**AAE 320 Problem Set #1** **Name:** ANSWER KEY

**Due September 20, 2019**

1) You plant 500 acres of soybeans every year. Because of low market prices and high costs, you are considering reducing your seed costs by not buying an insecticidal seed treatment (just a fungicidal seed treatment). You would plant more seeds per acre due to expected stand loss (from belowground insects), and plant on average a few days later because you do not have early season insect control, and so would wait to plant until soils were warmer so seeds would emerge more quickly and outgrow pest problems faster. Talking to your seed salesman, you can buy seed without the insecticide seed treatment and save $10 per acre, but would plant more seeds per acre and increase your seed costs by $4 per acre, so that in net, you would save $6 per acre in seed costs. With later planting, you expect to lose 1 bushels per acre in yield.

a) Use the information given to conduct a partial budget analysis for the net gain for all 500 acres if you were to stop using an insecticidal seed treatment. Show your calculations in the space provided. Use a soybean price of $8.00 per bushel.

<table>
<tr><td colspan="2">Benefits</td><td colspan="2">Costs</td></tr>
<tr><td colspan="2">Additional Revenues<br>What will be the added revenues?<br>None</td><td colspan="2">Additional Costs<br>What new costs will be added?<br>Buy more seed for $4/ac<br>$4/ac x 500 ac = $2,000</td></tr>
<tr><td colspan="2">Costs Reduced<br>What costs will be eliminated?<br>Eliminate $10/ac for seed treatment cost<br>$10/ac x 500 ac = $5,000</td><td colspan="2">Revenues Reduced<br>What revenues will be lost?<br>Lose 1 bu/ac<br>1 bu/ac x $8.00/bu x 500 ac = $4,000</td></tr>
<tr><td>Total Benefits</td><td>$5,000</td><td>Total Costs</td><td>$6,000</td></tr>
<tr><td colspan="3">Total Benefits – Total Costs = Net Gain</td><td>–$1,000</td></tr>
</table>

Based on these results, is stopping use an insecticidal seed treatment a profitable decision?

*No, the partial budget analysis shows a net loss of $1,000. The cost savings of $10/ac from not using a seed treatment are not enough to compensate for the $4/ac cost increase for more seeds and the $8/ac loss due to lower yield.*

b) Repeat the partial budget analysis for all 500 acres using different assumptions. You would not plant later, but plant even more seeds per acre to compensate. Again you can buy seed without the insecticide seed treatment and save $10 per acre, but would now plant even more seeds per acre and so increase your seed costs by $8 per acre, so that in net, you would save $2 per acre in seed costs. However, even with on time planting, you still expect to lose 0.25 bushels per acre from some insect damage. Show your calculations in the space provided. <u>Use a soybean price of $8.00 per bushel.</u>

<table>
<tr><td colspan="2">Benefits</td><td colspan="2">Costs</td></tr>
<tr><td colspan="2"><u>Additional Revenues</u><br>What will be the added revenues?<br><br>None</td><td colspan="2"><u>Additional Costs</u><br>What new costs will be added?<br><br>Buy more seed for $8/ac<br><br>$8/ac x 500 ac = $4,000</td></tr>
<tr><td colspan="2"><u>Costs Reduced</u><br>What costs will be eliminated?<br><br>Again, eliminate $10/ac for seed treatment cost<br><br>$10/ac x 500 ac = $5,000</td><td colspan="2"><u>Revenues Reduced</u><br>What revenues will be lost?<br><br>Lose 0.25 bu/ac<br><br>0.25 bu/ac x $8.00/bu x 500 ac = $1,000</td></tr>
<tr><td>Total Benefits</td><td>$5,000</td><td>Total Costs</td><td>$5,000</td></tr>
<tr><td colspan="3">Total Benefits – Total Costs = Net Gain</td><td>$0</td></tr>
</table>

Based on these new results, is not using an insecticidal seed treatment a profitable decision?

*With the small yield loss, the partial budget analysis shows no net gain or loss from making the switch, it's a break even change. In this case, then other factors not included in the partial budget analysis will be used to swing the choice one way or the other, such as risk, time/labor changes, convenience, etc.*

.

2) You are a crop consultant helping a grain farmer in Wisconsin's Central Sands determine his economically optimal irrigation level. Using research data from his own on-farm experiments in deficit irrigation over the last three years, you calculated his average yield for different levels of total water (rainfall plus irrigation) during the growing season.

Fill in the table below and answer the following questions.

| Total Water (acre inches) | Average Corn Yield (bu/ac) | Marginal Product (bu/ac) | Value of the Marginal Product ($/ac) |
|---|---|---|---|
| 12 | 270.0 | --- | --- |
| 14 | 278.0 | *4.00* | *12.00* |
| 16 | 285.6 | *3.80* | *11.40* |
| 18 | 292.2 | *3.30* | *9.90* |
| 20 | 297.6 | *2.70* | *8.10* |
| 22 | 301.6 | *2.00* | *6.00* |
| 24 | 304.6 | *1.50* | *4.50* |
| 26 | 307.0 | *1.20* | *3.60* |

*Marginal Product (MP) is $\Delta Q/\Delta X$, or change in output divided by change in the input level. For the first two rows, $\Delta Q/\Delta X = (278.0 - 270.0)/(14 - 12) = 4.00$ bu/acre. The rest are in the table.*

*Value of the Marginal Product (VMP) is the price of output (here corn) times the Marginal Product. For the second row of the table, this is $3.00 per bu times the MP of 4.0 bu per acre, or 3.00 x 4.0 = $12.00. The rest are in the table.*

When he plants, he forward contracts to sell his corn at a price of $3.00/bu. The cost of pumping one acre inch of water is $6.00 per acre inch.

a) Suppose your client typically makes sure his corn gets 22 inches of water and this year he wants to go with 24 inches. Answer the following questions in order to explain to him why this is not a good plan if he wants to maximize his net returns:
   i. When he goes from 22 to 24 inches, how much does his average yield increase?

   *Yield increase is Q with 24 inches minus Q with 22 inches, or 304.6 – 301.6 = 3.0 bu.*

   ii. How much is this extra yield worth?

   *3.0 bu x $3/bu = $9.00*

   iii. How much will it cost him to pump these extra 2 inches?

   *Cost is $6.00 per inch, so 2 inches x $6.00 = $12.00.*

   iv. If he wants to maximize his net returns, is adding these two inches of water a good idea? Why or why not?

   *No, he would pay $12.00 per acre to pump these two more inches, but only gain $9.00 more in corn. It does not make sense to spend $12.00 to get $9.00.*

b) Assume he wants to maximize his net returns.
i. How much water should he plan make sure his corn has (you may need to interpolate)?

*In class, we showed that the optimal input use occurs where VMP = r, so here, where VMP = \$6.00 per acre, which occurs in the Table at <u>22 inches of water per acre</u>.*

ii. At this amount of water, what is his average corn yield and what is its value at \$3.00/bu?

*With 22 inches of water, yield = 301.6 bu/A, then at \$3.00/bu = \$904.80/A in revenue*

iii. If it usually rains 12 inches during the growing season, how much water will he have to pump? What will it cost to pump this much water if pumping costs \$6.00 per acre inch?

*The goal of 22 inches – 12 inches in rain = 10 inches to pump, so at \$6.00 per inch x 10 inches/A = \$60.00 per acre*

iv. Assuming he has \$700/ac in other costs, what are his net returns per acre?

Net returns = *\$904.80/A – \$60.00/A – \$700.00/A = 144.80/A*

c) Suppose he replaces his current high-pressure irrigation system with a more efficient low-pressure system that uses less energy and wastes less water, and as a result, pumping costs decrease to \$3.60 per acre inch. Assume he still wants to maximize his net returns.

How much water should he plan on making sure his corn has?

*If the cost of the input water is \$3.60/acre inch of water with the new system, then the optimality condition VMP = r occurs at 26 inches of water.*

d) Suppose a group wants to reduce agricultural use of water in the area and to do so, they are offering farmers subsidies to replace older high-pressure irrigation systems with new more efficient low-pressure systems that use less energy and waste less water and so have lower pumping costs per acre-inch. (In other words, the older systems are like in parts 1a and 1b and the newer systems are like in part 1c.) Their logic for these subsidies is that with these new more energy efficient systems, farmers will pump less water per acre. These new systems are more expensive to buy and install than a conventional system, but once in place, the new system is more energy efficient and so has a <u>lower cost</u> to pump one acre inch of water. Comment on how effective you think this program will be at reducing water use for crop production – <u>How does economically optimal input use respond to a lower input price</u>?

*The new more efficient system actually reduces the cost of pumping water, which is the same as decreasing the "price" of the water input, and so farmers will use more of the input, just like the difference in the answers in problem 1b versus 1c. When water decreases in cost from \$6.00 per inch to \$3.60 per inch (a 40% decline in cost), optimal water use went from 22 inches per acre to 26 inches per acre (an 18% increase). This type of response happens commonly today in energy demand and computer speed demand – make a more efficient system and people actually use more energy and demand more computer speed. It's been known since the 1800s and is called Jevon's Paradox in the history literature or the rebound effect in the modern energy literature (Google it if you are interested).*

3) You are the same crop consultant, but now determining the economically optimal nitrogen rate for your client's corn fields using Extension nitrogen fertilizer recommendations. You will first derive the optimal rate using calculus, and then using an online tool.

Suppose expected corn yield is $Y = 165 + 0.996N - 0.0023N^2$, where Y is corn yield in bushels per acre and N is the total nitrogen applied as pounds of N per acre. Assume the expected corn price is $3.00/bu and Urea N nitrogen fertilizer solution (45% N by weight) costs $450/ton.

a) The production function uses nitrogen in pounds of N per acre, but the price is $450 per ton of fertilizer. Convert the price of the fertilizer from $450/ton of fertilizer to $/lb of N. If urea N nitrogen fertilizer solution (45% N by weight) costs $450/ton, what is the price of nitrogen N in $ per pound?

   *Based on the numbers above, the calculations are:*

$$\frac{\$450}{\text{1 ton of Fertilizer}} \text{ x } \frac{\text{1 ton of Fertilizer}}{\text{2,000 pounds of Fertilizer}} \text{ x } \frac{\text{1 pound of Fertilizer}}{\text{0.45 pounds of Nitrogen}} = \frac{\$0.50}{\text{1 pound of N}}$$

   *or $0.50/pound for N.*

b) Using the price for N, a corn price of $3.00/bu, and the given production function, write the profit ($\pi$) equation for the farmer's net return per acre.

   $\pi = pQ - rX$, *where* $Q = f(X)$. *Here X is nitrogen, or N, so we write*
   $\pi = 3.00(165 + 0.996N - 0.0023N^2) - 0.5N$

c) Using calculus, what N rate maximizes profit for the farmer? Give the first order condition, solve it for the optimal N rate, and then check the second order condition.

   $\pi(N) = 3.00(170 + 0.996N - 0.0023N^2) - 0.5N$

   *The first order condition (FOC):* $d\pi/dN = 3.00(0.996 - 0.0046N) - 0.5 = 0$.

   *Solving FOC for N gives* $N = 180.3$ *or 180 lbs of N per acre.*

   *The second order condition (SOC) is* $d^2\pi/dN^2 = -0.0138 < 0$, *which satisfies the condition for a maximum.*

d) At this nitrogen rate, what is his yield (bu/ac)? What is his per acre revenue? How much will it cost ($/ac) to buy this much nitrogen fertilizer? If he has $700/ac in other costs, what are his per acre net returns (profit) at this nitrogen rate?

   *Substitute* $N = 180$ *into the production function* $Y = 165 + 0.996N - 0.0023N^2$
   $Y = 165 + 0.996(180) - 0.0023(180)^2 = 269.8$ *bu per acre*

   *Revenue = Corn Price x Yield = 3.00 x 269.8 = $809.40 per acre*

   *Fertilizer Cost = N Price x N = 0.50 x 180 = $90.00 per acre*

   *Profit = Revenue – Cost = $809.40 – $90.00 – $700.00 = $19.40 per acre*

e) Assume you find some cheaper Urea fertilizer for a price of $400/ton, but the price of corn is now $3.25/bu. Using the same production function, what is the optimal nitrogen rate to apply? What is the expected yield at this nitrogen rate? Again, assuming $700/ac in other costs, what are his per acre returns at this nitrogen rate?

$$\frac{\$400}{\text{1 ton of Fertilizer}} \times \frac{\text{1 ton of Fertilizer}}{\text{2,000 pounds of Fertilizer}} \times \frac{\text{1 pound of Fertilizer}}{\text{0.45 pounds of Nitrogen}} = \frac{\$0.44}{\text{1 pound of N}}$$

*or \$0.44/pound for N.*

$\pi = 3.25(165 + 0.996N - 0.0023N^2) - 0.44N - 700$

*The first order condition (FOC):* $d\pi/dN = 3.25(0.996 - 0.0046N) - 0.44 = 0$.

*Solving FOC for N gives* $N = 187.1$ *or 187 lbs of N per acre.*

*The second order condition (SOC) is* $d^2\pi/dN^2 = -0.01495 < 0$, *which satisfies the condition for a maximum.*

*Substitute* $N = 187$ *into the production function* $Y = 165 + 0.996N - 0.0023N^2$

$Y = 165 + 0.995(187) - 0.0023(187)^2 = 270.8$ *bu per acre*

*Revenue = Corn Price x Yield = 3.25 x 270.8 = \$880.10 per acre*

*Fertilizer Cost = N Price x N = 0.44 x 187 = \$82.28 per acre*

*Profit = Revenue – Cost = \$880.10 – \$82.28 – \$700.00 = \$97.82 per acre*

f) Many Midwestern states use this method to develop Extension recommendations for nitrogen fertilizer use in corn. Go to http://cnrc.agron.iastate.edu/ for the Corn Nitrogen Rate Calculator and read the "About" tab, especially "Definitions." Next, choose "Single Price" and then choose "Wisconsin" for the state, "Corn following Soybean" for the rotation, and "Irr. Sands" for the soil type. Choose the right form of nitrogen "Urea (45% N)" and enter the nitrogen and corn prices from part a and hit the "Calculate" button.

   i) Does the price of N in \$/lb match your answer in part a? You should answer "Yes" here, if not, go back and get the price right in part a or enter the correct inputs here. Note that the program rounds to the nearest full cent per pound. *You should get \$0.50/pound. See Figure 1 below.*

   ii) At a urea N fertilizer price of \$450/ton and a corn price of \$3.00/bu, what does the tool indicate is the optimal N rate? *MRTN Rate = 181 pounds of N per acre. See Figure 1 below.*

   iii) If the Urea N nitrogen fertilizer price is \$400/ton and the corn price is \$3.20/bu, what does the tool indicate is the optimal N rate? *MRTN Rate = 187 pounds of N per acre. See Figure 2 below.*

   iv) How do these compare to your answers in parts a and e? They should be very close to the same amount; if not, go back and get things right. *They are very similar. The tool and equation are within one pound per acre.*

The UW Extension Nutrient and Pest Management Program (http://ipcm.wisc.edu/) has developed free apps for iPhones/iPads and Android Smartphones/Tablets, the "Corn N Rate Calculator" and the "N Price Calculator". Search in the iTunes Store or Google Play (or see http://ipcm.wisc.edu/apps/) and download them if you want to. When you do, you will see lots of other interesting apps available as well.

Figure 1. Corn Nitrogen Rate Calculator output for $300/ton urea and $3.00/bu corn

## Rates and Charts

State: Wisconsin
Soil Type: Irr. Sands
Number of sites: 4
Rotation: Corn Following Soybean

| | |
|---|---|
| Nitrogen Price ($/lb): | 0.50 |
| Corn Price ($/bu): | 3.00 |
| Price Ratio: | 0.17 |
| MRTN Rate (lb N/acre): | 181 |
| Profitable N Rate Range (lb N/acre): | 168 - 192 |
| Net Return to N at MRTN Rate ($/acre): | $229.48 |
| Percent of Maximum Yield at MRTN Rate: | 98% |
| Urea (45% N) at MRTN Rate (lb product/acre): | 402 |
| Urea (45% N) Cost at MRTN Rate ($/acre): | $90.50 |

N Price ($/lbs of N)

Optimal N Rate

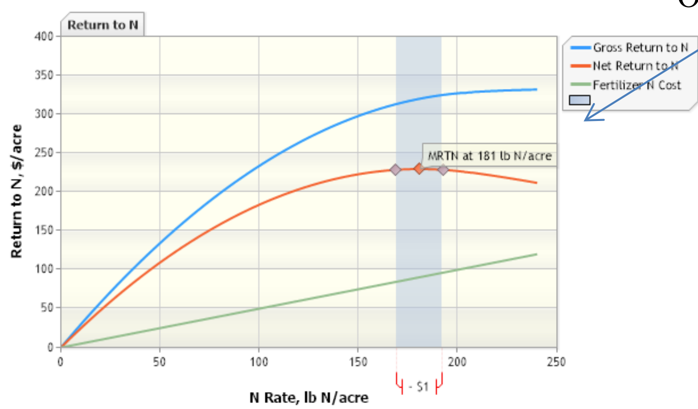


Figure 2. Corn Nitrogen Rate Calculator output for $400/ton urea and $3.20/bu corn

State: Wisconsin
Soil Type: Irr. Sands
Number of sites: 4
Rotation: Corn Following Soybean

| | |
|---|---|
| Nitrogen Price ($/lb): | 0.44 |
| Corn Price ($/bu): | 3.25 |
| Price Ratio: | 0.14 |
| MRTN Rate (lb N/acre): | 187 |
| Profitable N Rate Range (lb N/acre): | 176 - 198 |
| Net Return to N at MRTN Rate ($/acre): | $267.32 |
| Percent of Maximum Yield at MRTN Rate: | 98% |
| Urea (45% N) at MRTN Rate (lb product/acre): | 415 |
| Urea (45% N) Cost at MRTN Rate ($/acre): | $82.28 |

N Price ($/lbs of N)

Optimal N Rate