Return on Investment: What will Make Remote Sensing Profitable for Potato Growers?

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Potato Remote Sensing Conference

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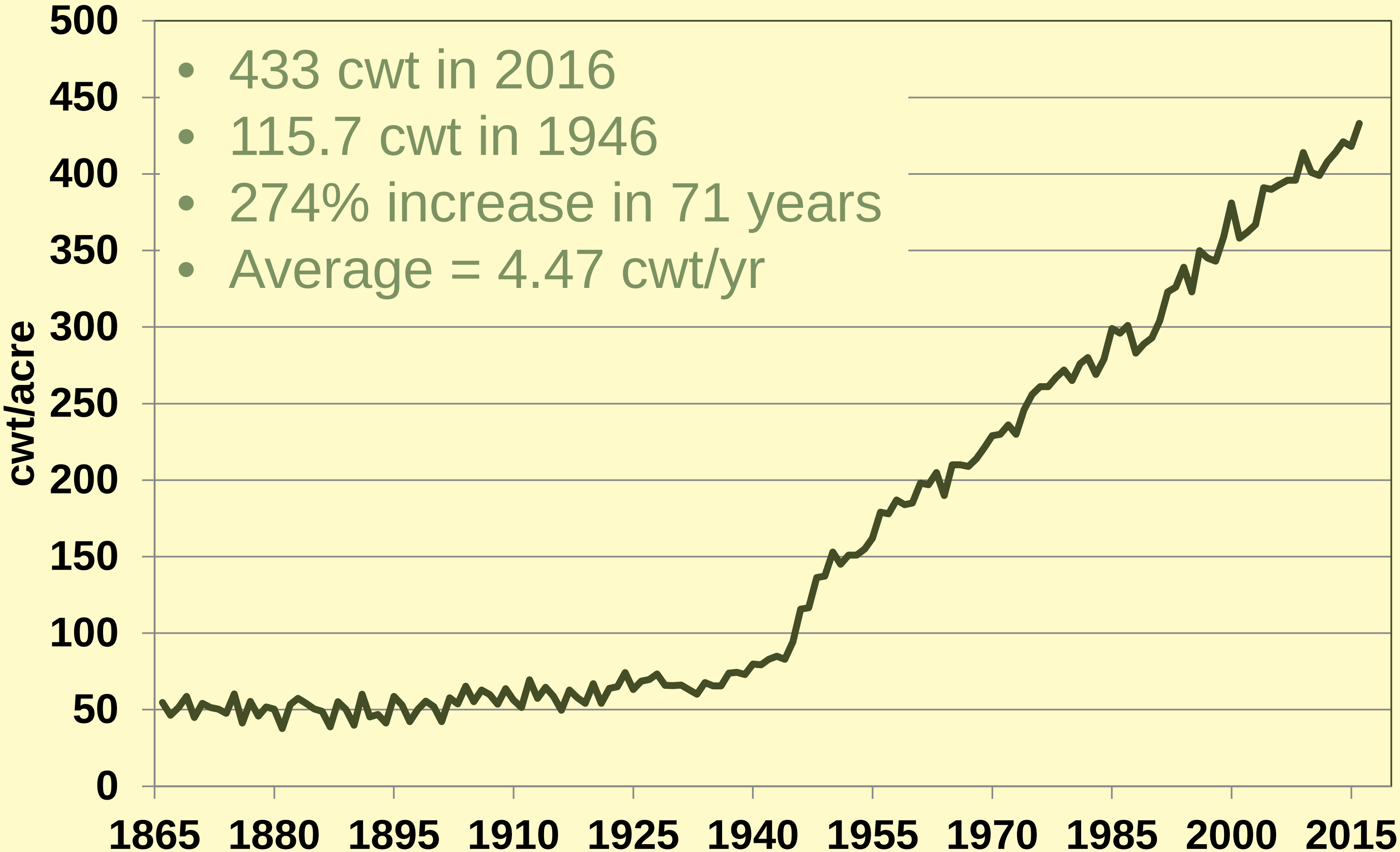
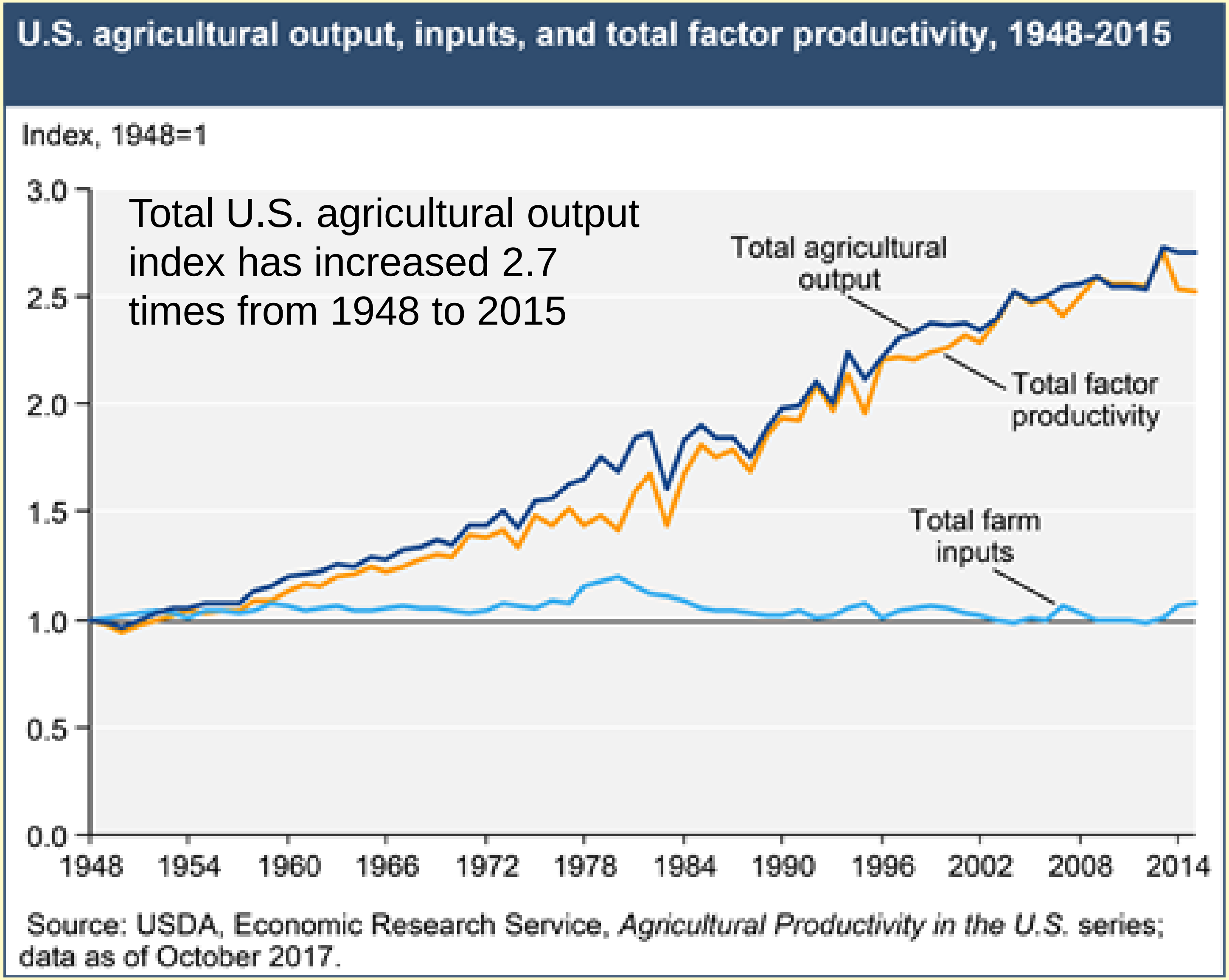
U.S. Average Potato Yield 1866-2016



Source: USDA NASS Quick Stats Online

It's The Story of U.S. Agriculture



Source: https://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us/summary-of-recent-findings/

Agricultural Productivity

- How do you increase total output?
  - Use more inputs (the moron principle)
  - Use inputs better (managerial productivity)
  - Use better inputs (technological productivity)
- Input use index has in general remained constant, so the gains are from managerial & technological improvements
- Remote Sensing is <u>one</u> of the next big improvements

Private R&D In Ag Big Data

- Lots of investment in Ag Big Data, from Google on down
- AgFunder tracks venture capital investment in ag tech startups (https://agfunder.com/research)
- 2014 $2.36 billion 264 deals
- 2015 $4.6 billion 527 deals
- 2016 $3.2 billion 580 deals

- 2017 mid-year report says VC investment back up again
- Big pull back in 2016 was part of global trend in VC investments, but especially in Ag Big Data as expectations were not being realized, especially for drones

Ag Big Data has been a Big Disappointment

- Wall Street Journal May 15, 2017: “For farmers—and the tech companies that want them as customers—data has been a disappointment.”
  - https://www.wsj.com/articles/why-big-data-hasnt-yet-made-a-dent-on-farms-1494813720
- AgFunder News, June 22, 2017: “Agriculture data has been a big disappointment for the majority of farmers, particularly in the US.”
  - https://agfundernews.com/how-to-ensure-big-data-brings-value-to-farmers.html
- Industry is coming at Ag Big Data with more realistic expectations, and renewed funding

How to Ensure Big Data Brings Value to Farmers (AgFunder News June 22, 2017)

- 1) Define a clear unique selling point (USP), making a conscious choice between providing a platform and data/intelligence
- 2) <u>Deeply integrate agronomy with digital technologies to interpret the data from a farmer's perspective</u>
- 3) Make a distinction between data, information and knowledge
- 4) <u>Customize products to the specific needs of a particular market segment, crop, and region</u>
- 5) Focus initially on the technology-savvy and innovative growers to bring the product to the market

Source: https://agfundernews.com/how-to-ensure-big-data-brings-value-to-farmers.html

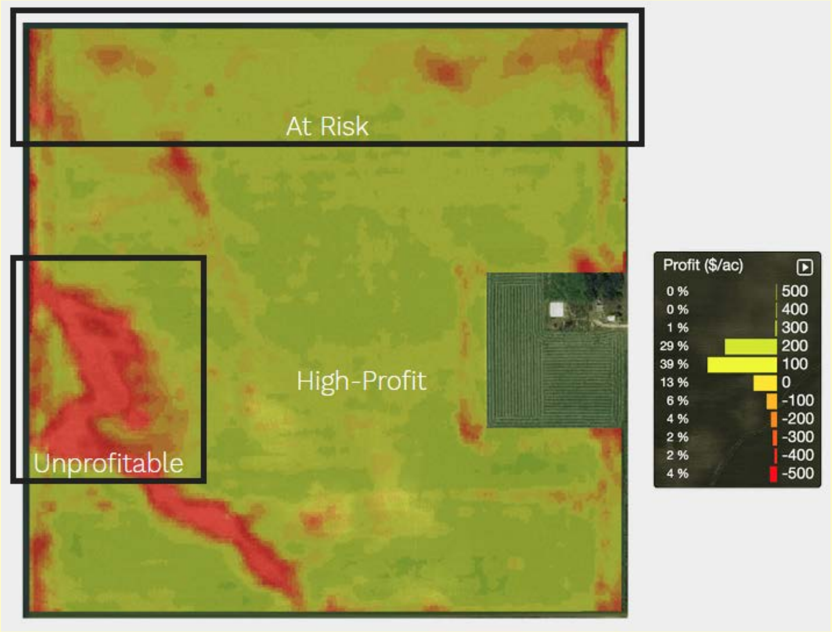
Remote Sensing: Where are we going?

- Phase I: Take a picture, is something wrong?
- Phase II: Observational Big Data
- Phase III: On-farm experimentation and reinforcement learning

- We are just getting started on Phase II

Remote Sensing: Phase I

- Take a picture and see if "Something is Wrong"
- Immediate Term: pest/pathogen problem, seed/seed rate, nutrients, pH, irrigation, drainage, …
  - Go out and look at it and see if you can fix it
- Longer Term: profitably analysis
- AgSolver: https://agsolver.com/
- 3%-15% of acres consistently unprofitable to farm
- Initially drove the drone craze, then big R&D pullback in 2016 as farmers asked, "Now what?"

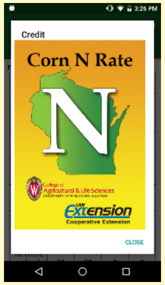


Remote Sensing Phase II: Big Data

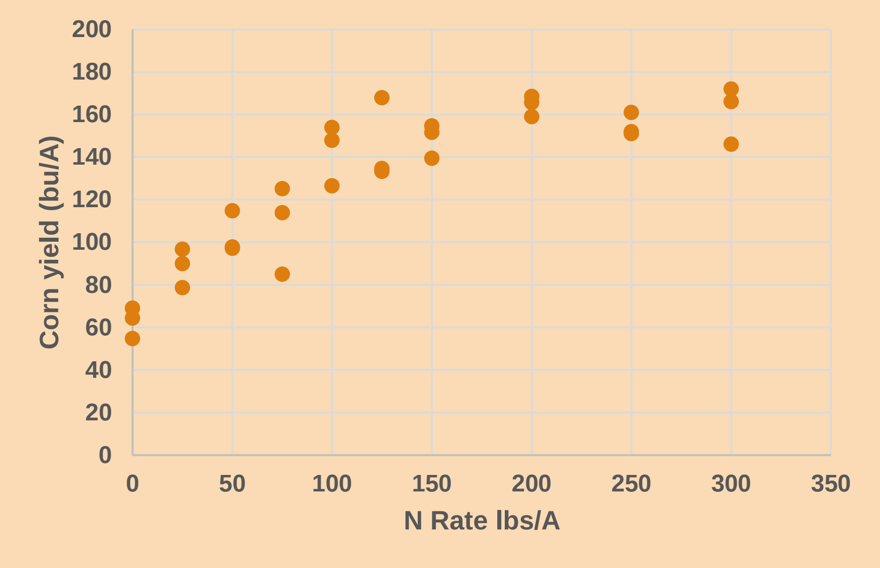
- Lots of data available for each field/sub-field
  1. Fixed effects: location, soil, crop history, variety, …
  2. Random effects: rain, temperature, humidity, pests, …
  3. Management: inputs and activities by date
  4. Crop status: observed on many spectra at many times
  5. Outputs: yield and quality
- How do we create value from this?
  - Yield and quality vary between years and among fields
  - Fixed and Random effects and Management vary
- **We want to identify the input response curves so we can optimize the system**

Why We Want Input Response Curves

- Yield Y Response Curve to Input X: $Y = a + bX + cX^2$
- Optimized input X: profit maximization
- Max $\pi = pY - rX = p(a + bX + cX^2) - rX$
  - $X^* = (r/p - b)/(2c)$
- Standard MRTN recommendations: experimental data to estimate coefficients: http://cnrc.agron.iastate.edu/



- Optimal N rate varies with Prices, plus Fixed Effects (soil, previous crop), Random Effects (rainfall, temperature) and Management (planting density, variety, irrigation & pesticide type, timing & amount)



How To Identify Input Response Curves: Experiments

- Small plot field trials with replication and randomization
- Vary one input over several rates under different fixed and random effects, hold other inputs constant
- Nitrogen response curve for different soils, varieties, pH, … under different weather
- Problem: lots of inputs to choose and they likely interact:
  - Nitrogen with pests and diseases and with planting density and with irrigation regimes and …
- Very expensive to do all the experiments for all of the inputs under all of the different fixed effects and quickly before the technology changes

How To Identify Input Response Curves: Observational Big Data

- Collect data on as many relevant variables as possible
  - Fixed effects, Random effects, Inputs and Activities by date, Yield and Quality, and Crop Status
- Multi-variate regression analysis of the whole production system to estimate relationships among yield/quality and inputs/management
  - Estimate how these relationships vary with fixed & random effects
- Problem: Observational data are not the same as Experimental data

Analysis of Observational Data

- Observational data have a problem that is called by several different names: endogeneity, simultaneity, co-determination, reverse causation, correlation ≠ causation
  - Common issue in social sciences, epidemiology, public health, ecology, policy, …
- We know X causes Y, but observed input choices X and output/quality Y are co-determined simultaneously, both endogenous to higher-level process
- Example: Observe that fields where farmers use cover crops have higher average yields
- Do cover crops cause higher yields or are farmers with higher yields more likely to spend money on cover crops?

Solutions to Address Endogeneity

1) Conduct experiments
2) Use “natural experiments”
3) Model the co-determining process (structural model)

Panel Data Methods

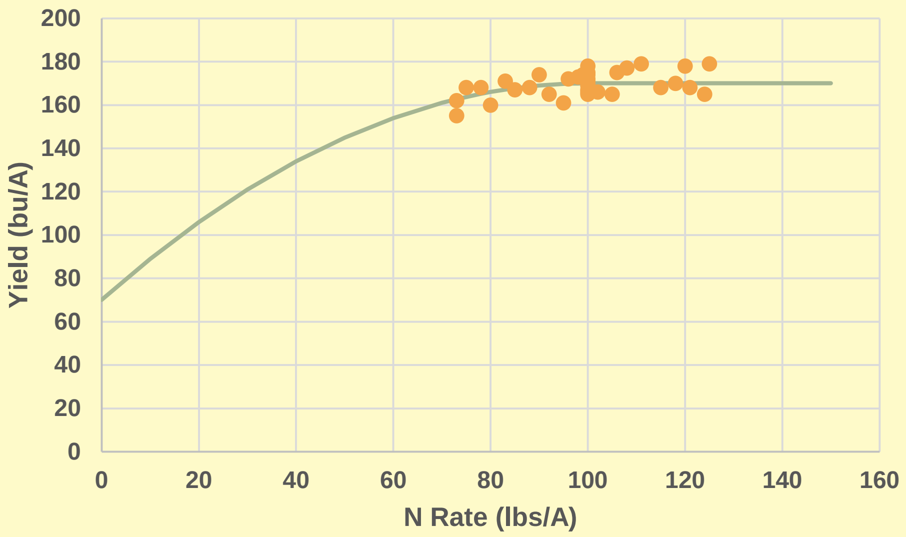
4) Instrumental Variables (cross-sectional data)
5) Fixed Effects and Control Variables (longitudinal data)

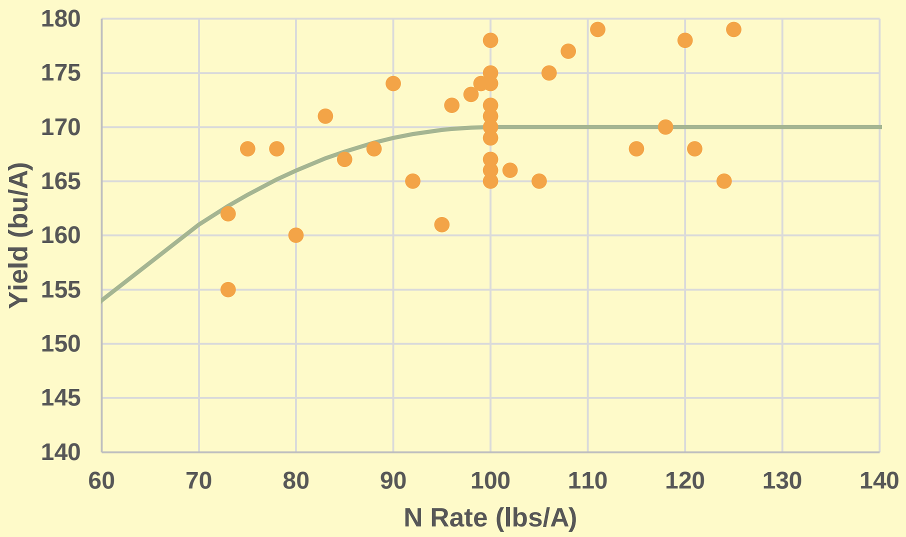
Phase III: Reinforcement Learning

- Observational approaches have limits as well
- Human behavior models are not completely accurate
  - Profit maximization, risk management, or ???
- Observational Equivalence: many structural models can fit the same data about as well, but imply different optima
- Sometimes a little experimentation is more efficient than a lot of observational data for identifying a response curve
- Longer term: we need to merge experimental and observational approaches
- Reinforcement Learning: Spend some effort now learning so you can improve future returns
  - Exploitation vs Exploration

Operationalize On-Farm Experimentation

- On-farm experiments to trace out the response curve around the optimum
- If N* = 100 lbs/A is optimal rate, then field mostly at 100 lbs/A, but estimate N response curve with some "plots" with super-optimal and sub-optimal rates
- Link fertilizer application with yield monitor to automate application, estimation & optimization





Summary

- It’s all about increasing productivity
- Ag Big Data has been a Big Disappointment so far
- Remote Sensing: We need input response curves to optimize management
- Phase I: Take a picture to identify problems
- Phase II: Big data, analyze observational data appropriately (structural models & panel data)
- Phase III: Automate on-farm experimentation and use reinforcement learning to improve the system

Thanks for your Attention

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