A Method for Estimating Yield Losses from Nutrient Rate Reductions

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Introduction

Farmers need some way of using the law of diminishing returns to estimate how much yield they can reasonably expect to lose if they reduce their nutrient rates by a given amount.

The quadratic equation is commonly used to model crop response to nutrients:

$$y = a + bx + cx^2$$

where y = crop yield and x = nutrient rate.

Equations for estimating quadratic coefficients were developed by van Raij and Cantarella (1996), and this paper expands upon their work.

(van Raij, B. and H. Cantarella. 1996. A quadratic model for fertilizer recommendations based on results of soil analyses. Comm. Soil Sci. Plant Anal. 27:1595-1610)

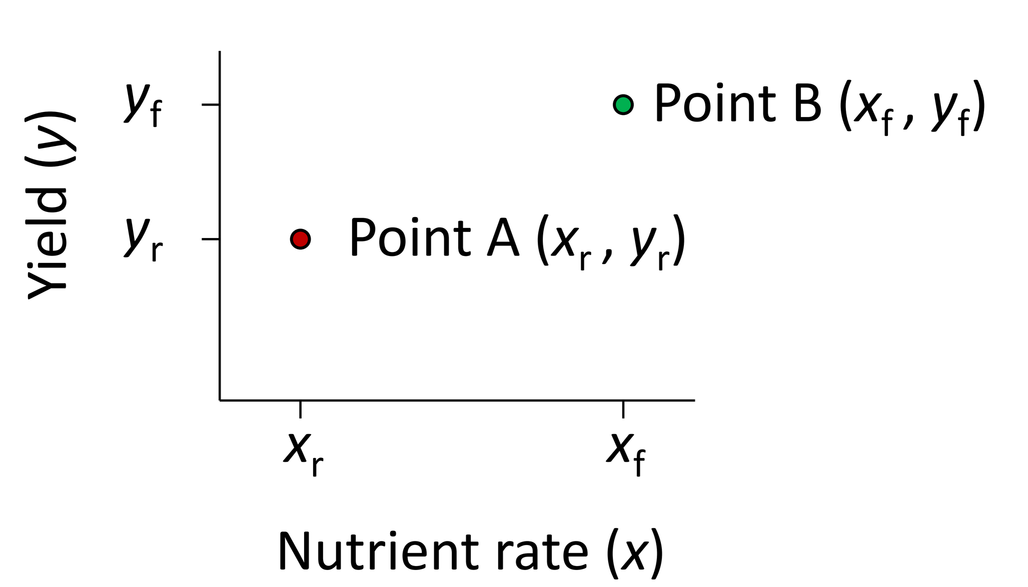
Objective:

To estimate the coefficients (*a*, *b*, *c*) of a quadratic crop response equation using only two data points

Mathematical Approach: Data Needed

Two data points are needed:

1. Point A (x_r, y_r):
   a rate that is less than what the farmer usually applies (x_r) and the associated yield (y_r). Data can come from:
   a. omission plots
   b. nutrient misapplications
   c. soil test calibration relationships
   d. regional databases of crop response
2. Point B (x_f, y_f):
   the nutrient rate the farmer usually applies (x_f) and the associated expected yield (y_f)



Mathematical Approach: Assumptions

General assumptions:

- Only one nutrient is considered at a time (no interactions)
- Crop response follows the law of diminishing returns: $b \geq 0$ and $c \leq 0$

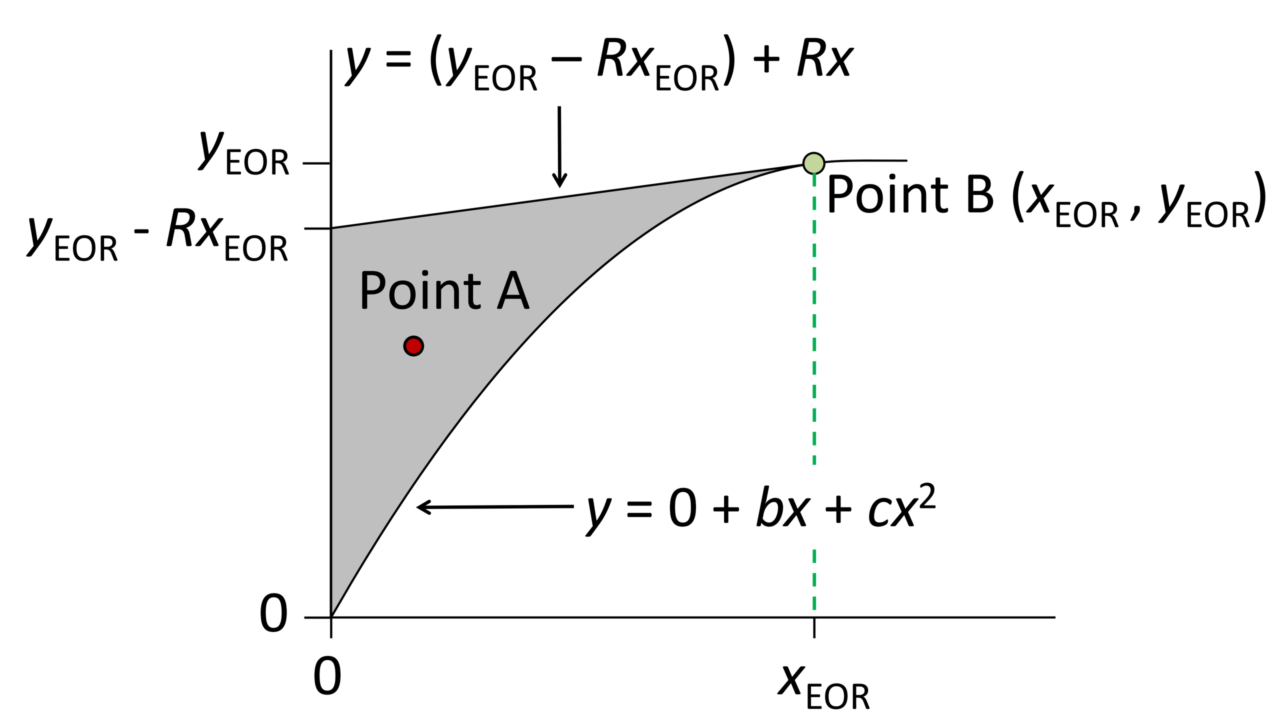
Assumptions about Point B:

It is either

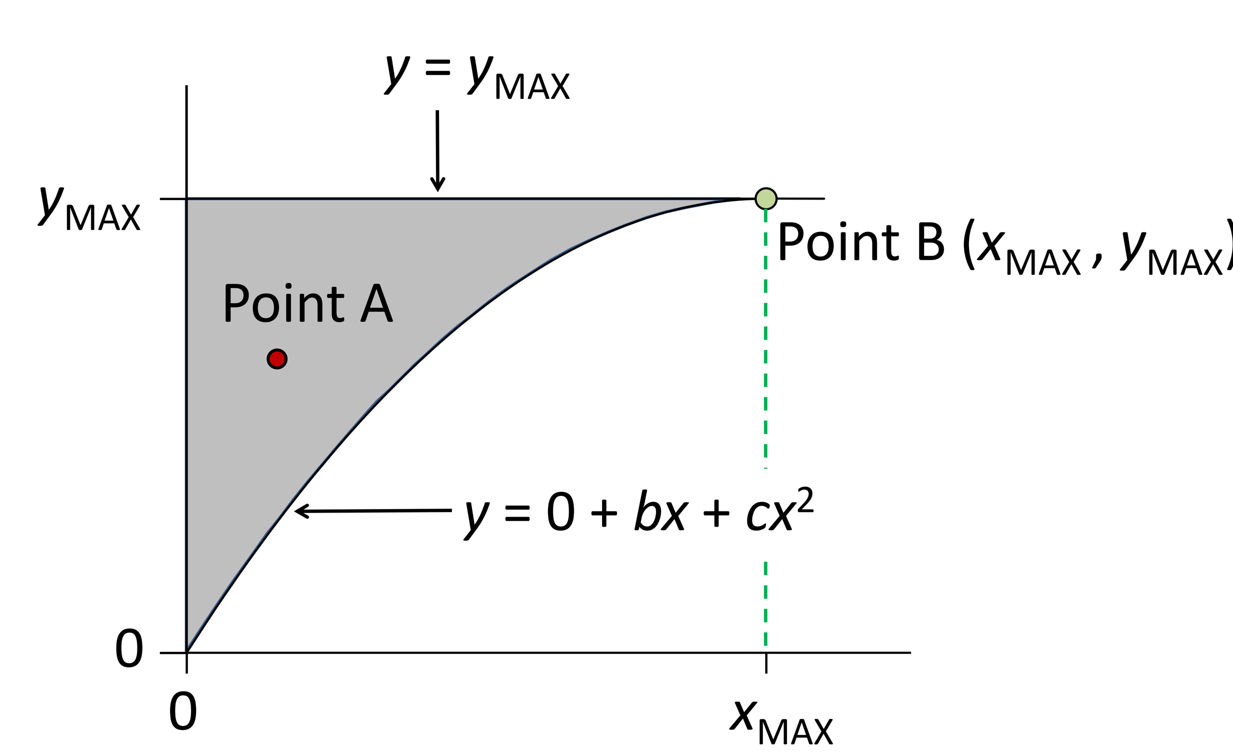
- the economically optimum rate (EOR) and associated yield:
  (x_f, y_f) = (x_{EOR}, y_{EOR})
  - or -
- the rate just needed to maximize yield:
  (x_f, y_f) = (x_{MAX}, y_{MAX})

Assumptions about Point A:

- If Point B is the EOR, then point A must be in the shaded 2-dimensional space, where R = the nutrient to crop price ratio:



- If Point B is the rate just needed to maximize yield, then Point A must be in the shaded 2-dimensional space:



Estimates of Quadratic Coefficients

When Point B = (x_{EOR}, y_{EOR}):

$$c = \frac{(y_{EOR} - y_r - Rx_{EOR} + Rx_r)}{(-x_{EOR}^2 + 2x_r x_{EOR} - x_r^2)}$$

$$b = R - 2cx_{EOR}$$

$$a = y_r - Rx_r + c(2x_{EOR}x_r - x_r^2)$$

When Point B = (x_{MAX}, y_{MAX}):

$$c = \frac{(y_r - y_{max})}{(x_{max} - x_r)^2}$$

$$b = -2cx_{max}$$

$$a = y_r + c(2x_r x_{max} - x_r^2)$$

Example

- A farmer expects 12 500 kg ha^{-1} of maize using 200 kg ha^{-1} of nitrogen (maximum yield and rate)
- In a strip trial, the farmer measured 8 000 kg ha^{-1} of grain when only 50 kg ha^{-1} of N was applied
- What is the expected yield reduction if the normally used rate is reduced by 30 kg ha^{-1}?
- Estimated quadratic coefficients:
  a = 4500; b = 80; c = -0.2

Scenario Results

Estimated yield loss (yield units):	180.00
Estimated yield loss (% of normal yield):	1.44%