	
38	NST201726FF004	27228470	IN	SiLo	3.4	171	180	180	NutrientStar spreadsheet states the trial has manure, but not in the Adapt-N account
39	NST201726FF005	27235184	IN	SiCl	2.6	189	170	190	
40	NST201726FF006	27235185	IN	SiClLo	2.0	210	190	210	
41	NST201727AN001	27235147	MN	ClLo	5.0	248	200	250	Fall manure.

Table 3. 2016 season trials quadratic response curve parameters. Trials marked in red had a statistically non-significant response curve.

ID in this report	ID in program	ZSID in adapt-N	Intercept	Intercept sig.	QD 1st	QD 1st sig.	QD 2st	QD 2st sig.	QD RSE	QD R2	QD R2 sig.
1	NST-01BCS00293	27235088	108.54	0.00	1.26	0.00	-0.00292	0.02	10.60	0.68	0.00
2	NST-01BCS00294	27235089	169.36	0.00	0.65	0.01	-0.00162	0.03	6.59	0.46	0.01
3	NST-01BCS00295	27235090	49.09	0.03	1.67	0.00	-0.00364	0.00	7.00	0.93	0.00
4	NST-01BCS00296	27235091	146.02	0.00	0.79	0.01	-0.00190	0.02	7.06	0.58	0.00
5	NST-01BCS00297	27235092	168.71	0.00	0.60	0.03	-0.00137	0.08	7.10	0.52	0.00
6	NST-01BCS00298	27235093	159.30	0.00	0.49	0.00	-0.00108	0.01	3.69	0.77	0.00
7	NST-01BCS00299	27235094	198.51	0.00	0.48	0.06	-0.00103	0.14	6.59	0.51	0.00
8	NST-01BCS00300	27235095	196.20	0.00	0.46	0.00	-0.00096	0.00	2.21	0.92	0.00
9	NST-02MOF00002	27235096	167.76	0.00	0.22	0.17	-0.00052	0.24	4.20	0.17	0.12
10	NST-03ATA00007	27235098	111.86	0.00	0.49	0.19	-0.00102	0.32	9.94	0.32	0.03
11	NST-03ATA00008	27235099	200.58	0.00	0.03	0.87	-0.00009	0.86	4.99	-0.15	0.98
12	NST-03ATA00009	27235100	86.15	0.00	0.76	0.00	-0.00154	0.02	5.82	0.84	0.00
13	NST-03ATA00010	27235101	96.42	0.00	0.45	0.01	-0.00069	NS	4.26	0.89	0.00
14	NST-03ATA00128	27235102	190.67	0.00	0.02	0.97	-0.00013	0.92	11.40	-0.13	0.89
15	NST-04PAS00003	27235103	102.43	0.00	0.34	0.15	-0.00077	0.30	5.21	0.53	0.01
16	NST-04PAS00004	27235104	121.10	0.00	0.21	0.23	-0.00048	0.59	10.66	0.31	0.08
17	NST-05GRN00014	27235105	178.40	0.00	0.30	0.26	-0.00069	0.33	4.54	0.15	0.19
18	NST-05GRN00015	27235106	178.16	0.00	0.39	0.21	-0.00065	0.45	7.07	0.64	0.00
19	NST-05GRN00016	27235107	145.68	0.00	0.65	0.13	-0.00155	0.20	9.62	0.28	0.09
20	NST-05GRN00017	27235108	190.25	0.00	0.20	0.24	-0.00044	0.35	3.87	0.27	0.10
21	NST-05GRN00018	27235109	43.97	0.29	1.63	0.01	-0.00370	0.02	11.88	0.76	0.00
22	NST-07NAG00013	27235132	86.68	0.00	0.81	0.00	-0.00171	0.01	5.06	0.84	0.00
23	NST-07NAG00014	27235133	131.81	0.00	0.43	0.03	-0.00076	0.16	5.09	0.79	0.00
24	NST-09OTE00001	27235111	81.79	0.00	0.59	0.01	-0.00113	0.04	5.06	0.82	0.00
25	NST-09OTE00003	27235112	205.56	0.00	0.01	0.90	0.00006	0.86	3.38	0.03	0.32
26	NST-09OTE00004	27235113	112.37	0.00	0.68	0.00	-0.00164	0.01	5.24	0.50	0.00
27	NST-09OTE00005	27235114	254.21	0.00	-0.19	0.13	0.00063	0.17	4.40	0.08	0.24
28	NST-10MCN00011	27235115	72.17	0.35	1.22	0.19	-0.00302	0.24	24.38	0.06	0.25
29	NST-10MCN00012	27235116	34.15	0.12	1.16	0.00	-0.00262	0.00	6.59	0.83	0.00
30	NST-10MCN00013	27235117	191.90	0.00	-0.15	0.65	0.00027	0.78	9.43	0.00	0.38
31	NST-12DAL00003	27235118	123.43	0.00	0.11	0.50	-0.00025	0.60	4.56	0.00	0.40
32	NST-13DAR00013	27235119	175.16	0.00	0.05	0.87	-0.00012	0.90	9.65	-0.14	0.95
33	NST-13DAR00120	27235120	162.16	0.00	-0.10	0.82	0.00027	0.83	12.17	-0.15	0.97
34	NST-14GKC00013	27235121	109.67	0.00	0.45	0.04	-0.00090	0.12	5.43	0.66	0.00
35	NST-14GKC00016	27235122	100.96	0.00	0.70	0.02	-0.00133	0.08	7.56	0.77	0.00
36	NST-14GKC00017	27235135	119.16	0.00	0.20	0.22	-0.00052	0.28	4.6	0.03	0.32
37	NST-14GKC00018	27235123	191.22	0.00	0.22	0.25	-0.00040	0.46	5.24	0.43	0.01
38	NST-16HAS00006	27235124	134.50	0.00	0.23	0.15	-0.00049	0.27	4.28	0.34	0.03
39	NST-16HAS00016	27235125	120.06	0.00	0.73	0.11	-0.00158	0.21	12.00	0.41	0.01
40	NST-16HAS00017	27235126	111.40	0.00	0.81	0.00	-0.00185	0.00	4.58	0.83	0.00
41	NST-16HAS00018	27235127	119.82	0.00	0.19	0.63	-0.00037	0.73	9.89	-0.03	0.49
42	NST-16HAS00019	27235128	119.86	0.00	0.43	0.13	-0.00106	0.18	6.85	0.17	0.11
43	NST-16HAS00020	27235129	223.04	0.00	-0.10	0.60	0.00033	0.53	5.18	-0.07	0.63
44	NST-18ANZ00001	27235130	134.18	0.00	0.77	0.02	-0.00144	0.04	6.25	0.65	0.00
45	NST-19EXT00001	27235131	138.83	0.00	0.78	0.00	-0.00195	0.01	3.13	0.85	0.00

NS – not significant

Table 4. 2017 season trials quadratic response curve parameters. Trials marked in red had a statistically non-significant response curve.

ID in this report	ID in program	ZSID in adapt-N	Intercept	Intercept sig.	QD 1st	QD 1st sig.	QD 2st	QD 2st sig.	QD RSE	QD R2	QD R2 sig.
1	NST2017ILLB001	27234987	180.81	0.00	0.79	0.04	-0.00165	0.13	10.05	0.62	0.00
2	NST2017ILLB002	27235201	208.52	0.00	0.32	0.15	-0.00057	0.36	5.92	0.59	0.00
3	NST201702MO001	27235206	169.81	0.00	0.34	0.53	-0.00021	0.89	15.08	0.48	0.01
4	NST201704PA001	27235137	152.09225	0.00	0.28	0.45	-0.00049	0.63	9.83	0.18	0.11
5	NST201704PA002	27232187	45.23	0.02	1.18	0.00	-0.00217	0.00	5.57	0.95	0.00
6	NST201705GR002	27235191	158.09	0.00	0.56	0.02	-0.00109	0.10	6.22	0.74	0.00
7	NST201705GR003	27235190	31.75	0.12	1.48	0.00	-0.00266	0.00	5.66	0.97	0.00
8	NST201707NA001	27235195	37.01	0.15	1.00	0.01	-0.00194	0.06	7.97	0.86	0.00
9	NST201707NA002	27235194	-335.68	0.00	4.94	0.00	-0.01175	0.00	8.48	0.92	0.00
10	NST201708MA001	27235181	25.89	0.38	1.13	0.01	-0.00175	0.10	6.98	0.93	0.00
11	NST201709OT001	27235152	65.82	0.14	1.17	0.04	-0.00256	0.10	14.58	0.56	0.00
12	NST201709OT002	27235151	112.29	0.00	0.86	0.00	-0.00341	0.00	7.08	0.82	0.00
13	NST201710MC001	27235178	198.60	0.00	0.25	0.02	-0.00052	0.08	2.69	0.69	0.00
14	NST201710MC002	27235179	-218.31	0.01	3.54	0.00	-0.00790	0.00	16.00	0.72	0.00
15	NST201710MC003	27235180	61.65	0.03	0.95	0.01	-0.00208	0.03	8.66	0.70	0.00
16	NST201713DA001	27235208	141.98	0.00	0.69	0.01	-0.00157	0.02	5.89	0.69	0.00
17	NST201714GK003	27235186	36.27	0.45	1.74	0.01	-0.00379	0.03	16.09	0.71	0.00
18	NST201714GK005	27235189	100.83	0.00	1.08	0.01	-0.00262	0.07	13.09	0.74	0.00
19	NST201714GK006	27235187	53.60	0.10	1.69	0.00	-0.00387	0.01	11.57	0.82	0.00
20	NST201716HA001	27235087	69.34	0.02	0.74	0.01	-0.00134	0.03	5.19	0.76	0.00
21	NST201716HA002	27235203	-27.21	0.56	1.35	0.01	-0.00252	0.03	9.05	0.73	0.00
22	NST201716HA003	27235204	72.70	0.00	1.28	0.00	-0.00272	0.00	4.78	0.94	0.00
23	NST201716HA004	27235086	34.57	0.58	0.95	0.11	-0.00171	0.20	11.53	0.45	0.01
24	NST201716HA005	27235205	97.98	0.00	0.98	0.00	-0.00218	0.00	4.92	0.93	0.00
25	NST201719EX001	27235172	177.07	0.00	0.58	0.04	-0.00127	0.09	7.47	0.51	0.00
26	NST201719EX003	27235154	108.89	0.00	1.00	0.00	-0.00224	0.00	5.45	0.86	0.00
27	NST201721CN002	27235144	69.95	0.14	1.58	0.01	-0.00341	0.04	14.96	0.69	0.00
28	NST201721CN003	27235146	253.89	0.00	-0.17	0.56	0.00069	0.41	8.07	0.16	0.13
29	NST201721CN001	27235145	113.44	0.00	1.41	0.00	-0.00448	0.04	16.84	0.87	0.00
30	NST201723CB004	27235198	137.03	0.00	1.17	0.00	-0.00273	0.00	5.20	0.88	0.00
31	NST201723CB005	27235199	120.93	0.00	0.58	0.03	-0.00107	0.13	6.58	0.77	0.00
32	NST201723CB006	27235200	180.26375	0.00	0.15	0.64	-0.00033	0.72	8.86	-0.07	0.62
33	NST201723CB007	27235196	183.41	0.00	0.61	0.00	-0.00102	0.05	4.77	0.91	0.00
34	NST201723CB008	27235197	165.1775	0.00	0.20	0.21	-0.00056	0.22	4.31	-0.02	0.44
35	NST201724SS001	27235176	156.22	0.00	0.62	0.04	-0.00124	0.12	7.43	0.67	0.00
36	NST201724SS002	27235175	40.52	0.06	1.71	0.00	-0.00400	0.00	6.79	0.90	0.00
37	NST201726FF002	27235183	31.41	0.29	1.47	0.00	-0.00323	0.01	9.96	0.81	0.00
38	NST201726FF004	27228470	81.97	0.00	1.11	0.00	-0.00351	0.03	14.74	0.84	0.00
39	NST201726FF005	27235184	39.23	0.47	1.62	0.03	-0.00436	0.03	18.41	0.25	0.06
40	NST201726FF006	27235185	110.94	0.00	0.82	0.03	-0.00173	0.09	9.42	0.65	0.00
41	NST201727AN001	27235147	214.31	0.00	0.62	0.00	-0.00269	0.00	6.03	0.82	0.00

4. Results and discussion

a. Examination of trial implementation by Nutrient Star

Based on past experience, five key input parameters were examined that are critical to generating good N rate recommendations in Adapt-N: 1) soil type; 2) soil organic matter content (SOM); 3) rooting depth; 4) expected yield; and 5) sidedress date (growth stage). A summary of findings is:

1) Soil type – there were 5 trials in the 2017 season where the field in the Adapt-N system had 2 zones with different soil types. In the absence of soil type data in the NutrientStar report, a judgment call was made regarding what zone and soil type to use.
2) SOM - there were four trials where default SOM values were used. Adequate quantification of the field SOM is critical to correctly simulating SOM mineralization dynamics, and the inputted SOM value directly affects N recommendations. While Adapt-N does supply default SOM values based on regional databases for user convenience, a scientific evaluation should be based on field-specific soil test analyses. In addition, several other trials had unexpectedly low SOM for the respective soil types. For example, an unusually low value of 1.0% was associated with a silty clay loam soil (trial #29 in the 2016 season), and a value of 1.5% for a silt soil (#28 in the 2016 season). There was no way to determine whether these SOM contents were inappropriate, and these values were therefore used in the re-analysis with the understanding that they likely had a negative impact on the outcomes.
3) Rooting depth – the rooting depth value directly affects soil N availability and losses prior to sidedress date, and consequently affects sidedress N recommendations. In the 2016 season there were 8 trials (18%) where a very shallow rooting depth was assigned (12”). This is the shallowest depth possible in the Adapt-N system and would represent highly compacted field conditions. While we have no way to corroborate actual field conditions, typical soil profiles and rooting depths in the Midwest are generally much deeper. Again, this was not corrected, but likely affected the trial outcomes.

4) Expected yield (EY) - the expected yield parameter drives the N mass balance equation used to generate N recommendations in Adapt-N. It is one of the most important inputs to Adapt-N as it directly affects N recommendations through the mass balance equation. Comparison of the inputted expected yield with the maximum yield achieved in each trial showed that the EY was underestimated in 21 trials (47%, mean difference of -20 bu/ac) in the 2016 season, and in 23 trials (56%, mean difference of -28 bu/ac) in the 2017 season. Two and six trials in the 2016 and 2017 seasons, respectively, underestimated the EY by more than 40 bu/ac. While uncertainty exists regarding yield potentials, good estimates are critical for evaluating Adapt-N. Underestimates of 40 and 50 bu/ac in the EY indicate inadequate knowledge of the field's yield potential and should not occur where the grower has good historical yield records. Yield adjustments were evaluated in this re-analysis.

   A minority of fields measured maximum yields below the inputted expected yields, which were not adjusted. These invariably involved "low" yields (below 180 bu/ac) where presumably the genetic yield potential was not achieved during that growing season due to abiotic or biotic stresses (pests, drought, excess water, etc.). With Adapt-N, recommendations are based on *potential* yield and include a post-application risk factor. Further in-season crop stresses are not assumed to impact EONR. Overall, while inaccurate estimates of yield potential are conceivable in real production environments, an objective evaluation of the performance of Adapt-N needs to consider correctable user errors.

5) Sidedress dates – Adapt-N recommendations become more precise as the growing season progresses and weather conditions can be accounted for in the recommendations. In order to reduce uncertainty in future seasonal rainfall and potential N losses, and to eliminate early crop N deficiencies, recommended sidedress dates for the in-season Adapt-N tool range from the V6 (at the very earliest) to the V12 growth stages. The data suggest that 38 trials (63%) were sidedressed in growth stages outside of this range (Tables 5 and 6). While most of the suboptimal sidedress dates were before V6, a few trials (notably in 2016) were sidedressed very late, at growth stages V17-20. As mentioned previously, these cases do not allow for optimal evaluation of the potential

performance of Adapt-N (or any other in-season tool). This was especially relevant in 2017 when many early-sidedressed fields experienced high post-application rainfall. Nevertheless, application timing of the trials could not be adjusted retroactively, therefore limiting our ability to determine Adapt-N optimum performance if N application timing were optimized.

Tables 5 and 6 compare the total N rates generated with Adapt-N by NutrientStar and those from this reanalysis. For the 2016 season Adapt-N rates reflect adjustments made if discrepancies were found between field set ups and the experimental data. For 2016, 17/29 (59%), 8/29 (28%) and 4/29 (14%) of the N rates generated by NutrientStar were either lower, higher or identical (respectively) to the ones generated in this reanalysis. For the 2017 season, 29/31 (94%) and 2/31 (6%) were either lower or higher than the ones generated for this reanalysis. This suggests that NutrientStar-generated Adapt-N rates were mostly lower than our estimates for both seasons, most prominently in 2017. For the 2016 season, our reanalysis showed estimated Adapt-N recommendations that were on average 4.6 lbs/ac higher than those for the NutrientStar analysis, which led to an average increase in estimated yield (from yield response curves) of 2.0 bu/ac (Table 5) and a statistically significant (alpha=0.05) average reduction in profit loss of $6.2/ac (i.e., better performance for Adapt-N). For 2017, our reanalysis resulted in Adapt-N recommendations that were higher on average by 11.8 lbs/ac, which led to an average yield increase of 5.1 bu/ac (Table 6) and an average reduction in profit loss of $15.5/ac (also an improvement for Adapt-N).

b. Comparison of recommended N rates as impacted by differential price ratio factors

Given model, field set up, and simulation date being the same, an additional factor that explains NutrientStar's lower N rates for Adapt-N is the assumed fertilizer and grain price ratios, impacting the Adapt-N profit_risk factor. This is an economic adjustment factor that integrates corrections for fertilizer and grain prices, as well as a stochastic assessment of the relative (asymmetric) profit risk of under-fertilization vs. over-fertilization. Until September 2016, the default values set in the Adapt-N software for grain and fertilizer prices were $4/bu and $0.5/lbs, or a price ratio of 0.125. After September 2016, the default value was changed to $3.5/bu and $0.5/lbs, or a price ratio of 0.1425. As

Table 5. 2016 season - trials application timing, N rates, and agronomic efficiency. Cases where Adapt-N rates by NutrientStar were lower or higher than in this analysis are marked in red and blue (respectively). Shaded cells are cases where NutrientStar found the AONR to be out of the 100-250 lbs/ac range.

ID in this report	ID in program	ZSID in adapt-N	SD date	Growth stage at SD date	Grower N rate (lbs/ac)	Adapt-N rate (lbs/ac) as reported in NS	Adapt-N rate (lbs/ac) using original EY	Adapt-N yield (bu/ac) from NS N rates	Adapt-N yield (bu/ac) from reanalysis	Difference in yield (bu/ac)	**Adapt-N rate adjusted EY (lbs/ac)**	AONR (lbs/ac)	EONR (lbs/ac)
1	NST-01BCS00293	27235088	July 5th	19	180	100	100	205.6	205.6	0	**145**	216	199
2	NST-01BCS00294	27235089	June 27th	17	200	110	125	221.6	225.7	-4.1	**150**	202	171
3	NST-01BCS00295	27235090	July 5th	20	180	100	120	179.7	197.1	-17.4	**140**	229	216
4	NST-01BCS00296	27235091	June 29th	19	200	100	100	205.9	205.9	0	**115**	207	181
5	NST-01BCS00297	27235092	June 29th	19	180	135	150	224.9	228.1	-3.2	**160**	219	183
6	NST-01BCS00298	27235093	June 14th	8	170	90	95	194.4	195.9	-1.4	**110**	226	180
7	NST-01BCS00299	27235094	June 16th	11	180	100	120	235.9	240.9	-5.0	**150**	231	183
8	NST-01BCS00300	27235095	June 11th	9	165	110	170	235.5	247.2	-11.7	**170**	241	189
10	NST-03ATA00007	27235098	June 14th	4	223	128	119	158.4	156.2	+2.2	**119**	242	193
12	NST-03ATA00009	27235100	June 12th	4	174	69	78	131.4	136.2	-4.8	**103**	247	214
15	NST-04PAS00003	27235103	May 26th	4	151	183	178	138.7	138.4	+0.3	**178**	221	155
16	NST-04PAS00004	27235104	May 28th	3	118	158	143	141.8	140.8	0.9	**143**	183	112
18	NST-05GRN00015	27235106	May 12th	3	208	198	213	230.6	232.5	-1.9	**248**	250	226
19	NST-05GRN00016	27235107	June 10th	4	207	212	195	212.9	212.6	+0.3	**205**	208	176
20	NST-05GRN00017	27235108	June 10th	4	200	170	170	211.5	211.5	0	**185**	226	113
21	NST-05GRN00018	27235109	June 16th	6	203	168	173	212.6	214.4	-1.8	**198**	220	206
22	NST-07NAG00013	27235132	June 17th	6	222	127	127	161.9	161.9	0	**127**	237	208
23	NST-07NAG00014	27235133	June 8th	6	206	153	128	180.7	175.1	+5.6	**128**	250	222
24	NST-09OTE00001	27235111	June 15th	5	210	160	150	147.9	145.5	+2.4	**150**	255	219
26	NST-09OTE00004	27235113	May 24th	3	187	207	152	181.8	177.1	+4.7	**152**	206	175
29	NST-10MCN00012	27235116	June 13th	5	203	178	188	158.0	160.0	-2.0	**188**	222	203
34	NST-14GKC00013	27235121	June 5th	3	179	159	174	157.7	159.9	-2.2	**174**	247	192
35	NST-14GKC00016	27235122	June 15th	4	203	83	90	150.3	153.7	-3.3	**145**	256	228
37	NST-14GKC00018	27235123	June 16th	6	200	125	135	213.0	214.2	-1.2	**145**	250	155
38	NST-16HAS00006	27235124	June 30th	11	210	70	75	148.1	148.9	-0.8	**75**	232	130
39	NST-16HAS00016	27235125	May 31st	5	230	150	160	194.1	196.5	-2.4	**160**	231	199
40	NST-16HAS00017	27235126	June 8th	4	191	136	192	186.9	198.1	-11.2	**192**	218	191
44	NST-18ANZ00001	27235130	June 8th	4	51	236	220	236.5	236.5	0	**220**	267	93
45	NST-19EXT00001	27235131	June 20th	7	140	183	192	215.4	215.8	-0.4	**192**	199	173
Grand mean					**185**	**141**	**146**	**188.7**	**190.8**	**-2.0**	**157**	**229**	**182**

Table 6. 2017 season - trials application timing, N rates, and agronomic efficiency. Cases where Adapt-N rates by NutrientStar were lower or higher than in this analysis are marked in red and blue (respectively). Shaded cells are cases where NutrientStar found the AONR to be out of the 100-250 lbs/ac range.

ID in this report	ID in program	ZSID in adapt-N	SD date	Growth stage at SD date	Grower N rate (lbs/ac)	Adapt-N rate (lbs/ac) as reported in NS	Adapt-N rate (lbs/ac) using original EY	Adapt-N yield (bu/ac) from NS N rates	Adapt-N yield (bu/ac) from reanalysis	Difference in yield (bu/ac)	**Adapt-N rate adjusted EY (lbs/ac)**	AONR (lbs/ac)	EONR (lbs/ac)
1	NST2017ILLB001	27234987	June 21st	11	200	99	155	243.3	264.3	-21.0	**200**	241	211
2	NST2017ILLB002	27235201	June 21st	13	200	109	119	237.0	239.0	-2.0	**129**	250	197
6	NST201705GR002	27235191	June 1st	5	185	150	160	217.5	219.7	-2.2	**195**	250	210
8	NST201707NA001	27235195	June 20th	6	224	131	141	134.4	139.0	-4.7	**141**	234	231
9	NST201707NA002	27235194	June 3rd	4	184	144	154	132.8	147.2	-14.4	**154**	210	206
11	NST201709OT001	27235152	June 13th	8	167	182	187	194.4	195.5	-1.1	**187**	229	210
12	NST201709OT002	27235151	June 16th	6	80	45	55	143.9	149.0	-5.1	**55**	126	111
13	NST201710MC001	27235178	June 29th	8	199	119	129	221.0	222.2	-1.2	**189**	241	145
14	NST201710MC002	27235179	May 29th	6	226	196	201	172.5	174.5	-2.0	**201**	224	218
15	NST201710MC003	27235180	June 21st	14	190	130	115	149.5	143.0	+6.5	**115**	227	203
16	NST201713DA001	27235208	June 28th	5	137	130	140	204.8	207.4	-2.6	**185**	219	187
17	NST201714GK003	27235186	June 9th	6	240	160	175	218.2	225.3	-7.1	**250**	230	217
18	NST201714GK005	27235189	June 16th	4	230	235	250	212.0	212.0	0	**250**	206	187
19	NST201714GK006	27235187	June 15th	5	175	120	155	201.1	223.1	-22.0	**205**	219	206
20	NST201716HA001	27235087	June 16th	8	225	105	115	132.1	136.6	-4.4	**115**	276	238
21	NST201716HA002	27235203	June 13th	3	190	100	105	82.2	86.4	-4.2	**105**	268	248
22	NST201716HA003	27235204	June 8th	5	200	145	155	201.3	205.9	-4.7	**180**	236	217
23	NST201716HA004	27235086	June 25th	7	196	96	106	110.4	116.5	-6.1	**106**	279	250
24	NST201716HA005	27235205	June 21st	8	210	90	100	168.5	174.1	-5.7	**115**	225	202
25	NST201719EX001	27235172	June 9th	5	147	106	117	224.8	228.1	-3.3	**152**	231	191
26	NST201719EX003	27235154	July 7th	10	144	153	149	209.4	208.1	+1.3	**198**	223	201
27	NST201721CN002	27235144	June 1st	5	152	170	180	239.5	243.3	-3.8	**195**	231	217
30	NST201723CB004	27235198	June 12th	5	136	121	131	238.8	243.7	-4.8	**156**	215	197
31	NST201723CB005	27235199	June 15th	5	147	160	169	187.1	189.1	-2.1	**169**	250	226
35	NST201724SS001	27235176	June 26th	5	203	163	174	224.5	226.7	-2.2	**184**	250	210
36	NST201724SS002	27235175	June 24th	8	150	157	167	210.9	215.0	-4.2	**167**	214	202
37	NST201726FF002	27235183	June 8th	4	185	150	160	178.7	183.3	-4.6	**185**	227	211
38	NST201726FF004	27228470	June 19th	3	110	65	95	139.2	155.6	-16.4	**95**	150	144
39	NST201726FF005	27235184	June 29th	4	170	105	115	161.7	168.4	-6.7	**140**	186	175
40	NST201726FF006	27235185	June 21st	4	185	142	152	192.5	195.6	-3.1	**177**	237	208
41	NST201727AN001	27235147	June 8th	4	80	69	84	244.4	247.5	-3.2	**144**	116	97
Grand mean					**176**	**131**	**142**	**188.0**	**193.1**	**-5.1**	**163**	**223**	**199**

price ratios in Adapt-N are not adjusted for individual growers or fields, but done at the agronomist level, NutrientStar presumably used the default values to generate the recommendation in Adapt-N, but assumed $4/bu and $0.4/lbs (ratio=0.1) for the determination of the EONR and subsequent economic analysis. Shifting from a price ratio of 0.14 to 0.1 will drive Adapt-N recommendation upward at about 10 lbs/ac. Further background information on the impact of price ratios on Adapt-N recommendations is provided in Appendix B.

c. Agronomic efficiency following correction of yield

The total N rates for either Grower, Adapt-N or the Economical Optimum N rate (EONR) are presented in Tables 5 and 6, and in Figure 1. For Adapt-N, two N rates are presented – where the original EY was used (as found in Adapt-N fields set up by NutrientStar) and where the EY was adjusted. For the latter, we changed EY to the respective trial maximal yield value (rounded to the nearest 5 bu/ac) if the prescribed EY underestimated the maximal achieved yield. The results suggest that when the original EY was used, Adapt-N underestimated the EONR with a mean difference (mean absolute difference) of -36 (55) lbs/ac for the 2016 season, and -57 (61) lbs/ac for the 2017 season. The respective RMSEs with the EONR for the 2016 and 2017 seasons were 68 and 69 lbs/ac, respectively. When the EY was modified to correct for cases where it was underestimated, Adapt-N recommendations improved considerably, with a mean difference (mean absolute difference) of -25 (47) and -37 (49), and an RMSE of 57 and 61 lbs/ac, for the 2016 and 2017 seasons, respectively. It is noted that using the more conservative quadratic-plateau response function to calculate the EONR significantly improves Adapt-N performance. This is further discussed in section e.

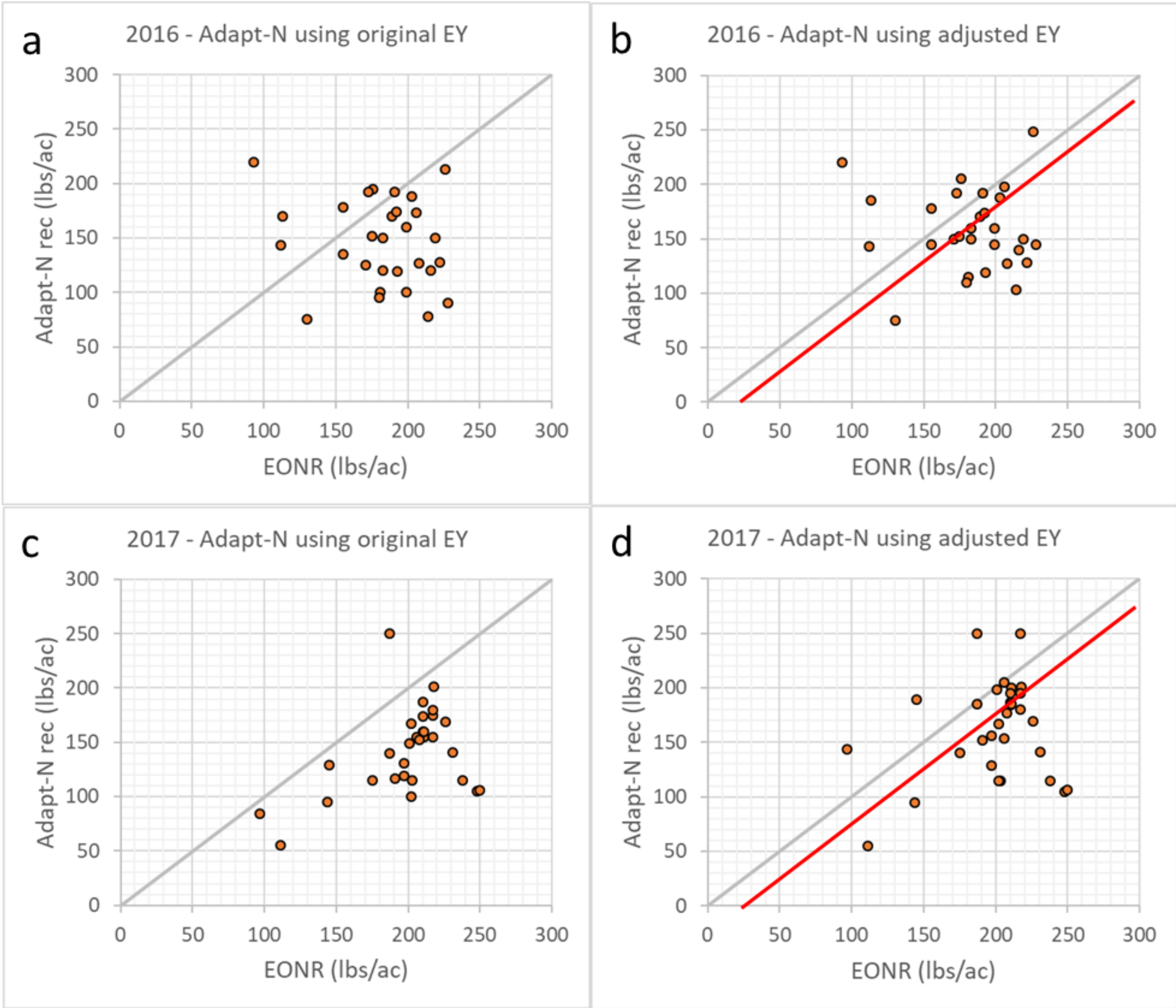

Figure 1. Comparison of Adapt-N total N recommendation and the EONR (quadratic response function; 2016, top; 2017, bottom) when N recommendation were generated using the original EY (a,c) or the adjusted EY (b,d). Red lines in graphs b and d represent the translation of the 1:1 line with EONR adjustment from quadratic to quadratic-plateau adjustment discussed in section e.

d. Economic efficiency

To conform to the NutrientStar analysis, the profit loss from the EONR was calculated assuming values of $0.4 per lbs of N and $4 per bushel of yield. The results are presented in Tables 8 and 9 for the 2016 and 2017 seasons, respectively. For the trials we were able to reconstruct, Adapt-N profit loss from the EONR averaged $27/ac and $43/ac for the 2016 and 2017 seasons, respectively, which is an improvement over the ones published by NutrientStar ($38/ac and $61/ac, respectively). These differences can be explained by the following:

a. Adjustments to field set ups in the 2016 season based on information from the spreadsheet provided by NutrientStar (discussed in section 3a).
b. A subtle increase in N rates in our re-analysis from different price ratios used by NutrientStar. This issue was discussed in section 4b. The effect of the price ratio factor on N recommendations is discussed in Appendix B.
c. The NutrientStar report includes a trial where Adapt-N rates presumably led to a very high profit loss of $357/ac from the EONR, disproportionally affecting the mean loss value. This trial was however absent from the Adapt-N account database and could not be reconstructed or tested, and was therefore disregarded from our analysis. This outlier trial suggests problems with implementation anyway.
d. There were 7 and 5 trials in 2016 and 2017, respectively, where NutrientStar found the AONR to be equal or higher than the highest N rate applied (250 lbs/ac). NutrientStar opted to analyze these trials separately. In this reanalysis we chose to leave these trials in and consider them to be valid, as the calculated EONR is lower than the highest N rate. The average profit loss for these trials was $38/ac and $27/ac, for the 2016 and 2017 seasons, respectively. For 2017 these losses are notably lower than the average Adapt-N profit loss reported by NutrientStar.

As expected, when the adjusted expected yield was used to generate the N recommendation, the profit loss from the EONR decreased to $25.6/ac.

Table 10 presents the economic results for the trials where the N response curve was found statistically insignificant ($p>0.1$). The EONR here was assumed to be at the lowest N rate of 100 lbs/ac. For these trials the generally lower N recommendations by Adapt-N did much better than Grower, with an average profit loss from EONR of $24/ac (Adjusted EY) and $39/ac, for Adapt-N and Grower, respectively.

Table 11 presents the economic results for trials where the EONR was calculated to be at the highest N rate in the trial. It was assumed here that the EONR is at the highest N rate. These trials show clear advantages for the higher N rates when updated for the use of an efficiency factor.

Overall, following input corrections and using the quadratic response function, Adapt-N results were marginally less economical than the Grower N management with less N inputs: $17 lower profit achieved with 21 lbs/ac lower N rate for trials where the EONR could be established, and within $10 profit with 23 lbs/ac lower N rate considering all reconstructed trials.

Table 8. 2016 season – economic efficiency based on the quadratic response function. $4/bu and $0.4/lb were used to calculate the return. Shaded cells are cases where NutrientStar found the AONR to be out of the 100-250 lbs/ac range and didn't report the loss of Adapt-N rate from the EONR.

ID in this report	ID in program	ZSID in adapt-N	Grower loss from EONR ($/ac)	Adapt-N loss from EONR ($/ac) as report by NS	Adapt-N loss from EONR ($/ac)	Adapt-N + EY correction loss from EONR ($/ac)
1	NST-01BCS00293	27235088	4.2	117	114.5	34.1
2	NST-01BCS00294	27235089	5.5	25	13.6	3.0
3	NST-01BCS00295	27235090	18.5	201	133.2	83.2
4	NST-01BCS00296	27235091	2.8	50	49.8	33.3
5	NST-01BCS00297	27235092	0.0	11	5.9	2.9
6	NST-01BCS00298	27235093	0.4	33	31.0	21.0
7	NST-01BCS00299	27235094	0.0	31	13.7	4.4
8	NST-01BCS00300	27235095	2.2	20	1.4	1.4
10	NST-03ATA00007	27235098	3.7	19	22.3	22.3
12	NST-03ATA00009	27235100	10.1		114.9	76.6
15	NST-04PAS00003	27235103	0.1	4	1.6	1.6
16	NST-04PAS00004	27235104	0.1		1.9	1.9
18	NST-05GRN00015	27235106	0.8		0.4	1.3
19	NST-05GRN00016	27235107	6.1	11	2.3	5.3
20	NST-05GRN00017	27235108	13.3	3	5.7	9.1
21	NST-05GRN00018	27235109	0.1	21	16.3	1.0
22	NST-07NAG00013	27235132	1.4	118	44.5±	44.5
23	NST-07NAG00014	27235133	0.7		26.5	26.5
24	NST-09OTE00001	27235111	0.3		21.3	21.3
26	NST-09OTE00004	27235113	0.9	5	3.5	3.5
29	NST-10MCN00012	27235116	0.0	7	3.0	3.0
34	NST-14GKC00013	27235121	0.6	4	1.1	1.1
35	NST-14GKC00016	27235122	3.4		101.0	36.6
37	NST-14GKC00018	27235123	3.2		0.7	0.1
38	NST-16HAS00006	27235124	12.5	7	6.0	6.0
39	NST-16HAS00016	27235125	6.0	14	9.8	9.8
40	NST-16HAS00017	27235126	0.0	26	8.1	8.1
44	NST-18ANZ00001	27235130	10.0	111	44.0	44.0
45	NST-19EXT00001	27235131	8.5	2	2.8	2.8
Mean (sd)			**4.0 (4.8)**	**38.2 (50.4)**	**27.5 (38.12)**	**17.6 (21.8)**

Table 9. 2017 season – economic efficiency based on the quadratic response function. $4/bu and $0.4/lb were used to calculate the return. A few cases where the difference in economics between Nutrientstar and our analysis is substantial are marked in red. Shaded cells are cases where NutrientStar found the AONR to be out of the 100-250 lbs/ac range and didn't report the loss of Adapt-N rate from the EONR.

ID in this report	ID in program	ZSID in adapt-N	Grower loss from EONR ($/ac)	Adapt-N loss from EONR ($/ac) as report by NS	Adapt-N loss from EONR ($/ac)	Adapt-N + EY correction loss from EONR ($/ac)
1	NST2017ILLB001	27234987	0.8	82	20.5	0.8
2	NST2017ILLB002	27235201	0.0		13.9	10.6
6	NST201705GR002	27235191	2.8		11.1	1.0
8	NST201707NA001	27235195	0.4		63.1	63.1
9	NST201707NA002	27235194	23.1	182	128.0	128.0
11	NST201709OT001	27235152	18.5	8	5.2	5.2
12	NST201709OT002	27235151	13.0	59	42.5	42.5
13	NST201710MC001	27235178	6.1	1	0.5	4.1
14	NST201710MC002	27235179	2.0	15	9.0	9.0
15	NST201710MC003	27235180	1.5	45	65.0	65.0
16	NST201713DA001	27235208	15.8	21	14.0	0.0
17	NST201714GK003	27235186	6.7	49	26.4	10.7
18	NST201714GK005	27235189	13.5	15	21.5	21.5
19	NST201714GK006	27235187	14.8	114	40.2	0.0
20	NST201716HA001	27235087	1.0	95	81.6	81.6
21	NST201716HA002	27235203	33.5	220	204.9	204.9
22	NST201716HA003	27235204	3.2	57	42.1	15.1
23	NST201716HA004	27235086	20.0	162	141.7	141.7
24	NST201716HA005	27235205	0.5	109	90.7	66.0
25	NST201719EX001	27235172	9.9	37	27.9	7.8
26	NST201719EX003	27235154	29.0	21	24.1	0.1
27	NST201721CN002	27235144	57.0	30	18.3	6.4
30	NST201723CB004	27235198	39.9	62	46.8	17.9
31	NST201723CB005	27235199	27.0		14.1	14.1
35	NST201724SS001	27235176	0.2	11	6.5	3.4
36	NST201724SS002	27235175	42.5	32	19.1	19.1
37	NST201726FF002	27235183	9.0	49	34.1	9.0
38	NST201726FF004	27228470	15.9		33.2	33.2
39	NST201726FF005	27235184	0.4	85	62.6	21.3
40	NST201726FF006	27235185	3.7	30	21.9	6.7
41	NST201727AN001	27235147	3.1	8	1.8	15.1
Mean			**13.4 (14.4)**	**61.5 (55.6)**	**43.0 (45.0)**	**33.1 (47.4)**

Table 10. Economic efficiency of trials with non-significant response curves. The EONR is assumed to be at 100 lbs/ac, and shaded cells are trials with N rates lower than this value. $4/bu and $0.4/lb were used to calculate the return.

ID in this report	Season	ID in program	ZSID in adapt-N	Grower loss from EONR ($/ac)	Adapt-N loss from EONR as reported by NS ($/ac)	Adapt-N loss from EONR ($/ac)	Adapt-N + EY correction loss from EONR ($/ac)
9	2016	NST-02MOF00002	27235096	59.2	NA	24.4	24.4
11	2016	NST-03ATA00008	27235099	48.4	7.0	4.8	14.8
14	2016	NST-03ATA00128	27235102	66.4	16.0	24.4	28.4
17	2016	NST-05GRN00014	27235105	42.4	24.0	24.0	32.0
25	2016	NST-09OTE00003	27235112				
27	2016	NST-09OTE00005	27235114		22.0	10.0	20.0
28	2016	NST-10MCN00011	27235115	20.0	14.0	24.0	32.0
30	2016	NST-10MCN00013	27235117	52.0	16.0	20.0	20.0
31	2016	NST-12DAL00003	27235118	28.0	36.0	12.0	12.0
32	2016	NST-13DAR00013	27235119		26.0	26.0	26.0
33	2016	NST-13DAR00120	27235120	21.6	24.0	27.6	27.6
36	2016	NST-14GKC00017	27235135	36.0			
41	2016	NST-16HAS00018	27235127	46.0			
42	2016	NST-16HAS00019	27235128	46.0			
43	2016	NST-16HAS00020	27235129	50.8	7.0	10.8	10.8
4	2017	NST201704PA001	27235137	16.0	NA	14.0	14.0
28	2017	NST201721CN003	27235146	36.0	NA	36.0	50.0
32	2017	NST201723CB006	27235200	20.0			
34	2017	NST201723CB008	27235197		28.0	20.0	20.0
Mean				**39.3 (15.0)**	**20.0 (8.5)**	**19.9 (8.1)**	**23.7 (10.0)**

NA – trial not found at the non-significant list of trials by Nutrient Star

Table 11. Economic efficiency of trials where the EONR was at or higher than the maximal N rate used in the trial based on the quadratic response function. The EONR was assumed here to be at the maximal N rate. $4/bu and $0.4/lbs were used to calculate the return. In 2017 Nutrient Star didn't publish losses from max applied N rate for Adapt-N trials, only the respective losses from the grower N rates.

ID in this report	Season	ID in program	ZSID in adapt-N	Grower loss from EONR ($/ac)	Adapt-N loss from EONR as reported by NS ($/ac)	Adapt-N loss from EONR ($/ac)	Adapt-N + EY correction loss from EONR ($/ac)
13	2016	NST-03ATA00010	27235101	14.8	81.0	72.0	59.5
3	2017	NST201702MO001	27235206	10.3		42.0	26.0
5	2017	NST201704PA002	27232187	49.1		96.3	70.7
7	2017	NST201705GR003	27235190	67.6		95.6	16.0
10	2017	NST201708MA001	27235181	68.6		53.4	53.4
33	2017	NST201723CB007	27235196	42.6		56.2	47.0
Mean (sd)				**42.1 (22.9)**		**69.2 (20.8)**	**45.4 (18.9)**

e. The effects of the N response fitting function

The choice of the mathematical function used in fitting N response to yield can significantly impact the outcome of technology evaluations from field trials. Cerrato and Blackmer (1990) concluded that "… the most commonly used model, the quadratic model, did not give a valid description of the yield responses and tended to indicate optimal rates of fertilization that were too high. The quadratic-plus-plateau model best described the yield responses observed in this study (Fig. 2)." In their analysis of Iowa N response trials, estimated EONRs using the quadratic-plateau (QP) model function were 24 lbs/ac lower than using the quadratic function (QD; using price ratio=0.1 bu/lb; Table 5 in C&B1990), primarily because the quadratic function poorly models N response near and above the EONR (Figs. 1 and 2 in C&B1990; Fig. 2 in this report). This resulted in an estimated difference in mean economic losses of $7/ac[2].

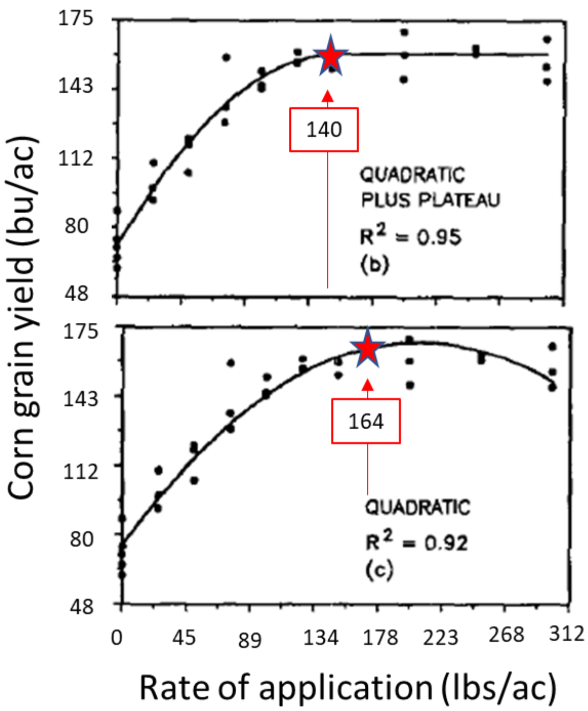

Figure 2. Effect of quadratic-plateau vs. quadratic N response function on the estimation of the Economic Optimum N Rate (red star; 140 lbs/ac for QP and 164 lbs/ac for QD). Graphs and data from Cerrato and Blackmer (1990) with conversions to English units.

[2] Cerrato and Blackmer determined a profit differential from the use of quadratic vs. quadratic-plateau of $16/ha at a price ratio of 3.36 kg/kg (Table 6 in C&B1990), which is equivalent to a price ratio of 0.06 bu/lb. At a price ratio of 0.1 and conversion to English units, the effect of the model fitting function is estimated to be between $16-20/ha or $6-8/ac.

On-farm strip trials, like the ones used in NutrientStar, generally involve a relatively low number of N rates without a check treatment to accommodate uncomplicated implementation and limit grower yield losses at lower rates. But this generally complicates the use of the more appropriate QP function because computational convergence cannot be achieved for many trial analyses. In other words, it is often not possible to derive the best estimates of the EONR and calculate the best estimates of relative partial profits for different recommendation systems.

In a similar study (Sela et al. (2018)), we addressed this concern by analyzing on-farm trials using both the QD and the linear-plateau (LP) functions, which generally provide computational convergence but equally overestimate and underestimate, respectively, the EONR from the more appropriate but computationally elusive QP function (Cerrato and Blackmer, 1990). The mean difference between the EONR derived either by the QD or LP functions in that study was 35 lbs/ac. Assuming that the QP EONR lies at the middle of this range (as found in Cerrato and Blackmer, 1990), the QP EONR for the Sela et al. 2018 study is estimated to be 18 lbs/ac lower than the QD EONR. In the Sela et al. (2018) study the average Adapt-N rate was lower than the EONR when using the QD function (by 20 lbs/ac) but higher than the EONR when using the LP function (by 15 lbs/ac). The average losses from the EONR were minimally impacted by the choice of response function. However, the response function mattered greatly in the economic comparison between Adapt-N vs. MRTN recommendations (which averaged 25 lbs/ac higher). With the QD function Adapt-N provided $3/ac higher profits than MRTN, while using the LP function it averaged $20/ac higher profits, i.e., a profit differential of $17/ac. In other words, profit loss for lower N recommendations are greatly reduced when a more conservative function is used than the QD function. Use of the QP function would be expected to provide a profit benefit for Adapt-N that is intermediate to QD and LP, estimated at $8/ac, aligned with the above estimated $7/ac from the Cerrato and Blackmer analysis. The NutrientStar results are very similar to those in the Sela et al, (2018) paper, where Adapt-N estimates averaged 22 and 25 lbs/ac higher, respectively, than the comparison treatments (Grower and MRTN, respectively).

The analyses by Cerrato and Blackmer (1990) and Sela et al. (2018) are therefore in general agreement that the use of the preferred QP over the QD function impacts the estimated EONR and relative profits: (i) the average EONR is 18-24 lbs/ac lower and (ii) relative profits when comparing tools (here: Adapt-N vs.

Grower) are $6-8/ac higher for the one that averages lower recommendations. We applied intermediate adjustments of -21 lbs/ac for the average EONR and +$7/ac for average profits from the effect of using QP instead of QD functions. Note that the economic effect of shifting from a QD to QP function might vary from trial to trial, and in some cases the reverse happens, but the +$7/ac assumption realistically reflects the average economic response. Based on the QP model, average Adapt-N recommendations with the expected yield adjustments were 9 lbs/ac below the EONR (Table 12). Average Adapt-N profits with QP were $10 lower than Grower for trials where the EONR could be established, and $3 lower partial profit than Grower considering all reconstructed trials. Using the QP function therefore shows Adapt-N with slightly lower profitability than Grower, but with 21 lbs/ac lower N rates.

Based on this NutrientStar data analysis, a new function was developed for Adapt-N to address lower N use efficiencies with poor-yielding fields. I.e., it accounts for the fact that low-yielding fields tend to have other abiotic and biotic constraints (e.g., compaction, drainage, etc.) that reduce N uptake efficiencies. Incorporating this new function resulted in $3 higher profits for Adapt-N vs. Grower considering all reconstructed trials. This is not further discussed in this report, but background information can be made available upon request.

Table 12. Season-average economic optimum N rates based on quadratic and quadratic-plateau response functions compared to Adapt-N and Grower recommendations.

Season	**Quadratic function**	**Quadratic-plateau function**†	**Adapt-N original**	**Adapt-N_ adjusted expected yield**	**Grower**
	Avg EONR	Avg EONR	Avg N rec	Avg N rec	Avg N rec
	- - - - - - - - - -	- - - - - - - - - -	lbs/ac	- - - - - - - - - -	- - - - - - - - - -
2016	182	161	146	157	185
2017	199	178	142	163	176
Average	190	169	144	160	181

† Quadratic-plateau EONR estimates are (quadratic-21).

f. Continued monitoring and the potential benefit of a 2nd sidedress application

Forty two out of 60 trials (70%; Tables 5-6) had sidedress dates earlier than V8. Application of N early in the growing season increases the likelihood for crop N deficiencies later in the season if the sidedress application is followed by a significant amount of rainfall. It was of interest to explore whether continued monitoring of root zone N would identify these N deficiencies and recommend application of supplemental "rescue" N.

Table 13. 2nd sidedress N recommendations for trials where the original sidedress date was earlier than V8. Cases where Adapt-N recommended a 2nd sidedress are marked in red. Cases where there was significant rainfall post first sidedress, but Adapt-N didn't call for a second sidedress application, are marked in blue.

ID in this report	Season	ID in program	ZSID in adapt-N	Original sidedress date	Original growth stage at side dress date	Adapt-N + EY corr N recommendation at original sidedress date (lbs/ac)	V16 sidedress date	Rainfall between 1st and 2nd sidedress dates (in)	N recommendation for growth stage V16 (lbs/ac)
10	2016	NST-03ATA00007	27235098	June 14th	4	119	July 18th	4.5	0
12	2016	NST-03ATA00009	27235100	June 12th	4	103	July 18th	5.5	0
15	2016	NST-04PAS00003	27235103	May 26th	4	178	June 30th	3.1	0
16	2016	NST-04PAS00004	27235104	May 28th	3	143	July 6th	4.0	0
18	2016	NST-05GRN00015	27235106	May 12th	3	248	June 30th	6.1	0
19	2016	NST-05GRN00016	27235107	June 10th	4	205	July 11th	5.8	0
20	2016	NST-05GRN00017	27235108	June 10th	4	185	July 14th	8.1	0
21	2016	NST-05GRN00018	27235109	June 16th	6	198	July 11th	3.5	0
22	2016	NST-07NAG00013	27235132	June 17th	6	127	July 11th	1.9	0
23	2016	NST-07NAG00014	27235133	June 8th	6	128	July 4th	1.9	0
24	2016	NST-09OTE00001	27235111	June 15th	5	150	July 14th	2.3	0
26	2016	NST-09OTE00004	27235113	May 24th	3	152	July 4th	4.1	0
29	2016	NST-10MCN00012	27235116	June 13th	5	188	July 7th	3.7	0
34	2016	NST-14GKC00013	27235121	June 5th	3	174	July 17th	4.8	0
35	2016	NST-14GKC00016	27235122	June 15th	4	145	July 17th	2.0	0
37	2016	NST-14GKC00018	27235123	June 16th	6	145	July 12th	3.5	0
39	2016	NST-16HAS00016	27235125	May 31st	5	160	June 30th	2.5	0
40	2016	NST-16HAS00017	27235126	June 8th	4	192	July 11th	1.9	0
44	2016	NST-18ANZ00001	27235130	June 8th	4	220	July 12th	7.3	20
45	2016	NST-19EXT00001	27235131	June 20th	7	192	July 12th	3.7	0
6	2017	NST201705GR002	27235191	June 1st	5	195	June 30th	5.1	0
8	2017	NST201707NA001	27235195	June 20th	6	141	July 16th	6.8	0
9	2017	NST201707NA002	27235194	June 3rd	4	154	July 4th	5.2	0
12	2017	NST201709OT002	27235151	June 16th	6	55	July 11th	7.6	0
14	2017	NST201710MC002	27235179	May 29th	6	201	June 19th	2.3	0
16	2017	NST201713DA001	27235208	June 28th	5	185	July 25th	5.1	0
17	2017	NST201714GK003	27235186	June 9th	6	250	July 2nd	4.2	0
18	2017	NST201714GK005	27235189	June 16th	4	250	July 20th	4.9	0
19	2017	NST201714GK006	27235187	June 15th	5	205	July 11th	8.6	5
21	2017	NST201716HA002	27235203	June 13th	3	105	July 19th	9.7	15
22	2017	NST201716HA003	27235204	June 8th	5	180	July 3rd	6.3	0
23	2017	NST201716HA004	27235086	June 25th	7	106	July 15th	8.7	5
25	2017	NST201719EX001	27235172	June 9th	5	152	July 12th	6.1	0
27	2017	NST201721CN002	27235144	June 1st	5	195	June 30th	2.7	0
30	2017	NST201723CB004	27235198	June 12th	5	156	July 12th	7.5	0
31	2017	NST201723CB005	27235199	June 15th	5	169	July 16th	3.3	0
35	2017	NST201724SS001	27235176	June 26th	5	184	July 29th	4.7	0
37	2017	NST201726FF002	27235183	June 8th	4	185	July 14th	9.8	20
38	2017	NST201726FF004	27228470	June 19th	3	95	July 27th	10.6	0
39	2017	NST201726FF005	27235184	June 29th	4	140	July 30th	8.0	30
40	2017	NST201726FF006	27235185	June 21st	4	177	July 22nd	11.0	30
41	2017	NST201727AN001	27235147	June 8th	4	144	July 16th	5.0	0

Therefore, for all trials where the original sidedress N was applied earlier than growth stage V8, an additional recommendation was generated at growth stage V16. The results are summarized at Table 13. For the majority of trials, no additional N was needed at V16. In the cases where it was recommended, it was associated with high rainfall after the sidedress application, typically more than 8" of cumulative rainfall (marked red in Table 13). However, there were a few cases where no additional N was recommended despite more than 8" of cumulative rainfall after application (marked blue), possibly due to better rainfall distribution, high profile rooting depth, or other factors affecting the availability of N in the root zone. In general, this suggests that Adapt-N accounts adequately for the increased risk of losses with early N rate recommendations and that additional N is only recommended in cases of very high and intense post-sidedress rainfall.

Conclusions

This report presents a re-analysis of the NutrientStar trial data conducted in the US Corn Belt states. Although the overall statistical analysis by NutrientStar appears correctly executed, issues were identified with input data for some trials, including underestimated yield potentials, unusual SOM levels for some soils, and abnormally shallow rooting depths. Many trials also involved sidedress recommendations and applications that were outside the optimal time window for an in-season tool like Adapt-N (mostly very early applications). In addition, N responses were fitted with a quadratic function which tends to predict high EONRs and can considerably underestimate the economic benefits of conservative N recommendation tools like Adapt-N.

Differences were found between this reanalysis and the results published by NutrientStar for several other reasons:

- differences between N applications reported in raw experimental data spreadsheet and the actual field set up by NutrientStar;
- differential price ratios used by NutrientStar to generate Adapt-N recommendations compared to those used in the economic analysis;

- the inclusion in this reanalysis of a few trials NutrientStar chose to analyze separately due to the AONR being at the highest N rate applied.

Overall, the NutrientStar evaluation of Adapt-N was considerably impacted by specifics around field trial implementation and the use of input information. Some of these concerns could not be corrected after the fact, e.g., trials involving very early sidedress applications and uncorrectable soil input values. This analysis demonstrated the sensitivity of Adapt-N to imprecise model inputs. NutrientStar consultants presumably used their best judgment to supply proper values but yet there were multiple instances of incorrect or unusual input values, notably for the expected yield which was appreciably underestimated by NutrientStar consultants in more than 50% of the cases. The consultants presumably based this on guidelines in an older version of the Adapt-N manual (Moebius-Clune et al., 2014) where it is suggested to use the fourth highest yield in the last five yield records available. For unknown reasons, this apparently resulted in generally low yield potential estimates. It is unclear whether this was the result of (i) user error, (ii) poor or unavailable yield records, or (iii) low past yield achievements due to abiotic or biotic stresses, including systematic under-fertilization.

After corrections, increases in N rates for Adapt-N in this reanalysis made a considerable difference in the calculated yield, and consequently the economic results (profit loss from EONR reduced to $35/ac in this reanalysis from $57.5/ac in the published NutrientStar report). This was more notable for the generally wetter 2017 season where we found a much-lower profit loss (from $61/ac to $43/ac) in the trials we were able to reconstruct (note that NutrientStar reports a higher loss of $72/ac in their report). When the expected yields were corrected for the trials where they were underestimated, the profit loss further decreased significantly to $26/ac. The early sidedress dates had a modest impact in that several sites in 2017 would have benefitted from continued monitoring of the field N status. <u>These results reflect the Adapt-N evaluation with more correct use of the tool, but still with the use of quadratic N response functions.</u>

Based on the quadratic response function, Adapt-N on average showed profits somewhat lower than the Grower practice. However, the choice of N response function, quadratic vs. quadratic-plateau, also impacted the partial profit analysis of Adapt-N vs. Grower. We determined that the use of the preferred quadratic-plateau N response equation generates average Adapt-N rates which are near the EONR, and near-identical profits for Adapt-N relative to Grower with significantly lower N inputs. Thereby, Adapt-N proved overall strong sustainability credentials despite the implementation of the trials that was suboptimal for an in-season management tool like Adapt-N.

A final comment about challenges with independent evaluation of Adapt-N and similar tools. Based on the outcomes from this study, those from other independent evaluations, and our own earlier on-farm trials, we have observed inherent challenges with evaluations of dynamic-adaptive N management tools like Adapt-N:

- The full potential of the tool is associated with later in-season N applications than done in many of those trials.
- Use of input data is critical. Outcomes may be considerably different when based on fully correct use of the tool vs. use by less experienced practitioners. Also, pre-planned experimental designs don't adequately consider retroactive adjustments that can be impactful to the results, and they do not encompass the notion that a tool's use may initially be inexact but improves with experience, coaching, and refinement (e.g., yield adjustments when they proof incorrect).
- The choice of N response function significantly impacts conclusions around the economic value of N technologies. On-farm trials are often analyzed using the quadratic rather than the more appropriate quadratic-plateau response function, but this disfavors N tools that offer conservative (more sustainable) recommendations.

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Appendix A – List of N application discrepancies between original field set up and raw data provided by NutrientStar

ID in program	ZSID in adapt-N	Original comments in the spreadsheet	comments
NST-01BCS00300	27235095	Agrotain & 100 lbs N from UAN Spring Pre-plant & Sidedress Injected	Comments suggest pre plant of 100, and it is set to 45 in the interface
NST-02MOF00002	27235096	31 lbs N from Starter & 69 lbs N from NH3 Sidedress	comments disregard 27 lbs of fall N
NST-03ATA00007	27235098	42 lbs N from Starter & 63 lbs N from NH3 Sidedress	Comments disregard 21 lbs of fall N
NST-03ATA00008	27235099	42 lbs N from Starter & 58 lbs N from UAN Sidedress	Comments disregard 21 lbs of fall N
NST-03ATA00009	27235100	18 lbs N from Starter & 82 lbs N from UAN With Planter & Sidedress Injected	Comments suggest starter of 18, and it is set to 39 in the interface
NST-03ATA00010	27235101	20 lbs N from Starter & 84 lbs N from UAN With Planter & Sidedress Injected	Comments suggest starter of 20, and it is set to 41 in the interface
NST-03ATA00128	27235102	61 lbs N from Starter & 50 lbs N from NH3 Sidedress	Comments suggest starter and preplant of 61, and it is set to 76 in the interface
NST-05GRN00014	27235105	15 lbs N from Starter & 100 lbs N from UAN With Planter & Sidedress Injected	Comments disregard 11 lbs of Spring N
NST-05GRN00016	27235107	20 lbs N from UAN With Planter & 80 lbs N from NH3 Sidedress	Comments disregard 27 lbs of Fall N
NST-05GRN00017	27235108	100 lbs N from NH3 Sidedress	Comments disregard 20 lbs of Spring preplant and starter
NST-10MCN00011	27235115	5 lbs N from Starter & 50 lbs N from UAN With Planter & 50 lbs N from NH3 Sidedress	Adapt-N inputs disregard 5 lbs of Spring preplant and starter.
NST-12DAL00003	27235118	100 lbs N from UAN Spring Pre-plant & Sidedress Injected	Comments disregard 20 lbs of Fall preplant and starter
NST-13DAR00013	27235119	35 lbs N from Urea Sidedress & 65 lbs N from Swine Surface Applied (1 yrs)	Comments disregard a starter of 35 lbs.
NST-14GKC00013	27235121	4 lbs N from Starter & 96 lbs N from UAN With Planter & Sidedress Injected	Comments say starter of 4 while it is 39 in adapt-N.
NST-14GKC00016	27235122	10 lbs N from Starter & 91 lbs N from UAN With Planter & Sidedress Injected	Comments suggest starter of 10 while it is 23 in adapt-N.

Appendix B - Explanation of profit risk factor

The mass balance equation used by Adapt-N accounts for the price ratio in the Nprofit_risk component:

Nrec = Nexp_yld – Ncrop_now – Nsoil_now – Nrot_credit – Nfut_gain_loss – **Nprofit_risk**

where Nrec is the N rate recommendation; Nexp_yld is the crop N content needed to achieve a yield target; Ncrop_now and Nsoil_now are the N content in the crop and soil as calculated by the PNM model for the current simulation date; Nrot_credit is the (partial) N credit from soybean crop rotation; Nfut_gain_loss is a probabilistic estimate of future N gains minus losses until the end of the growing season, based on model simulations with historical rainfall distribution functions; and Nprofit_risk is the economic adjustment factor that integrates corrections for fertilizer and grain prices, as well as a stochastic assessment of the relative profit risk of under-fertilization vs. over-fertilization.

In essence, when grain price is high relatively to the fertilizer price, more N is needed to alleviate the risk of yield loss. If the NutrientStar economic analysis had been based on the same price ratio as used in generating the Adapt-N recommendations, they would have been adjusted upward.