Optimal Nitrogen Fertilizer Rates Given Current Fertilizer and Crop Prices

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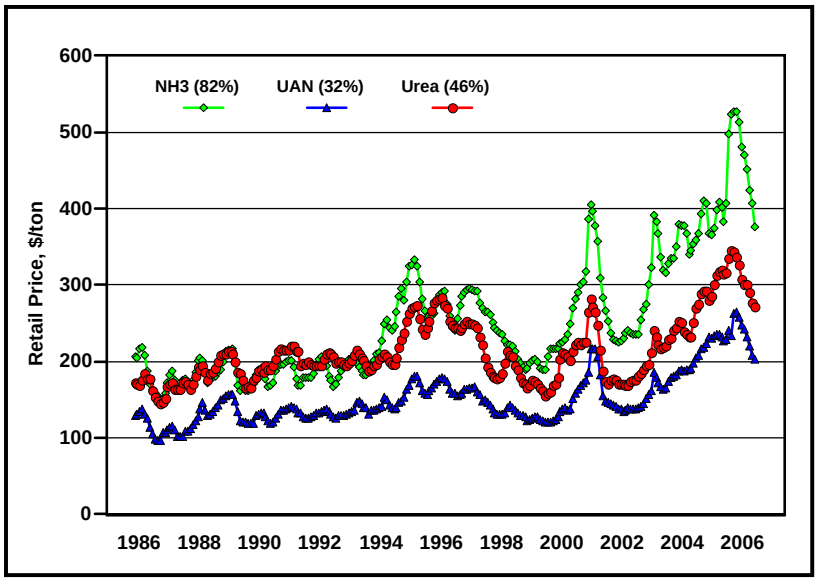
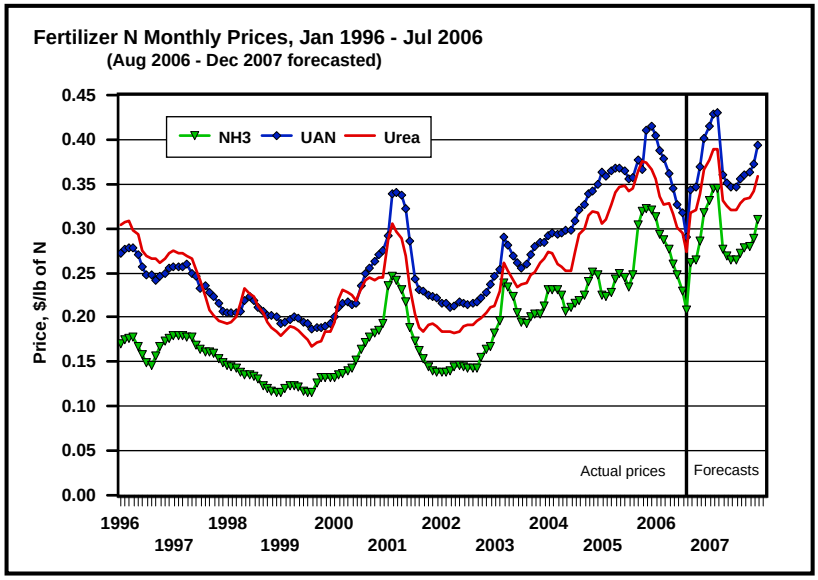
Historical monthly nitrogen fertilizer prices, Corn Belt



After reaching highs last winter, nitrogen prices have been falling throughout 2006…

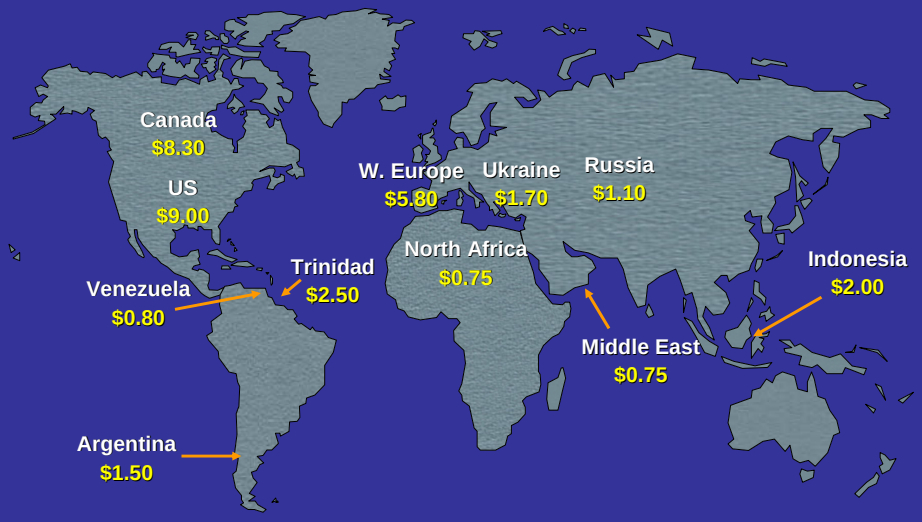
Historical and forecasted nitrogen prices, Corn Belt



… unfortunately, forecasts suggest prices are going to increase back to previous highs.

World Natural Gas Costs

2005F - $US/MMBtu



Protectionist policies could be very costly to U.S. agriculture

Source: Fertecon, PotashCorp

Forecasted N fertilizer prices are at historically high levels…

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 (based on 7/31/06 closing NYMEX natural gas futures prices and KSU model)

Forecasted crop prices are at recent highs…

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 on forward bids and 2007 forecasts are based on futures adjusted for basis).

KSU nitrogen recommendations…

Corn and grain sorghum

N rec = (Yield Goal x 1.6) – (%SOM x 20) – Profile N – Manure N – Other N Adjustments
+ Previous Crop Adjustments

Wheat

N rec = (Yield Goal x 2.4) – (%SOM x 10) – Profile N – Manure N – Other N Adjustments
+ Previous Crop Adjustments + Tillage Adjustments + Grazing Adjustments

Sunflowers

N rec = (Yield Goal x 0.075) – (%SOM x 20) – Profile N – Manure N – Other N Adjustments
+ Previous Crop Adjustments

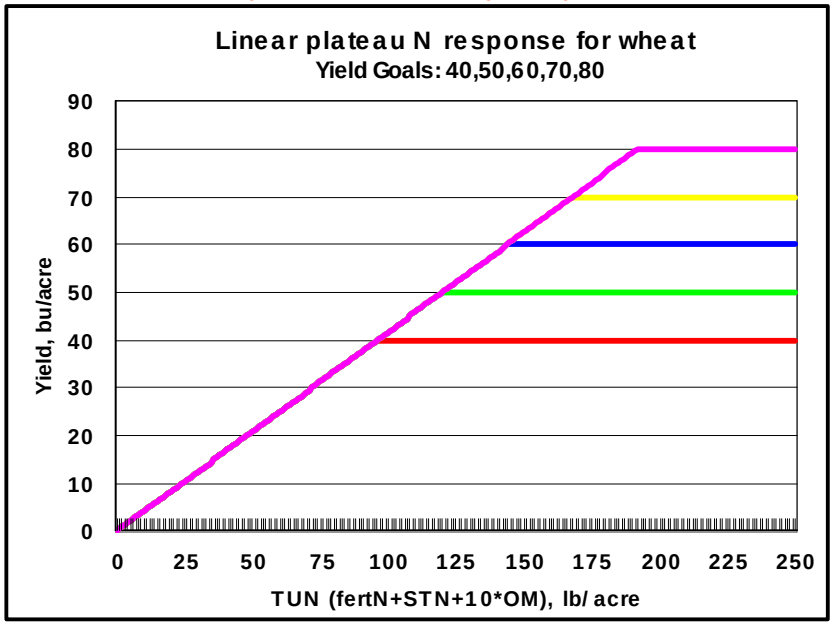
KSU nitrogen recommendations vs. N price

- Recommendations do not explicitly include prices
- Mathematical relationship between expected yield and nitrogen (i.e., production function) is needed in order to adjust recommendations for prices
- Similar issues pertain to P & K recommendations (i.e., no way to adjust them for prices)
- We assume KSU had in mind these prices:
  - Wheat $3.20/bu
  - Corn $2.35/bu
  - fertN $0.21/lb N

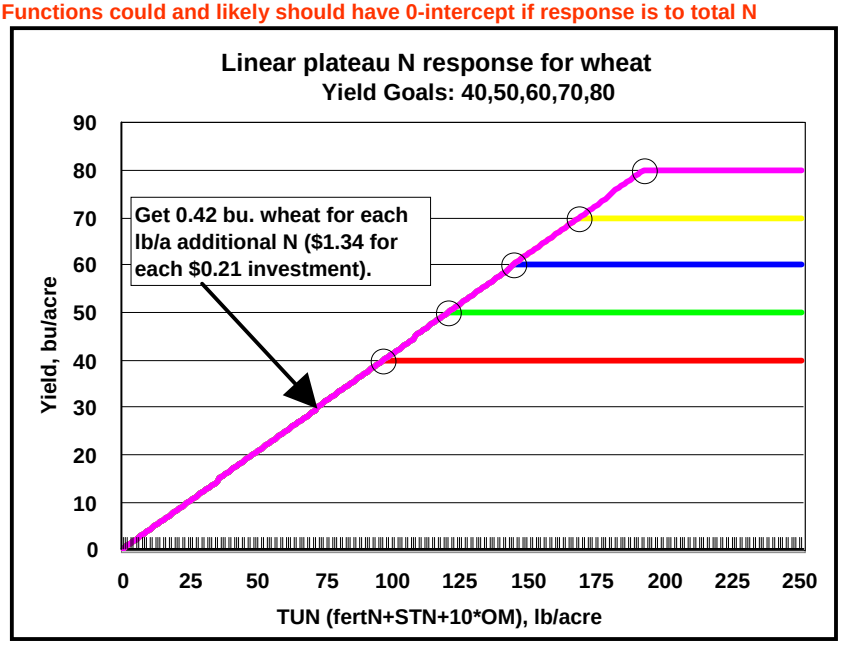
Nitrogen production function…

- In a limiting factor framework, it is generally believed that relationship between N and yield is linear for any given year and location (implies linear plateau production function)
- Linear plateau production function implies that optimal N will either be 0 or level where yield plateaus
- Average of multiple linear plateau production functions can be non-linear and this represents expectations of future N:yield relationship

Functions could and likely should have 0-intercept if response is to total N

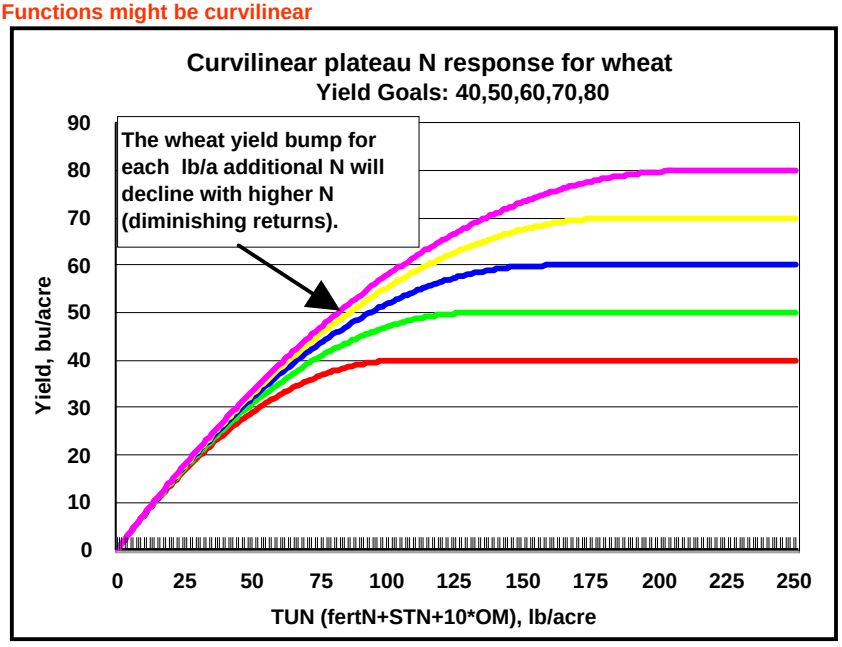


Functions could and likely should have 0-intercept if response is to total N

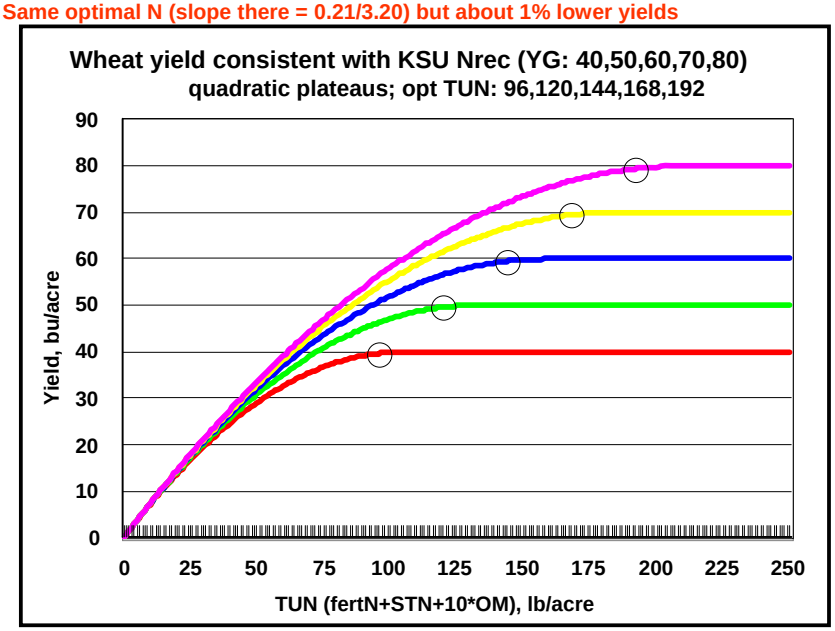


Price won't matter until fertN = $1.34/lb, then optimal is 0 lb/acre

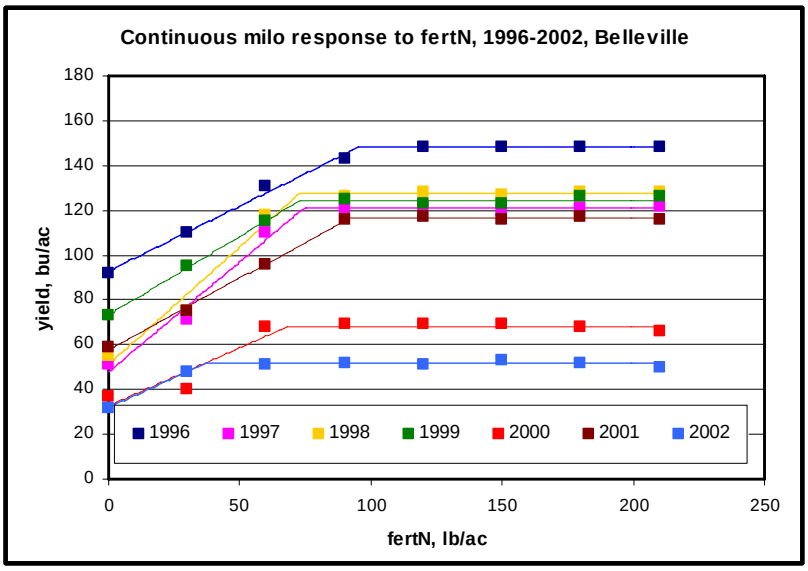
Functions might be curvilinear



Same optimal N (slope there = 0.21/3.20) but about 1% lower yields

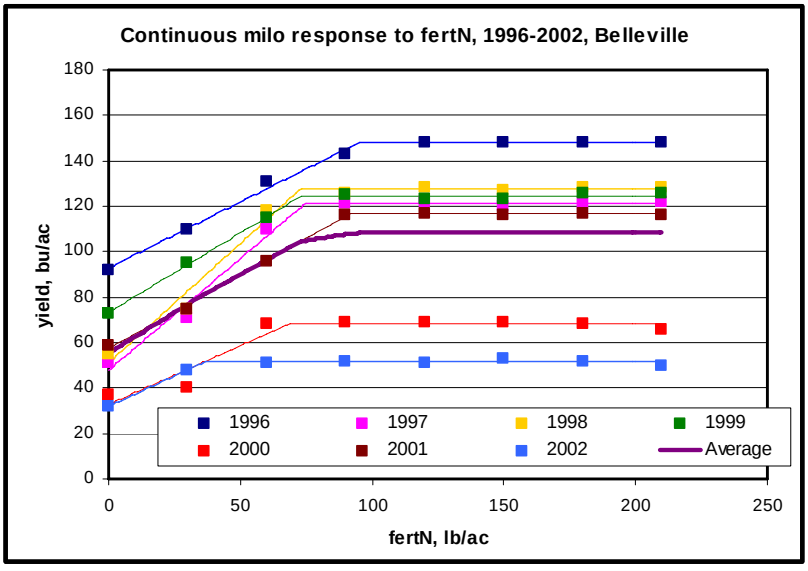


Yield response by year – linear plateau "fits" data quite well…

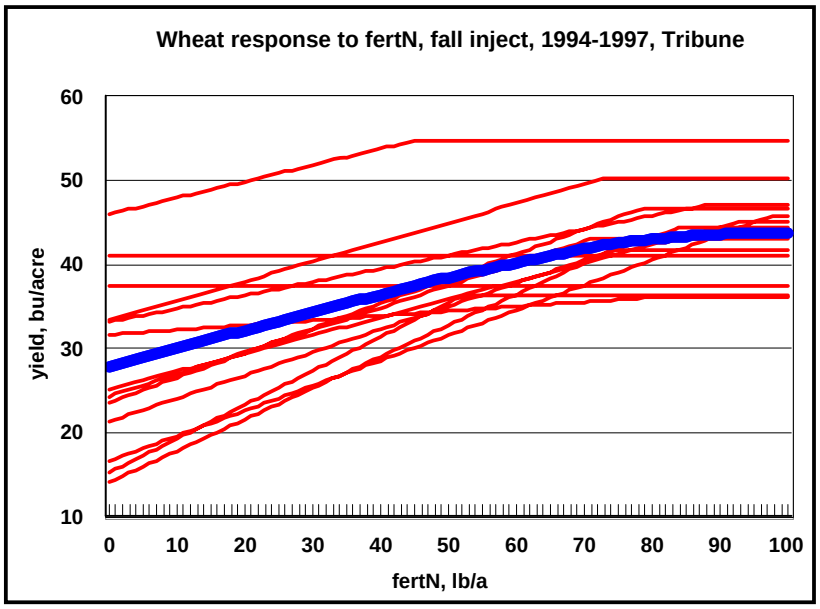


What would yield be for given fertN next year?

Average of linear plateaus can become non-linear…



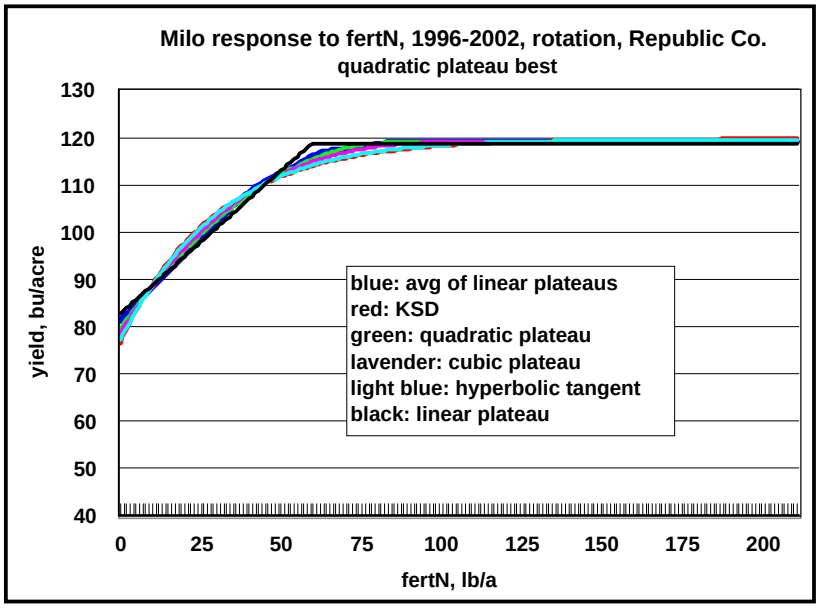
Average of linear plateaus can become non-linear…



Functional form…

- Numerous functional forms could be used that would meet objectives. We considered:
  - Linear plateau, along with four different curvilinear forms
- Based on nitrogen fertilizer research studies from north central and western Kansas on wheat, corn, and milo, quadratic plateau model fit data better than alternatives most often
- Most non-linear models "look" very similar, but results (i.e., optimal N versus N price) do vary

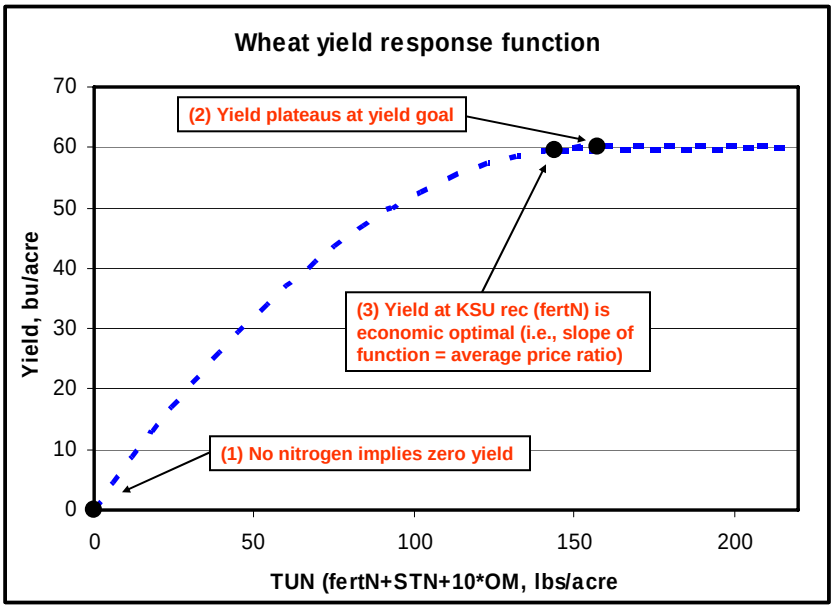
Here, a quadratic plateau fit blue line the best



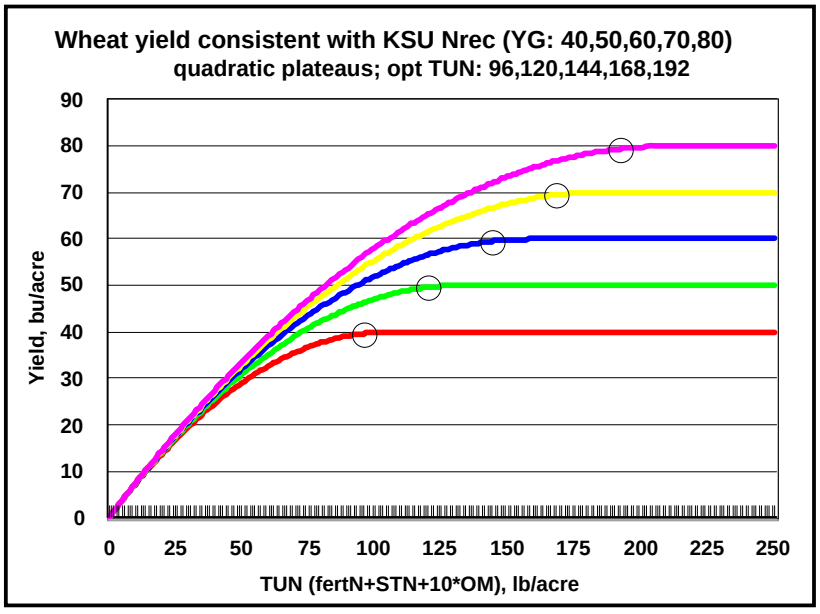
Nitrogen production function…

- Nice property of non-linear production function is that it implies diminishing marginal returns and thus prices matter
- Assumed functional form is quadratic plateau which allows diminishing returns – consistent with linear plateau in any given year
- Estimate model parameters such that
  - KSU Nrec is economic optimum at historical average prices
  - Yield plateau is equal to yield goal
  - Intercept goes through origin (i.e., 0 N equates to 0 yield)

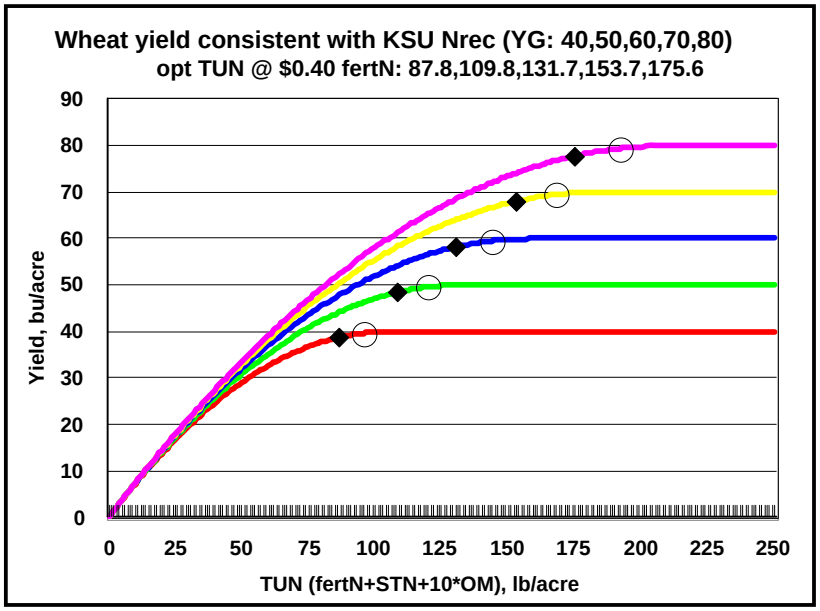
Defined points that allowed quadratic-plateau function to be defined…

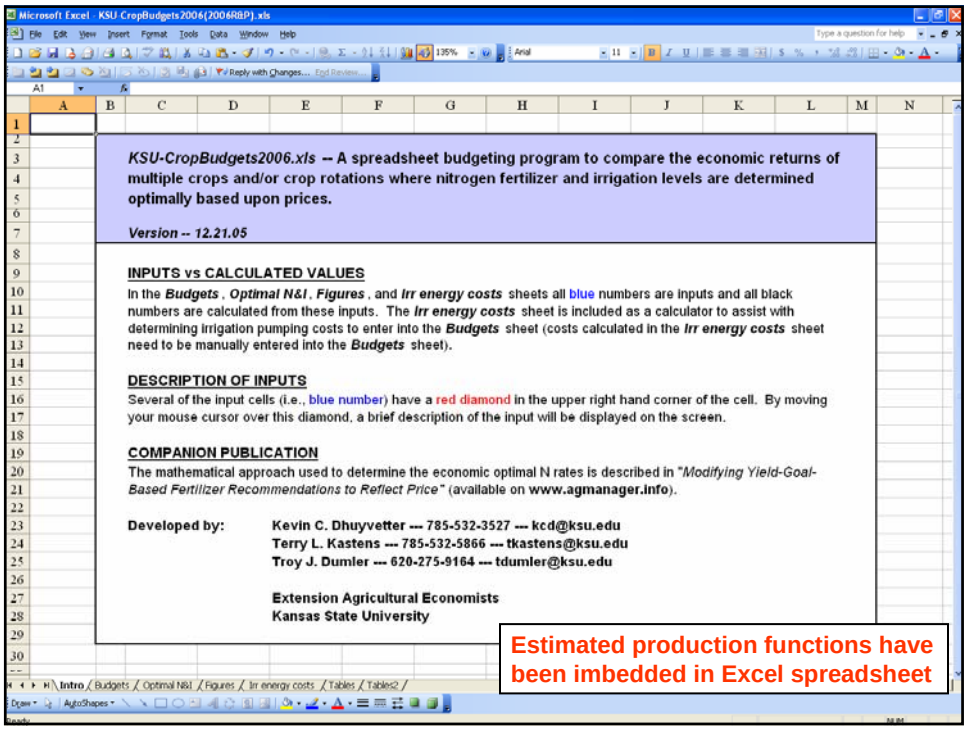


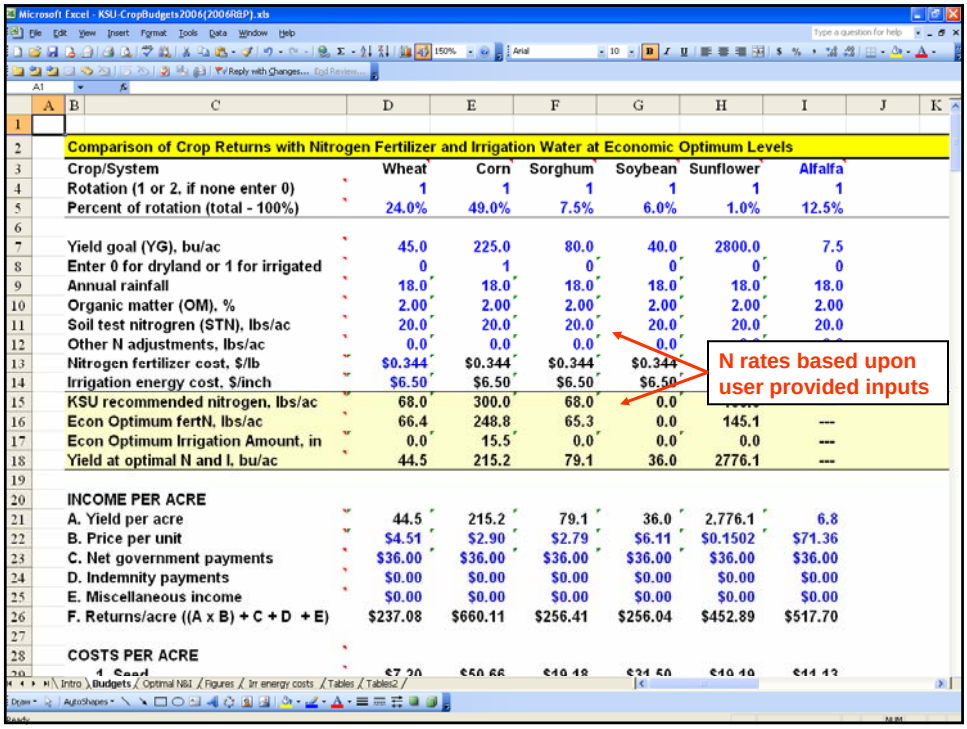
Same optimal N (slope there = 0.21/3.20) but yields about 1% lower than plateau



Slope at diamonds is 0.40/3.20







Adjustments to KSU Nrecs at various wheat and N prices

Nitrogen Recommendations for Wheat

Yield goal, bu/ac			45					60		
KSU N rec, lbs/ac*			68					104		
N price	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
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	66	68	69	70	71	101	104	106	107	108
$0.25	63	65	67	68	70	97	100	103	105	106
$0.30	60	63	65	67	68	93	97	100	102	104
$0.35	56	60	63	65	66	89	93	97	99	101
$0.40	53	57	60	63	64	84	90	94	97	99
N price										
	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%
$0.25	7.8%	4.0%	1.3%	-0.7%	-2.3%	6.8%	3.5%	1.2%	-0.6%	-2.0%
$0.30	12.4%	7.8%	4.6%	2.1%	0.2%	10.8%	6.8%	4.0%	1.9%	0.2%
$0.35	17.0%	11.6%	7.8%	5.0%	2.8%	14.8%	10.2%	6.8%	4.4%	2.4%
$0.40	21.5%	15.5%	11.1%	7.8%	5.3%	18.8%	13.5%	9.7%	6.8%	4.6%

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)

Adjustments to KSU Nrecs at various corn and N prices

Nitrogen Recommendations for Corn

Yield goal, bu/ac			75					125		
KSU N rec, lbs/ac*			60					140		
N price	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
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	59	60	61	62	63	138	140	142	144	145
$0.25	56	58	59	60	61	133	136	139	141	142
$0.30	53	55	57	58	60	129	132	135	137	139
$0.35	50	53	55	56	58	124	128	131	134	136
$0.40	48	50	53	55	56	119	124	128	131	133
N price										
	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%
$0.25	6.7%	3.6%	1.3%	-0.6%	-2.1%	4.8%	2.6%	0.9%	-0.4%	-1.5%
$0.30	11.4%	7.7%	4.9%	2.6%	0.8%	8.1%	5.5%	3.5%	1.9%	0.6%
$0.35	16.1%	11.8%	8.5%	5.9%	3.8%	11.5%	8.4%	6.1%	4.2%	2.7%
$0.40	20.8%	15.9%	12.1%	9.1%	6.7%	14.9%	11.4%	8.7%	6.5%	4.8%

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)

Adjustments to KSU Nrecs at various sorghum and N prices

Nitrogen Recommendations for Grain Sorghum

Yield goal, bu/ac			60					90		
KSU N rec, lbs/ac*			36					84		
N price	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
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	36	37	38	39	39	83	85	87	88	89
$0.25	33	35	36	37	38	80	82	84	86	87
$0.30	31	33	34	35	36	76	79	81	83	85
$0.35	28	31	32	34	35	73	76	79	81	82
$0.40	26	29	31	32	33	69	73	76	78	80
N price										
	Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	1.0%	-2.7%	-5.5%	-7.7%	-9.5%	0.6%	-1.8%	-3.6%	-5.0%	-6.1%
$0.25	7.7%	3.1%	-0.4%	-3.2%	-5.4%	5.0%	2.0%	-0.3%	-2.0%	-3.5%
$0.30	14.5%	9.0%	4.7%	1.4%	-1.2%	9.3%	5.8%	3.1%	0.9%	-0.8%
$0.35	21.3%	14.8%	9.9%	6.0%	2.9%	13.7%	9.5%	6.4%	3.9%	1.9%
$0.40	28.0%	20.6%	15.0%	10.6%	7.1%	18.0%	13.3%	9.7%	6.8%	4.5%

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)

What are the consequences of ignoring prices when making fertilizer N decisions?

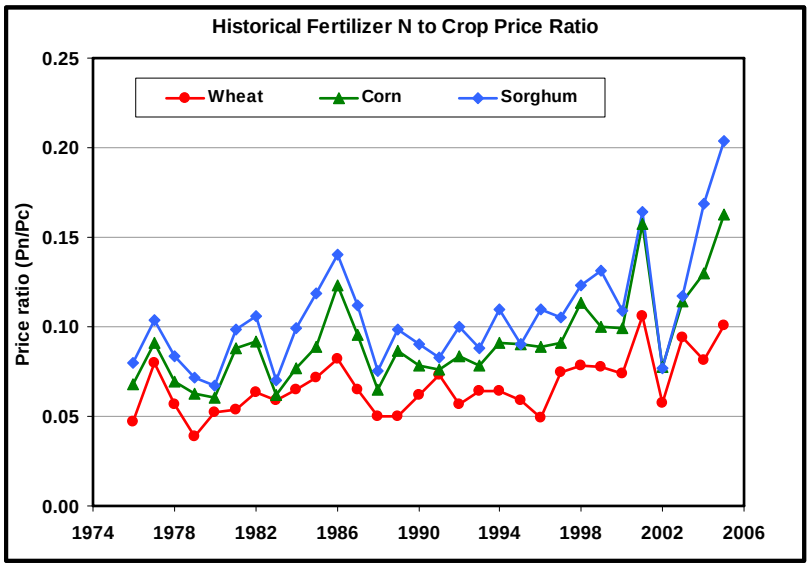
Excess N applied x N price

– Yield advantage x crop price

Cost of being "non-optimal"*

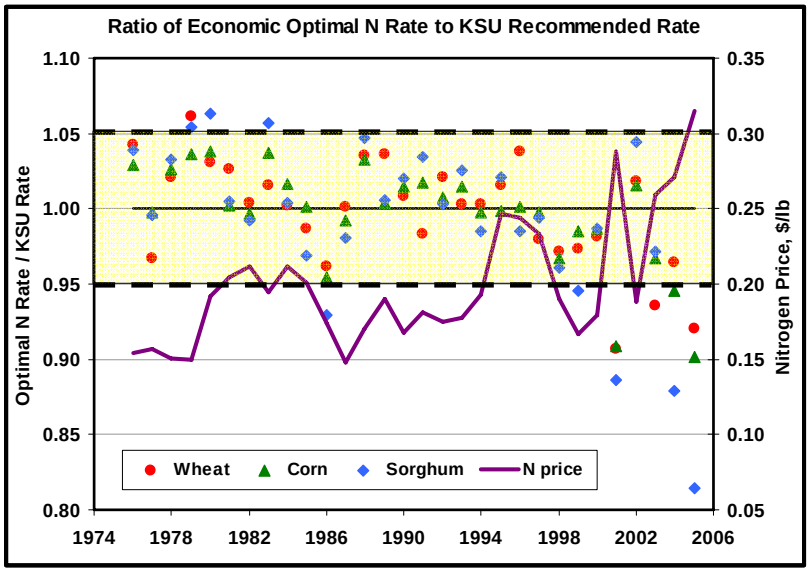
*** Assumes KSU N rec > optimal N rate**

Fertilizer-to-crop price ratio used to estimate "cost" of being non-optimal



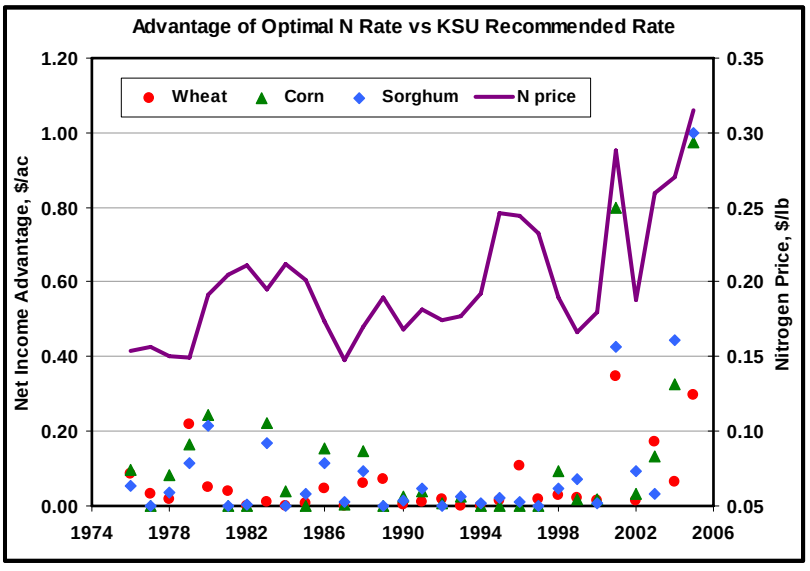
Variability in ratio, which determines optimal N rate, appears to be increasing

Cost of being "non-optimal" has increased in recent years…



KSU Nrec, ignoring prices, is within 5% of optimal N rate most of the time.

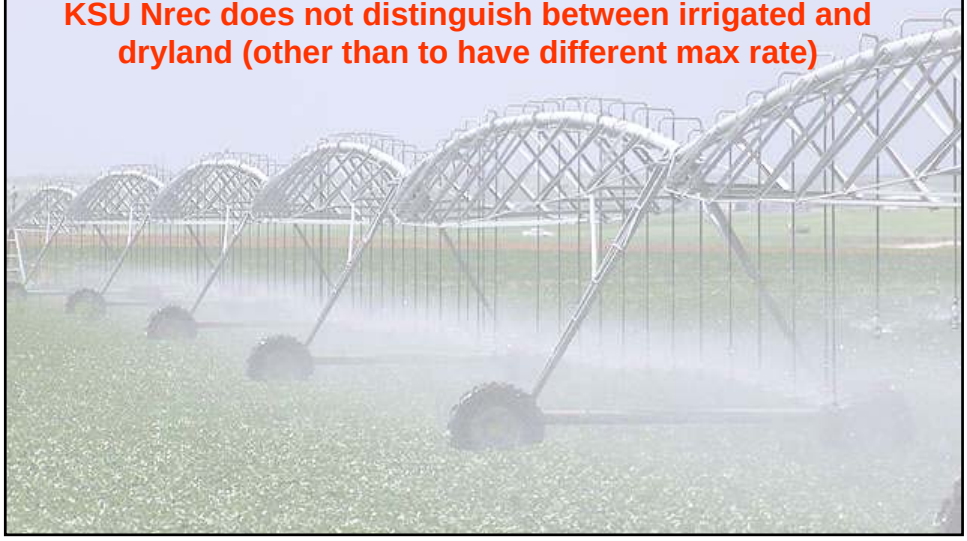
As N prices have increased, cost of being non-optimal has also increased…



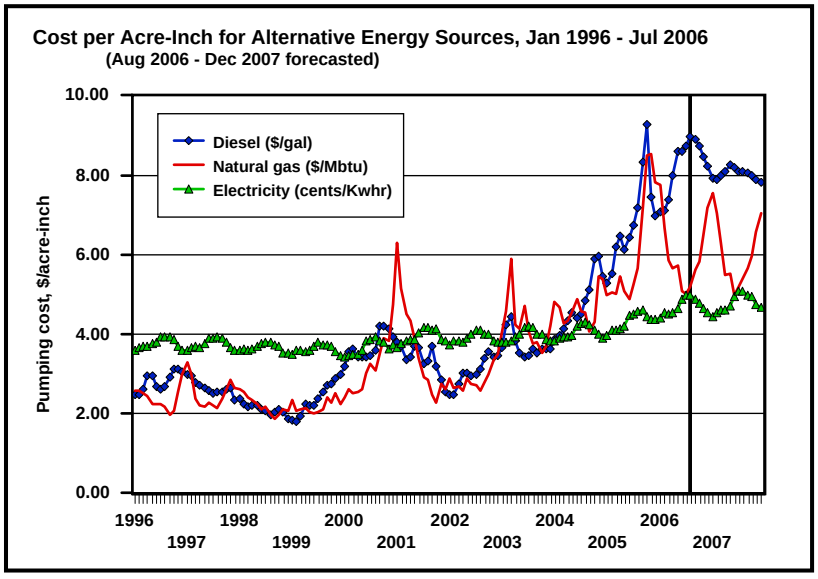
76.7% of observations < $0.10/ac (86.7% < $0.20)

What about N rates under irrigation?

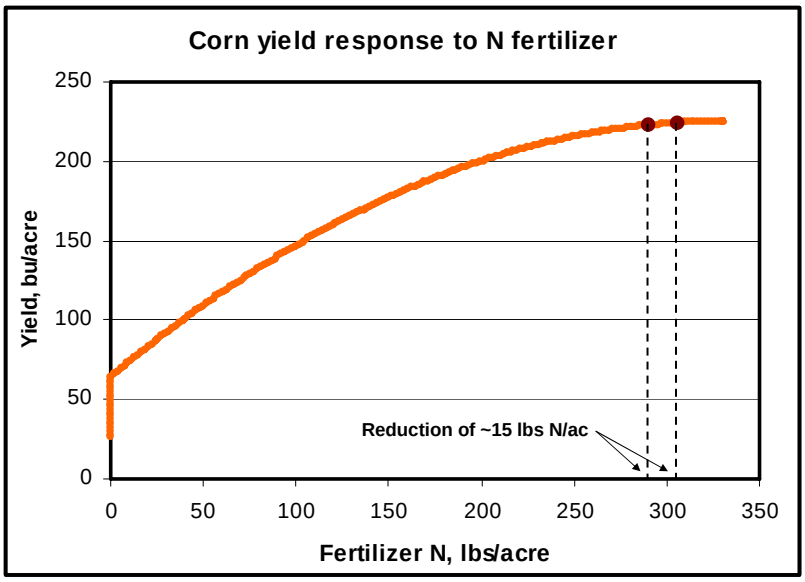
KSU Nrec does not distinguish between irrigated and dryland (other than to have different max rate)



Rising energy prices imply irrigation pumping costs have been increasing significantly…

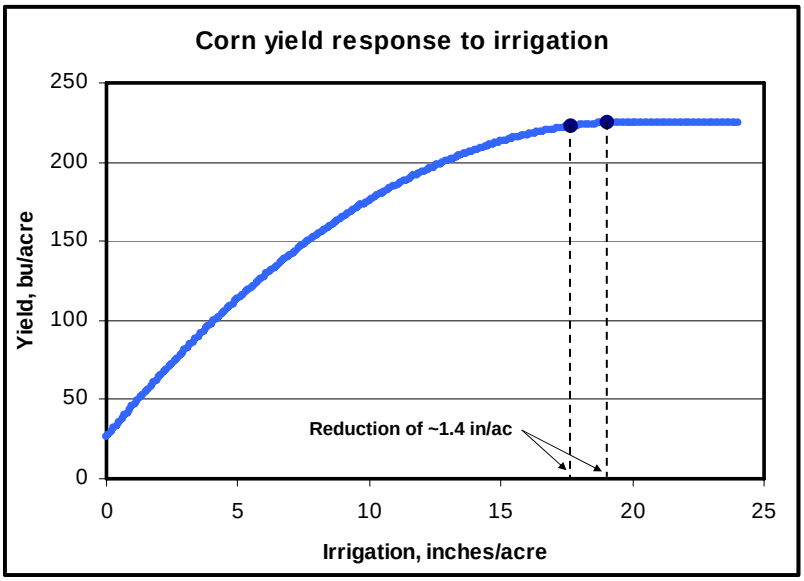


At projected corn prices, change in optimal N is relatively small due to higher N price…



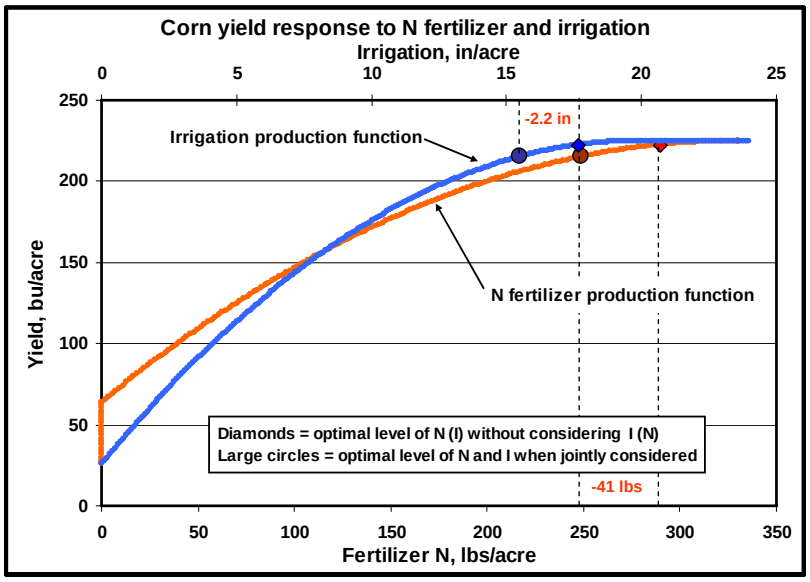
Corn $2.90/bu; N cost = $0.21/lb vs. $0.344/lb

At projected corn prices, change in optimal water is relatively small due to higher pumping costs price…



Corn $2.90/bu; irrigation cost = $2.50/in vs. $6.50/in

When considering irrigation and N together, optimal values decrease significantly…



Corn $2.90/bu; N $0.344/lb, irrigation cost = $6.50/in

Adjustments to KSU Nrecs at various corn and N prices

Nitrogen Recommendations for Irrigated Corn

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

Adjustments to KSU Nrecs at various corn and N prices*

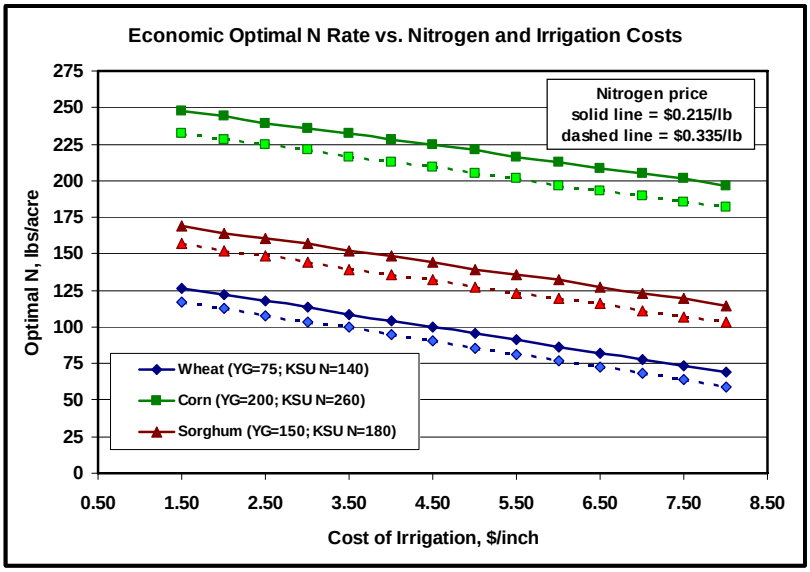
Nitrogen Recommendations for Corn

Yield goal, bu/ac			175					225		
KSU N rec, lbs/ac*			220					300		
N price	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
	Price adjusted N rec, lbs/ac					Price adjusted N rec, lbs/ac				
$0.20	217	221	223	225	227	296	301	304	307	309
$0.25	211	215	218	221	223	288	293	298	301	304
$0.30	204	209	213	216	219	279	286	291	295	299
$0.35	197	203	208	212	215	271	279	285	289	293
$0.40	191	198	203	207	211	263	271	278	284	288
N price										
	Price adjusted N rec reduction					Price adjusted N rec reduction				
$0.20	1.3%	-0.3%	-1.5%	-2.4%	-3.2%	1.2%	-0.3%	-1.4%	-2.3%	-3.0%
$0.25	4.3%	2.3%	0.8%	-0.4%	-1.3%	4.0%	2.2%	0.8%	-0.4%	-1.3%
$0.30	7.3%	4.9%	3.1%	1.7%	0.5%	6.8%	4.6%	2.9%	1.6%	0.5%
$0.35	10.2%	7.5%	5.4%	3.7%	2.4%	9.7%	7.1%	5.1%	3.5%	2.3%
$0.40	13.2%	10.1%	7.7%	5.8%	4.3%	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)

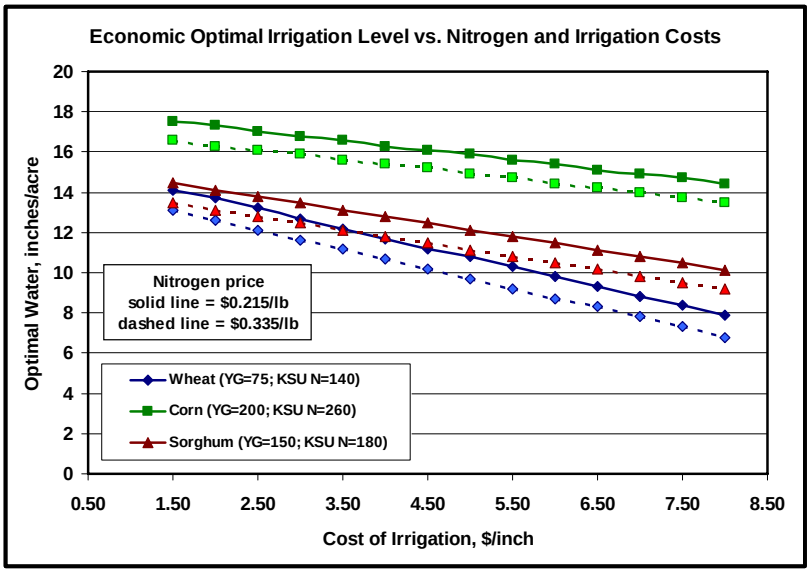
*** Optimal rates do not consider irrigation pumping costs**

Optimal N rate…



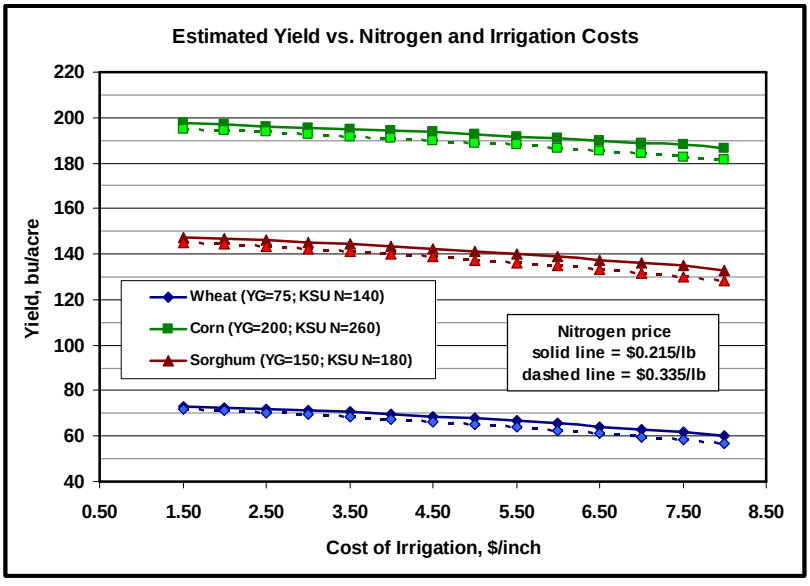
Increase in NUE = 29.6%, 14.3%, 21.7% for wheat, corn, and sorghum, respectively. ($3/ac-in & $0.215/lb N prices → $6/ac-in & $0.335/lb N)

Optimal irrigation rate…

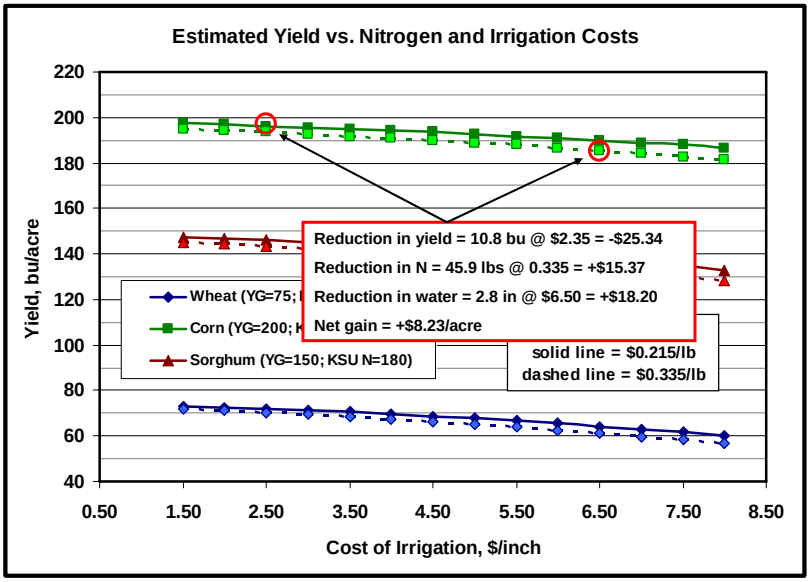


Increase in IWUE = 28.0%, 11.2%, 19.3% for wheat, corn, and sorghum, respectively.
($3/ac-in & $0.215/lb N prices ➔ $6/ac-in & $0.335/lb N)

Estimated yield…



Impact of reduced yield…



Summary …

- In order to determine how to adjust fertN rates in response to prices, a mathematical relationship between N and yield is needed
- A quadratic-plateau function can be “backed out” of KSU N recs
- Quadratic-plateau function allows diminishing returns, but is also consistent with linear plateau within any site-year
- Even with N prices at historical highs, economic optimal N rates for 2007 dryland crops are only slightly less (2-5%) than KSU N recs due to strong crop prices

Summary …

- Cost of ignoring prices in N recommendations has been low in the past, but with increasing N prices, cost of following non-optimal rate increases
- Optimal N rates for irrigated fields is considerably lower than KSU N recs (10-20%) due to high pumping costs as well as high N prices
- Nitrogen fertilizer and irrigation production functions have been estimated and imbedded within the *KSU-CropBudgets2006.xls* spreadsheet that allow producers to determine optimal N rates for their own farms/fields