

Kastens Inc., Herington, Kansas
 301 DRI 2000 Harvesting rig

From Data to Decisions: a case study in Variable Rate Fertilizer

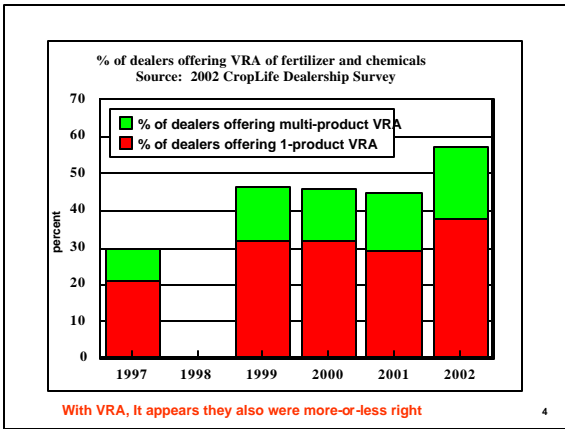
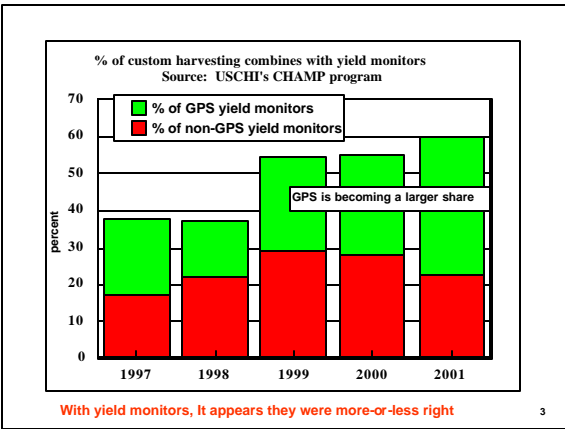
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 Dietrich L. Kastens, Farmer/geographer

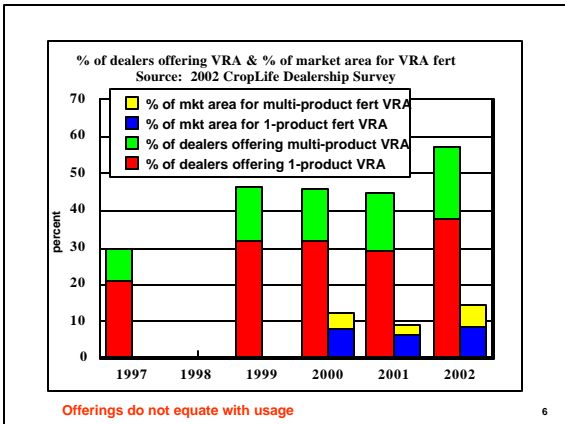
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Precision ag pioneers of the early 1990's believed that yield GPS-based yield monitors would be adopted quickly and that VRA of fertilizer and other inputs would quickly follow.



- ### Offerings do not mean usage
- Many custom harvesting customers do not actually request the yield maps
 - The 2002 CropLife survey suggests 17% of the market area is harvested with yield monitors (with GPS?)
 - The 2002 CropLife survey suggests less than 15% of the market area uses VRA of fertilizer
 - Dealers have repeatedly overestimated the expected rate of VRA adoption



Some PA technologies quickly adopted

- 44% of the 2002 CropLife dealerships apply fertilizers and chemicals with rigs that use lightbars (up from 24% in 2000)
- Anecdotal evidence suggests farmer use of lightbars has also increased dramatically over the last several years

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Early adopters get the profits

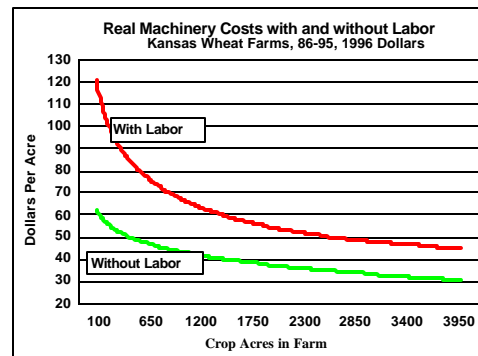
- New technologies are constantly being bid into land values and rents
- Rents rise and folks have to adopt just to breakeven
- Non-adopters don't break even, they go broke
- It is almost as though land markets anticipate new technologies

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Speed of adoption is based on:

- Magnitude of expected gain
- Confidence in that magnitude
- Does the technology save labor?
 - Farmers are averse to involving employees
 - But farmers want the economies of size gains
 - So they often focus on labor-reducing technologies

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Constant PER ACRE labor for larger farms means they want to adopt labor saving technologies so they can get the other size gains w/o adding labor

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Economics and Technology

- Obvious (belly-button) technologies
 - RR beans: \$5-\$6/a advantage but easy to assess
 - Quickly capitalized into land
 - Can't distinguish managers (all use it)
 - Small but sure gains mean fast adoption
 - Must adopt, but not long-run profit enhancing
 - GPS-guided automatic steering?
- Less-obvious technologies
 - Tractors, fertilizer, no-till, VRA of inputs
 - Require investment in manager education
 - Adopting managers have an edge for years

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VRA of crop inputs

- Gains are not well known
 - Yield response is flat near optimal fertilizer rates
 - Will it pay to find that 90 lb/a is more correct than 100?
 - Better to shift the whole curve up or down, meaning profitable VRA will depend on other non-fertility data
 - But, mathematical rate algorithms poorly developed
- Informational costs might appear "too high"
 - \$7.30/a 2.5 acre grid sampling against a total fertilizer cost on wheat of \$15/a
- Information may not be accurate enough
 - Interpolating between 2.5 a centroids???
- Not labor saving – at least yet
- VRA adoption will be slow, but VRA is a good long-run profitability candidate

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The Kastens case farm

- In Rawlins Co. (northwest Kansas)
- Average rainfall of 21 inches
- 5,700 acres cropland
 - Dryland crops are mainly wheat and corn
 - Some alfalfa and forage sorghum
 - Maybe sunflowers and soybeans
 - Around 1/4 to 1/5 fallow
 - Rapidly moving to total no-till
 - Nearly 100% of the cropland is contour-terraced
- 3,700 acres pasture
 - Cow-calf program of 300-350 cows
 - Cows graze crop residue

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People of the Kastens farm

- Gary Kastens
 - a hands-on, day-to-day manager guy
- Dietrich Kastens
 - a computer, geography, and electronic technology guy
- Terry Kastens (part-time)
 - a business, economics, and analysis guy
- Lester Yoos
 - A can-do operational guy

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We agreed that . . .

The belly-button aspects of PA investment should take place with minimal investment in analysis

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Short-run PA investment

- Much investment (the belly-button parts) will occur with minimal analytical investment
 - Yield monitor – based on faith
 - Lightbar – for assessing future guidance needs
 - GPS-guided steering – based on:
 - Simple swath overlap economics
 - Assessment of reduced operator fatigue
- For the most part, with the stroke of a pen (signing a check) the neighbors can compete

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We agreed that . . .

To capture long run gains to PA, the focus should be on long-run data-intensive decisions

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Long-run PA investment

- VRA of crop inputs
 - Primarily phosphorus
 - But also nitrogen
- Eventually seeding rates
- Maybe herbicides

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We agreed that . . .

New PA machinery investments should piggy-back on any concurrent changes in a farm's farming practices

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Piggy-backing of VRA machinery

- **A fertilizer rig for no-till is needed anyway**
 - Now, the VRA component becomes a small add-on expenditure
- **Similarly, more no-till means back-and-forth**
 - Easier to justify lightbars and GPS-steering
- **Based on years of research, site-specific building up of STP for the farm had become a major goal**

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The 2-product VRA rig

- Not sure of dry vs. liquid on P
- Wanted NH₃ but became untenable
- Decided on a 9x6 undercutter with Flexicoil openers (bought the undercutter)
 - Would work with either dry or liquid
 - Design problems with the UC (gave up)
 - Flexicoil openers would not work in wheat
- Researched deep vs. coulter injection vs. surface application
- Chose a DMI 40 foot rig (15 inch spacing)
 - Didn't have to build ourselves, better resale potential
 - Efficiency losses over formal deep placement not too large
 - Faster travel, lower draft, and less repairs
 - Wheat capability really swung the deal

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For Sale! FK XL 9x6 Sweep, Good Deal!



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Folks are really frustrated . . .

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Data and decisions cause consternation

- **Labor intensive**
- **Endless possibilities**
 - Mental overload and un-attained goals
- **Managers wish they could analyze data better**
 - Lack of education or training
 - Can't find trustworthy people to do it for them
- **Frustrated with the software**
- **Focusing on principles might help**

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We've pulled together a few principles that might help folks move forward . . .

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Principle 1. Adhere to scientific (causal and statistical) principles

- Early adopters don't have empirical evidence so must rely on principles
- Predictions based on principles are more accurate and hence result in more profitable decisions

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Principle 2. Bound the problem

- Agree to follow principles
 - No “turn the crank” mindless unsupervised data searches for poorly-understood, but systematic, data relationships
- Stay focused on smaller parts of the larger problem
 - VRA of only fertilizer for the case farm
 - Asks pointed questions of software
- Keep some things fixed for several years
 - Especially when evidence is scant or confusing
 - “the management unit shall be 1 acre”

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Principle 3. There are no comprehensive point-and-click softwares

- Endemic within the industry
 - No commonality among PA managers' goals
 - No commonality among software writers' goals
- There are comprehensive softwares; they are just not point-and-click
 - MapInfo
 - Matlab
 - spreadsheets

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Principle 4. Long-run PA activities are labor intensive – at least early on

- “I haven't accomplished as much as I thought I would have by now”
- “What's that PA guy been doing all these years?”
- Think of labor as a capital investment
 - Labor intensiveness is irrelevant – if it pays, then make the investment

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Principle 5. Comprehensive databases are mostly a dream

- A digitally-stored collection of data
- Something we've been learning the hard way
 - Big databases hard to debug, hard to transmit
 - “Quit thinking so big!”
 - “Just give me the data you have in whatever format it is, and I will extract and transform the information I need. Then, let me know what information you need back, and I will be sure my output to you contains that somewhere.”
 - Liberal use of identifier variables
- Formal database software programs?
 - Too many calculations and data transformations to be practical?

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- **Kastens Inc. Short-run DB Goal**
 - Many small database's with relational joins such as 1-acre grid ID's.
 - Advantages
 - Easy to manage by hand
 - Easy to perform Quality Control
- **Kastens Inc. Long-run DB Goal**
 - A single comprehensive DB for each year
 - Advantages
 - Improved user ability for data storage, archive, query and analysis tasks
 - Allows for permanent automation, and thus improved processing efficiency

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- **Choose Software Wisely**

- A geographical information system (GIS) is a database program that also allows for spatial information manipulation and mapping
- Assess your computer programming skills and/or your desire to do some programming before buying any core software for use in your precision ag program
- Unlike learning most farm operations, flexible GIS and database software programs have learning curves in the 100's of hours

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Principle 6. Consider different classes of data, by purpose

- **LaterData**
 - e.g., running time data, elevation data, speed
 - Inexpensive to collect
 - May have a purpose later
 - Keep in raw form – let the CD's build!
- **IdeaData**
 - Mapable
 - Many LaterData never make it to IdeaData status
- **WorkingData**
 - Highest degree of immediacy
 - May not be mapable (at least until end)
 - Don't be afraid to expend the labor

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Working Data

- Cleansed, sanitized, error free.....
- Yield production models generated from working data will only be as accurate as the underlying data
- Every effort should be made to identify and correct problems in the raw data
- Almost every dataset has errors
 - These errors range from easy to correct to difficult to correct
 - 0 and negative values
 - Values outside of the area of interest

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Working Data – Error Example

- Two fields A and B were soil sampled on a 2.5 ac grid and Veris data were collected.
- A simple correlation was conducted between Shallow EC and Clay %
 - Field A = 0.42
 - Field B = 0.20
 - Combined Fields A & B = -0.57

Does This Make Sense?

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Principle 7. Document everything!

- Eases duplication at a later date
- Data collection, transformation, and decision-making procedures arise from much effort in creative thinking, deductive thinking, and consensus building
 - Re-creations are expensive and compete for your creative energies
- Helps decide which points might benefit from future scientific debate among PA people
- You might die

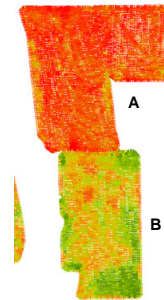
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Principle 7 Cont. (METADATA)

- Collection of data about the collected data
 - Knowing where weed, disease or insect problems impact a yield map, rather than soil limiting factors
- Date, weather, field conditions, equipment problems should all be kept with the data so that this data can be useful indefinitely
- Use comments in macro's extensively for your own sake and others who may use it

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Principle 7. Example



Veris Data
Field A – 118 acres
Field B – 81 acres

Data Collection
Field A & B – Dec 15

On Ground
Field A – wheat stubble
Field B – corn stubble

Both fields Grazed

What would we say caused the difference in mean Veris data 5 years from now? What would a consultant do if this were seen?

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Principle 8. Don't invest in too much database automation early on

- Automation is a large investment of time
- There will be many dead ends
- Automation makes debugging hard
 - Break into smaller pieces, so can ease into the automation part (Modular Coding)
- Probably more of a problem that is unique to Dietrich and Terry

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Principle 9. Rely on others to provide constructive criticism

- Everything is gray, with only degrees of truth
 - Degree of truth judged by acceptance of other researchers or logical thinkers
- “Should I give away my trade secrets?”
 - Copy cats will never capture all the gains
 - Will miss the subtle points and will miss some changes
 - Followers are always one step behind
 - Ensures you will always “know the competition”
 - Provides you a low-cost tester
- Probably only relevant for narrow geographical areas anyway (30-50 miles)

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Back to more detail of the case farm's PA program . . .

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Detail on the case farm's VRA program

- Low annual but high investment costs
 - Dryland crops imply little room to work
 - Investment can be spread over years and acres
 - Ensures comparative advantage for years
- High dependency on long-run P investment
 - Targeting optimal build-up of STP
 - Research based
 - Comparative advantage in that many are fearful of it because of cash flow requirements

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Detail on the case farm's VRA program

- **Production function (yield model) approach**
 - $Y = f(\text{fertN, fertP, STN, STP, OM, SAND, CLAY, PH, SALT})$
 - Supported by research
 - Implies discovering the model will be an important task of the data
- **A 1-acre management unit**
 - Management zones not reliable nor repeatable
 - Size is more-or-less arbitrary
 - Means an estimate of each soil factor value for each acre will be needed – an important task of the data

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Detail on the case farm's VRA program

- **Yield data handled by the MPGM program**
 - Dietrich, Randy Taylor, and Terry
 - Field yields will match scale tickets
 - Deals with swath width errors
 - Deals with a combine without a yield monitor
 - Condenses data to 60x60 cells
 - Then yields are aggregated as needed
- **3 soil samples per field**
 - A 25-30 core composite (geo-referenced cores)
 - Represents field (constrains 1-acre estimates)
 - Two site-specific samples
 - Used for fertilizer trials to enhance yield model

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Detail on the case farm's VRA program

- **2 unique data frameworks for 2 unique goals**
 - Building and improving the yield model
 - Uses MPGM yields from around the sample points
 - Currently around 500 data points; 150 new points / year
 - The VRA management data set
 - Separate data set for each year
 - 7,100 data points, one for each management unit
 - Tied together with centroid lat/lon and other identifiers
- **Little reliance on spatial interpolation**
 - Kastens & Staggenborg found weaknesses
 - We use the KSD entropy approach
 - Uses yield and fertilizer rate information for each acre to help predict the causal variable values
 - EC data soon to come (also elevation & remote sensing)

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Detail on the case farm's VRA program

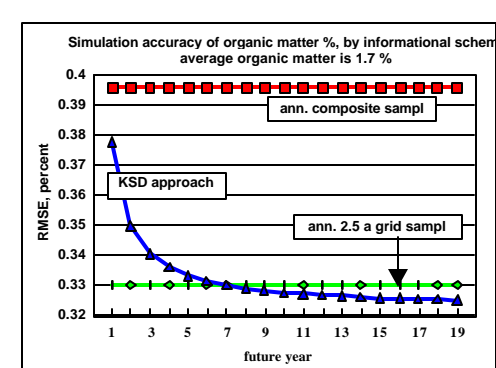
- **Software**
 - Dietrich: the GIS program MapInfo
 - Terry: the matrix language Matlab
 - Both use spreadsheets
 - Intuitive presenters of data
 - Good for finding outliers
 - Excellent for capturing intended mathematics (what-if)
 - Good for debugging thought processes
 - "Do Matlab and Lotus get the same results?"
 - Good way to show/teach procedures
 - But, spreadsheets get way too big to be feasible!
 - FarmWorks used for prescriptions
 - Red Hen for site-specific sampling

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Detail on the case farm's VRA program

- **We desire a program where accuracy and profitability improve over time**
 - Accurate enough to be profitable
 - The KSD-based soil factor estimations need to improve in accuracy over time (at least the ones not impacted by management)
 - Hope for accuracy equivalent to annual 2.5-acre grid soil sampling
 - Expect profit to rise with time as accuracy mounts
 - Expect the KSD program to be substantially more profitable than a grid-sampling one
- **We examine with a large simulation**
 - More detail in the paper

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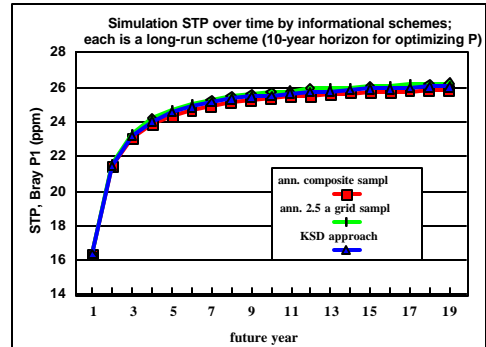


KSD-based accuracy does improve over time

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- Using the KSD method, the estimation accuracy for OM, SAND, CLAY, PH, and SALT each improved over time
- STN accuracy stayed about constant
- STP accuracy got worse with time
 - But STP increases over time
 - RMSE / avg(STP) stayed about constant

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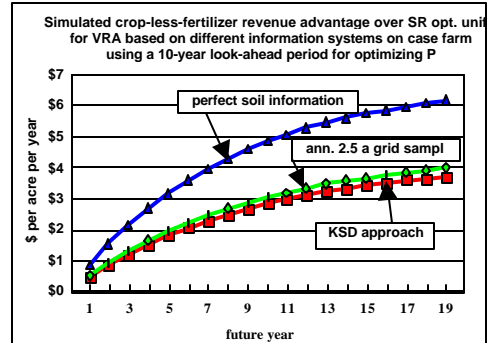
Why STP accuracy as measured by RMSE got worse

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What about profitability?

- Returns to fertilizer (crop sales less fertilizer cost) were measured against a benchmark that assumed optimal uniform *short-run* fertilizer rates (one rate for each field)
- The benchmark method built STP up to around 19 ppm by year 19 rather than the 26 ppm associated with the long-run uniform scheme, the long-run grid-sampling scheme, and the long-run KSD scheme shown in the figure

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What about profitability?

- Returns to fertilizer increase over time for both grid-sampling and the KSD method
 - Gross returns are similar
 - But the KSD method avoids the annual grid sampling cost, so probably is more profitable
- Expected KSD profits in the figure are conservative
 - The benchmark already has PA gains embedded
 - Would we know to build STP without the PA program?
 - New spatially-dense data (EC, elevation, etc.) will improve soil factor estimation accuracy (& profit)
 - New spatially-dense data will improve yield model
 - Thus soil factor estimation accuracy
 - Thus profitability

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Will (can) the case farm's PA program work for other farms?

- Short answer is yes
 - Anyone can follow the procedures for his/her farm
- More realistically, no
 - Most managers will not choose to follow such a numerically intensive program that depends so heavily on human capital investment
- But, managers may choose to “purchase” such a program if market forces cause it to be provided through consultation or software

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