Scientific Considerations for Allocating Funds to Various Fertilizer Nutrients

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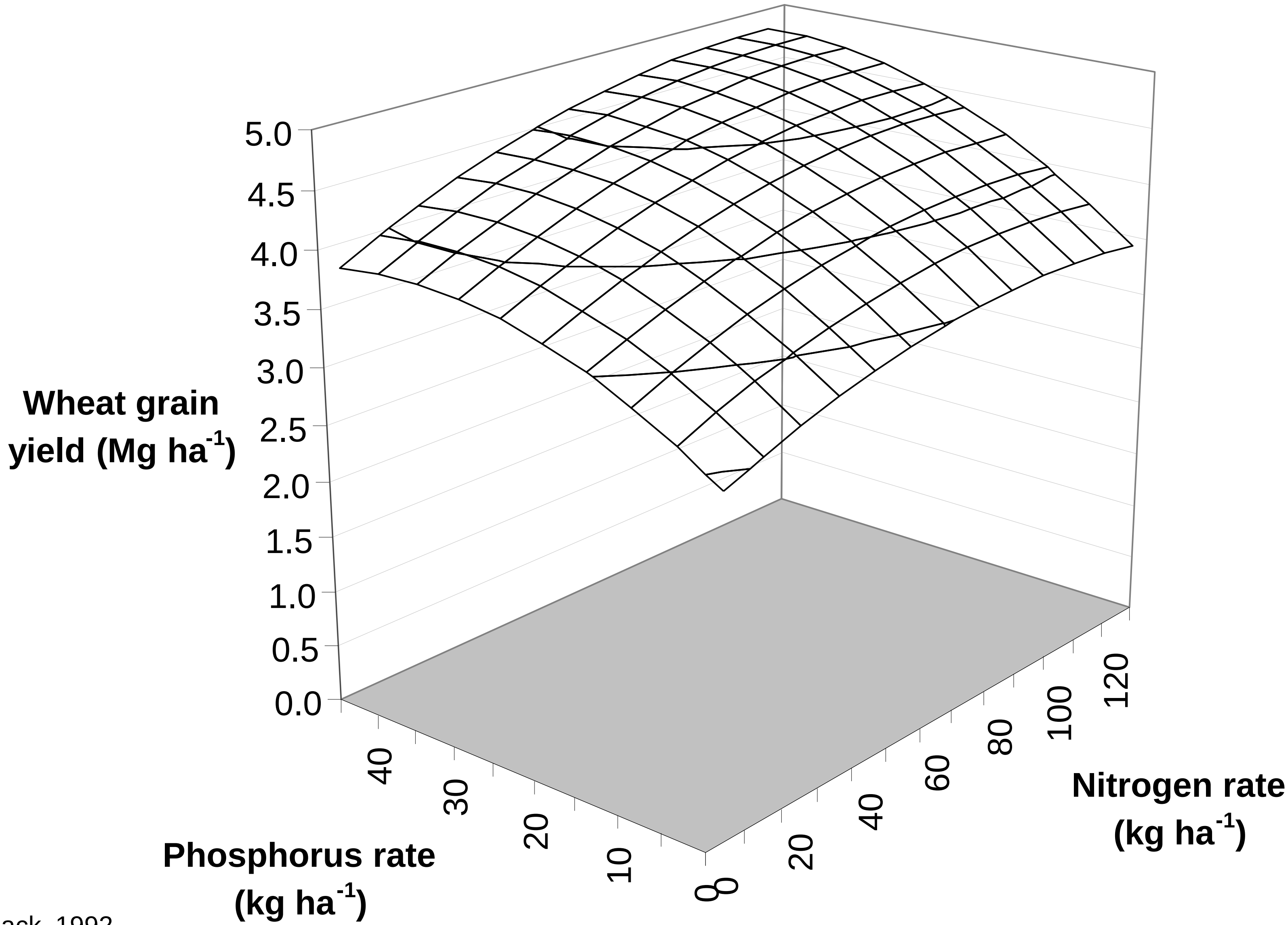
"I can't afford what's being recommended. Where's the best place to spend the money I do have?"

How have others addressed this issue?

- Most university Extension recommendations consider each nutrient separately
  - Interactions are generally not considered
  - Guidance is lacking on how to quantify how much of each nutrient is needed, accounting for interactions
- C.A. Black reviewed the mathematical approaches needed:
  - 2-7.8. “Combination for maximum profit”
  - 2-7.7. “Most profitable combination for a given expenditure”
  - Considered two nutrients: nitrogen (N) and phosphorus (P)
  - *Black, C.A. 1992. Soil fertility evaluation and control. Lewis Publishers, London.*

Quadratic response surface example: Wheat response to N and P



Black, 1992

Finding the combination for maximum profit:
N and P example

$$y = a + b_1 N + c_1 N^2 + b_2 P + c_2 P^2 + d_{12} NP$$

P_N = price of N
P_P = price of P
P_y = price of a unit of harvested crop

Solution - Find the rates of N and P that produce an incremental yield response equal in value to their incremental costs:

$$\mathrm{d}y(Py) = \mathrm{d}N(P_N)$$

$$\mathrm{d}y(Py) = \mathrm{d}P(P_P)$$

Result: an economically optimum combination of N and P

Black, 1992

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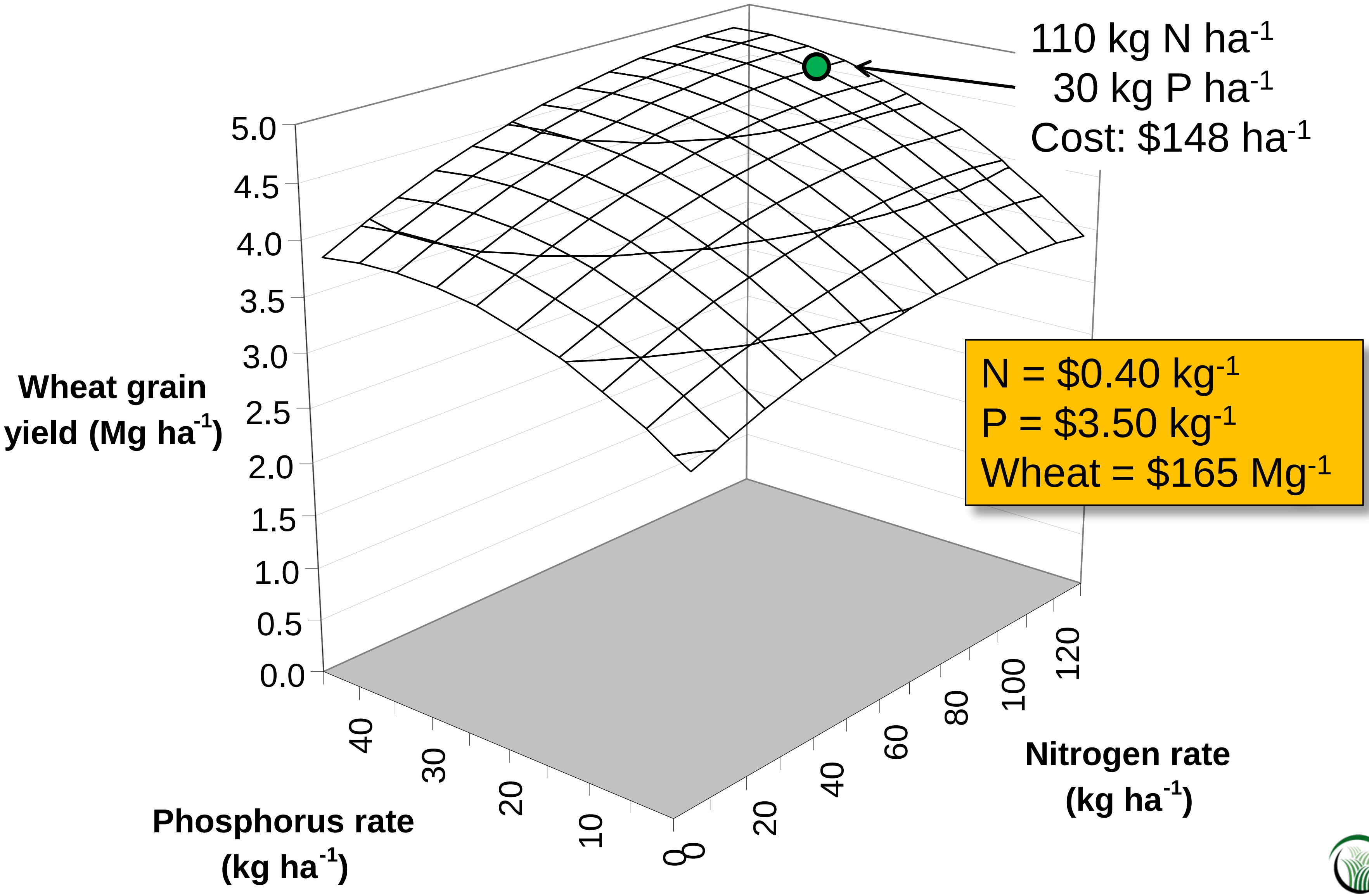
Combination for maximum profit:

Wheat response to N and P



Most profitable combination for a given expenditure

- Solve two equations simultaneously:
  - Total desired fertilizer cost (*T*) must als be factored in:

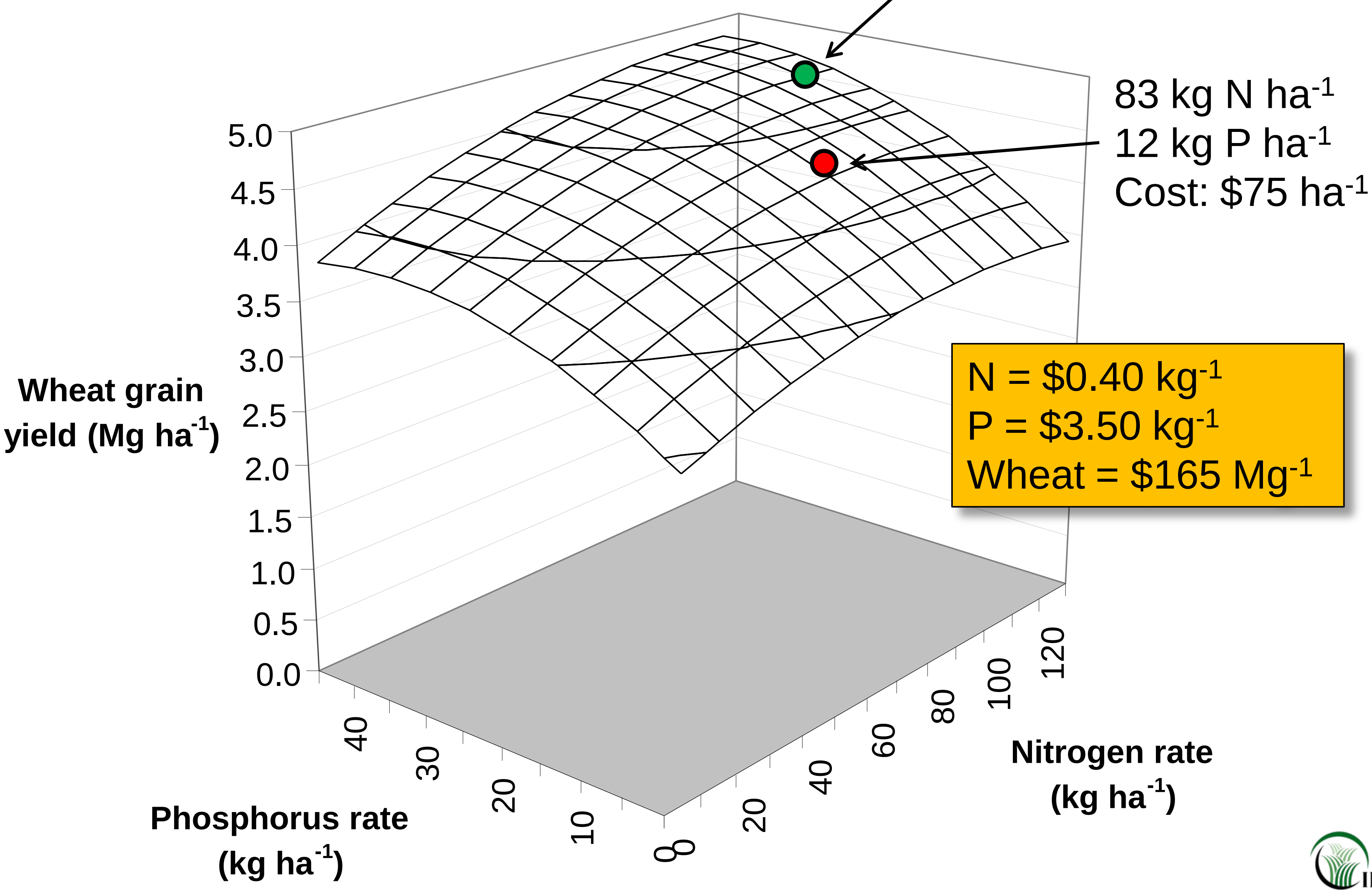
$$T = P_N(N) + P_P(P)$$

  - Most profitable combination occurs when an incremental increase in the cost of each nutrient produces the same incremental increase in crop revenue

$$\frac{dy(Py)}{dN(P_N)} = \frac{dy(Py)}{dP(P_P)}$$

Black, 1992

Farmer can only afford $75 ha^{-1}



The challenge

- Two-factor interaction data are sparse and confined to small inference spaces
- Can response surfaces for two nutrients be estimated using the sparse data available to consultants?
  - Farmer's expected yield
  - Recommended nutrient rates
  - Estimates of yield responses for each nutrient considered separately:
    - Soil test calibration data (unfertilized relative yields)
    - Databases of crop response (average responses)
    - Omission plots (yields without nutrient additions)

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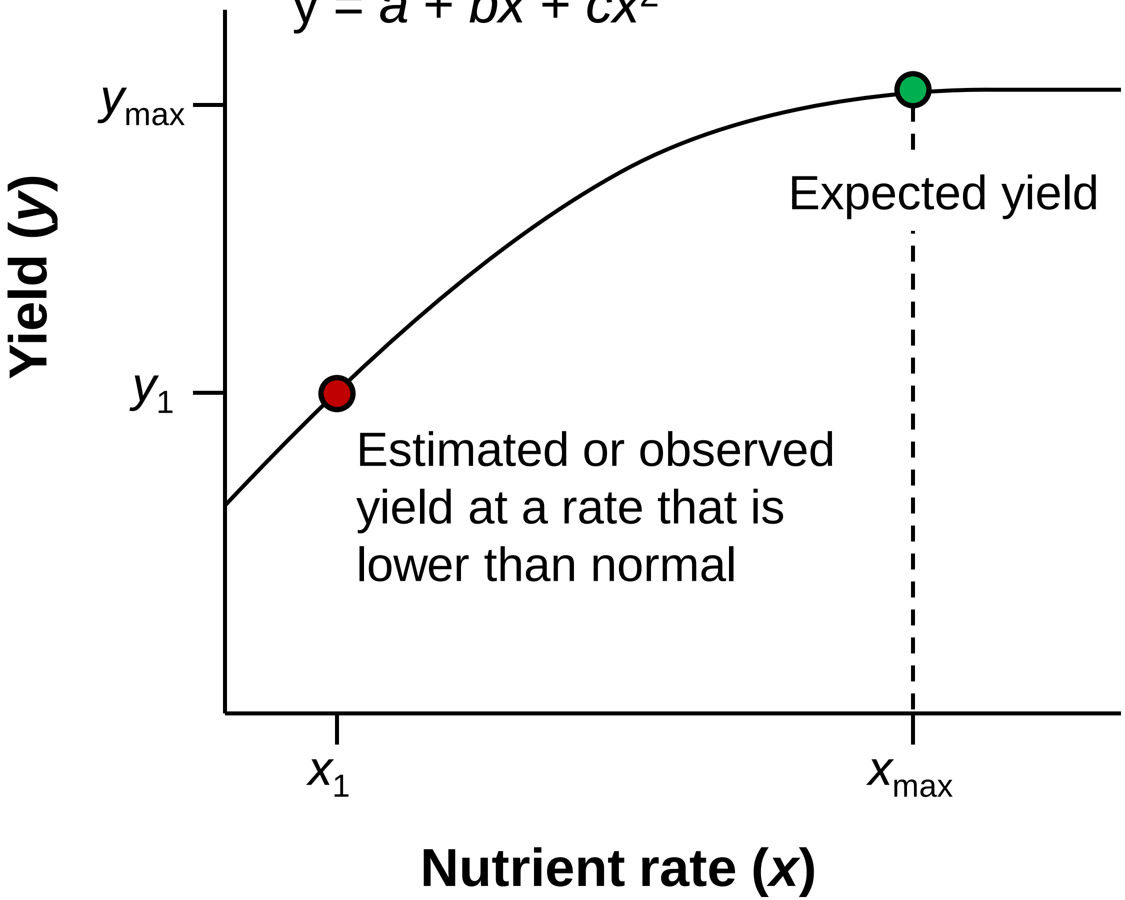
Estimating a quadratic response from two points: expected yield = maximum yield

Quadratic equation:

$y = a + bx + cx^2$



3 unknowns: *a*, *b*, *c*

3 equations:

1) $dy/dx_{max} = 0$

2) $y_1 = a + bx_1 + cx_1^2$

3) $y_{max} - y_1$

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

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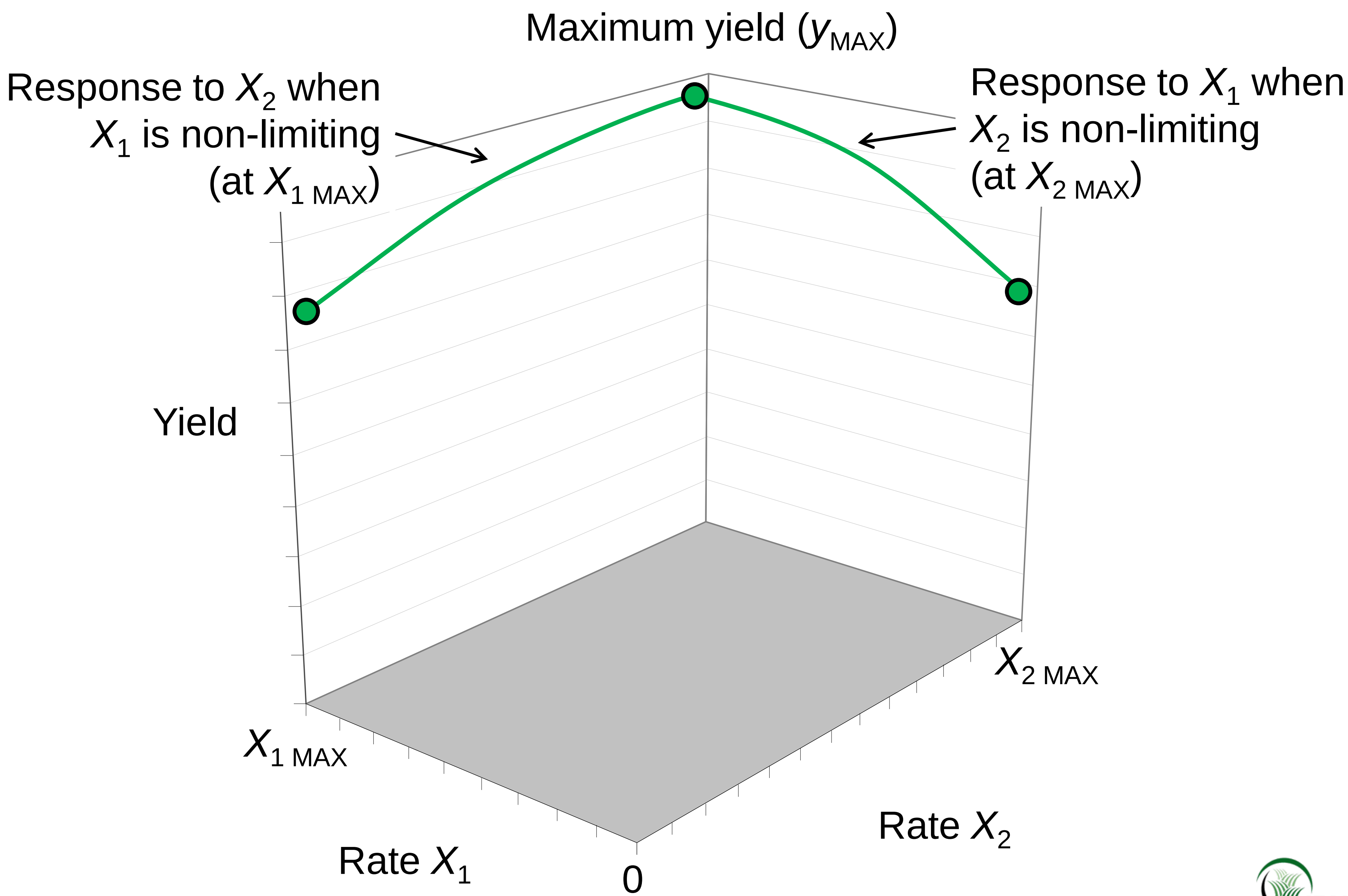
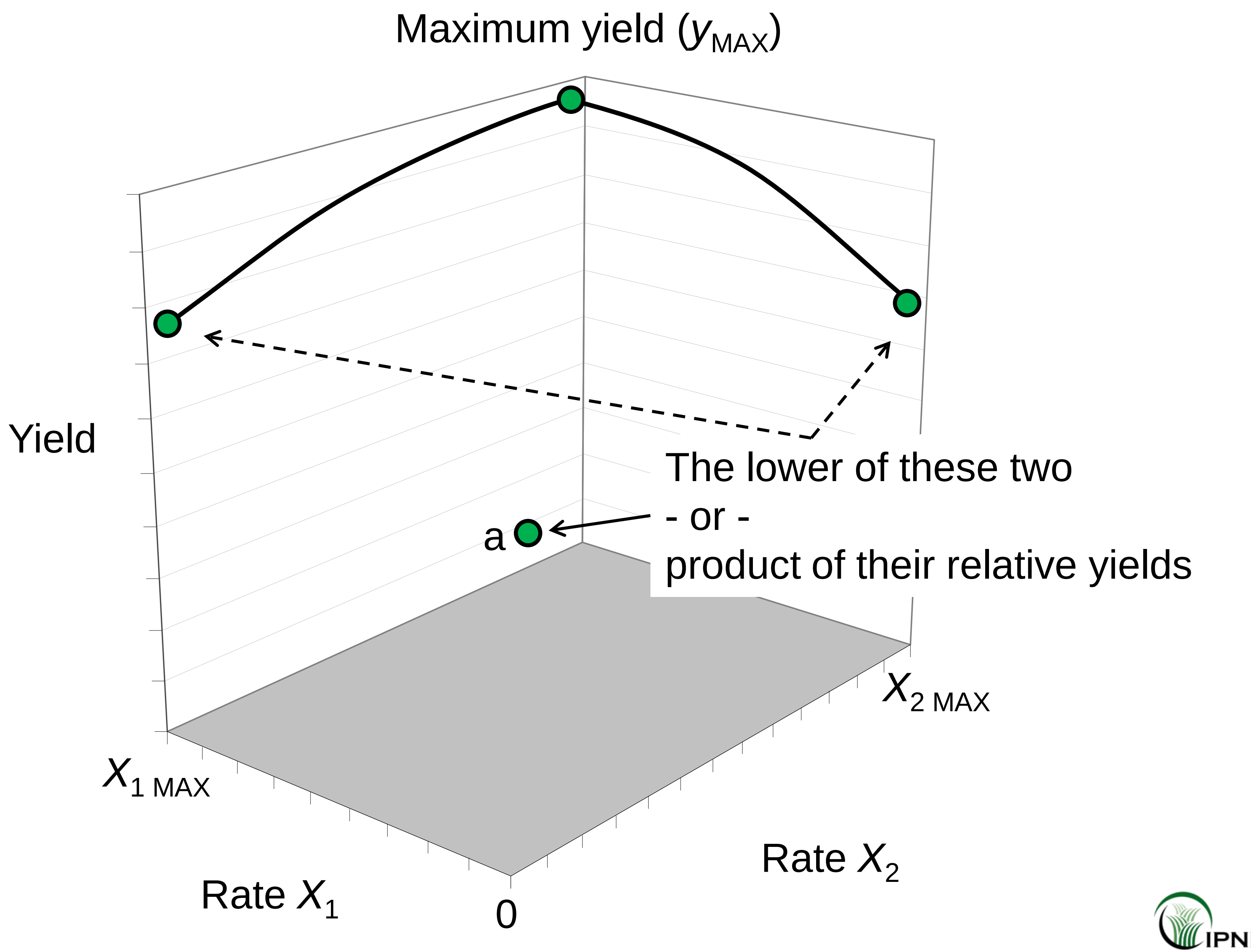


Maximum yield (y_{MAX})
Response to X_2 when X_1 is non-limiting (at $X_{1\ MAX}$)
Response to X_1 when X_2 is non-limiting (at $X_{2\ MAX}$)
Yield
$X_{2\ MAX}$
$X_{1\ MAX}$
Rate X_2
Rate X_1
0



Maximum yield (y_{MAX})
Yield
The lower of these two
- or -
product of their relative yields
a
$X_{2\ MAX}$
$X_{1\ MAX}$
Rate X_1
0
Rate X_2
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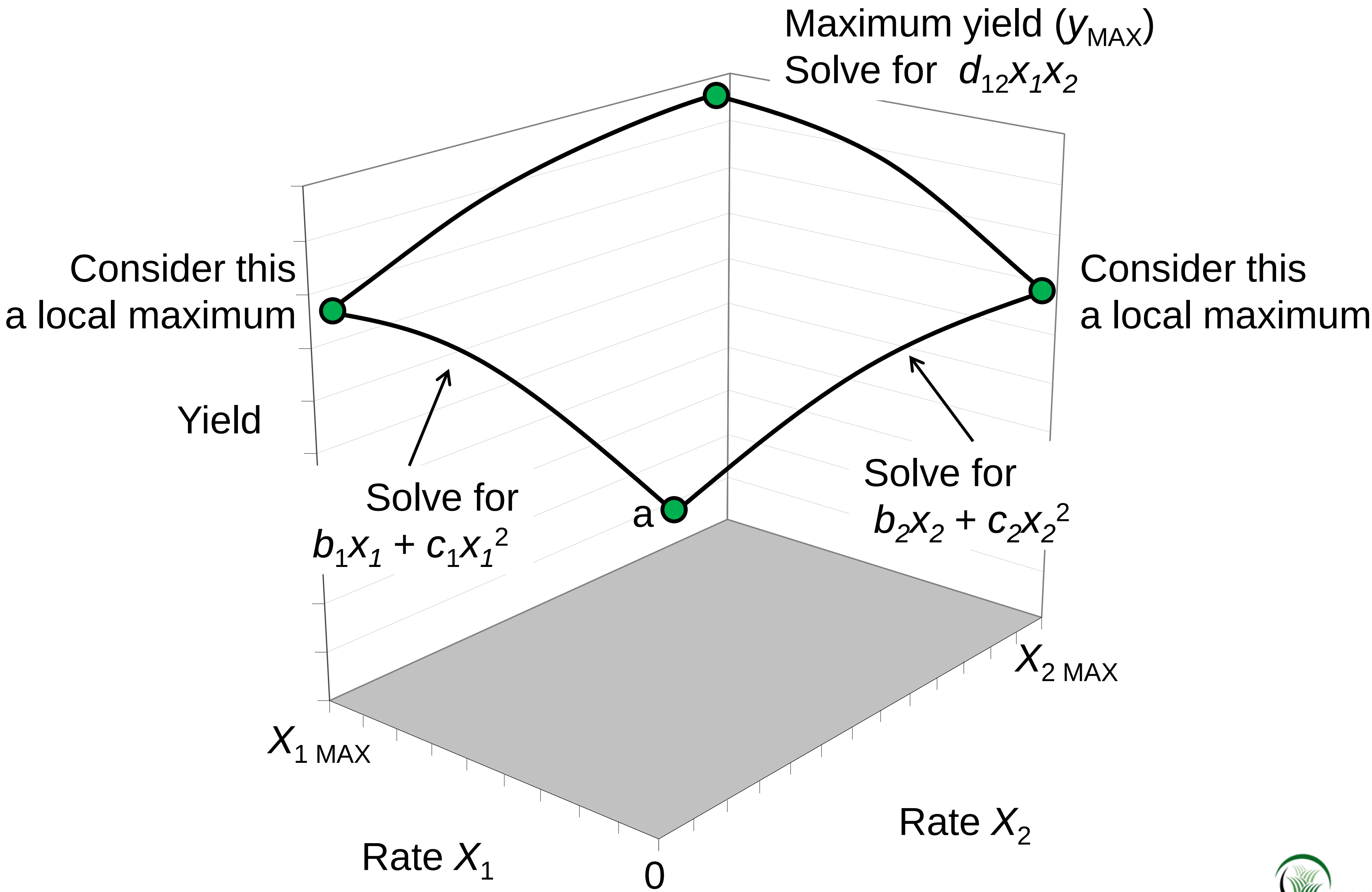
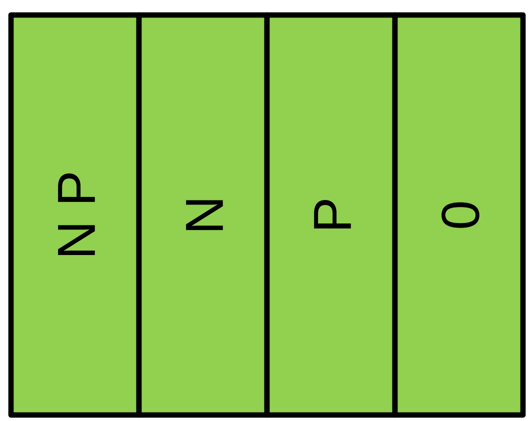
$$y = a + b_1x_1 + c_1x_1^2 + b_2x_2 + c_2x_2^2 + d_{12}x_1x_2$$



Some of the many assumptions made

- Recommended rates are those needed to just maximize yield
  - For P and K, recommendations following the sufficiency philosophy are closer to this than those following the build and maintenance philosophy
- Yield without one or both nutrients can be reasonably estimated
  - Can also be measured by omission plots (N and P example):



Conclusions

- Knowledge of how two nutrients interact is required to properly allocate limited funds
- Mathematically, response surfaces can be estimated, but the concept needs to be tested to determine the risks involved
  - Recommended rates consist of math + philosophy
  - The impact of the philosophy upon rate recommendations needs to be clearly understood and quantified
- Approaches outlined focus on short-term returns, but long-term impacts on fertility and risk need also to be evaluated
- **Can we make better use of the data that's already been collected while we simultaneously move toward more comprehensive recommendation systems?**

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