Optimal Nitrogen Fertilizer Rates Given Current Fertilizer and Crop Prices

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based on crop and fertilizer price forecasts made 7/31/06

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Abstract

Given the recent increase in nitrogen prices, it is ever more important for producers to make management decisions that account for both input (fertilizer) and output (crop) prices in order to maximize profits. Historically, few Universities explicitly considered prices when making fertilizer recommendations. The cost of ignoring prices was low given nitrogen prices such as those observed from 1976-1994, however as nitrogen prices have increased, the cost of ignoring prices in fertilizer decisions has increased. This paper presents results from previous research where prices are incorporated into K-State's official nitrogen fertilizer recommendations. The high crop prices forecasted for 2007 offset much of the impact of higher nitrogen prices, but irrigated producers still face high pumping costs which also need to be accounted for. Based on forecasts for nitrogen fertilizer prices and crop prices for the upcoming year, optimal nitrogen levels on dryland crops are generally 2% to 5% lower than official KSU recommendations. Reductions in optimal rates for irrigated crops are considerably higher, 10% to 20%, due to the impact of higher pumping costs as well as the higher nitrogen costs. It is important that producers consider optimal nitrogen rates for their own situations as opposed to relying upon general recommendations so as to maximize returns to nitrogen fertilizer.

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Background

Not surprisingly, for the last year or so web-based message boards frequented by crop production decision makers reveal considerable concern and frustration regarding the reduced expected profits induced by high fertilizer prices, and especially around the fertilizer decision itself. Farmers are asking questions like, Should I back off on my fertilizer rates? If so, how much? Should I change my application practices to get a bigger bang for my fertilizer buck? If so, how much can I back off on rates when I do this? Does the current strength in crop prices impact what I should do? Such questions can only be answered through an understanding of crop yield response to fertilizer. Hence, this paper discusses yield response functions (yield models) that were estimated for Kansas wheat, corn, and grain sorghum – functions that result in suggested adjustments to Kansas State University's (KSU) N recommendations (*Nrec*) for consideration by crop decision makers in the face of rapidly changing N and crop prices.

Prices

Nitrogen fertilizer prices have been increasing steadily from 2002 and reached historical highs, in nominal terms, in the winter of 2005/06. These high prices have generated considerable questions and discussion about how this impacts optimal fertilizer rates. Since peaking this past winter, nitrogen fertilizer prices have been falling, however forecasts for the second half of 2006 and 2007 show prices increasing from current levels (Figure 1). Figure 2 shows average prices for the fall/winter (Oct-Dec) and winter/spring (Feb-Apr) time periods the last six years as well as forecasts for the upcoming year by nitrogen source. Fall/winter prices for all nitrogen sources are forecasted to be down from last year by about 3¢ per unit (lb) of N, however winter/spring prices are forecasted to be up 3-4¢ per unit. Averaged across time periods and sources, prices are expected to be similar to last year; however, this is almost 13¢ per unit higher (+59.4%) than the longer term average (1999/00 - 2003/04). Thus, from a fertilizer price standpoint, decisions for this next year might be similar to last year, but considerably different from more "normal" years reflecting longer-term prices. The key point is that, given the forecasts for nitrogen fertilizer prices for this next year, applying the economical rate of nitrogen will be critically important. The cost of applying excess nitrogen is obviously high due to fertilizer prices. On the other hand, the cost of under-applying is also high if yields are reduced. Thus, understanding how relative prices impact optimal fertilizer levels is critical for producers wanting to maximize net returns.

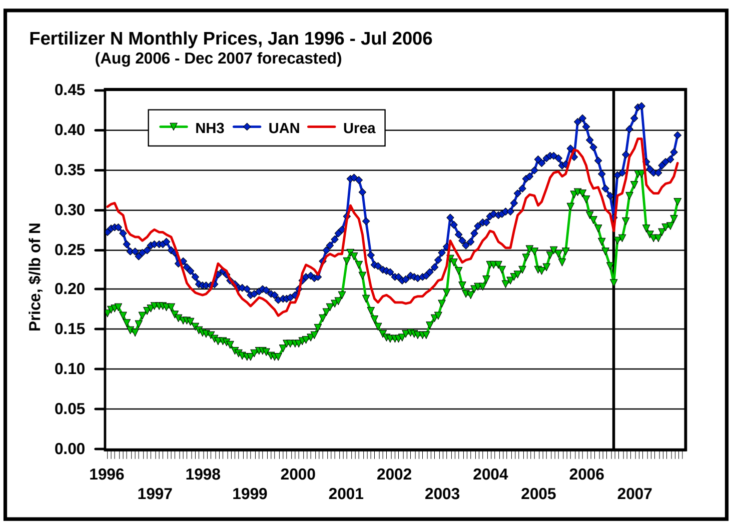

Figure 1

In addition to nitrogen fertilizer prices, Figure 2 shows average harvest-time crop prices for wheat, corn, sorghum, and soybeans in Kansas since 2000.[1] Forecasted wheat prices for 2007 are 28¢ per bushel lower than 2006 prices, but they are $1.55 per bushel higher than the 2000-04 5-year average. Corn and sorghum price forecasts for 2007 are 57¢ and 39¢ per bushel higher than 2006 prices, respectively, and they are over 80¢ per bushel higher than the 5-year average. Because optimal fertilizer rates depend on relative prices, i.e., price of fertilizer relative to price of crop, the higher crop prices may offset some or all of the impact of the higher nitrogen prices. That is, the higher crop prices may suggest that fertilizer rates should not be reduced in spite of the historically high nitrogen prices. Once again, it is important that producers understand how these relative prices impact optimal rates so they can make profit-maximizing fertilizer decisions this fall and winter.

Nitrogen Fertilizer Prices, Corn Belt

	Nitrogen Source / Time Period							
	NH3 (82%)		UAN (32%)		Urea (46%)		Weighted	
Year	Oct-Dec	Feb-Apr	Oct-Dec	Feb-Apr	Oct-Dec	Feb-Apr	Average*	% chg
1999/00	$0.132	$0.138	$0.191	$0.215	$0.181	$0.226	$0.176	-----
2000/01	$0.187	$0.240	$0.269	$0.338	$0.243	$0.297	$0.256	45.5%
2001/02	$0.141	$0.141	$0.224	$0.213	$0.191	$0.184	$0.177	-31.0%
2002/03	$0.162	$0.223	$0.229	$0.275	$0.206	$0.248	$0.219	24.1%
2003/04	$0.207	$0.228	$0.282	$0.294	$0.259	$0.263	$0.251	14.3%
2004/05	$0.246	$0.231	$0.343	$0.364	$0.316	$0.325	$0.296	18.1%
2005/06	$0.321	$0.285	$0.396	$0.376	$0.372	$0.330	$0.341	15.0%
2006/07 F	$0.289	$0.322	$0.372	$0.406	$0.342	$0.369	$0.344	1.0%
06/07 - 05/06	($0.032)	$0.037	($0.024)	$0.030	($0.030)	$0.040	$0.003	1.0%
06/07 - Avg(99/04)	$0.123	$0.128	$0.190	$0.198	$0.126	$0.126	$0.128	59.4%

* Weighted average based on 40% NH3, 25% UAN, and 35% Urea split equally between Oct-Dec and Feb-Apr

F = forecast

Harvest Crop Prices, Kansas^

Year	Wheat	Corn	Sorghum	Soybeans
2000	$2.59	$1.70	$1.68	$4.45
2001	$2.72	$1.90	$1.79	$4.11
2002	$3.14	$2.57	$2.46	$5.20
2003	$2.79	$2.14	$2.14	$6.87
2004	$3.41	$1.90	$1.72	$4.83
2005	$3.12	$1.71	$1.60	$5.30
2006 F	$4.75	$2.35	$2.40	$5.45
2007 F	$4.48	$2.92	$2.80	$6.07
2007 - 2006	($0.28)	$0.57	$0.39	$0.62
2007 - Avg(00/04)	$1.55	$0.88	$0.84	$0.97

^ Average of Colby, Scott City, Beloit, Hutchinson, Emporia, and Topeka

F = forecast (wheat in 2006 is an actual price) where 2006 forecasts are based forward bids and 2007 forecasts are based on futures adjusted for basis).

Figure 2

Production Function

Whether from the soil or from annual applications, nutrients such as nitrogen, phosphorus, and potassium are required for optimal crop production. The relationship between crop yield and nutrients, referred to as a production function, has long been researched in order to quantify that relationship so that fertilizer recommendations can be made. As a general rule, University fertilizer recommendations do not explicitly take into account fertilizer prices. That is, fertilizer recommendations are made, typically based upon soil test results and a yield goal, with no acknowledgment of crop or fertilizer prices. While this may make sense *agronomically*, it does not necessarily make sense *economically*. In other words, crop and fertilizer prices do not impact how a plant responds to inputs and thus what is optimal from a production standpoint (i.e, maximum yield) does not change. However, because inputs are not free, the optimal level of inputs to use generally will depend on relative prices.

[1] Soybean prices are included in the table for completeness, but the analysis of economic optimal nitrogen rates in this paper only considers wheat, corn, and sorghum.

The key factor determining if prices matter or not, i.e., whether they influence the economic optimal fertilizer level, is whether or not the production function is linear or nonlinear up to the point where yield levels off (plateaus) with additional levels of fertilizer. The literature in the agronomy publications on this topic is somewhat mixed, i.e., production functions are represented as both linear and nonlinear in the literature. From an economic standpoint, linear-plateau production functions are somewhat non-interesting as the economical optimal input level is basically "all or nothing." That is, it will either be economical to apply fertilizer consistent with where yields plateau or none at all, depending on relative prices. Even with the historically high nitrogen prices observed in the winter of 2005/2006, the linear relationships underlying basically all University fertilizer recommendations would suggest an "all" level of nitrogen, i.e., prices were not high enough to drop optimal levels all the way to zero N. On the other hand, if production functions are nonlinear, this implies that diminishing returns exist and the benefit or value of each additional pound of nitrogen applied is less than the previous pound applied. With non-linear production functions, prices do matter in terms of what is optimal.

Appendix A lists web sites for various University fertilizer recommendations. Almost all of these recommendations ignore prices and never provide an explicit production function – one exception is the factsheet for wheat in Nebraska. This implies that the authors of these publications either believe that production functions are linear and hence prices do not matter for all practical purposes, or that they are non-linear but changing prices have little effect on economic optimal fertilizer levels. Figure 3 shows U.S. nitrogen prices, on a per pound of nutrient basis, for three nitrogen sources from 1970-2006. It can be seen that from 1976-1994 nitrogen fertilizer prices were relatively stable from year to year. Thus, it may be that while those people making fertilizer recommendations believe that production functions are nonlinear, they recognize that the relatively stable and low prices of nitrogen never really "come into play" in the production function in a significant way. That is, if nitrogen price is low enough relative to crop prices, the optimal level might always be "close" to where yields are maximized. Hence, the added complexity wrought by incorporating prices into recommendations may be perceived to have little value. However, if this is the reason prices are not explicitly accounted for in fertilizer recommendations, one has to question if this is appropriate given the significant increase in nitrogen prices in recent years.

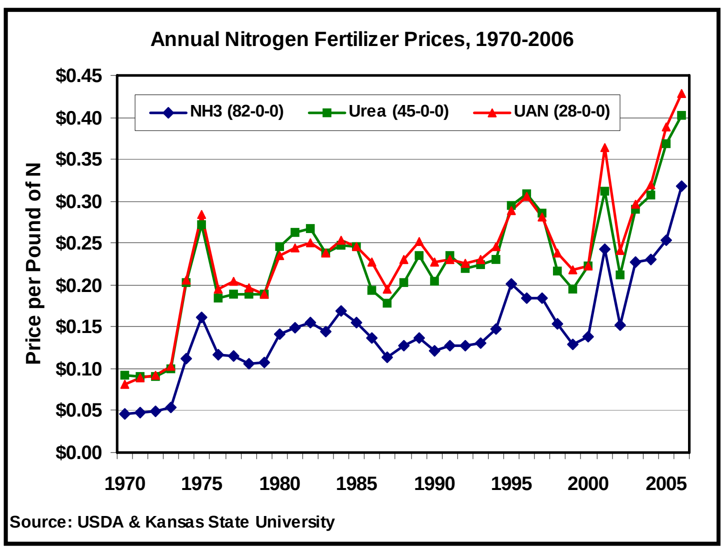

Figure 3

While prices have historically been ignored in nitrogen fertilizer recommendations, evidence that people recognize the potential problem with this is the number of "tools" that have been developed recently to help producers make economic decisions regarding fertilizer rates. That is, numerous web-based calculators and Excel spreadsheets have been introduced recently in response to the high nitrogen fertilizer prices. Appendix B identifies a number of the web sites / tools that are available. While these tools can be helpful for producers as they analyze how prices impact optimal fertilizer rates, producers need to be aware of some potential problems or limitations. Potential problems or limitations of some of these tools for an individual producer wanting to estimate fertilizer rates for a specific field are the following:

1. Inconsistency with published official University recommendations
2. Production function(s) based on limited data not representative of the producer's field
3. Failure to account for the specific yield level of the producer's field
4. Failure to account for the specific soil fertility levels of the producer's field

The relationship between yield and soil properties, nutrient levels, applied fertilizer, weather and other factors is extremely complex. By definition, models are intended to generalize and thus it is important to recognize that concerns such as those listed above (and others) are endemic to any model. However, some of these issues can be more serious in some cases and it is important for producers to at least be aware of them. For example, official University recommendations generally are based on long-term research studies covering wide geographical regions and soil types as well as theoretical relationships between grain yields and nutrient requirements; thus, large deviations from these recommendations should not be taken lightly. Production functions that are estimated from a few specific research trials likely will not match up with broader recommendations. The implication of this is that while the "tool" may be very useful in certain situations, i.e., those that match the specific trial, it will tend to be relevant for a smaller audience. Currently there is debate as to whether or not fertilizer recommendations should be based upon a yield goal (traditional approach). For example, the web tool available from Iowa State University for corn does not include a user input value for yield goal. While this approach is consistent with several research studies, it is not consistent with the fact that higher yields remove (require) higher levels of nitrogen and thus it questionable if this represents a sustainable approach in the long-term.

The bottom line is that any "decision tool" developed that allows producers to consider how prices impact optimal fertilizer rates will have problems. The goal is that production function(s) that serve as the foundation for decision tools are consistent with theoretical expectations, University recommendations (i.e., those that have stood the test of time), and yet can be tailored to reflect a producer's specific situation.

Production Functions and KSU Nitrogen Recommendations

A paper by Kastens et al., *Modifying Yield-Goal-Based Fertilizer Recommendations to Reflect Prices*, develops and outlines a mathematical approach to incorporating crop and nitrogen fertilizer prices into KSU official nitrogen recommendations. Based on an analysis of 18 nitrogen studies from north central and western Kansas, Kastens et al. determined that a quadratic-plateau function was the preferred functional form (of five considered). A quadratic-plateau production function is nonlinear such that relative prices matter, but yet is consistent with a linear-plateau in any given year, which is what many researchers argue based upon the limiting factor framework. Without going into all of the details here, quadratic-plateau production functions were estimated where the resulting economic optimal N rates, which are a function of prices, are exactly equal to the KSU recommendations at long-run crop and fertilizer N prices.[2] In other words, it was assumed that the official recommendations, that do not explicitly include prices, represent the economic optimal rates at long-term average prices. Estimating production functions in this manner results in model-derived rates being internally consistent with official recommendations, yet allows optimal rates to be determined at alternative prices. Readers interested in a more in-depth discussion of linear versus non-linear production functions, alternative functional forms, and the math behind the quadratic-plateau production functions are encouraged to read the Kastens et al. paper.

The estimated production functions for wheat, corn, and sorghum were imbedded in an Excel spreadsheet (Dhuyvetter, Kastens, and Dumler) where producers enter their yield goal, organic matter, soil test N, other N adjustments, and crop and nitrogen prices. Based on this information, “KSU N rec” and “Price adjusted N rec” rates are calculated. KSU N rec (or simply KSU rate) refers to the official University recommendation consistent with formulas reported in *Soil Test Interpretations and Fertilizer Recommendations* (Leikam, Lamond, and Mengel). Keep in mind that the KSU rate does not explicitly account for prices Price adjusted N rec (or optimal N rate) refers to the price-based economic optimal N rate. Economic optimal N rates are calculated where the crop value associated with an additional pound of N is exactly equal to the price of N. Thus the *KSU-CropBudgets2006.xls* spreadsheet (Dhuyvetter, Kastens, and Dumler) allows the user to see the impact prices have on recommended rates.

Nitrogen Recommendations for Wheat

Figure 4 shows the official KSU N recommendation (N rec) for three yield goals for wheat and assuming 2% soil organic matter (SOM), 20 pounds soil test nitrogen (STN), and no other N adjustments. With a 45 bushel yield goal, the recommendation not accounting for prices would be 68 pounds of N. The economic optimal N rates that are a function of wheat and nitrogen prices are also shown for each yield goal at various price combinations. At projected prices (approximately $4.50/bushel for wheat and $0.35/lb for N), the profit-maximizing nitrogen rate is 66 pounds per acre (2.8% less than official recommendation). Thus, it can be seen that the strength in the wheat market largely offsets the high nitrogen prices such that a producer would only want to make very minor changes to nitrogen rates. Furthermore, if nitrogen prices would fall and wheat prices remain strong, optimal rates could even exceed those recommended by KSU (e.g., optimal rate is 70 lbs/ac (+2 lbs) with wheat at $4.50 and N at $0.25). The optimal rates for the higher yield goals (e.g., 60 and 75 bu/ac) basically follow the same pattern of being slightly below KSU official recommendations at current projections for wheat and nitrogen prices. It should be noted that the percent reduction values reported in the bottom half of the figure are dependent on the baseline assumptions and thus producers are encouraged to analyze their own situations as opposed to relying on these values for making decisions. For example, the 2.8% reduction shown in Figure 4 associated with a 45 bushel yield goal ($4.50 wheat and $0.35 N) would increase to 5.0% for a field

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[2] Long-term price for nitrogen was assumed to be $0.21 per pound based on a weighted average of NH_3 (50%), urea (25%), and UAN (25%). Crop prices assumed were $3.20, $2.35, and $2.07 per bushel for wheat, corn, and sorghum, respectively. Long-term averages were based on the 10 years preceding the KSU fertilizer recommendation publication (1993-2002).

with 3% SOM and 40 lbs STN. In other words, percent changes are dependent on starting point, which will vary from field to field.

Nitrogen Recommendations for Wheat

Yield goal, bu/ac			45					60					75		
KSU N rec, lbs/ac*			68					104					140		
N price	Wheat price, $/bu					Wheat price, $/bu					Wheat price, $/bu				
$/lb	$2.50	$3.00	$3.50	$4.00	$4.50	$2.50	$3.00	$3.50	$4.00	$4.50	$2.50	$3.00	$3.50	$4.00	$4.50
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	66	68	69	70	71	101	104	106	107	108	136	140	142	144	145
$0.25	63	65	67	68	70	97	100	103	105	106	131	135	138	141	143
$0.30	60	63	65	67	68	93	97	100	102	104	126	131	135	138	140
$0.35	56	60	63	65	66	89	93	97	99	101	121	127	131	134	137
$0.40	53	57	60	63	64	84	90	94	97	99	116	122	127	131	134
N price															
	Price adjusted N rec reduction					Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	3.3%	0.2%	-1.9%	-3.6%	-4.8%	2.9%	0.2%	-1.7%	-3.1%	-4.2%	2.7%	0.2%	-1.6%	-2.9%	-3.9%
$0.25	7.8%	4.0%	1.3%	-0.7%	-2.3%	6.8%	3.5%	1.2%	-0.6%	-2.0%	6.4%	3.3%	1.1%	-0.6%	-1.9%
$0.30	12.4%	7.8%	4.6%	2.1%	0.2%	10.8%	6.8%	4.0%	1.9%	0.2%	10.0%	6.4%	3.7%	1.7%	0.2%
$0.35	17.0%	11.6%	7.8%	5.0%	2.8%	14.8%	10.2%	6.8%	4.4%	2.4%	13.7%	9.4%	6.4%	4.0%	2.2%
$0.40	21.5%	15.5%	11.1%	7.8%	5.3%	18.8%	13.5%	9.7%	6.8%	4.6%	17.4%	12.5%	9.0%	6.4%	4.3%

Soil organic matter (SOM)=2.0; Soil test nitrogen (STN)=20; Other N adjustment=0
* Based on formulas reported in *Soil Test Interpretations and Fertilizer Recommendations* (MF-2586)

Figure 4

Nitrogen Recommendations for Corn

The official KSU N recommendation (N rec) and the economic optimal N rate for three corn yield goals and assuming 2% SOM, 20 pounds STN, and no other N adjustments are shown in Figure 5. With a 125 bushel yield goal, the recommendation not accounting for prices is 140 pounds of N. The economic optimal N rate at projected prices (approximately $2.90/bushel for corn and $0.35/lb for N) is 134 pounds per acre (4.2% less than the official recommendation). Thus, similar to wheat, the high projected crop price offsets much of the impact of the higher N price. For example, if corn prices were closer to the longer-term average (e.g., $2.05) the optimal N rate would be about 15 lbs/acre less than the KSU recommendation (interpolating between points). Focusing on the 125 bushel yield goal portion of the figure, it can be seen that, over the range of corn and N prices, the economic optimal N rate varies by only 26 pounds per acre. That is, the optimal N rates when corn price is low and N price is high is 119 lbs, compared to 145 lbs when corn price is high and N price is low (i.e., the two extremes). While 26 pounds reflects almost $9/acre at current costs, it also helps explain why people making fertilizer recommendations may not have explicitly factored in prices in the past. That is, over ranges of N prices such as were observed from 1976 to 1994 (Figure 3), economic optimal rates may not vary substantially from year to year. At current projected prices, the economic optimal N rate is 6 lbs/acre less than the KSU recommendation, but that does not mean that returns are increased by $2.10/acre (6 x $0.35) because the corn yield will be slightly less with 134 lbs of N compared to 140 lbs. After accounting for the yield reduction, returns would be about $0.50/acre less with 140 lbs of N compared to the economic optimal of 134 lbs of N. Once again, even though N prices are almost 60% higher than the 2000-04 average, which clearly impacts cash flow, producers should only decrease N rates slightly compared to official KSU recommendations. This is due to partly to the "shape" of the production function, but more importantly because corn prices are projected to be considerably higher than long-term averages.

Nitrogen Recommendations for Corn

Yield goal, bu/ac			75					125					225		
KSU N rec, lbs/ac*			60					140					300		
N price	Corn price, $/bu					Corn price, $/bu					Corn price, $/bu				
$/lb	$2.00	$2.30	$2.60	$2.90	$3.20	$2.00	$2.30	$2.60	$2.90	$3.20	$2.00	$2.30	$2.60	$2.90	$3.20
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	59	60	61	62	63	138	140	142	144	145	296	301	304	307	309
$0.25	56	58	59	60	61	133	136	139	141	142	288	293	298	301	304
$0.30	53	55	57	58	60	129	132	135	137	139	279	286	291	295	299
$0.35	50	53	55	56	58	124	128	131	134	136	271	279	285	289	293
$0.40	48	50	53	55	56	119	124	128	131	133	263	271	278	284	288
N price															
	Price adjusted N rec reduction					Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	2.0%	-0.5%	-2.3%	-3.8%	-5.1%	1.4%	-0.3%	-1.7%	-2.7%	-3.6%	1.2%	-0.3%	-1.4%	-2.3%	-3.0%
$0.25	6.7%	3.6%	1.3%	-0.6%	-2.1%	4.8%	2.6%	0.9%	-0.4%	-1.5%	4.0%	2.2%	0.8%	-0.4%	-1.3%
$0.30	11.4%	7.7%	4.9%	2.6%	0.8%	8.1%	5.5%	3.5%	1.9%	0.6%	6.8%	4.6%	2.9%	1.6%	0.5%
$0.35	16.1%	11.8%	8.5%	5.9%	3.8%	11.5%	8.4%	6.1%	4.2%	2.7%	9.7%	7.1%	5.1%	3.5%	2.3%
$0.40	20.8%	15.9%	12.1%	9.1%	6.7%	14.9%	11.4%	8.7%	6.5%	4.8%	12.5%	9.5%	7.3%	5.5%	4.0%

Soil organic matter (SOM)=2.0; Soil test nitrogen (STN)=20; Other N adjustment=0
* Based on formulas reported in *Soil Test Interpretations and Fertilizer Recommendations* (MF-2586)

Figure 5

Nitrogen Recommendations for Grain Sorghum

Figure 6 shows the official KSU N recommendation (N rec) for three yield goals (2% SOM, 20 pounds STN and no other N adjustments) for grain sorghum along with the economic optimal N rate at various sorghum and N price combinations. With an 80 bushel yield goal, the recommendation not accounting for prices would call for 68 pounds of N. The economic optimal N rate at projected prices (approximately $2.80/bushel for sorghum and $0.35/lb for N) is 65 pounds per acre (4.3% less than official recommendation). At longer term prices (i.e., $1.95/bu), the economic optimal N rate would be approximately 60 pounds of N. Thus, it can be seen that the strength in the sorghum market offsets most of the impact of the high nitrogen prices. As with the other crops, if nitrogen prices would fall and sorghum prices remain strong, optimal rates would exceed those recommended by KSU (e.g., optimal rate is 70 lbs/ac (+2 lbs) with sorghum at $2.80 and N at $0.25). The economic optimal rates for the lower and higher yield goals (e.g., 60 and 100 bu/ac) basically follow the same pattern of being slightly below KSU recommendations at current projections for sorghum and nitrogen prices.

Economic Optimal N Rates at Historical Prices

Given that it appears that economic optimal N rates, which are a function of crop and N prices, do not vary significantly from the official KSU recommendations, a reasonable question one might ask is, What are the consequences of ignoring prices in making fertilizer decisions? That is, what if I simply followed KSU official recommendations and did not worry about crop and N prices? Figure 7 shows the ratio of model-derived optimal N rates to KSU recommended N rates for wheat, corn, and sorghum at historical N and crop prices (1976-2005). Economic optimal rates are based on 2% SOM, 20 lbs STN, no other N adjustments and yield goals of 45, 125, and 80 bu/acre for wheat, corn, and sorghum, respectively. As defined, a ratio less than 1.0 indicates that the economic optimal rate is less than the KSU rate (i.e., following KSU rate would reflect applying excess N) and a ratio greater than 1.0 indicates economic optimal N rates that exceed KSU rates.

Nitrogen Recommendations for Grain Sorghum

Yield goal, bu/ac			60					80					100		
KSU N rec, lbs/ac*			36					68					100		
N price	Grain sorghum price, $/bu					Grain sorghum price, $/bu					Grain sorghum price, $/bu				
$/lb	$1.90	$2.20	$2.50	$2.80	$3.10	$1.90	$2.20	$2.50	$2.80	$3.10	$1.90	$2.20	$2.50	$2.80	$3.10
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	36	37	38	39	39	68	69	71	72	73	99	102	103	105	106
$0.25	33	35	36	37	38	64	67	68	70	71	95	98	100	102	103
$0.30	31	33	34	35	36	61	64	66	67	69	91	95	97	99	101
$0.35	28	31	32	34	35	58	61	63	65	67	87	91	94	96	98
$0.40	26	29	31	32	33	55	58	61	63	65	83	88	91	94	96
N price															
	Price adjusted N rec reduction					Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	1.0%	-2.7%	-5.5%	-7.7%	-9.5%	0.7%	-1.9%	-3.9%	-5.5%	-6.7%	0.6%	-1.6%	-3.3%	-4.6%	-5.7%
$0.25	7.7%	3.1%	-0.4%	-3.2%	-5.4%	5.5%	2.2%	-0.3%	-2.2%	-3.8%	4.6%	1.9%	-0.2%	-1.9%	-3.2%
$0.30	14.5%	9.0%	4.7%	1.4%	-1.2%	10.2%	6.3%	3.3%	1.0%	-0.9%	8.7%	5.4%	2.8%	0.9%	-0.7%
$0.35	21.3%	14.8%	9.9%	6.0%	2.9%	15.0%	10.4%	7.0%	4.3%	2.1%	12.8%	8.9%	5.9%	3.6%	1.8%
$0.40	28.0%	20.6%	15.0%	10.6%	7.1%	19.8%	14.6%	10.6%	7.5%	5.0%	16.8%	12.4%	9.0%	6.4%	4.2%

Soil organic matter (SOM)=2.0; Soil test nitrogen (STN)=20; Other N adjustment=0

* Based on formulas reported in *Soil Test Interpretations and Fertilizer Recommendations* (MF-2586)

Figure 6

Remember that the price-dependent quadratic-plateau models were estimated based on prices for the time period 1993-2002; thus, the average ratio for this time period would be expected to be close to 1.0.[3] The 1993-2002 average ratio is 0.989, 0.987, and 0.983 for wheat, corn, and sorghum, respectively, indicating economic optimal rates that are slightly less than expected. The more important point from Figure 7 is that the majority of the points for all three crops fall within +/– 0.05 of 1.0, which suggests that following KSU recommendations without considering prices would generally result in N rates that were within 5% of what would have been optimal given actual prices (observed after the fact). However, in recent years, as N prices have been increasing, the ratio for all crops has generally been less than 1.0, indicating that ignoring prices and applying N based on KSU recommendations would have resulted in N rates 5-15% higher than what would have been optimal.

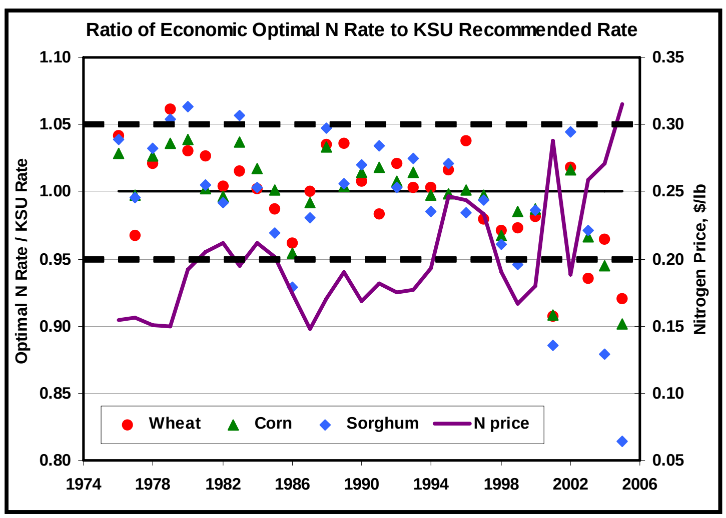

Figure 7

By definition, applying the economic optimal N rate will generate higher returns over nitrogen fertilizer cost than any other N rate. However, the "cost" of not applying the economic optimal N is not simply the difference in the N rates times the price of nitrogen because yield differences also

[3] Crop and N prices used to generate values for figure 7 are not the same source as those used to construct the models, thus the average ratio is not expected to equal 1.0 exactly.

have to be accounted for. For example, assume the KSU recommended rate is 75 lbs/acre and the economic optimal rate is 70 lbs/ac at N prices of $0.35/lb. The N savings would be $1.75/ac (5 lbs x $0.35/lb), however the yield with 70 pounds of N would be expected to be less than the yield with 75 pounds of N. This "lost" income also needs to be accounted for when calculating the cost of not applying the economic optimal N rate. Figure 8 shows the income advantage in dollars per acre for following the optimal N rate recommendations relative to the KSU rates. Put another way, the values in Figure 8 represent the cost of following the KSU rates, i.e., ignoring prices. At low nitrogen prices, the cost of not applying the optimal N rate is generally quite low (over three-fourths of the points are less than $0.10/ac). As expected, the cost increases with increasing N prices and reached approximately $1/ac for corn and sorghum in 2005. While many producers may feel that $1/acre is "not that big of deal," it is important to keep in mind that on $40/acre rent, this represents a 2.5% advantage. In times of tight margins, it is often these little things that make the difference between those producers that make money and those producers that lose money.

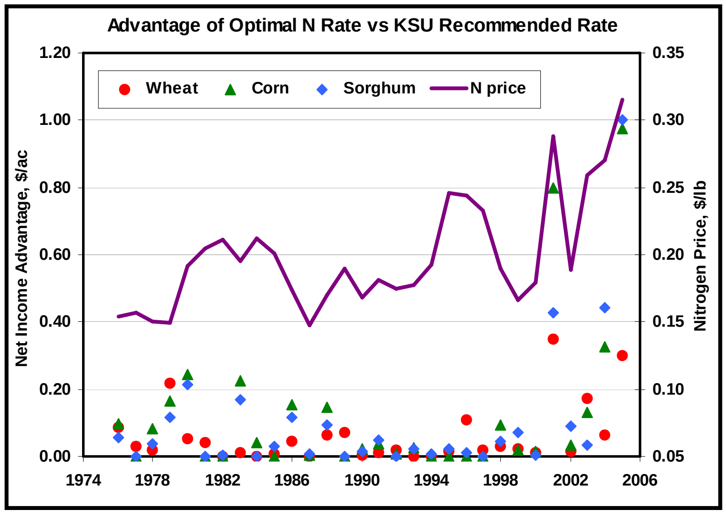

Figure 8

Information in Figures 4-6 suggest that economic optimal N rates for crops harvested in 2007 will be slightly less than official KSU recommendations due to the higher N prices. However, much of the impact of the higher N prices is offset due to higher crop prices and thus the cost of simply following KSU rates is expected to be relatively low. Most universities (including KSU) have historically ignored crop and nitrogen prices when making fertilizer N recommendations. At relatively low and stable nitrogen prices, the cost of ignoring prices has not been a serious problem. However, as nitrogen prices increase, the cost of ignoring prices in fertilizer recommendations is increasing (Figure 8) and this is especially true when crop prices are relatively low (such as 2005).

Price-Adjusted Nitrogen Recommendations for Irrigated Crops

Up to this point, no reference has been made as to whether crops were dryland or irrigated as that is consistent with KSU recommendations. That is, KSU does not differentiate nitrogen fertilizer recommendations for irrigated corn versus dryland corn other than differences that might exist in yield goal (MF-2586 does suggest a maximum N rec of 230 lbs/ac for dryland and 300 lbs/ac for irrigated corn). For example, the N rec for a field with 2% SOM, 20 lbs STN, no other N adjustments, and a yield goal of 150 bu/acre is 180 lbs of N/ac, regardless of whether the field is irrigated or dryland. However, once prices are accounted for in recommendations, this is likely not appropriate due to pumping costs associated with irrigated production. In the case of irrigated crops, the economic optimal N rate is calculated at the point where the crop value associated with an additional unit of N and water is exactly equal to the combined cost of the N and water. That is, it takes two inputs (N and water) to get one output (bushel of grain) and the price of both of these inputs need to be accounted for. Effectively, this increases the cost of N, which means that optimal N rates will be lower when irrigation costs are accounted for relative to when they are ignored. As with nitrogen, historically this may not have been that big of an issue as irrigation pumping costs were relatively low. However, as energy prices have increased, this is becoming increasingly more important.

Figure 9 shows the estimated pumping cost ($/ac-inch) for different energy sources from Jan 1996 through Dec 2007 (Jul 2006 through Dec 2007 are based on forecasted energy prices) assuming a 300 foot lift and 20 psi. The pumping cost per acre-inch for 2007 is forecasted to be above $6 for natural gas powered pumps, which is almost three times what it cost in the late nineties. Thus, irrigated corn producers in western Kansas have significantly higher costs for both water and nitrogen, both of which are needed to achieve higher yields.

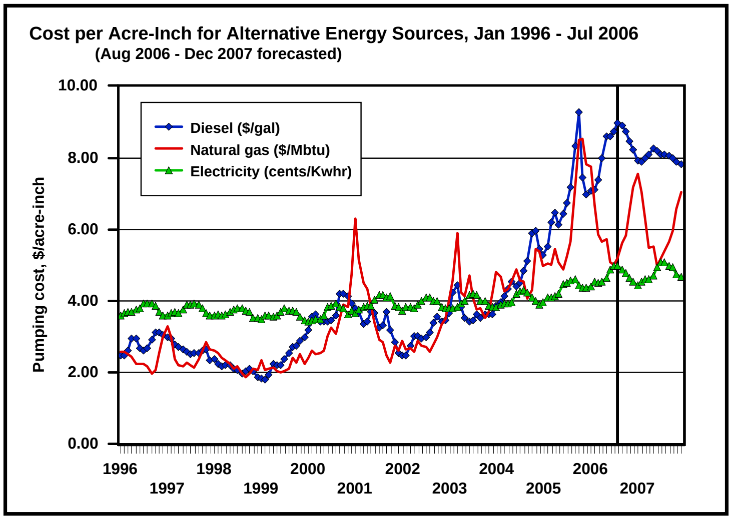

Figure 9

Figure 10 shows water and nitrogen fertilizer production functions for irrigated corn with a yield goal of 225 bu/acre. It is important to note that the definition of yield goal here is the *expected yield* that would be received when nitrogen (water) is non-limiting. This does not mean that yields cannot be higher in any given year, but rather this is what would be expected over many years. The economic optimal levels of each input individually (N and water), when the cost of the other input is ignored, are identified on the respective production functions with diamonds. These optimal levels suggest approximately 18 inches of irrigation water and a little over 290 lbs of N/ac (KSU N rec not accounting for prices is 300 lbs in this example). The interpretation of these optimal rates is that this is how much N a producer would apply if water were free, or water that should be applied if N were free. However, given that neither of these inputs has a cost of zero, the optimal rates for both inputs have to account for the cost of the other input. These accounting-for-other-input-prices-optimal rates are identified with the large circles on the respective production functions. When both input prices are accounted for, the optimal N rate decreases about 35 lbs/ac and the optimal irrigation water decreases about 2 in/ac. Obviously, as the levels of both inputs are decreased, the corresponding yield also decreases; but, it

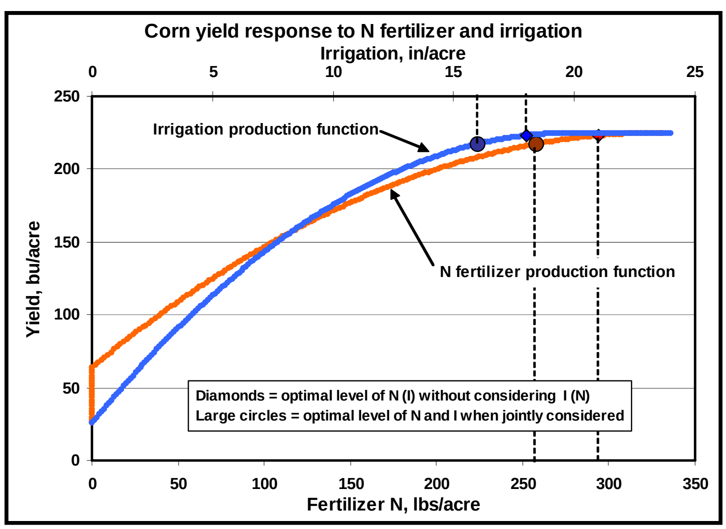

Figure 10

is important to remember that this lower yield is the point of profit maximization (assuming all other costs are fixed across yield level).

The optimal N fertilizer rates for irrigated corn with a 225 bushel yield goal at various corn and nitrogen prices and three pumping costs are reported in Figure 11.[4] It should be noted that Figure 5 also reported optimal N rates for a 225 bushel yield goal, but that did not account for irrigation costs. Thus, by comparing these two tables, the impact pumping costs have on optimal rates can be seen (remember that KSU's official recommendations do not distinguish between irrigated and dryland). Given a pumping cost of $6.50/ac-inch, the optimal N rate at projected corn and N prices ($2.90/bu and $0.35/lb) is 249 lbs/ac, which is a 17.1% reduction compared to the KSU N rec. This compares to a reduction of only 3.5% if irrigation pumping costs were ignored (Figure 5). Thus, the higher corn price might offset much of the impact of higher N prices, but it does not offset the combined effect of higher N and higher pumping costs. At pumping costs of $2.50/ac-inch, rates comparable to what were paid 10 years ago, optimal N rates are about 20 lbs/ac less when irrigation costs are accounted for (Figure 11) compared to when they are not factored in (Figure 5). Thus, when irrigation pumping and nitrogen costs were relatively low, ignoring both of these costs in nitrogen fertilizer recommendations was likely not that big of an issue. However, at current N prices and pumping costs, ignoring prices of inputs and outputs when making nitrogen fertilizer decisions is more serious, i.e., the cost associated with simply following KSU nitrogen recommendations is higher for irrigated crops.

Nitrogen Recommendations for Irrigated Corn

Yield goal, bu/ac			225					225					225		
KSU N rec, lbs/ac*			300					300					300		
Irrigation pumping cost, $/ac-in			$2.50					$4.50					$6.50		
N price	Corn price, $/bu					Corn price, $/bu					Corn price, $/bu				
$/lb	$2.00	$2.30	$2.60	$2.90	$3.20	$2.00	$2.30	$2.60	$2.90	$3.20	$2.00	$2.30	$2.60	$2.90	$3.20
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	273	280	286	291	295	254	265	273	278	284	236	249	258	265	271
$0.25	265	273	280	286	289	247	258	265	273	278	229	241	253	260	267
$0.30	256	265	273	280	284	238	251	260	267	273	219	234	245	254	262
$0.35	249	258	267	273	278	230	243	253	262	267	212	227	240	249	256
$0.40	240	251	260	267	273	221	236	247	254	262	203	219	232	243	251
N price															
	Price adjusted N rec reduction					Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	9.1%	6.6%	4.8%	2.9%	1.7%	15.2%	11.5%	9.1%	7.2%	5.4%	21.4%	17.1%	14.0%	11.5%	9.7%
$0.25	11.5%	9.1%	6.6%	4.8%	3.5%	17.7%	14.0%	11.5%	9.1%	7.2%	23.8%	19.5%	15.8%	13.4%	10.9%
$0.30	14.6%	11.5%	9.1%	6.6%	5.4%	20.7%	16.4%	13.4%	10.9%	9.1%	26.9%	22.0%	18.3%	15.2%	12.8%
$0.35	17.1%	14.0%	10.9%	9.1%	7.2%	23.2%	18.9%	15.8%	12.8%	10.9%	29.3%	24.4%	20.1%	17.1%	14.6%
$0.40	20.1%	16.4%	13.4%	10.9%	9.1%	26.3%	21.4%	17.7%	15.2%	12.8%	32.4%	26.9%	22.6%	18.9%	16.4%

Soil organic matter (SOM)=2.0; Soil test nitrogen (STN)=20; Other N adjustment=0

* Based on formulas reported in *Soil Test Interpretations and Fertilizer Recommendations* (MF-2586)

Figure 11

[4] The values reported in Figure 11 were calculated in the *KSU-CropBudgets2006.xls* Excel spreadsheet. This spreadsheet can also calculate similar values for irrigated wheat, grain sorghum, and sunflowers.

Summary

Fertilizer recommendations made by most Universities seldom explicitly account for the relative prices of inputs (nitrogen) and outputs (grain). If the relationship between nitrogen fertilizer and yields (the production function) is non-linear, suggesting diminishing returns to fertilizer, ignoring prices will result in non-optimal decisions. Non-optimal decisions imply that returns are not maximized. However, when nitrogen prices were relatively low and stable from year to year (e.g., 1976-1994), the cost of non-optimal decisions was low. As nitrogen prices have increased, the cost of ignoring these prices when making nitrogen fertilizer decisions also has increased, especially in years with low crop prices, such as 2005. Nitrogen prices are forecasted to be high in this upcoming year, which would typically suggest cutting back on N rates. However, the relatively high forecasted crop prices lead to optimal N rates that are similar to KSU recommendations, i.e., those that do not explicitly consider prices. Based on current price projections for grain (wheat, corn, and sorghum) and nitrogen, optimal N rates for dryland producers in Kansas will be 2-4% lower than KSU N recommendations assuming 2% soil organic matter and 20 lbs/ac soil test nitrogen.

Conclusions for optimal nitrogen rates for irrigated fields are somewhat different than for dryland situations, due to the impact of higher pumping costs as well as the higher N prices. Because optimal N rates vary based on both soil nutrient levels (i.e., soil organic matter, soil test nitrogen, other N adjustments) and economic factors (i.e., N price, irrigation pumping cost, crop price), it is important for producers to determine optimal N rates for their own fields as opposed to relying on general recommendations. An Excel spreadsheet (*KSU-CropBudgets2006.xls*) available at www.agmanager.info can be used to generate crop budgets based on optimal N rates for wheat, corn, grain sorghum, and sunflowers, where the optimal N rates are consistent with official KSU N recommendations, but are adjusted for relative prices.

References

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Leikam, D.F., R.E. Lamond, D.B. Mengel. "Soil Test Interpretations and Fertilizer Recommendations." Kansas State Univ. Coop. Ext. Serv. Bull. MF-2586. September 2003. Available at http://www.oznet.ksu.edu/library/crpsl2/mf2586.pdf

Appendix A – Various University Fertilizer Recommendation Websites/Publications

Kansas State University – all crops
http://www.oznet.ksu.edu/library/crpsl2/mf2586.pdf

Colorado State University – wheat
http://www.ext.colostate.edu/pubs/crops/00544.html

Oklahoma State University – all crops
http://www.soiltesting.okstate.edu/Extn_Pub/SFHB2006C.pdf

University of Nebraska – wheat (includes prices)
http://www.ianrpubs.unl.edu/epublic/live/g1460/build/g1460.pdf

University of Missouri – all crops
http://soilplantlab.missouri.edu/soil/recommendationsonline.asp

North Dakota State University – all crops
http://www.ext.nodak.edu/extpubs/plantsci/soilfert/sf882w.htm

Iowa State University – all crops
http://www.extension.iastate.edu/Publications/PM1688.pdf

University of Minnesota – all crops
http://www.extension.umn.edu/distribution/cropsystems/DC6240.html

Ohio State University – corn, soybeans, wheat, and alfalfa
http://ohioline.osu.edu/e2567/index.html

Appendix B – Various Fertilizer Calculator Websites

Kansas State University – wheat, corn, grain sorghum, soybeans, and sunflowers

http://www.agmanager.info/crops/budgets/proj_budget/decisions/ – Excel spreadsheet for developing crop budgets where fertilizer nitrogen and irrigation levels are optimally determined based on prices.

Iowa State University – corn

http://extension.agron.iastate.edu/soilfertility/nrate.aspx – Website to calculate economic return to N application with different nitrogen and corn prices and to find profitable N rates directly from recent N rate research data. Method used follows a newly developed regional approach for determining corn N rate guidelines being implemented in several Corn Belt states (Iowa, Illinois, Minnesota, and Wisconsin).

University of Nebraska – corn

http://soilfertility.unl.edu/ – Excel spreadsheet that is based upon recently completed research at the University of Nebraska that has led to revised nitrogen recommendations for corn that account for corn and nitrogen prices to maximize economic return.

University of Missouri – corn, cotton, rice, and grain sorghum

http://agebb.missouri.edu/commag/crops/fert/nitro/index.htm – Excel spreadsheet (NITROMAX) designed to help farmers apply the most profitable rate of nitrogen fertilizer on crops. Response curves derived from fertility research on corn, cotton, and rice are used to predict crop yields at different nitrogen rates. In the program, quadratic equations are used to mathematically describe the response curves. Users select a response curve and enter crop price, and fertilizer price. The program calculates the maximum crop yield and its corresponding nitrogen rate as well as the most profitable N rate. In most crops, the most profitable N rate is 90 to 98% of the maximum yield.

Texas A&M University – cotton

http://lubbock.tamu.edu/soilfertility/calcinstructions.php – Website or Excel spreadsheet for determining the optimal nitrogen fertilizer for cotton in the High Plains region of Texas.

Ohio State University – corn

http://agcrops.osu.edu/fertility/ – Excel spreadsheet for calculating optimal nitrogen fertilizer rate for corn based on crop rotation and corn and nitrogen prices.

USDA – all crops

http://nfat.sc.egov.usda.gov/ – Energy Estimator for Nitrogen is a tool from Natural Resources Conservation Service (NRCS) developed to increase energy awareness in agriculture. This NRCS energy consumption tool enables user to calculate the cost of nitrogen product use on their farm or ranch. NRCS agronomists developed these cost estimates based on nitrogen fertilizer management methods for the predominant crops by state. *This tool does not provide field-specific recommendations.*