

### Total Product, Average Product, Marginal Product

Consider a corn farmer with two acres of land. Thus, the land is a fixed input. In addition to land, other factors of production include quantity of seeds, fertilizer, water, and labor. Assume the farmer has already decided how much seed, water, and labor he will be using this season. He is still deciding on how much fertilizer to use. As he increases the amount of fertilizer, the output of corn will increase. It may also reach a point where the output begins to decrease since too much fertilizer can become poisonous since land is fixed. Let's assume you have information on farmer's fertilizer input use at various situations and the yield.

1. At what point Total Product (TP) reaches its maximum?
2. How do we obtain the AP? Fill in the AP column. What happens to the AP as we move from A to E? then E to J?
3. At what point AP reaches its maximum?
4. Fill in columns 4, and 5. Since they are changes in input and output, use the lines in between A and B, B and C, etc. to write the changes
5. How do we obtain the MP (column 7)? For example, the MP between A and B is the change in yield between A and B divided by the change in the fertilizer used between A and B. Therefore, in this exercise we fill the MP in the row between the lines A and B, B and C, C and D etc.
6. How would you explain the number in the MP column between B and C? What does this number mean?
7. When does the MP reach its maximum?

| 1           | 2                     | 3                         | 4                   | 5              | 6                     | 7  |
|-------------|-----------------------|---------------------------|---------------------|----------------|-----------------------|--|
| Observation | Fertilizer (lbs/acre) | TP = Yield (bushels/acre) | $\Delta$ Fertilizer | $\Delta$ Yield | AP = Yield/Fertilizer | MP = $\Delta$ Yield/ $\Delta$ Fertilizer |
| A           | 100                   | 100                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| B           | 160                   | 300                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| C           | 200                   | 480                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| D           | 220                   | 650                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| E           | 260                   | 810                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| F           | 320                   | 960                       |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| G           | 400                   | 1080                      |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| H           | 500                   | 1160                      |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| I           | 620                   | 1160                      |                     |                |                       |  |
|             |                       |                           |                     |                |                       |  |
| J           | 760                   | 1145                      |                     |                |                       |  |

Below on page 4, are the TP curve, MP curve and AP curve. Using the figures, and the table above, answer the following question.

1. How is the TP curve related to the MP curve? Or what is the relationship between MP and TP?
2. Use the table to mark the regions of TP curve where the slope of the TP is increasing, the slope of the TP is decreasing, the slope is zero, and then negative?
3. What happens to the MP as the farmer uses more and more fertilizer? Think about the points from A to C. Then from C to I. Then after point I.
4. Based on your answer to part (1), could you explain the corresponding changes in the slope of the TP function?
5. Would you agree with the statement that as the farmer uses more and more of the variable input, the fertilizer, with a fixed amount of land, at some point the MP of the fertilizer begins to decline?

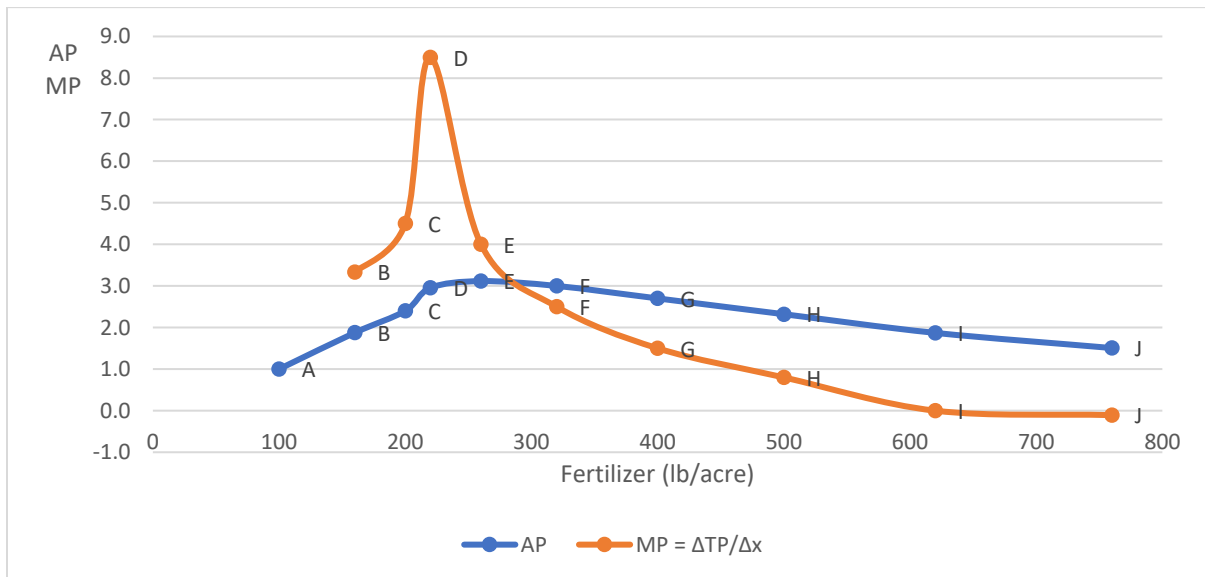
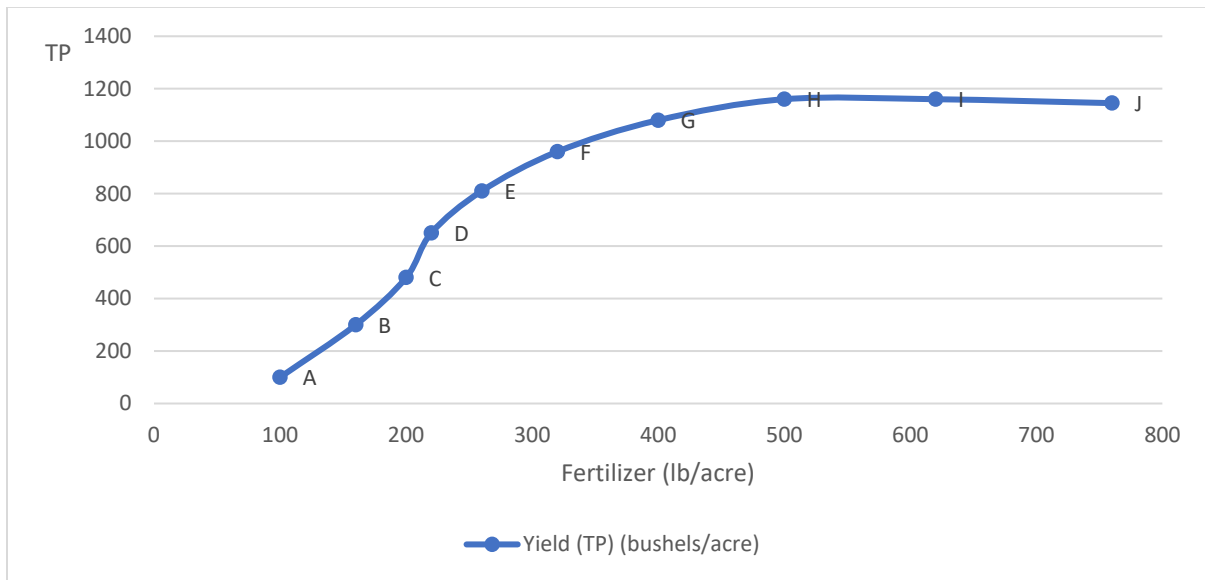
#### The Law of Diminishing Marginal Returns or Product

*The law of diminishing marginal product states that as increasing amounts of a variable input are combined with one or more fixed inputs, at some point the marginal product of the variable input will begin to decline.*

6. At what point does the law of diminishing returns set in?
7. Does the TP decrease when the MP starts to decline?
8. What is the MP when the TP reaches its maximum? In other words, what is the slope of the TP when the TP reaches its maximum?
9. Note that the MP intersects the horizontal line when the TP is maximum, and after that MP becomes negative.
  - a. At what point the MP curve intersects the AP curve?
  - b. Is the MP curve above or below the AP curve before both curves intersect?
  - c. Is the MP curve above or below the AP curve after both curves intersect?
  - d. When the MP curve is above the AP curve, does the AP increase or decrease?
  - e. When the MP curve is below the AP curve, does the AP increase or decrease?
  - f. Intuitively, how would you explain why AP and MP move together in the way you described above?

To illustrate this relationship, consider the simple example of a student who takes a course in which the final grade is based on the average of 10 quizzes. A maximum of 100 points may be earned on each quiz. Thus, a maximum of 1,000 points may be earned during the semester, or a maximum average for the course of  $1,000/10 = 100$ . Quizzes are the input and the maximum points are the output. Suppose that the student has taken six quizzes and has earned a total of 480 points, for an average grade of  $480/6 = 80$ . If the student receives a grade of 90 on the seventh quiz, then the student's average will rise from 80 to  $570/7 = 81.4$ . The marginal grade between the sixth and the seventh quiz is  $570 - 480 / 7 - 6 = 90$ . That is, since the marginal grade (90) is greater than the average grade to that point (81.4), the student's average will rise. On the other hand, if the student received a grade of 70 on the seventh quiz, the student's average will fall to  $550/7 = 78.6$  because the marginal grade is 70 which is below the average 78.6. Finally, if the student receives a grade of 80 on the

seventh quiz then, clearly, there will be no change in the student's average (i.e.,  $560/7 = 80$ ). Here the marginal grade = average grade  
 Use the above example and use a similar illustration to the farmer's case.



Let's add some economics to the production function. Suppose the cost of the fertilizer is \$40.3/lb. In addition to the variable fertilizer cost, assume that the fixed cost is \$500 (no matter how much output the farmer produces, he will incur this \$500 cost). For each bushel of corn sold, the farmer receives \$50.4. Fill in each column of the following table and answer the question on the following page.

**Profit maximizing input level in a One variable input-One output model**

| 1           | 2                         | 3                         | 4          | 5           | 6    | 7                           | 8                          | 9            | 10                            | 11              | 12                  | 13              | 14                               | 15  | 16  |
|-------------|---------------------------|---------------------------|------------|-------------|------|-----------------------------|----------------------------|--------------|-------------------------------|-----------------|---------------------|-----------------|----------------------------------|-----|-----|
| Observation | Fertilizer (x) (lbs/acre) | Yield (TP) (bushels/acre) | $\Delta x$ | $\Delta TP$ | AP   | $MP = \Delta TP / \Delta x$ | $TVP = TP * P = TP * 50.4$ | $\Delta TVP$ | $VMP = \Delta TVP / \Delta X$ | $VMP = MPP * P$ | $TF_c C = x * 40.3$ | $\Delta TF_c C$ | $MFC = \Delta TF_c C / \Delta x$ | TFC | NVP |
| A           | 100                       | 100                       | -          | -           | 1.0  |                             |                            |              |                               |                 |                     |                 |                                  |     |     |
| B           | 160                       | 300                       | 60         | 200         | 1.9  | 3.3                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| C           | 200                       | 480                       | 40         | 180         | 2.4  | 4.5                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| D           | 220                       | 650                       | 20         | 170         | 3.0  | 8.5                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| E           | 260                       | 810                       | 40         | 160         | 3.1  | 4.0                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| F           | 320                       | 960                       | 60         | 150         | 3.0  | 2.5                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| G           | 400                       | 1080                      | 80         | 120         | 2.7  | 1.5                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| H           | 500                       | 1160                      | 100        | 80          | 2.32 | 0.8                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| I           | 620                       | 1160                      | 120        | 0           | 1.9  | 0.0                         |                            |              |                               |                 |                     |                 |                                  |     |     |
| J           | 760                       | 1145                      | 140        | -15         | 1.5  | -0.1                        |                            |              |                               |                 |                     |                 |                                  |     |     |

## **Profit Maximization**

### **One output-One input**

#### **Input side**

1. If the farmer's goal is to maximize the Total Value Product (TVP), what would his TVP be? What are the two possible levels of fertilizer that maximize the TVP?
2. What column would you use to look at the profits?
3. Is the above approach in (10) the right way to decide how many units of input to use to if the farmer's goal is to maximize profit? Why or why not?
4. Given the answer to the above, when does the farmer maximize net value product i.e. profit? What is the profit maximizing level of input use?
5. The VMP is the value of the output produced by the last unit of a variable input. Explain what is meant by  $VMP = 226.8$ ?
6. The  $MF_cC$  is the cost of the last unit of a variable input used. Explain what is meant by  $MF_cC = 40.3$ ?
7. How does VMP change when more units of fertilizer are used? How does this relate to the marginal product (MP) in column (7)?
8. How does  $MF_cC$  change when more units of fertilizer are used? How does this relate to the unit cost of fertilizer?
9. What would it mean if  $VMP = MF_cC$ ? if  $VMP > MF_cC$ ? if  $VMP < MF_cC$ ?
10. Based on your answers above, what should be true when profit is maximized? i.e. which of these conditions should hold?  $VMP = MF_cC$  or  $VMP > MF_cC$  or  $MF_cC < MF_cC$ ? Why?
11. Verify your answer to (19) at the profit maximizing point of production.
12. If the farmer's goal is to maximize the yield (output), how many units of fertilizer he should use? What would his net value product be in this case? Is maximizing output equivalent to maximizing profit? Why?