Modifying Yield-Goal Based N and P Fertilizer Recommendations to Varying Input and Output Prices

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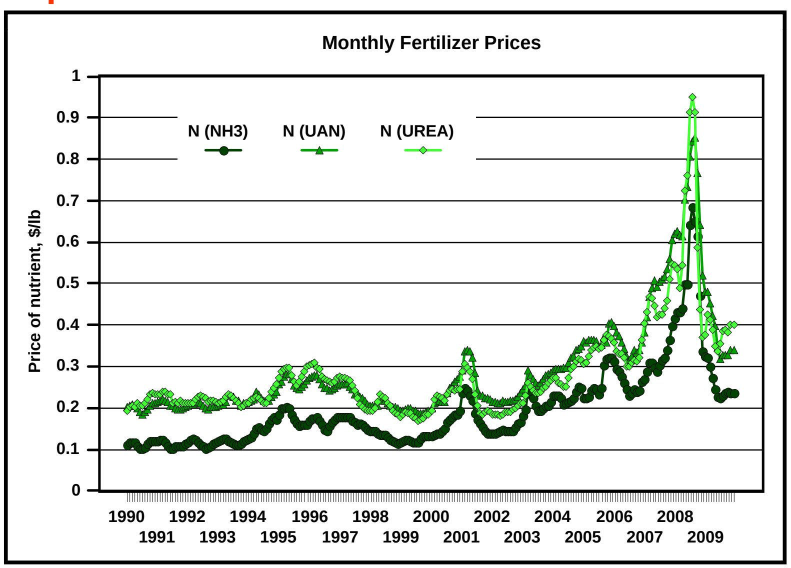
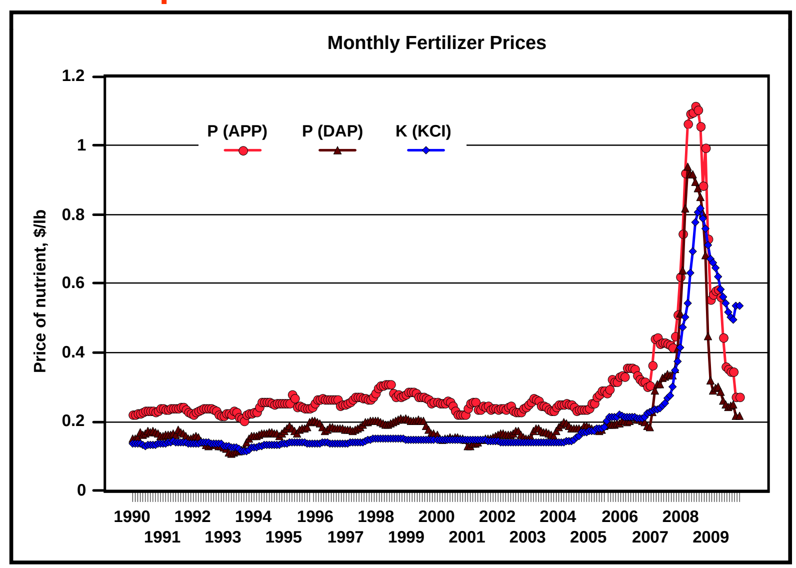
Situation…

- **Price volatility of crops and fertilizers have been at unprecedented levels in recent years** (similar for irrigation pumping costs)
- **Prices of all fertilizer nutrients increased** (and then decreased) **significantly in recent years, but the magnitude of changes varied considerably by nutrient and product**
- **Increased volatility has led to many questions from producers regarding recommended fertilizer rates** (i.e., do optimal levels change?)

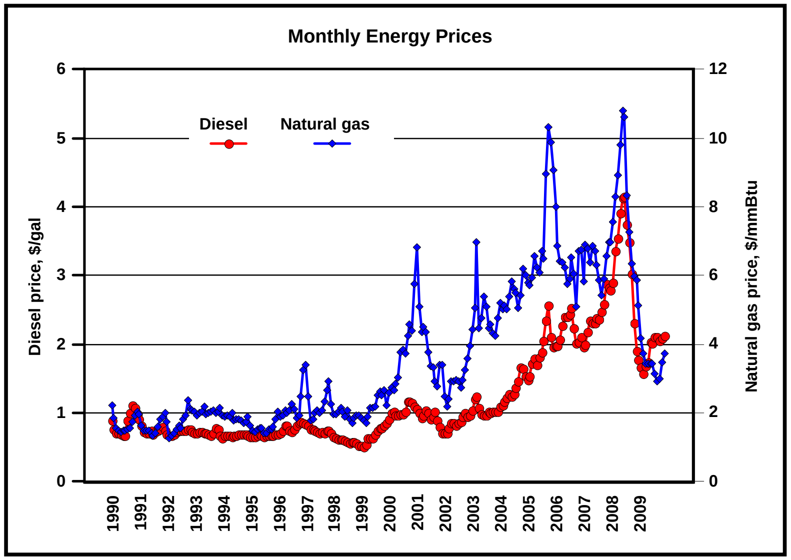
N prices…



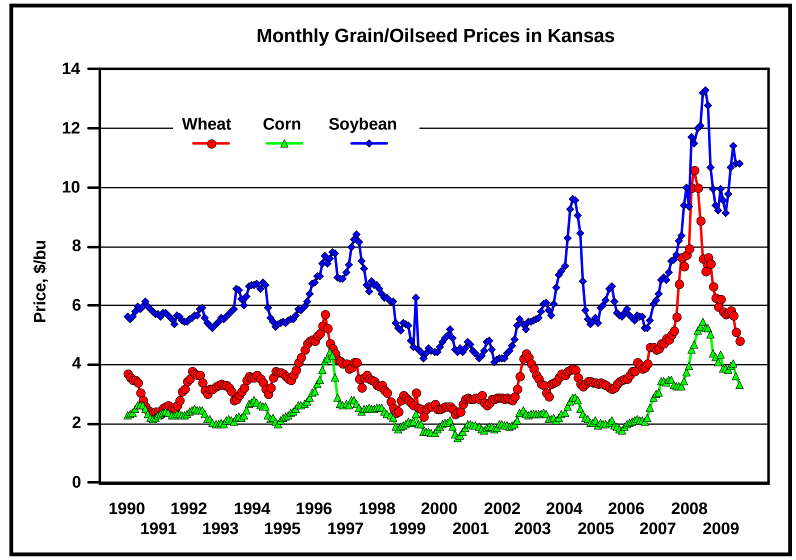
P and K prices…



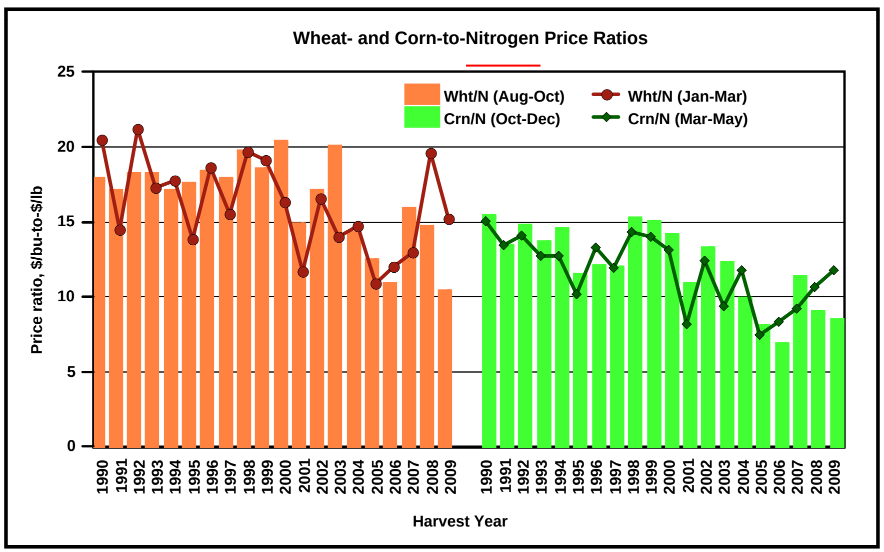
Energy prices (proxy for irrigation pumping costs)…



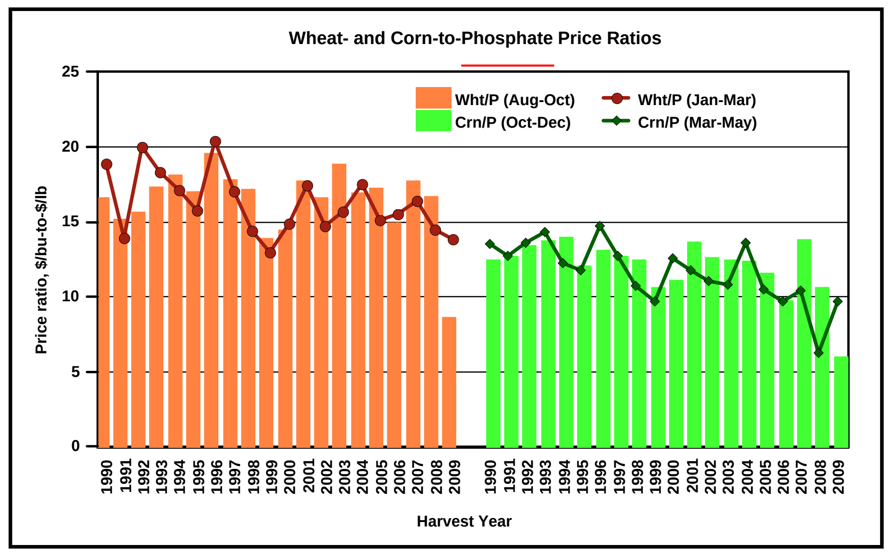
Grain prices…



Impact of grain-to-fertilizer price ratio on fertilizer rates?



Impact of grain-to-fertilizer price ratio on fertilizer rates?



Problem…

- Many fertilizer recommendations for a specific nutrient do not explicitly account for prices of the crop or the nutrient
- Very few (any?) of the fertilizer recommendations for one nutrient (e.g., N) explicitly account for costs of other nutrients/inputs (e.g., P)
- Subjective understanding of the issue allows recommendations to be modified with regard to direction, but quantifying magnitude is difficult…

Response to problem…

- Started with KSU fertilizer recommendations for N and P (MF-2586) and developed production functions that could incorporate prices
- Key assumptions behind analysis
  - KSU recommendations are economic optimal at long run prices (1993-2002 – 10-yr avg prior to publication)
    - Wheat = $3.22/bu; Corn =$2.35/bu;
    - N = $0.2094/lb; P = $0.2445/lb
  - Recommended rates for one nutrient (e.g., N) assume other management factors are non-limiting (implies that yield responds independently to various inputs)
  - Expected P-response can be represented using a quadratic plateau (similar to N-response, which was tested)

Initial efforts beginning in late 2005 (Kastens, Dhuyvetter, Schlegel, & Dumler) were based entirely on nitrogen

A little background info

K-STATE Kansas State University
Department of Agronomy
Soil Test Interpretations and Fertilizer Recommendations
MF-2586
Nutrient Management

KSU nitrogen recommendations … no prices

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

Each lb/a of N equates to 0.42 bu/ac

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

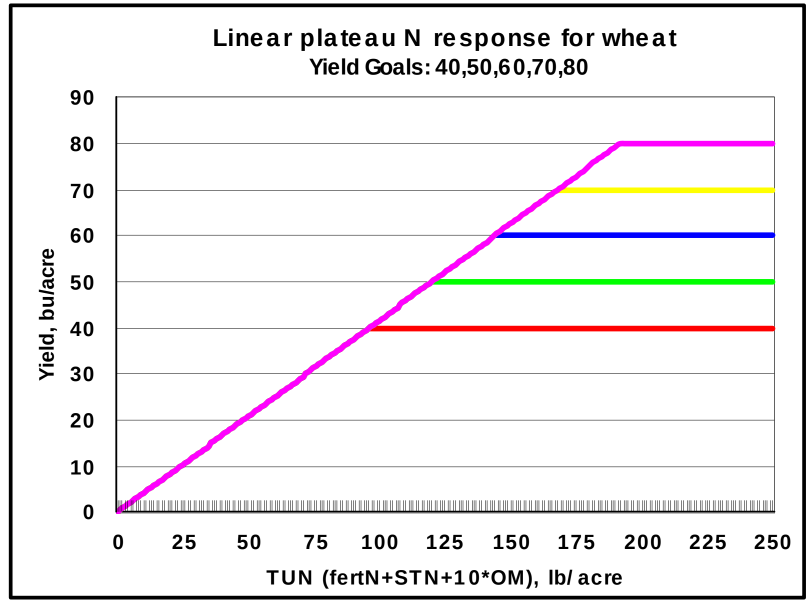
Sunflowers

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

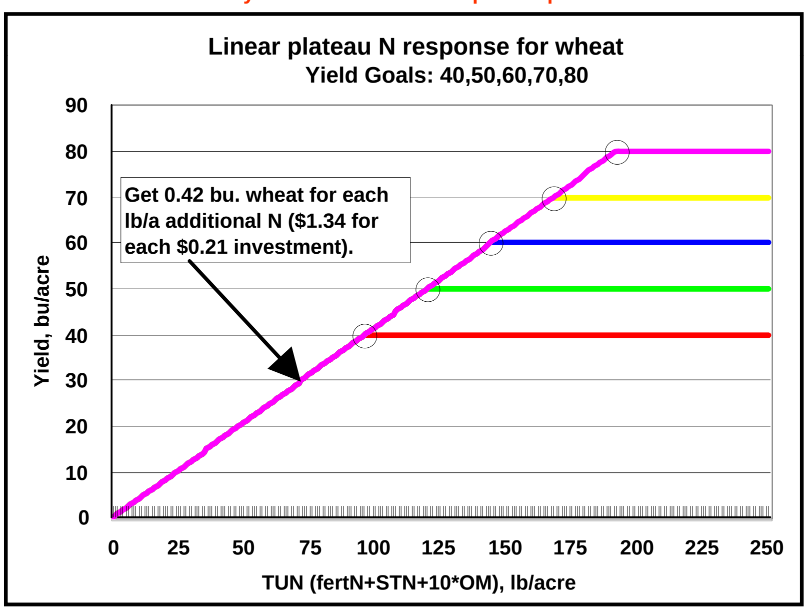
Nitrogen production function…

- 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

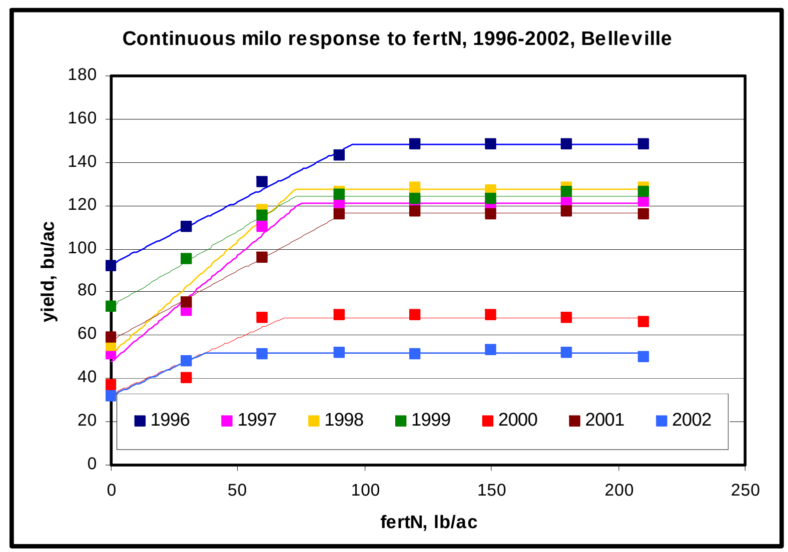


Functions could and likely should have 0-intercept if response is to total N



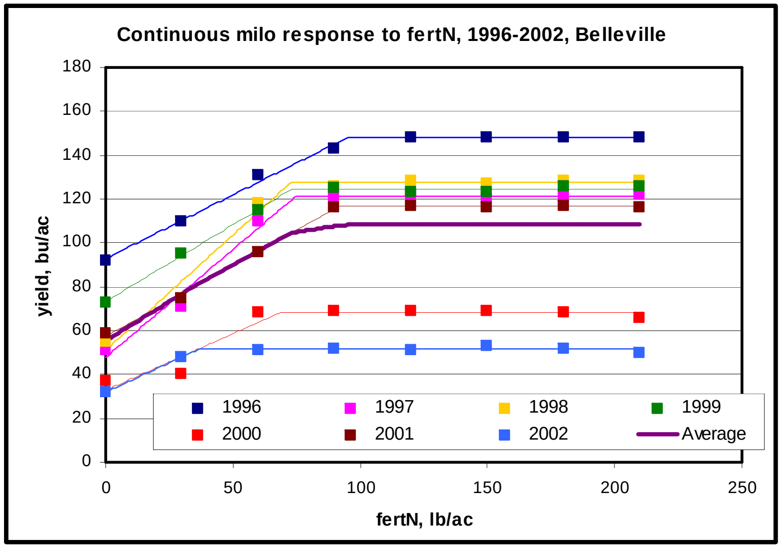
If wheat = $3.20/bu, N price won't matter until fertN = $1.34/lb, then optimal is 0 lb/acre

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

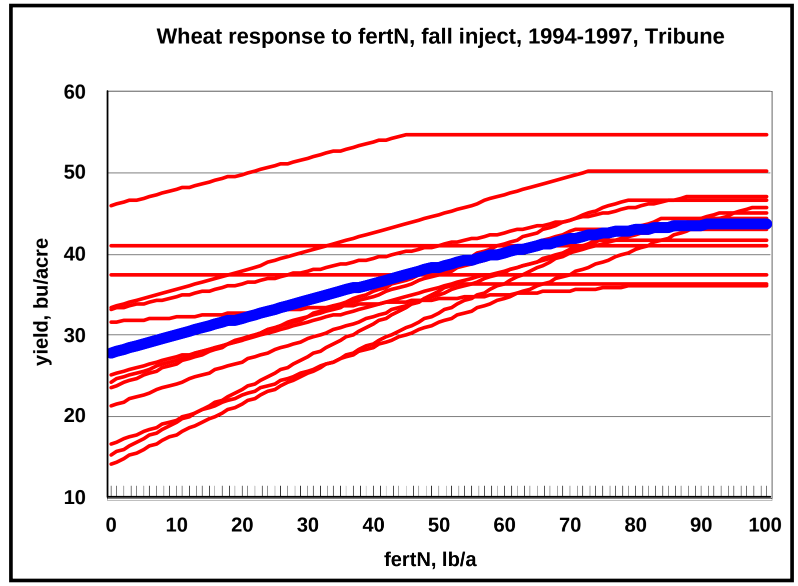


What would yield be for given fertN next year?

Average of linear plateaus can become non-linear…



Average of linear plateaus can become non-linear…



Blue line is NOT based on a mathematical function

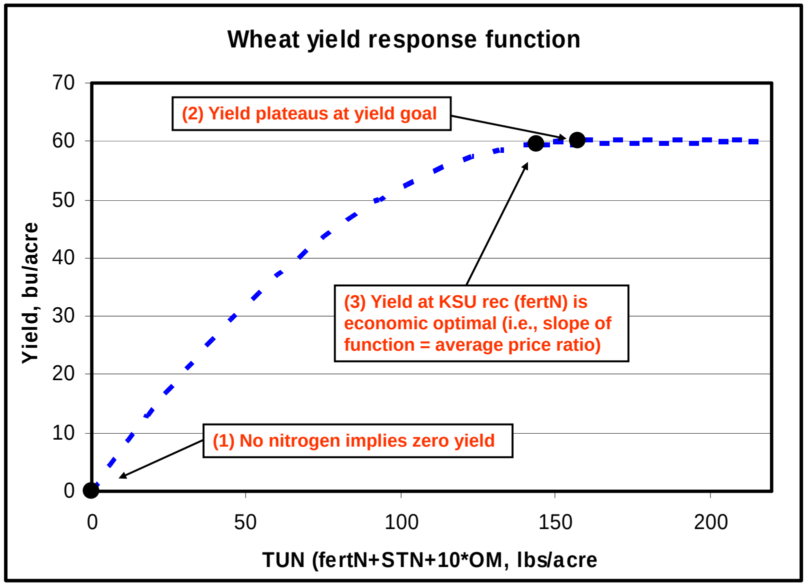
Functional form…

- **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**

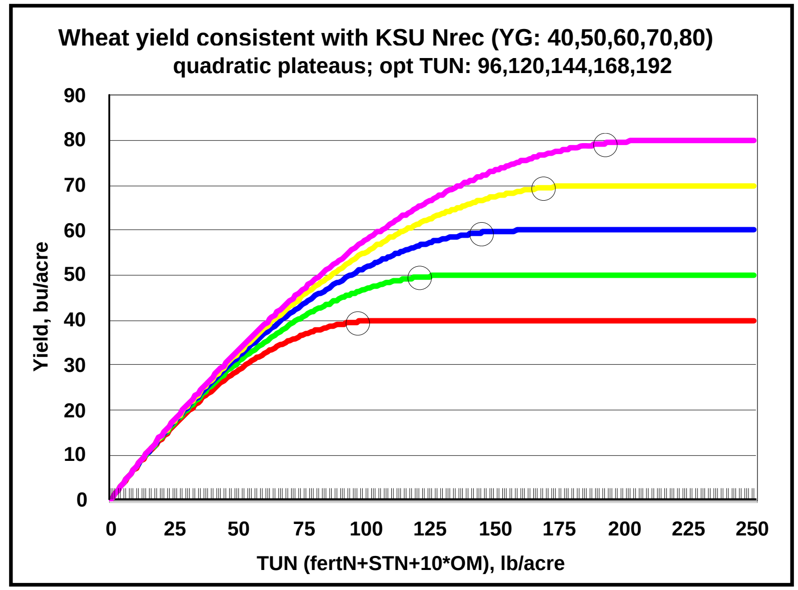
Nitrogen production function…

- **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)

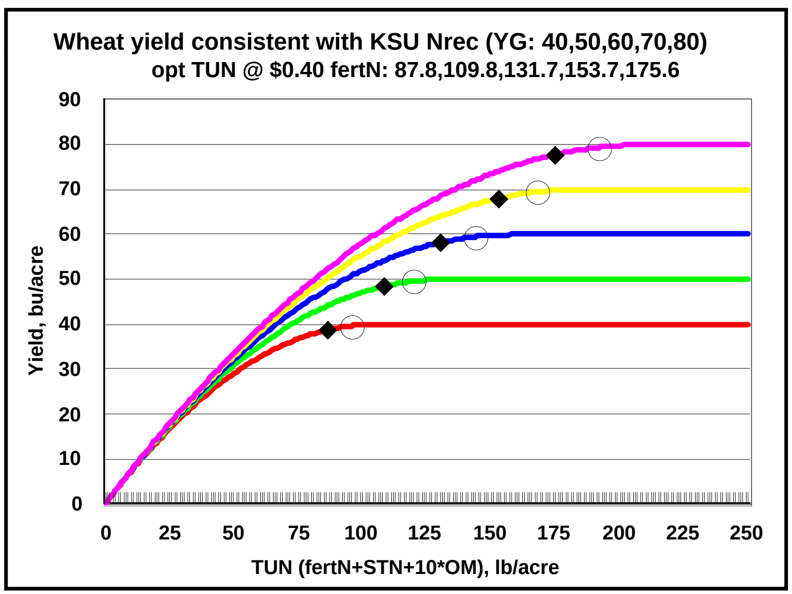
Defined points that allowed quadratic-plateau function to be defined…



Same optimal N (slope there = 0.21/3.22) but yields about 1% lower than plateau



Slope at diamonds is 0.40/3.22



With more expensive N, you make more money by applying less

Operationalizing production function…

- We believe we got to the point of "if you believe KSU's fertilizer recommendations you have to believe our price-dependent profit-maximizing rates"
- Everything was embedded in an Excel spreadsheet so that users could determine optimal fertilizer N rates based on fertilizer N prices and crop prices
- We could use the spreadsheet to recommend some "typical" percentage cutbacks on fertilizer – dealers had been requesting such info throughout 2005

What about N rates under irrigation?

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

We barely got the N spreadsheet completed and we felt the need to incorporate information regarding pumping costs – not surprising given that the issue in 2005 was higher fuel prices along with stagnant crop prices.

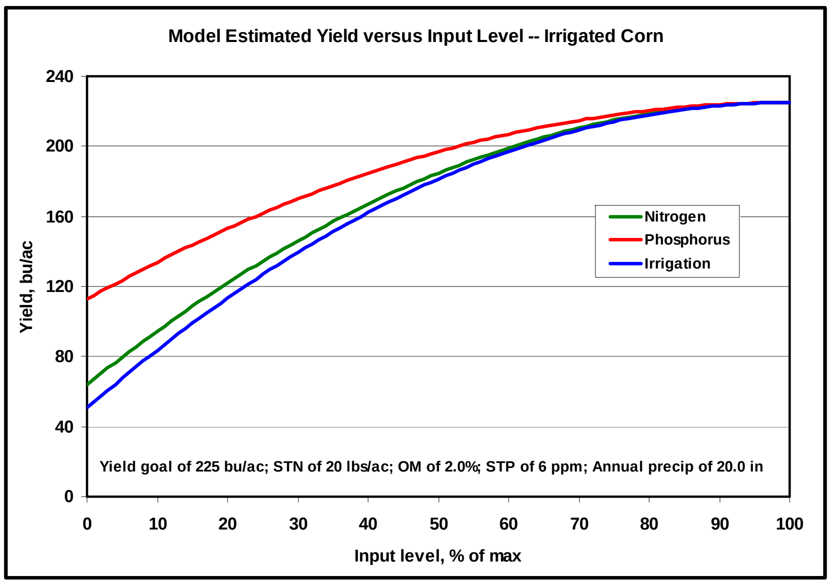
Spreadsheet was modified to incorporate irrigation production functions developed for western Kansas to account for irrigation pumping costs and N price simultaneously.

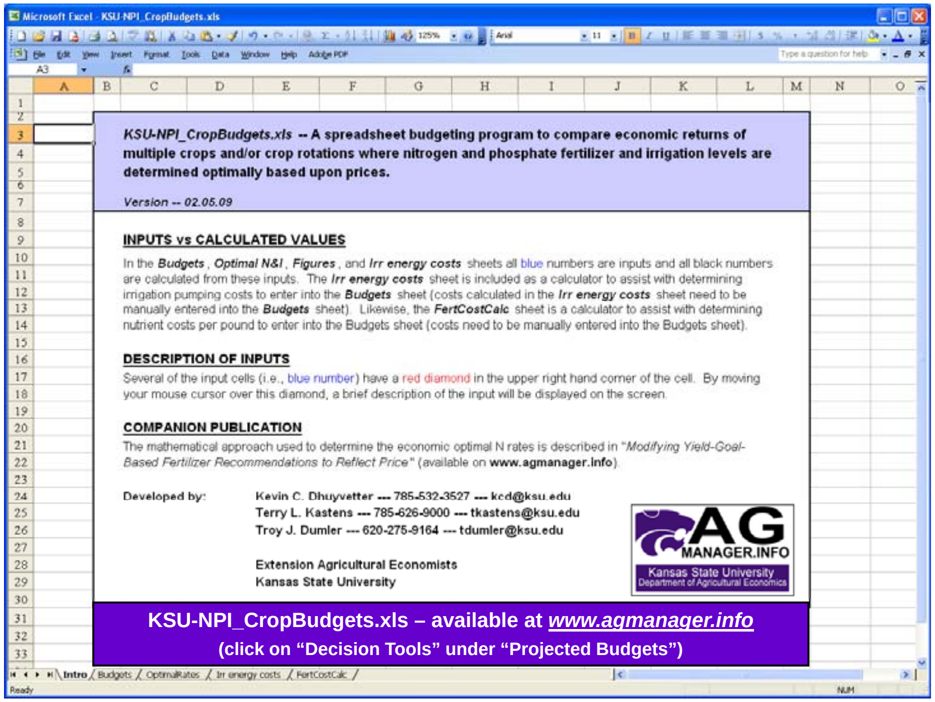
Late summer early Fall 2008 …

- Very high fertilizer prices and not just N
- Falling crop prices
- Producers asking about price-based adjustments again, especially related to high P prices ($1.20/lb P2O5??)

- And so we adjust the decision spreadsheet again… …this time incorporating P
  - Use MF-2586 sufficiency P recs

Three quadratic plateau (plateau = yield goal) production functions determine economic optimal levels of N, P, and I (irr water) inputs…





KSU-NPI_CropBudgets.xls **-- A spreadsheet budgeting program to compare economic returns of multiple crops and/or crop rotations where nitrogen and phosphate fertilizer and irrigation levels are determined optimally based upon prices.**

Version -- 02.05.09

INPUTS vs CALCULATED VALUES

In the ***Budgets*** , ***Optimal N&I*** , ***Figures*** , and ***Irr energy costs*** sheets all blue numbers are inputs and all black numbers are calculated from these inputs. The ***Irr energy costs*** sheet is included as a calculator to assist with determining irrigation pumping costs to enter into the ***Budgets*** sheet (costs calculated in the ***Irr energy costs*** sheet need to be manually entered into the ***Budgets*** sheet). Likewise, the ***FertCostCalc*** sheet is a calculator to assist with determining nutrient costs per pound to enter into the Budgets sheet (costs need to be manually entered into the Budgets sheet).

DESCRIPTION OF INPUTS

Several of the input cells (i.e., blue number) have a red diamond in the upper right hand corner of the cell. By moving your mouse cursor over this diamond, a brief description of the input will be displayed on the screen.

COMPANION PUBLICATION

The mathematical approach used to determine the economic optimal N rates is described in "*Modifying Yield-Goal-Based Fertilizer Recommendations to Reflect Price*" (available on **www.agmanager.info**)

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KSU-NPI_CropBudgets.xls – available at *www.agmanager.info*
(click on "Decision Tools" under "Projected Budgets")

Model “gives back” KSU N recommendations at long run prices and zero price on P and irrigation…

TABLE 1. Production Inputs Used for Budgets					1:04 PM	10/28/09
ITEM	Wheat	Corn	Sorghum	Soybean		
Price scenarios to consider					Use (Y=1, N=0)	
Long-run prices	$3.22	$2.35	$2.01	$5.46	1	
High-price scenario	$6.00	$4.50	$4.05	$11.00	0	
Current prices	$4.75	$3.50	$3.20	$8.65	0	
Yield goal (YG), bu/ac	60.0	225.0	125.0	40.0		
Enter 0 for dryland or 1 for irrigated	0	1	0	1		
Annual rainfall	20.00	20.00	20.00	20.00		
Soil test P (STP), ppm	12.00	12.00	12.00	12.00		
Organic matter (OM), %	2.00	2.00	2.00	2.00		
Soil test nitrogen (STN), lbs/ac	20.0	20.0	20.0	20.0		
Other N adjustments, lbs/ac	0.0	0.0	0.0	0.0		
KSU recommended nitrogen, lbs/ac	104.0	300.0	140.0	0.0		
Econ Optimum fertN, lbs/ac	104.3	299.9	140.5	0.0		
KSU recommended phosphate, lbs/ac	28.5	38.0	28.0	30.6		
Econ Optimum fertP, lbs/ac	25.8	32.7	24.1	34.1		
Econ Optimum Irrigation Amount, in	0.0	17.1	0.0	16.5		
Yield at optimal N, P, and I, bu/ac	59.6	223.7	124.0	40.0		
Change in STP, ppm	-0.22	-2.29	-1.42	0.12		
Fertilizer:					$/unit	
Nitrogen (N)	104.3	299.9	140.5	0.0	$0.2094 /lb	
Phosphate (P)	25.8	32.7	24.1	34.1	$0.0000 /lb	
Irrigation water, inches/acre	0.0	17.1	0.0	16.5	$0.00 /in	

“Blue” values represent user-entered inputs (all other values are calculated)

Model “gives back” KSU P sufficiency recommendations at long run prices and zero price on N and irrigation…

TABLE 1. Production Inputs Used for Budgets					1:01 PM	10/28/09
ITEM	Wheat	Corn	Sorghum	Soybean		
Price scenarios to consider					Use (Y=1, N=0)	
Long-run prices	$3.22	$2.35	$2.01	$5.46	1	
High-price scenario	$6.00	$4.50	$4.05	$11.00	0	
Current prices	$4.75	$3.50	$3.20	$8.65	0	
Yield goal (YG), bu/ac	60.0	225.0	125.0	40.0		
Enter 0 for dryland or 1 for irrigated	0	1	0	1		
Annual rainfall	20.00	20.00	20.00	20.00		
Soil test P (STP), ppm	12.00	12.00	12.00	12.00		
Organic matter (OM), %	2.00	2.00	2.00	2.00		
Soil test nitrogen (STN), lbs/ac	20.0	20.0	20.0	20.0		
Other N adjustments, lbs/ac	0.0	0.0	0.0	0.0		
KSU recommended nitrogen, lbs/ac	104.0	300.0	140.0	0.0		
Econ Optimum fertN, lbs/ac	110.4	317.8	153.2	0.0		
KSU recommended phosphate, lbs/ac	28.5	38.0	28.0	30.6		
Econ Optimum fertP, lbs/ac	28.7	37.1	28.3	30.6		
Econ Optimum Irrigation Amount, in	0.0	18.1	0.0	15.7		
Yield at optimal N, P, and I, bu/ac	59.9	224.8	124.9	39.9		
Change in STP, ppm	-0.07	-2.06	-1.20	-0.08		
Fertilizer:					$/unit	
Nitrogen (N)	110.4	317.8	153.2	0.0	$0.0000 /lb	
Phosphate (P)	28.7	37.1	28.3	30.6	$0.2445 /lb	
Irrigation water, inches/acre	0.0	18.1	0.0	15.7	$0.00 /in	

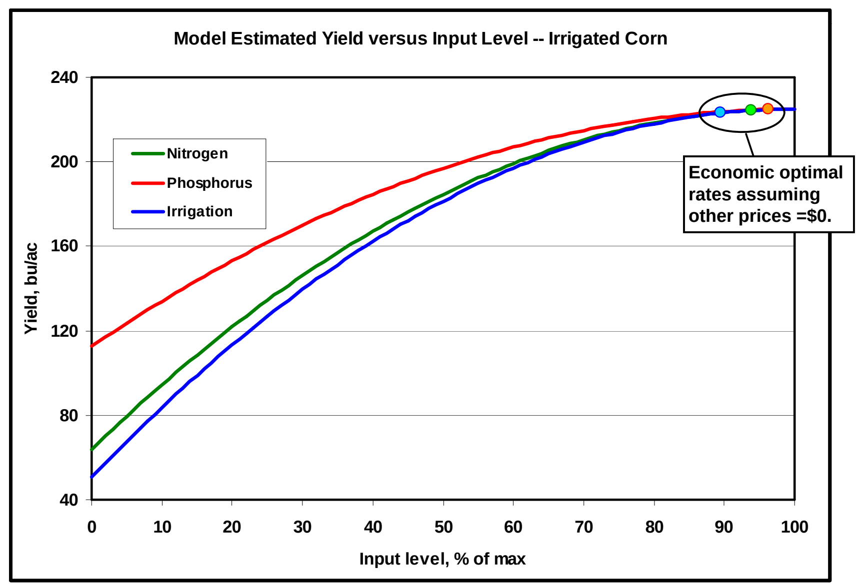
“Blue” values represent user-entered inputs (all other values are calculated)

At current prices, economic optimal N and P rates are lower by 7-12% and 15-22%, respectively, compared to recommended rates from MF-2586.

TABLE 1. Production Inputs Used for Budgets									3:38 PM	10/28/09
ITEM	Wheat		Corn		Sorghum		Soybean			
Price scenarios to consider									Use (Y=1, N=0)	
Long-run prices	$3.22		$2.35		$2.01		$5.46		0	
High-price scenario	$6.00		$4.50		$4.05		$11.00		0	
Current prices	$4.75		$3.50		$3.20		$8.65		1	
Yield goal (YG), bu/ac	60.0		225.0		125.0		40.0			
Enter 0 for dryland or 1 for irrigated	0		1		0		1			
Annual rainfall	20.00		20.00		20.00		20.00			
Soil test P (STP), ppm	6.00		6.00		6.00		6.00			
Organic matter (OM), %	2.00		2.00		2.00		2.00			
Soil test nitrogen (STN), lbs/ac	20.0		20.0		20.0		20.0			
Other N adjustments, lbs/ac	0.0		0.0		0.0		0.0			
KSU recommended nitrogen, lbs/ac	104.0		300.0		140.0		0.0			
Econ Optimum fertN, lbs/ac	93.0	-11%	263.7	-12%	129.9	-7%	0.0	n/a		
KSU recommended phosphate, lbs/ac	49.8		66.5		49.0		53.5			
Econ Optimum fertP, lbs/ac	41.8	-16%	52.1	-22%	41.6	-15%	44.9	-16%		
Econ Optimum Irrigation Amount, in	0.0		15.1		0.0		13.8			
Yield at optimal N, P, and I, bu/ac	58.6		218.5		122.6		39.1			
Change in STP, ppm	0.70		-1.11		-0.42		0.76			
Fertilizer:									$/unit	
Nitrogen (N)	93.0		263.7		129.9		0.0		$0.3600 /lb	
Phosphate (P)	41.8		52.1		41.6		44.9		$0.4200 /lb	
Irrigation water, inches/acre	0.0		15.1		0.0		13.8		$4.00 /in	

“Blue” values represent user-entered inputs (all other values are calculated)

Impact of considering prices of multiple inputs simultaneously…



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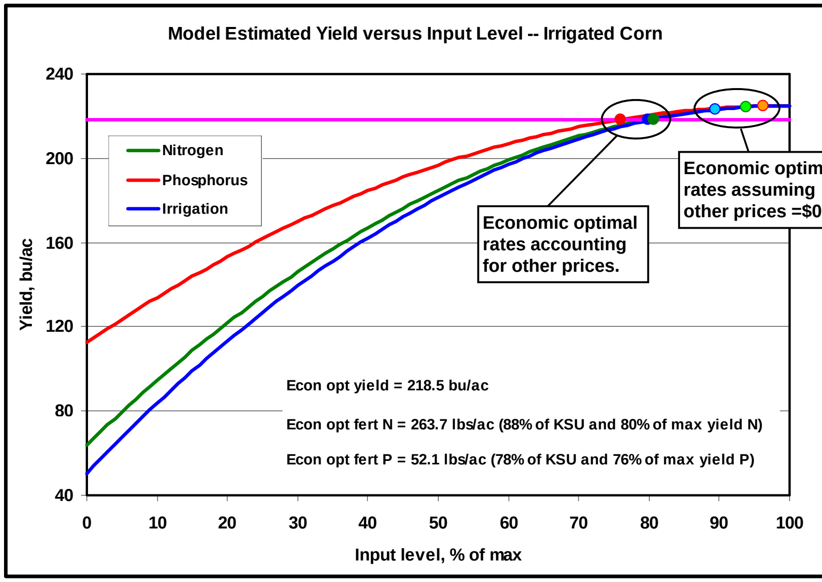

Changing one price assumption, impacts optimal levels of all three (N, P, I) inputs…

TABLE 1. Production Inputs Used for Budgets					3:52 PM 10/28/09
ITEM	Wheat	Corn	Sorghum	Soybean	
Price scenarios to consider					Use (Y=1, N=0)
Long-run prices	$3.22	$2.35	$2.01	$5.46	0
High-price scenario	$6.00	$4.50	$4.05	$11.00	0
Current prices	$4.75	$3.50	$3.20	$8.65	1
Yield goal (YG), bu/ac	60.0	225.0	125.0	40.0	
Enter 0 for dryland or 1 for irrigated	0	1	0	1	
Annual rainfall	20.00	20.00	20.00	20.00	
Soil test P (STP), ppm	6.00	6.00	6.00	6.00	
Organic matter (OM), %	2.00	2.00	2.00	2.00	
Soil test nitrogen (STN), lbs/ac	20.0	20.0	20.0	20.0	
Other N adjustments, lbs/ac	0.0	0.0	0.0	0.0	
KSU recommended nitrogen, lbs/ac	104.0	300.0	140.0	0.0	
Econ Optimum fertN, lbs/ac	89.3 -14%	259.3 -14%	126.1 -10%	0.0 n/a	
KSU recommended phosphate, lbs/ac	49.8	66.5	49.0	53.5	
Econ Optimum fertP, lbs/ac	40.0 -20%	51.0 -23%	40.3 -18%	43.2 -19%	
Econ Optimum Irrigation Amount, in	0.0	14.9	0.0	13.5	
Yield at optimal N, P, and I, bu/ac	58.1	217.6	122.0	38.8	
Change in STP, ppm	0.61	-1.15	-0.47	0.68	
Fertilizer:					$/unit
Nitrogen (N)	89.3	259.3	126.1	0.0	$0.3600 /lb
Phosphate (P)	40.0	51.0	40.3	43.2	$0.6000 /lb
Irrigation water, inches/acre	0.0	14.9	0.0	13.5	$4.00 /in

"Blue" values represent user-entered inputs (all other values are calculated)

Summary …

- In order to determine how to adjust fertilizer rates in response to prices, a mathematical relationship between nutrient and yield is needed
- A quadratic-plateau function can be "backed out" of KSU N and P recs
- Quadratic-plateau function allows diminishing returns, but is also consistent with linear plateau within any site-year
- If multiple inputs are considered simultaneously, economic optimal rates are lower than when other inputs are ignored (or have zero cost)

Questions ???

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