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Yield Monitors
Collecting and Utilizing Data

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Lets talk about the hardware….

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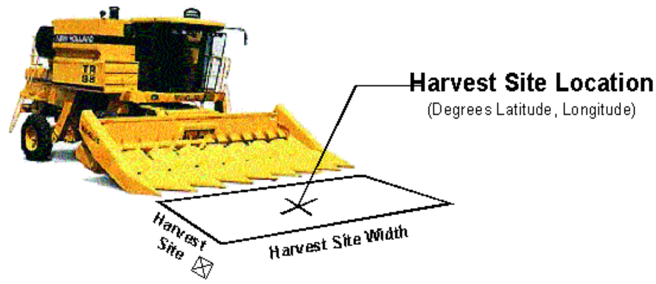
Yield Monitoring Process

- Yield Data is simply mass divided by the area of removal (lbs/acre) and associated with a Latitude / Longitude Point



Harvest Travel distance	Harvest Site Specifications	Area and Yield Calculations
speed / **(site length*)** 3 mph 4.4 feet/sec 4 mph 5.9 feet/sec 5 mph 7.3 feet/sec 6 mph 8.8 feet/sec *For 1-sec logging interval.	Location - Computed by DGPS unit. Width - Set by combine operator. Length - Computed as travel distance. Grain Volume - Computed from grain flow and moisture sensor data, and "standard" bushel information.	Harvest Site Area (acres) = Length (ft) x Width (ft) / 43,560 (ft^2/acre) Harvest Site Yield ⊠ = Grain Volume (bu) / Harvest Site Area ⊠

Yield Monitoring Hardware

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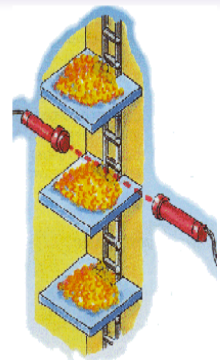
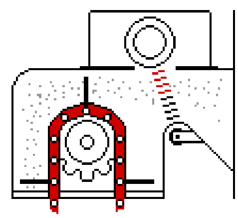
Measuring Grain - Volume

- Methods
  - Light (RDS, Loup, Claas, Topcon)
  - Radiation
- Benefits
  - Simple and Cheap
- Problems
  - We sell weight, not volume
  - Test weight becomes a factor
  - MOG becomes a factor
  - Radiation not “acceptable”





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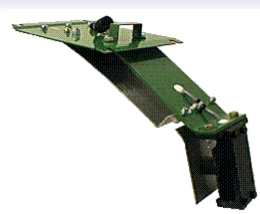
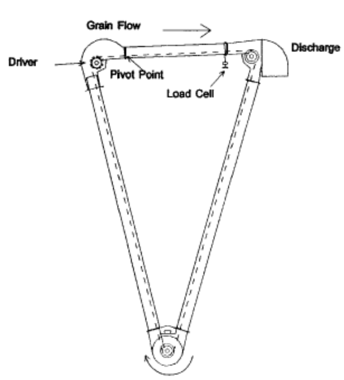
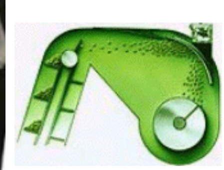
Measuring Grain - Mass

- Methods of Measurement
  - Weight (Schrock, et al.,)
  - Torque (Chaplin, et al.,)
  - Flow (force) (Meyer, et al.,)







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Measuring Grain – Mass

- Benefits
  - Accurate
  - Measures what we sell
  - Immune to test weight and MOG
- Problems
  - Requires a more intense calibration
  - Requires more mathematics / real-time processing
  - Geometry and dynamics of grain flow

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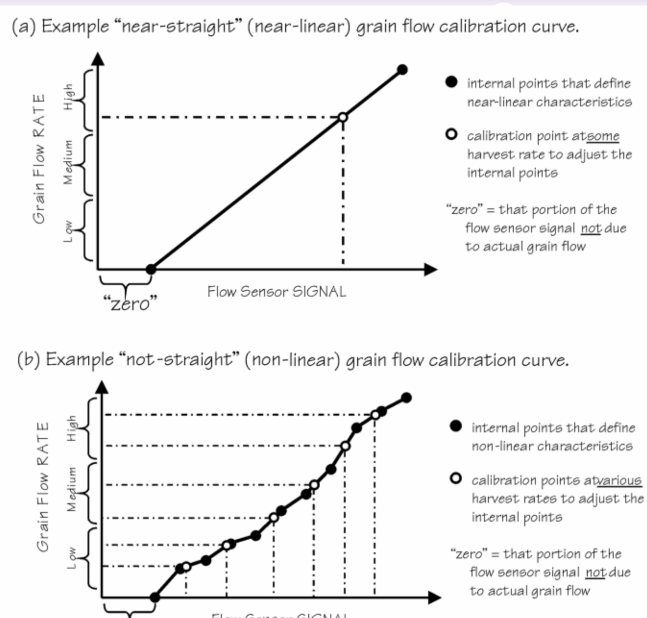
Yield Monitor Calibration



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Yield Monitor Calibration - General

- Confirm the accuracy of the moisture tester and weighing device used as a check (weigh wagon, truck scale, grain cart scale, etc.)
- Sample loads for mass flow should be of ample size (3000 lbs) and each should be harvested at a *consistent flow rate (bu./hr).*
- Samples for moisture sensor calibration should be relatively small, not on a truck load basis

Yield Monitor Calibration

Flow Rates for Calibration

- Full Flow – Drive faster than normal harvest speed (additional 1 - 2 mph), ensure the combine is operating at maximum capacity, note this flow rate (bu./hr)

Blank Area	Full Flow	Blank Area
	1/4 Full Flow	
	1/2 Full Flow	
	3/4 Full Flow	
	Additional Pass As Needed	

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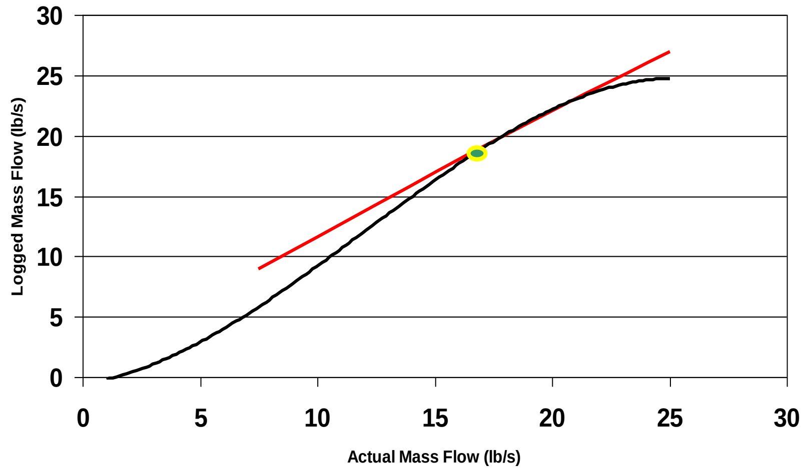
Mass Flow Calibration
John Deere – Old method



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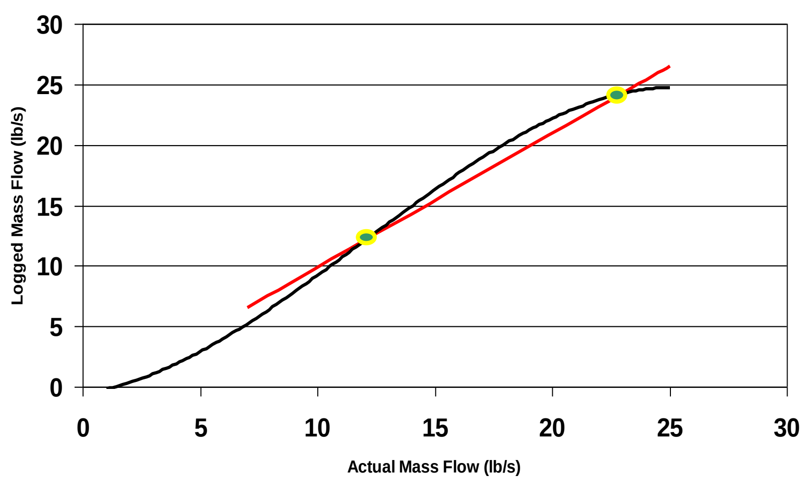
Mass Flow Calibration
John Deere – w/Low Flow Comp



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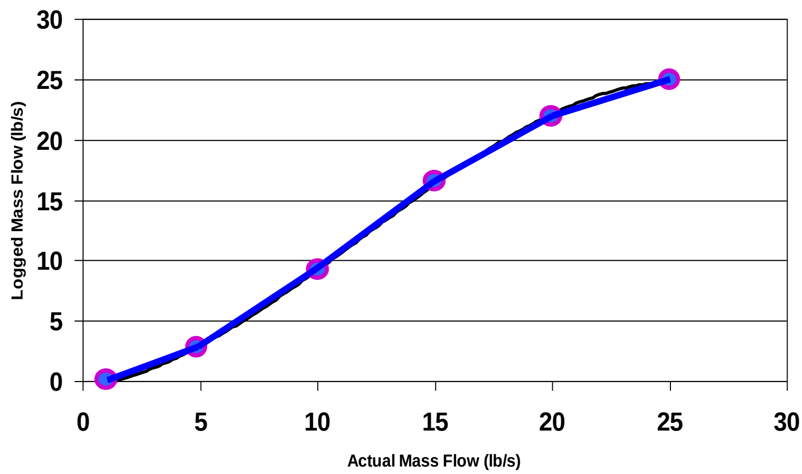
Mass Flow Calibration

Ag Leader, Case IH, Deere S-Series – Step Wise



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System Differences

- John Deere, prior to S-series
  - Advantage – easy to calibrate – 2 points
  - Disadvantage – Only 2 point – not as accurate
- Ag Leader Type Systems
  - Advantage – multistep calibration curve is more accurate
  - Disadvantage – more time/loads needed to calibrate

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Yield Monitor Calibration

- After calibration procedure error should be approximately 1.5 - 2.5%
- If error exceeds 5.0% then add additional calibration loads or remove loads that are suspect (observe individual load errors)

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Producer Implementation of Precision Ag

- Better whole-farm management
  - On-Farm Research
  - Logistics / Machinery Management
- Better whole-field management
  - Making changes from field to field
- Site Specific Management
  - Same process, different scale
- Better management beyond the farm – “Big Data”

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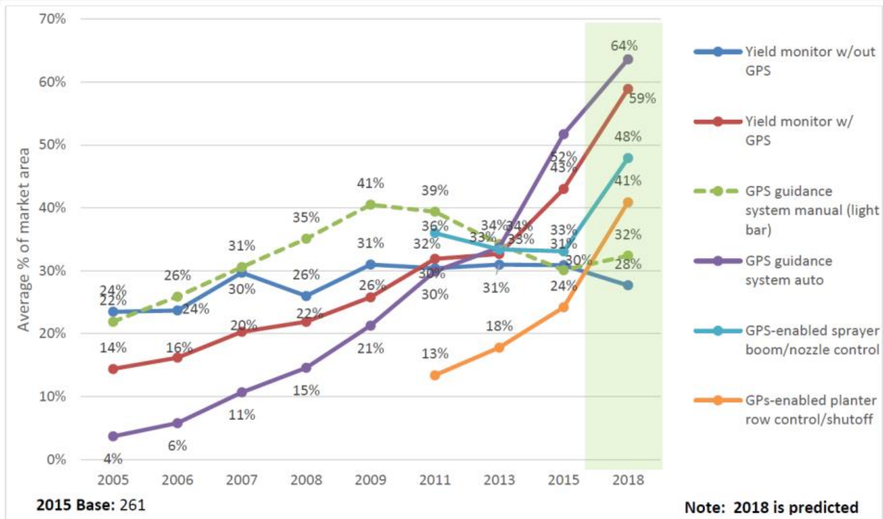
Yield Monitor Adoption History



Purdue/CropLife 2015 Precision Ag Adoption Survey

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Properties of Yield Data

- Error laden
- Often lacking in meta-data
  - Hybrids (split-planter), weather, etc.
- Temporal density dependent on:
  - Rotation, crop failures, combinability of crops
- **Spatially dense data**
- It is our ***best*** measurement of what we are trying to manage

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Is yield monitor data, big data, small data, or medium data?

YES

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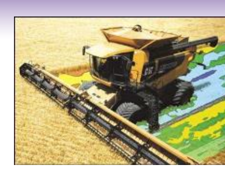
Yield Data Transcends Spatial Scales



- Small Data – Site and Time Specific
- Medium Data
  - Site Specific across Time
  - Field Level Data
  - Farm Level Data (Machinery Management)
- Big Data – Large Datasets Aggregated Across Space-Time
  - Regional, National, or Global Scale Across Time

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Advantage of Dense Data

Spatially and/or temporally dense data can be scaled up to any scale needed

however…..

Spatially and/or temporally sparse data can't be scaled down
(or only with a lot of error included)

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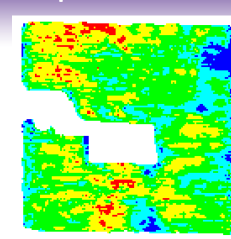
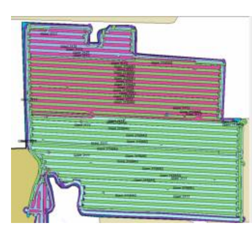
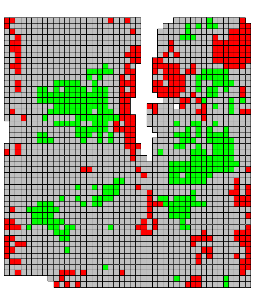
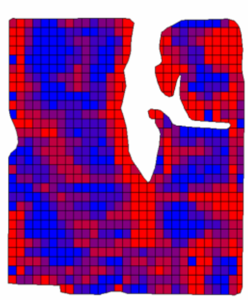
Yield Data Transcends Temporal Scales

- Single Year Information Value
  - Nutrient removal in current crop
  - Hybrid A vs. Hybrid B
- Multi-Year Information Value
  - Spatial-Temporal Yield Stability









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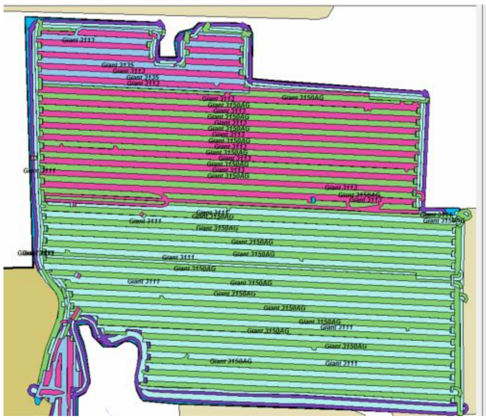
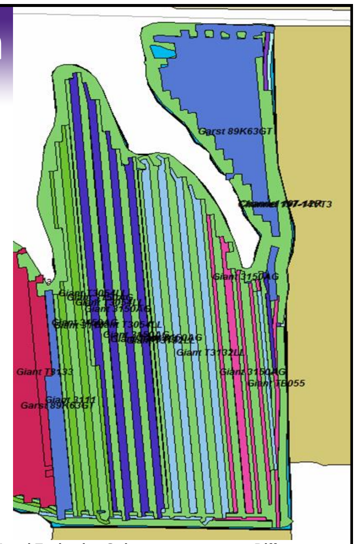
Hybrid Evaluation





West School Land Evaluation Strips		Difference
3150AG vs.	TB055	22.86
	T3132LL	-0.95
	T3054LL	-13.8
	3111	-19.56
	T3133	-26.6

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On-Farm Research Opportunities

- Grain Sorghum in 2012
- No-till summer fallow 2013
- 20 lbs. P2O5 on 8-29 with Case Nutri Placer
- Planted 9-26-2013
- TAM-111 Certified seed
- Ascend blended @ 4oz./cwt seed ($4.08/ac)
- 60 lbs/acre
- Drilled with 30 foot Great Plains HD double disc drill
- Treated strips 180 feet wide
- Untreated strips 180 feet wide
- Harvested with 32' Stripper Head

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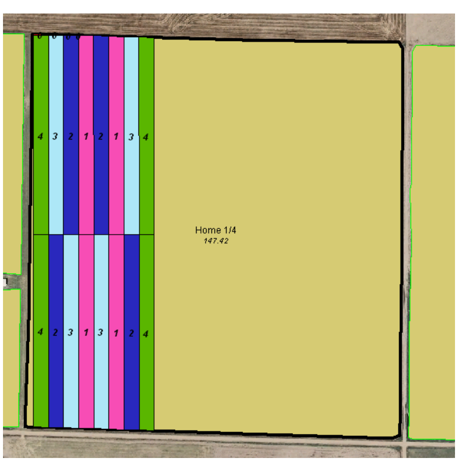
Wheat After Cover Crop Study



- Strip plot design
- 3 replications of 4 treatments
- 100ft wide strips
- Ensures at least 1 clean yield monitor pass

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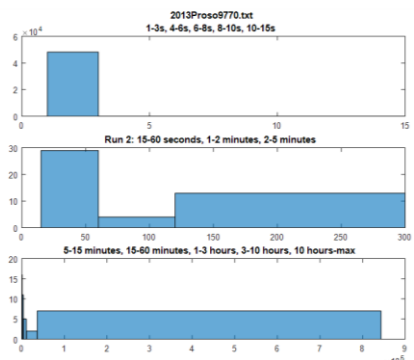
Medium Data – Machinery Management

2014	Acres / Seperator Hour	
	9770-09	9770-11
Wheat	21.47	22.14
Peas	.	.
Corn	14.33	17.51
Sorghum	20.97	.
Proso	.	9.82

2013	Acres / Seperator Hour	
	9660	9770
Wheat	24.41	21.02
Peas	.	.
Corn	13.61	18.17
Sorghum	.	24.88
Proso	.	28.17

2012	Acres / Seperator Hour	
	9660	9770
Wheat	20.58	20.78
Peas	.	.
Corn	13.90	11.64
Sorghum	.	.
Proso	.	.

Average field capacity difference between 8R and 12R corn head of 3.87 ac hr^{-1}. At \$221 hr^{-1} machine cost that's \$3.44 ac^{-1}.



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Site-specific management of inputs

- Which input?
  - Has a strong yield – input relationship
  - Data are available to drive the development
  - Opportunity for economic return
  - Ease of implementation
    - Data
    - Software
    - Method, product, and timing of application

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What data?

- What data sources would be useful in site-specific nutrient management?
  - What is our recommendation framework
  - What information do we need

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Management >>> Site-Specific Management

- How do you determine what seeding rate your going to use on corn?
- How do you determine how much nitrogen to apply?
- **Our decision making process is yield driven, either express or implied**
- **We are just changing the scale we are making those decisions at.**

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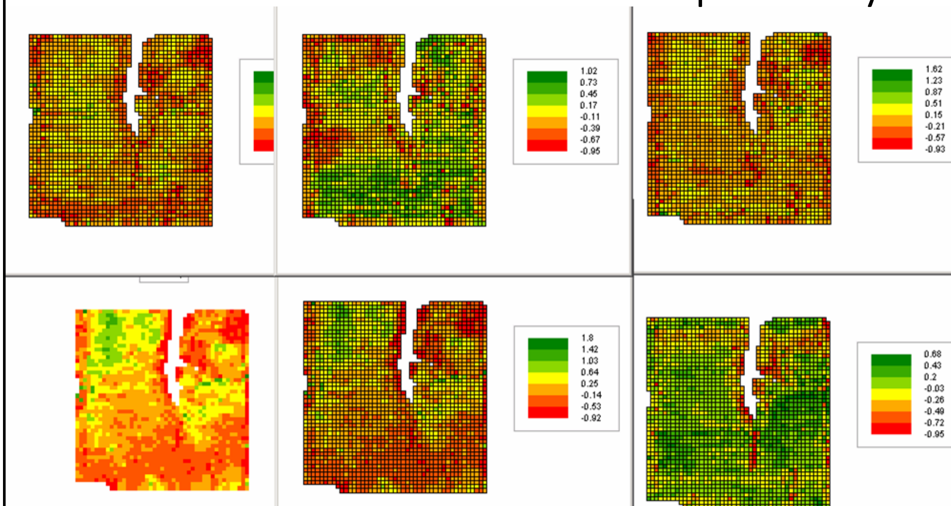
Normalized Yields from 3 different crops over 6 years



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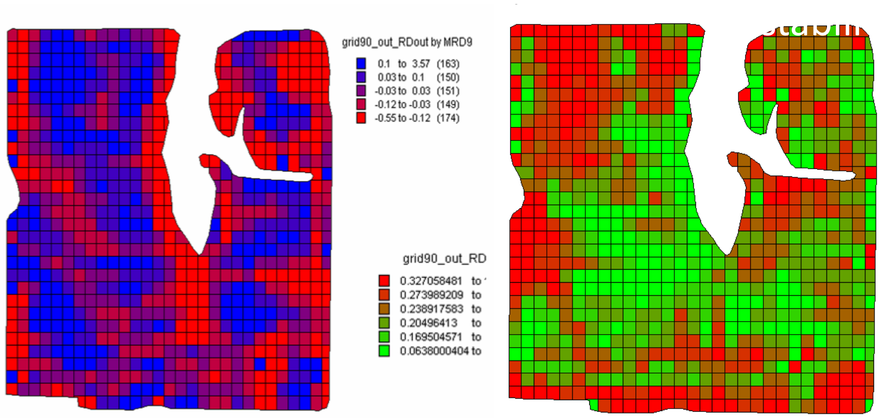
Putting it together…
Determining spatial-temporal yield



Normalized Yield

Standard Deviation (Temporal Stability)

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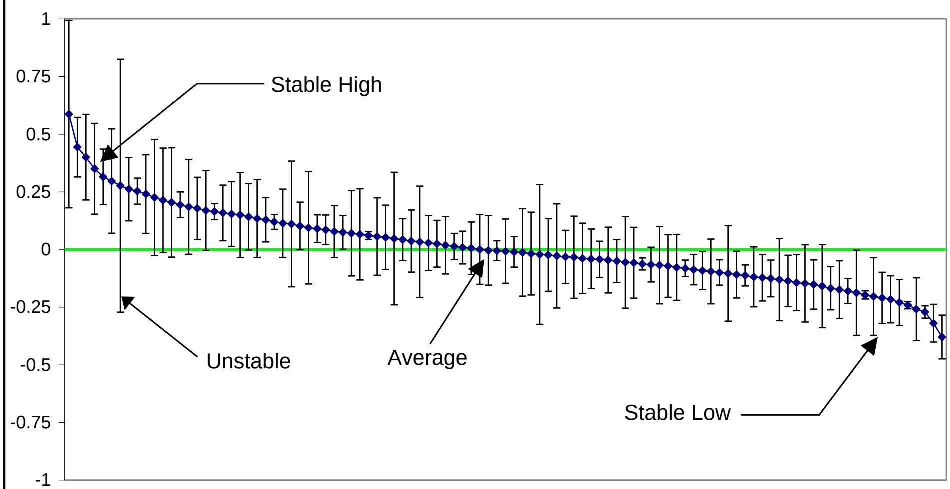
Yield Stability

Mean Relative Difference and Standard Deviation of Cells
1/10th of Population Represented



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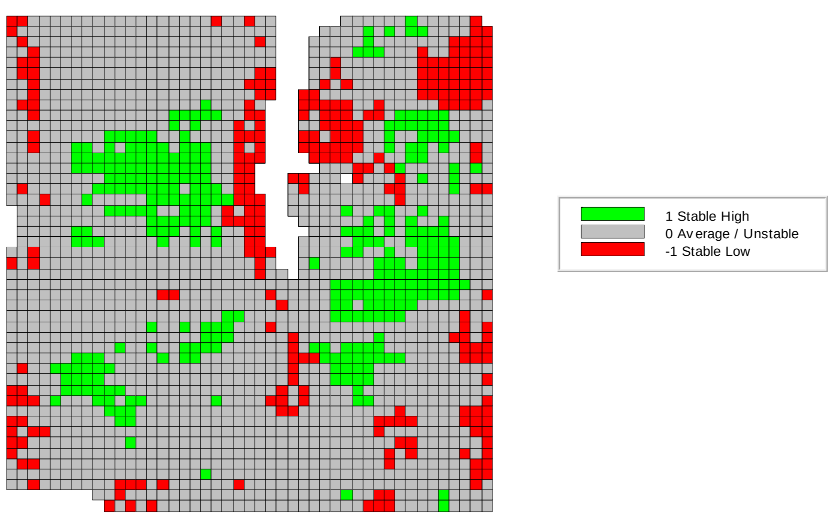
Yield Stability



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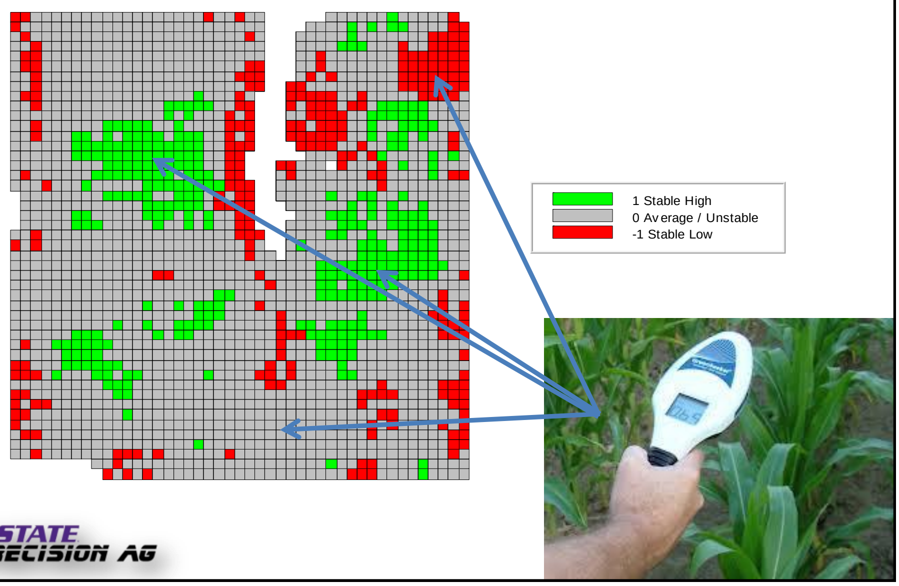
Topdress Nitrogen on Wheat



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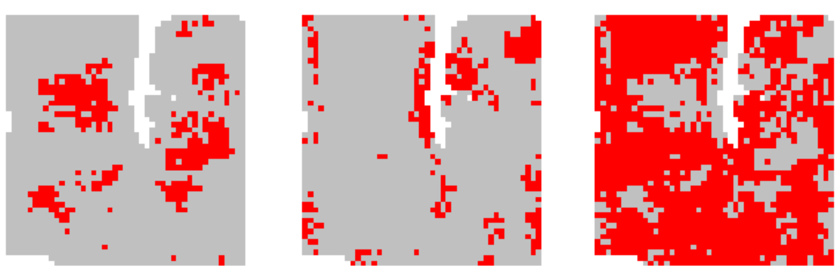
Yield Stability

Using classifications to adjust spatial yield goal



Stable High	Stable Low	Unstable / Average
SYG = YG * 1.15	SYG = YG * 0.95	SYG = YG * 1.0 or 1.05

Nitrogen Rec = SYG*1.6 - Credits or SYG*0.9

(K-State Recommendation)

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Steps to VRA Prescription Development

- Identify decision making approach
  - Equation or Decision based
  - *Example Nitrogen Recommendation Equation*

Example

- Wheat Nrec =
  (Yield Goal × 2.4)
  – (% SOM × 10)
  – Profile N
  – Other N Adjustments
  \+ Previous Crop Adjustments
  \+ Tillage Adjustments
  \+ Grazing Adjustments

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Steps to VRA Prescription Development

- Identify input variables needed AND determine if you have spatial data or NEED spatial data.
- Example
  - Yield goal, soil organic matter and Profile N could be spatial data

Example Inputs

- Yield Goal (S)
- SOM (S or U)
- Profile N (S or U)
- Other N Adjustments (U)
- Previous Crop Adjustments (U)
- Tillage Adjustments (U)
- Grazing Adjustments (U)

S = spatial

U = Uniform field wide

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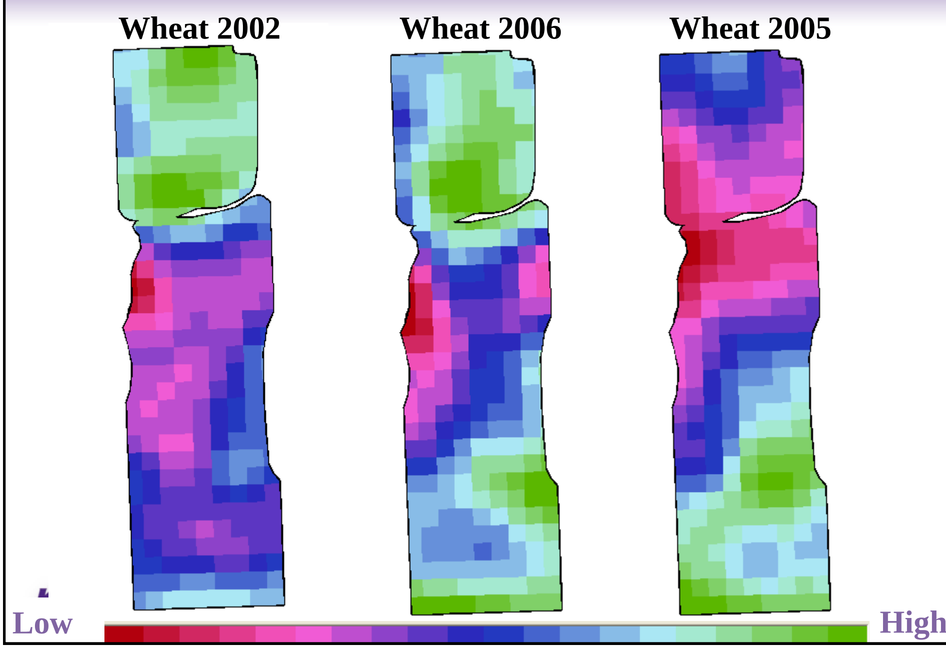
Steps to VRA Prescription Development



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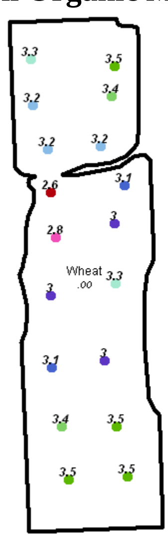
Steps to VRA Prescription Development

Soil Organic Matter



Uniform Inputs

- Profile N = -30 lb/acre
- Previous Crop Adjustments = 0 (soybean)
- Tillage Adjustments = +20 lb/acre for no-till
- Grazing Adjustments = 0 for no grazing

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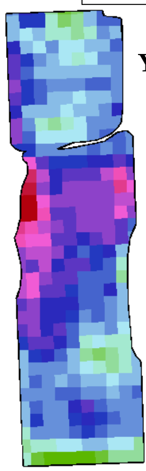
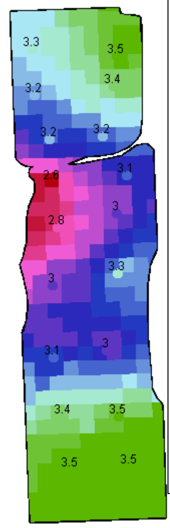
Steps to VRA Prescription Development

Spatial Inputs



Yield Goal * 2.4

- SOM * 10



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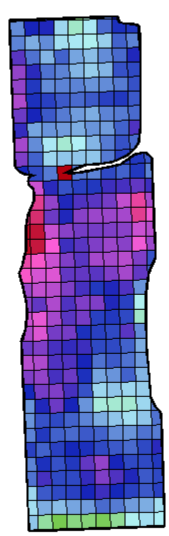
Steps to VRA Prescription Development



Nitrogenn Recommendation in lbs N/acre

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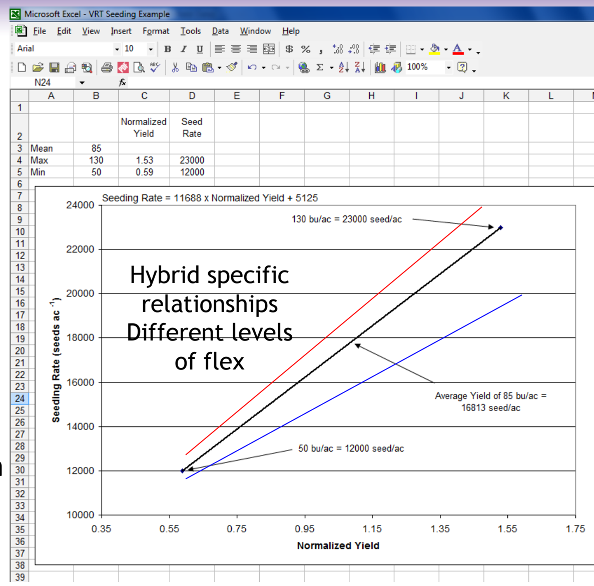
VRT Seed and N

- Seed and Nitrogen are typically our inputs most directly tied to yield goal
- Nitrogen is fairly straight forward Nrec = 1.6*YG – Credits
- Can we develop a seeding rec based on bounds
- If KP remains fairly constant than we can derive seeding rate from yield goal



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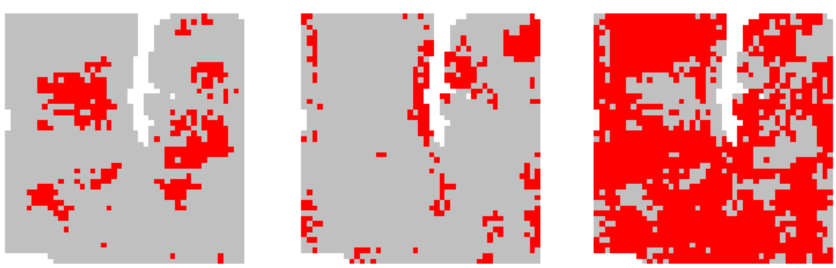
Yield Stability

Using classifications to adjust spatial yield goal



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Nitrogen Rec = SYG*1.6 – Credits or SYG*0.9

(K-State Recommendation)

Seed Rec = SYG * 11688 + 5125

(from our spreadsheet)

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Shifting gears… longer term management
Fertilizer Recommendations

- N_{rec} = (YG*1.6)-(SOM*2.5)-Profile N-other adjustments
- P_{rec} = 50 + (YG*0.2)+(STP*-2.5)+(YG*STP*-0.01)
- K_{rec} = 73 + (YG*0.21)+(STK*-0.565)+(YG*STK*-0.0016)
- $Lime_{6.8}$ = [12,810-(3,180*BpH)+(BpH^2*98)]+Depth (in)

- All are soil test driven – accepted as the most effective methods for fertilizer decisions
- **All are yield goal driven (except lime), but phosphorus management is heavily guided by soil test levels**

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Soil Testing Expense

- Soil Test Cost
  - Lab costs – between $5 and $25
  - Labor "costs" is the limiting factor for soil testing. *Finding time to do it.*
- Fertilizer decisions are often made without the benefit of soil tests.
  - Crop removal/replacement method
  - Standard annual rate method
  - Expected yield without regard to soil test levels

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Soil Test Use Plan

- Crop removal & replacement method
  - Crop yield (bu/a) * removal rate (lb/bu) = lb/a
- Soil Testing method
  - Soil test and use recommendation equations
  - Soil test initially, model removal, test periodically to adjust models.

Use yield monitor data to estimate soil test levels?

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Phosphorus removal values

Crop	Unit	P_2O_5 (lb)
Corn	bushel	0.33
Grain Sorghum	bushel	0.40
Wheat	bushel	0.50
Sunflowers	pound	0.02
Oats	bushel	0.25
Soybeans	bushel	0.80

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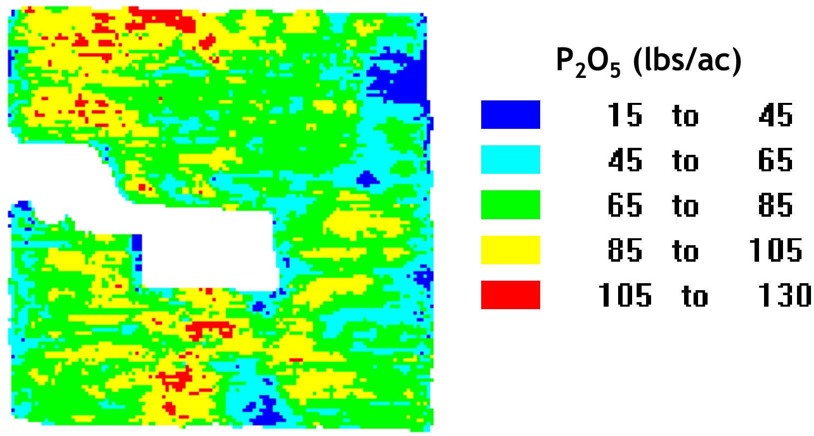
Using yield monitor data to look back



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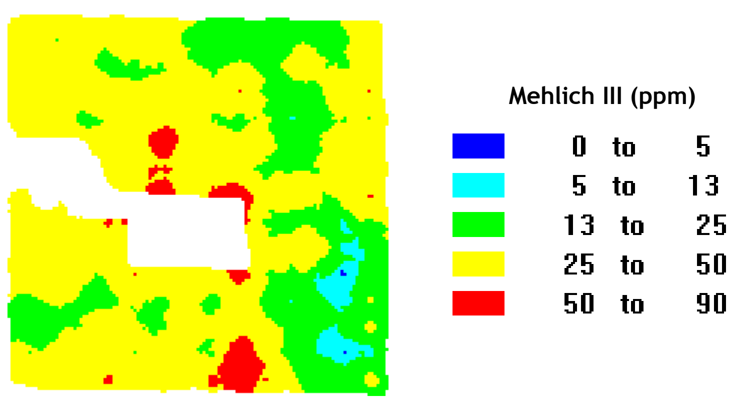
Soil Test P



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Crop Removal – the next step

- Calculate crop removal
- Depending on over/under applications after crop removal, soil test levels will change.
- 18 lbs P_2O_5 is required to change STP one ppm.

- One cycle of a W-C-F rotation (using field averages)
  - Wheat yield = 60 bu/a, Corn yield = 110 bu/ac
  - STP = 22 ppm, P_2O_5 = 30 lb/a
  - Wheat Removal = 60 * .50 = 30 lbs P_2O_5 removed
  - Corn Removal = 110 * .33 = 36 lbs P_2O_5 removed
  - Total Crop Removal = 30+36 = 66 lbs P_2O_5 removed
  - STP change = [30-66]/18 = 2 ppm drop
  - Final STP = 22 – 2 = 20 ppm
- Just perform this process at every point in the field

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Crop Removal – the next step

- Perform crop removal and STP calculations at a site-specific scale for the field
- Potential Decision Rules
  - Land ownership/tenancy makes a difference
  - Decisions based on STP
    - IF STP > 30 then apply 0 or very minimal amount (intentional mining)
    - IF STP is >20 and <30 then apply removal rates
    - IF STP is <20 then apply removal + build (build rate?)
- VRT apply P to meet management goals

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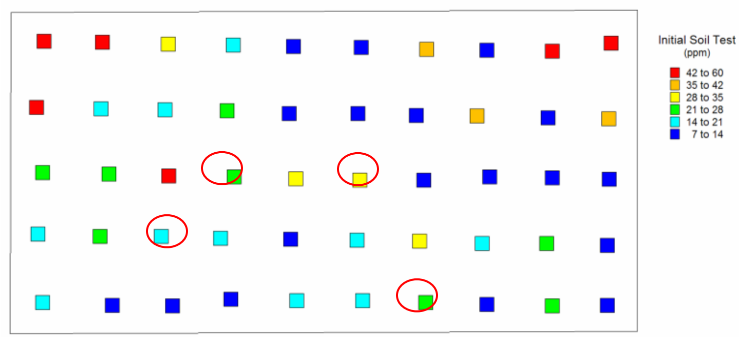
Benchmarks

- Establish bench marks that get sampled to calibrate models and evaluate fertilizer program progress.



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Other Datasets

- Soil EC
- Soil pH
- Soil nutrient sampling (grid, directed zone, etc.)

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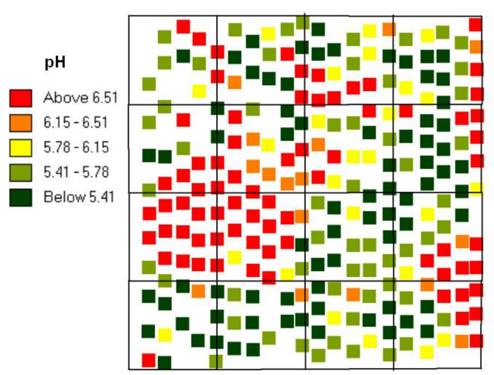
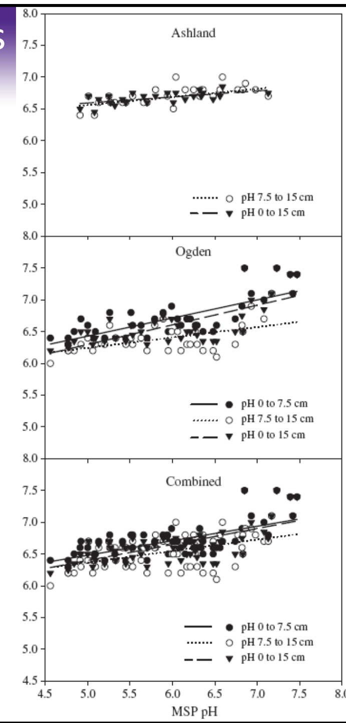
On-the-go Sensors





Staggenborg, Carignano, and Haag. 2007. Agron J. 99:854-861

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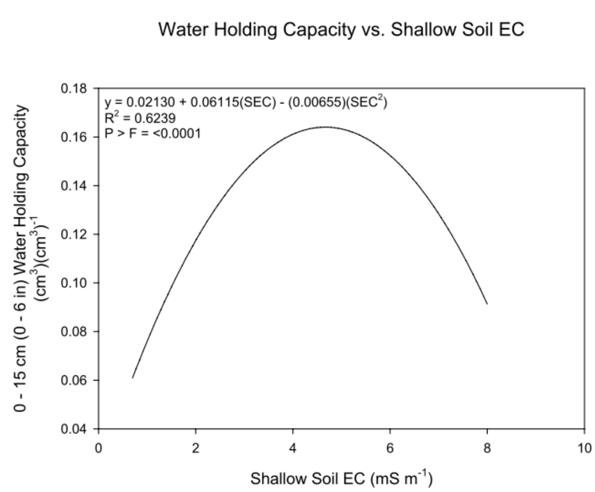
Building relationships from spatially dense data (soil EC)



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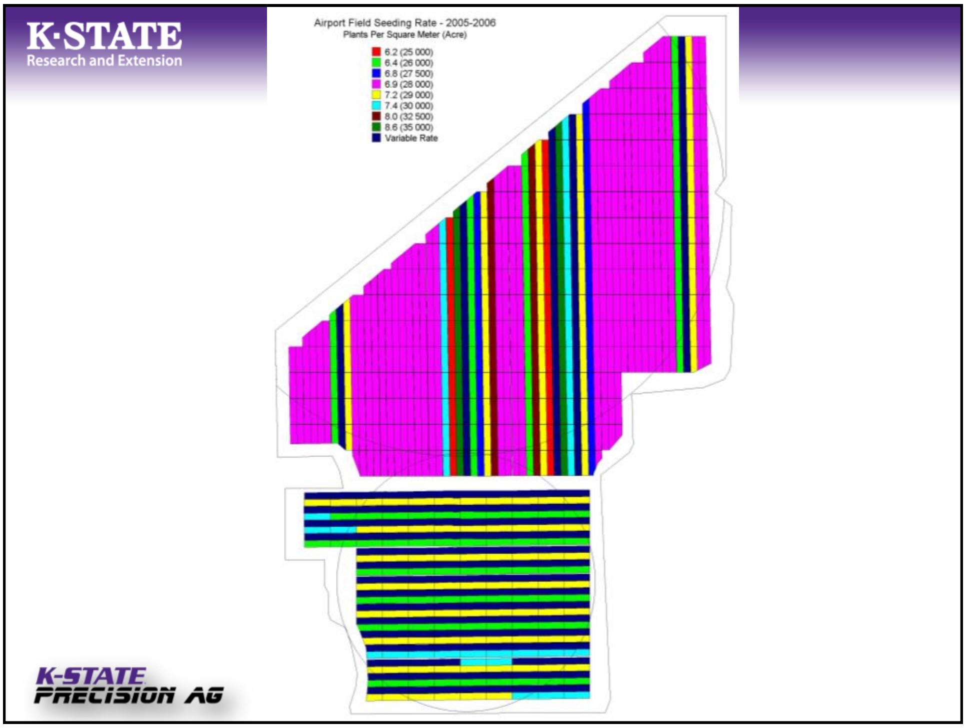
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Airport Field Seeding Rate - 2005-2006
Plants Per Square Meter (Acre)
6.2 (25 000)
6.4 (26 000)
6.8 (27 500)
6.9 (28 000)
7.2 (29 000)
7.4 (30 000)
8.0 (32 500)
8.6 (35 000)
Variable Rate
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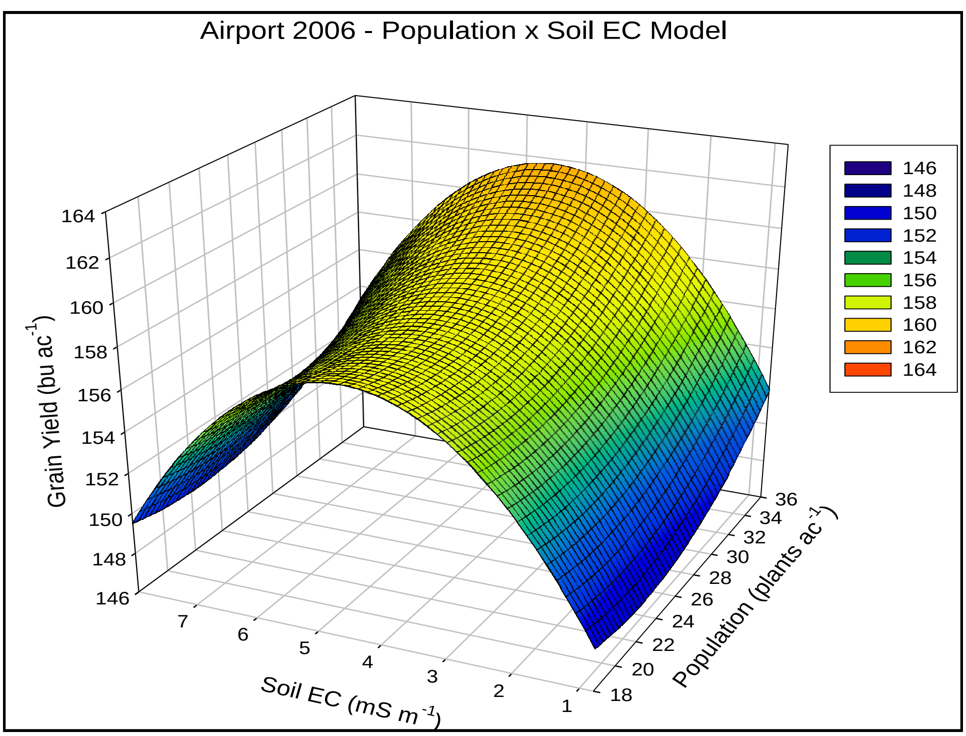
Airport 2006 - Population x Soil EC Model
Grain Yield (bu ac-1)
164
162
160
158
156
154
152
150
148
146
Soil EC (mS m-1)
7
6
5
4
3
2
1
Population (plants ac-1)
18
20
22
24
26
28
30
32
34
36
146
148
150
152
154
156
158
160
162
164

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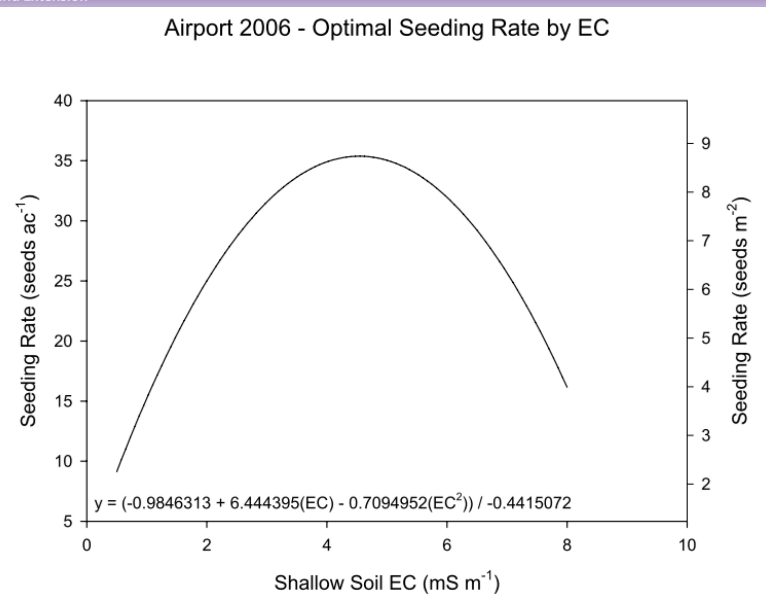

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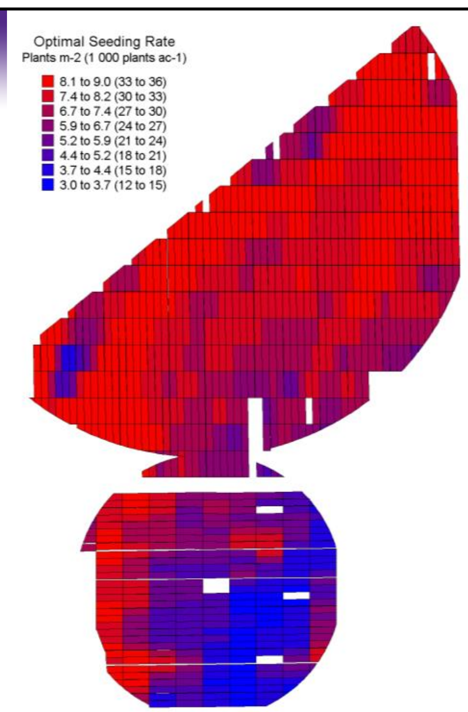

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VRT Seeding Analysis

- Optimal seeding rate derived from yield response curves varied between 12,500 and 35,375 seeds ac^{-1}
- Use of the producers standard seeding rate of 28,000 seeds ac^{-1} would result in 67% of the field area seeded under optimal and 33% above optimal

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The Future

- Data Quality
  - Challenges Remain
  - Reprocessing of Old Data
  - Continued Improvements in Hardware
- Data Use
  - More "Turn-Key" Solutions
  - Site-Specific Crop Modeling

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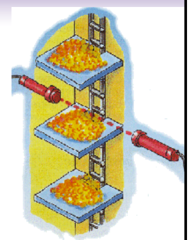
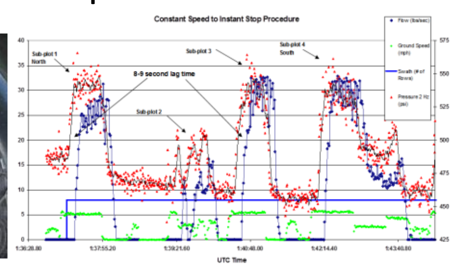
Challenges Remain



- Calibration
  - Dealing with real-time data, multiple machines
- Continued proliferation of “second-class” volumetric yield monitoring systems
- Continued hardware development



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Site-Specific Crop Modeling

- Crop modeling more accepted in other parts of the world at the field scale
- In the market in some forms
  - AdaptN, Encirca Nitrogen Mgt., Climate Corp, etc.
- What about calibration? Ground truthing?

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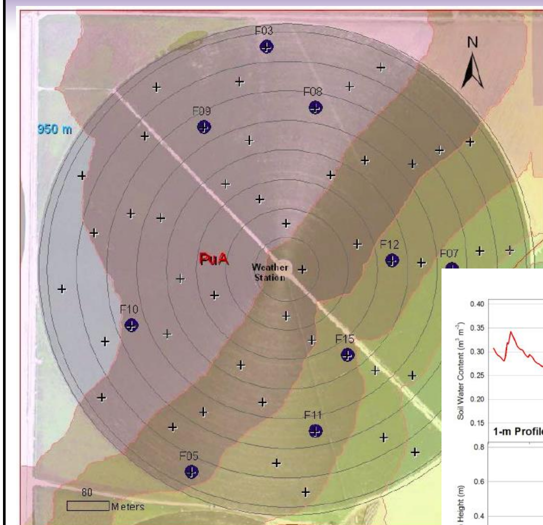
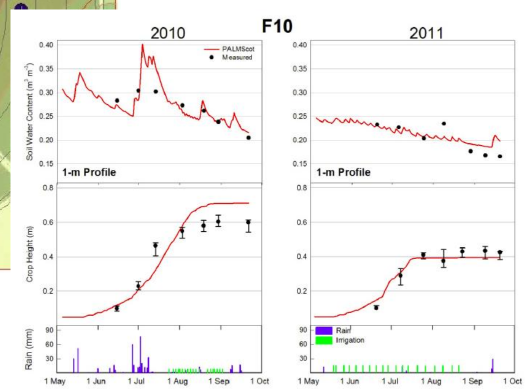
The Future - Site-Specific Crop Modeling





J.D. Booker, Ph.D. Dissertation, TTU

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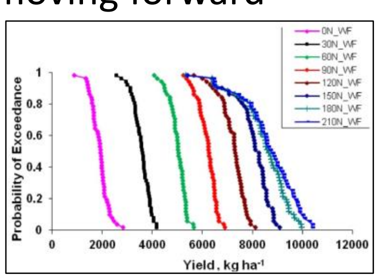
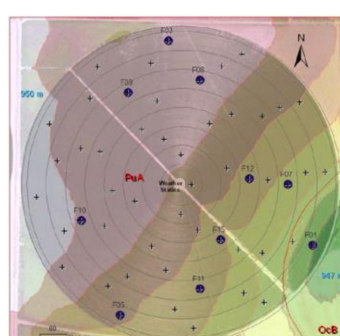
The Future - Site-Specific Crop Modeling

- Provide probability distributions of potential management strategies
- Yield data is necessary to calibrate and validate the model
- Yield data is necessary to evaluate model results moving forward





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Site-specific management questions to consider:

- **Does it make sense agronomically?**
  - Are we addressing a factor that affects yield?
  - Do we adequately understand the input vs. yield response of what we are managing?
  - Are we addressing the issue in an environmentally sound way?
  - Do I have a way to evaluate this method of management?
- **Does it make sense technically?**
  - Can my method of application accurately apply my intentions?
  - Do I have a way to evaluate the results? (as-applied maps)
- **Does it make sense economically?**
  - What are the true costs of implementation? (don't forget to value your time)
  - What is the probability distribution of years in which this will pay?
  - Is there an easier (cheaper) way to achieve most of the benefit with less cost?
  - Am I collecting enough data in my agronomic and technical evaluations that I can evaluate the economics of the practice?

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Questions?

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Other emerging precision ag technologies / opportunities

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The future…

- Data quality, reprocessing
- sUAV's (drones) - ?
- Telematics, mining machinery data
- Crop models?
- What about livestock?

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Planting costs (with section controllers)…

Estimated Cost of Planting			
Planter size, rows	16		
Row controllers	8		
Base acres	2,800		Tractor hours
Downtime during day, hrs	1.50		Planting = 130
Seed tender time, minutes	30.0		Engine = 209
Field shape (1=Normal, 2=Bad, 3=Good)*	1		
	Corn	Soybeans	Total
Percent of acres	66.7%	33.3%	100.0%
Planting speed, mph	5.50	5.50	5.50
Planting days	10.69	6.01	16.70
Total cost of planting, $/acre	$17.37	$18.53	$17.75
Benefit of row shutoffs, $/acre	$7.27	$1.92	$5.49
Total cost of planting, $/year	$32,436	$17,277	$49,712
Benefit of row shutoffs, $/year	$13,584	$1,789	$15,373
Total cost of planting, $/tractor hr	$242.67	$229.98	$238.10

* Average angle of incidence = 45, 30, and 75 degrees for normal, bad, and good fields, respectively.

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Planting costs (with section controllers and improved tendering)…

Estimated Cost of Planting			
Planter size, rows	16		
Row controllers	8		
Base acres	2,800		
Downtime during day, hrs	1.50		Tractor hours
Seed tender time, minutes	20.0		Planting = 130
Field shape (1=Normal, 2=Bad, 3=Good)*	1		Engine = 193
	Corn	Soybeans	Total
Percent of acres	66.7%	33.3%	100.0%
Planting speed, mph	5.50	5.50	5.50
Planting days	10.01	5.45	15.46
Total cost of planting, $/acre	$16.81	$17.60	$17.07
Benefit of row shutoffs, $/acre	$7.27	$1.92	$5.49
Total cost of planting, $/year	$31,403	$16,407	$47,810
Benefit of row shutoffs, $/year	$13,584	$1,789	$15,373
Total cost of planting, $/tractor hr	$250.95	$240.92	$247.42

* Average angle of incidence = 45, 30, and 75 degrees for normal, bad, and good fields, respectively.

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Spraying costs…

Costs of spraying under alternative assumptions[1]

Avg road speed, mph	Tank fill time, minutes 15.0	5.0	Tank fill time, minutes 15.0	5.0
	Acres sprayed annually[2]		Total cost/acre[3]	
Miles between fields = 3.0				
28.0	29,641	35,379	$4.40	$3.97
35.0	29,995	35,895	$4.36	$3.93
Miles between fields = 6.0				
28.0	28,015	33,082	$4.60	$4.17
35.0	28,649	33,966	$4.52	$4.09

[1] All model inputs were held constant except tank fill time, road speed, and sprayer investment (assumed an extra $20K for faster tendering scenarios).

[2] Sprayer engine hours are held constant at 500 for all scenarios (if acres are held constant rather than sprayer hours, gain to faster fill rate decreases)

[3] Includes an estimate of tendering as well as sprayer owneship and operating

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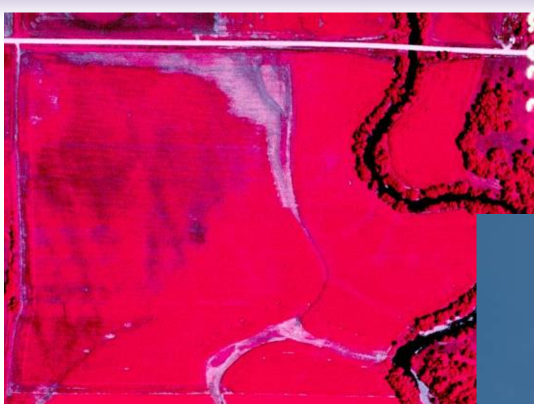
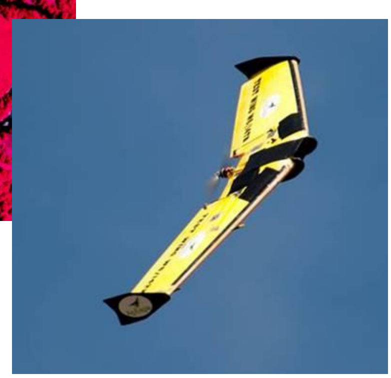
Imagery





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UAV Imagery – Rawlins County 2013

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UAV Imagery – Rawlins County 2013

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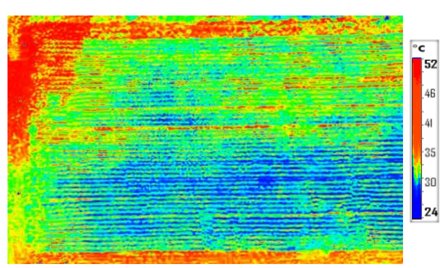
Development of high spatial corn canopy thermal maps using small unmanned aircraft systems for irrigation management



Dr. Ajay Sharda and Dr. Lucas Haag
Biological and Agricultural Engineering
Northwest Research-Extension Center
Kansas State University

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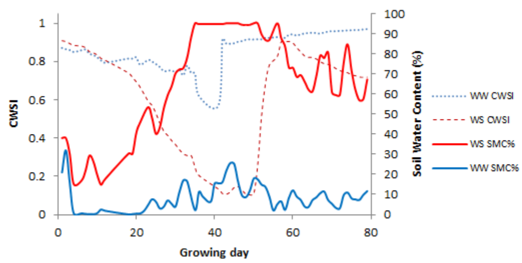
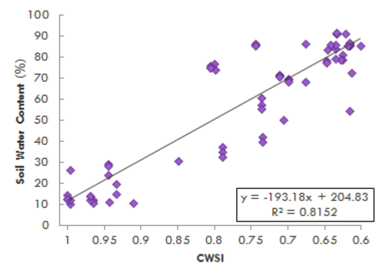
CWSI and Soil moisture





CWSI can be used to predict soil moisture

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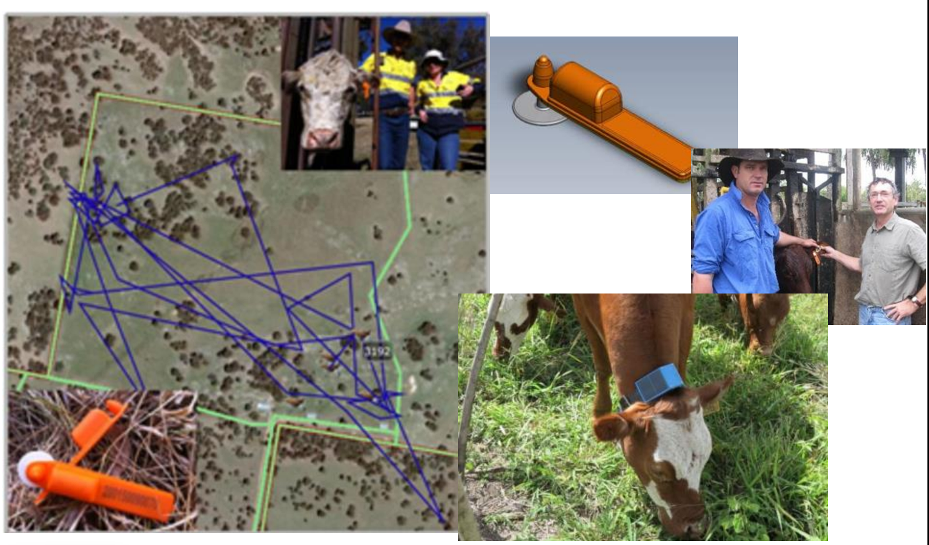
What About Livestock?



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What About Livestock?

- Facilities monitoring
- Herd monitoring
- Herd health monitoring
- Grassland assessment and grazing planning

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