Development of On-the-go Nitrogen Application Algorithms for Cotton Production Based on Active Reflectance Sensors

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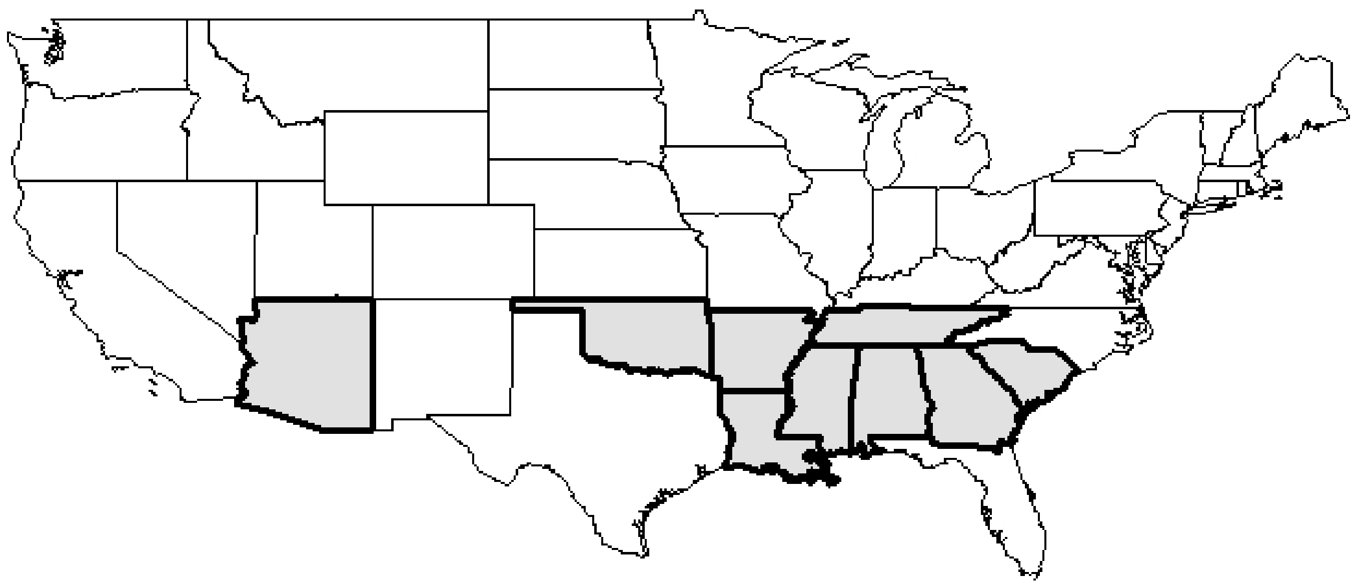
Cotton NDVI Studies

- Collaborators from 9 states
  - Funding from Cotton Inc.
  - Applied nitrogen studies



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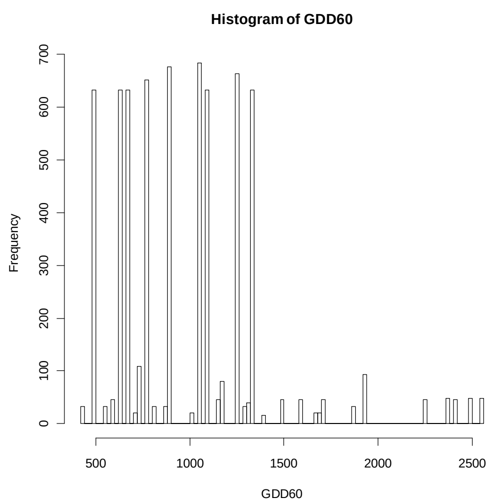
Caveats

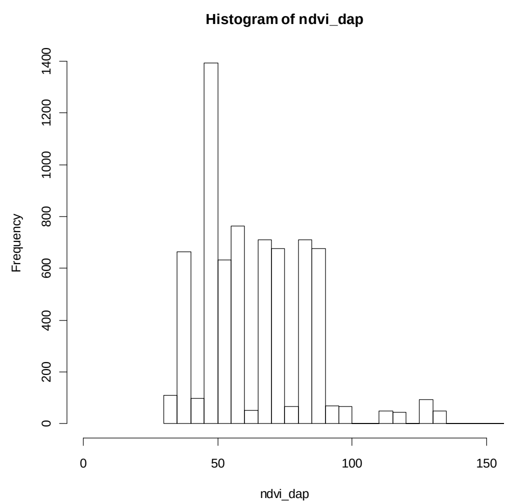
- No economic analysis conducted
  - Statistical analysis of bio-physiological data

Choosing Unit of "Time"

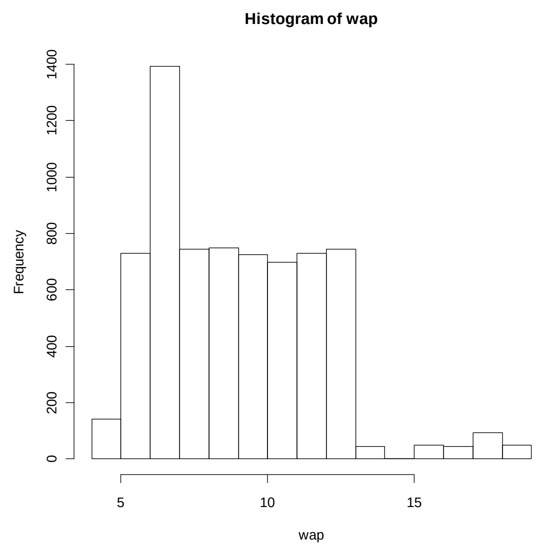
- Heat unit accumulation preferred to 'time'…
  - Algorithm development requires 'categorized' time
  - Rather than GDD60, using WAP
  - DAP resulted in too many 'bins' for given amount of data



GDD60



DAP



WAP

Precision Ag: The Tale of Two Technologies Information-intensive & Embodied-knowledge

Information-intensive

- Field level data to make decisions
- Requires additional data and skill
- IPM

Embodied-knowledge

- Information purchased in the form of an input
- Requires minimal additional data/skill
- Round-up Ready or Bt

Two Faces of Precision Agriculture

<u>Information-intensive</u>

- Yield monitors
- Traditional variable rate applications
- ***Data**

<u>Embodied-knowledge</u>

- Automated guidance
- On-the-go sensors applying variable rates
- ***Automated**

Motivation and Issue

- Analyses have been conducted for single datasets
- Failed to model multiple climates, systems, etc.
- Global response estimated from all datasets
- Objective: Develop on-the-go N application algorithm

Motivation and Issue

- Analyses have been conducted for single datasets
- Failed to model multiple climates, systems, etc.
- Global response estimated from pooled dataset
- Derive on-the-go nitrogen application algorithms
- Objective: analyze multi-state experiment data to estimate response between active sensor reflectance and cotton yield for on-the-go nitrogen management
  - Develop on-the-go N application algorithm

Data and Methods

- Pooled model
  - Multiple site-years; 9 states, >=11 PI, >=13 studies
  - All data (sites and years) in single dataset
  - Datasets normalized and controlled for heterogeneity
  - Conditioned by year, location
- Correlation among?
  - yield, nitrogen rate, NDVI values and timing
- Regression analysis of pooled dataset

Challenges

- Cotton is a perennial
- N rate sufficient to cause yield penalty
- Identifying appropriate timing for NDVI
  - DAP, GDD60
- No economic analysis conducted
  - Statistical analysis of bio-physiological data

Challenges

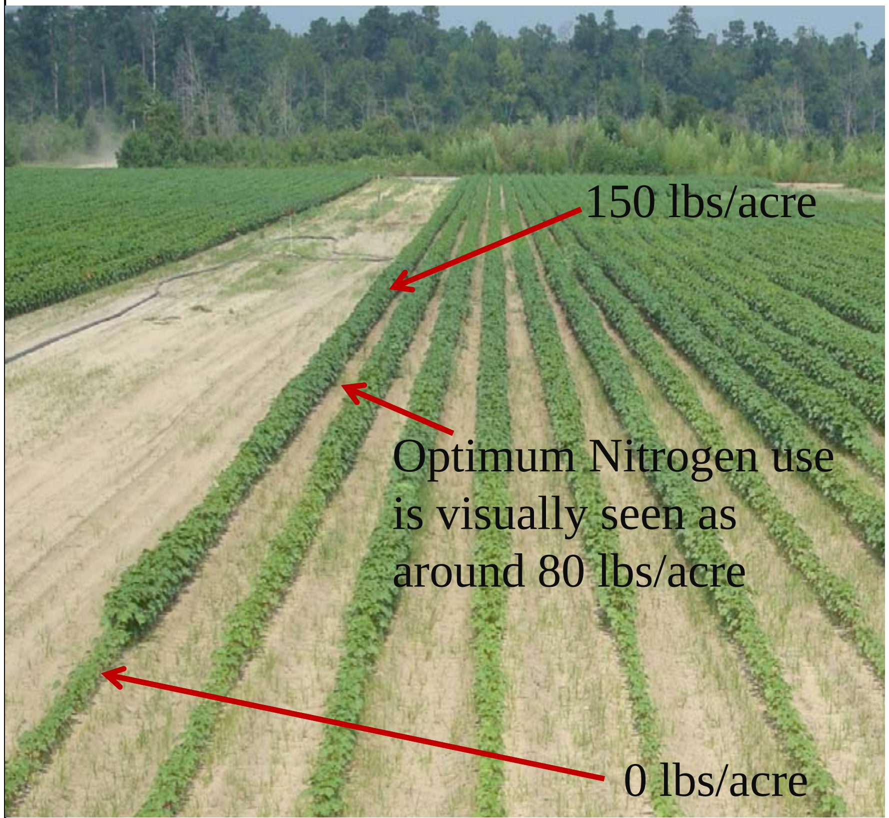
- Cotton is a perennial
- N rate sufficient to cause yield penalty
- Identifying appropriate timing for NDVI
  - DAP, GDD60
- Testing functional forms of relationships
- Testing indexes for algorithm
  - Variety, location, and GDD60 specific
  - Global algorithm with local intercept/slope shifters
- No economic analysis conducted
  - Statistical analysis of bio-physiological data

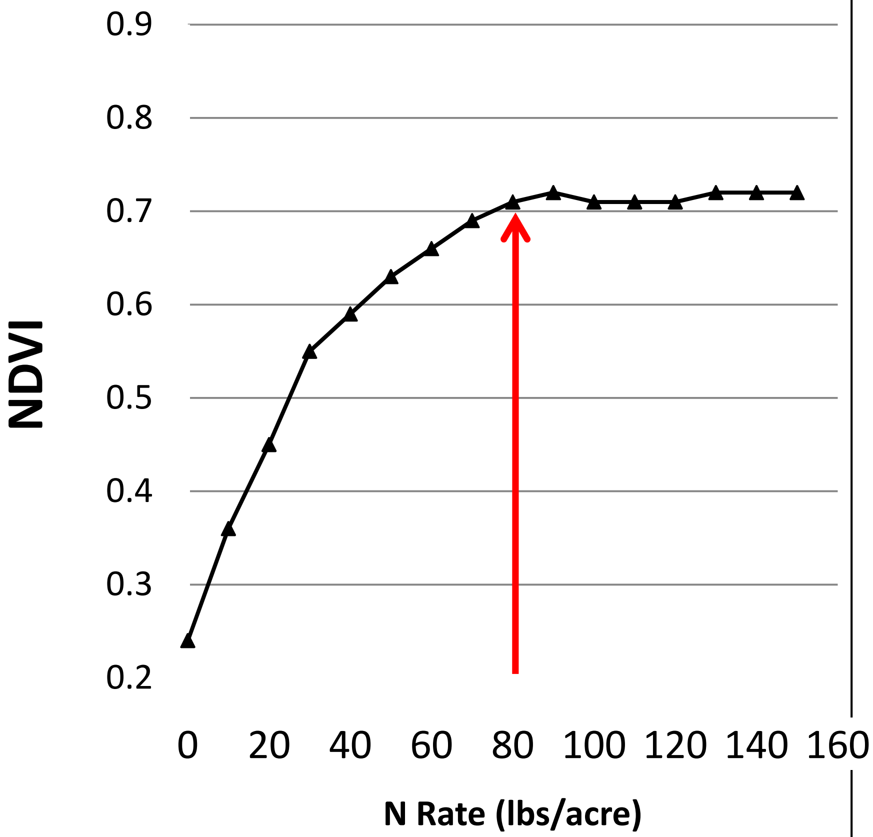
Sensor-Base N Status

- “Yield Potential” approach available for growers not mapping soils
- OSU approached “worked” everywhere evaluated (SC, TN, LA, OK); however:
  - How early can readings be taken? In some cases response not clear until 4-weeks after early bloom
  - Debate if soil specific reference strips needed

Visual/NDVI use of Ramp Strips

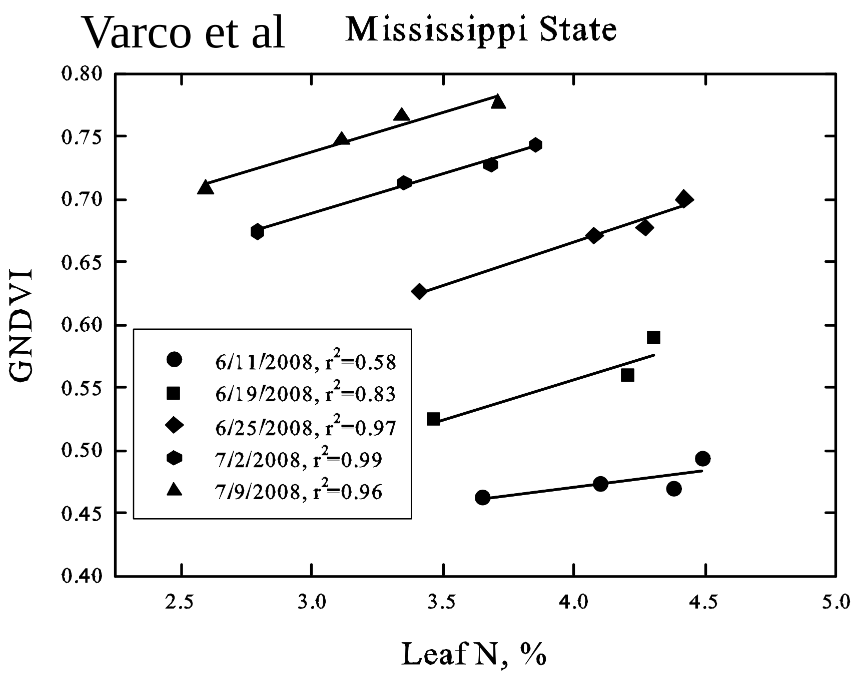
The Green Seeker data collection verified what was seen visually in the ramp strips in SC. 30% N savings over blanket application with no yield reduction US modified OSU approach – 2007 to 2009



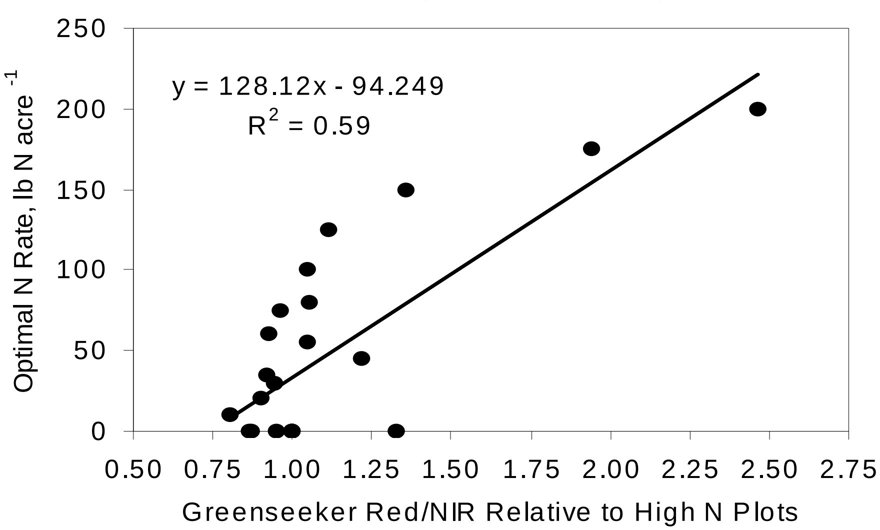


Other Indexes and Relationships

Varco et al

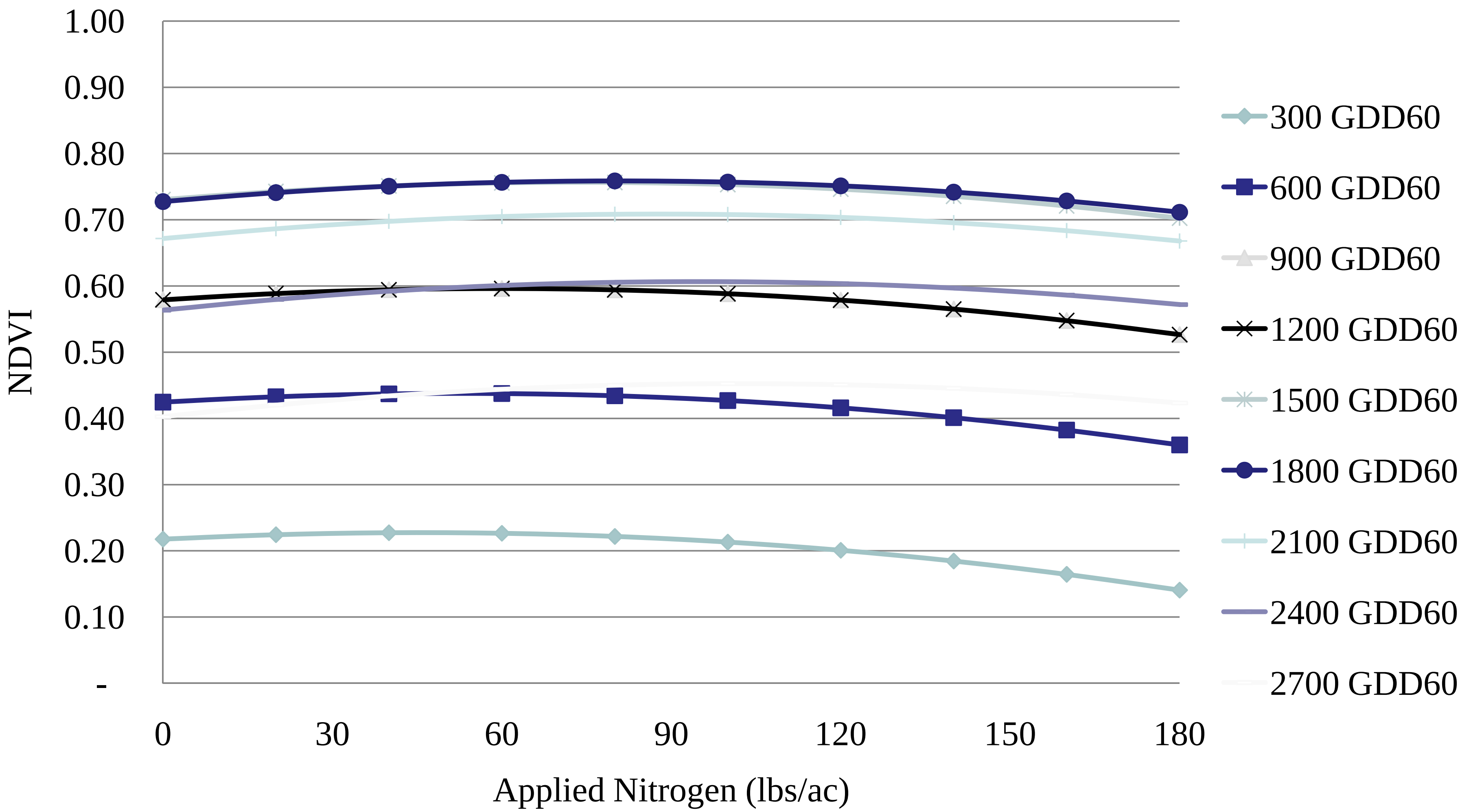


Missouri (Scharf et al.)

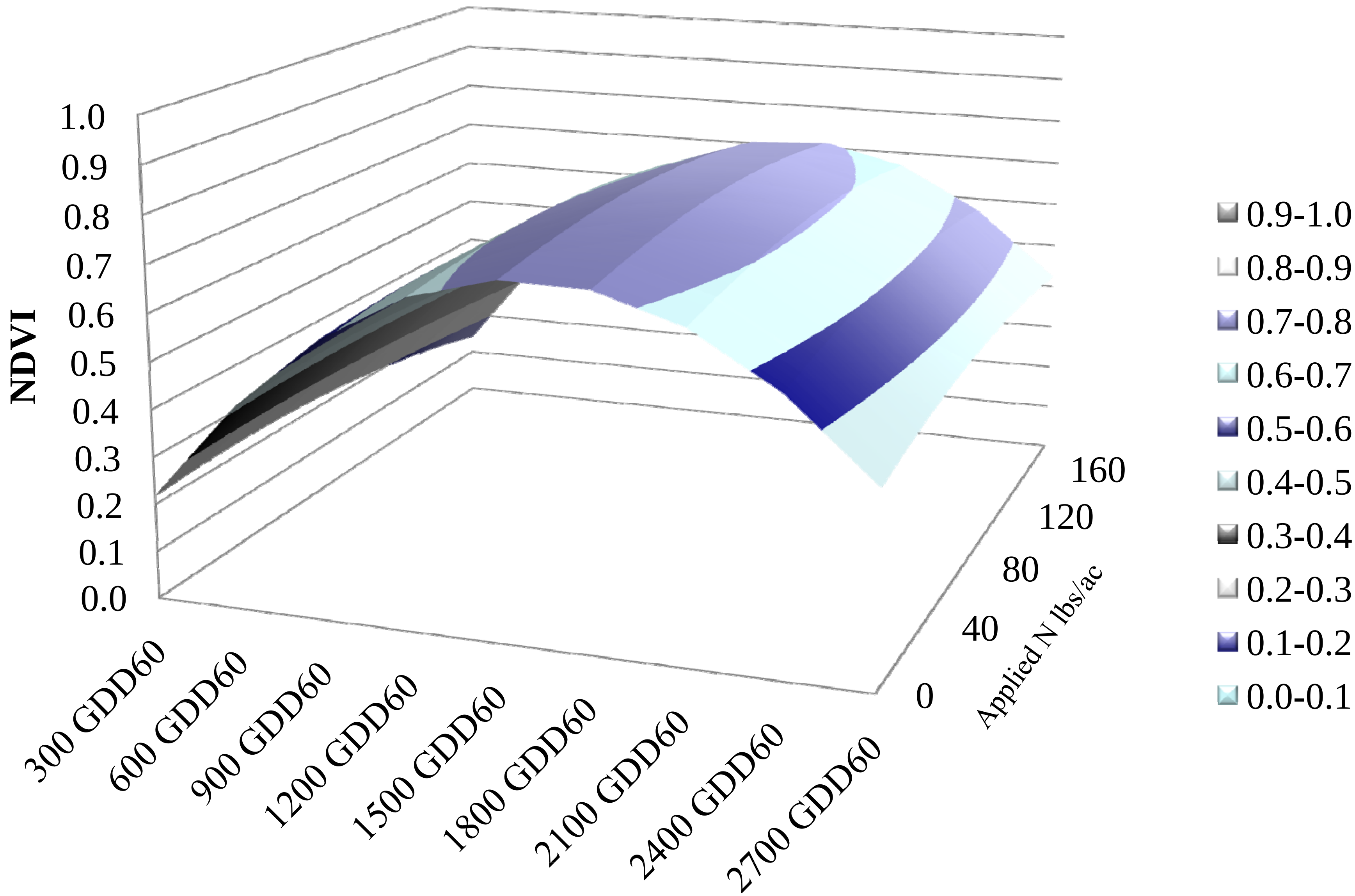


NDVI ~ N by HUA

Not as useful for developing algorithms… need categorical time

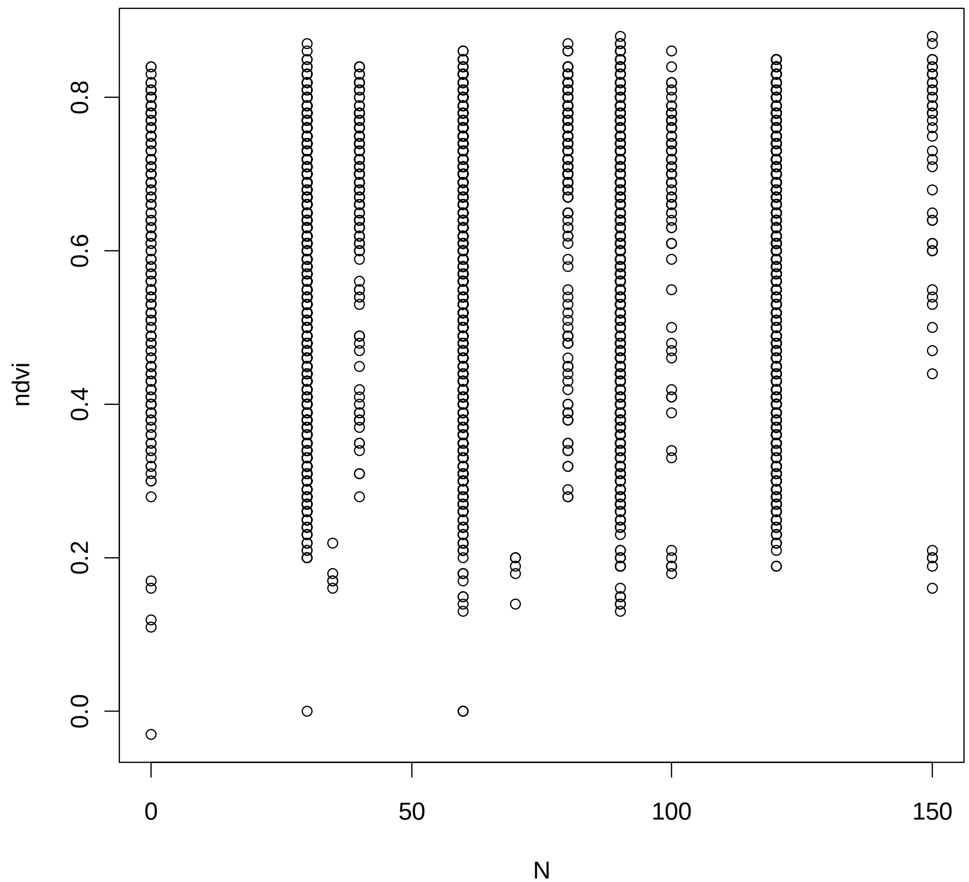


NDVI response to N application by time of measurement



NDVI and Applied Nitrogen

- Determine the shape of the functional form
  - Linear
  - Quadratic
  - Other?
  - No relationship?
- Can NDVI proxy for applied N?



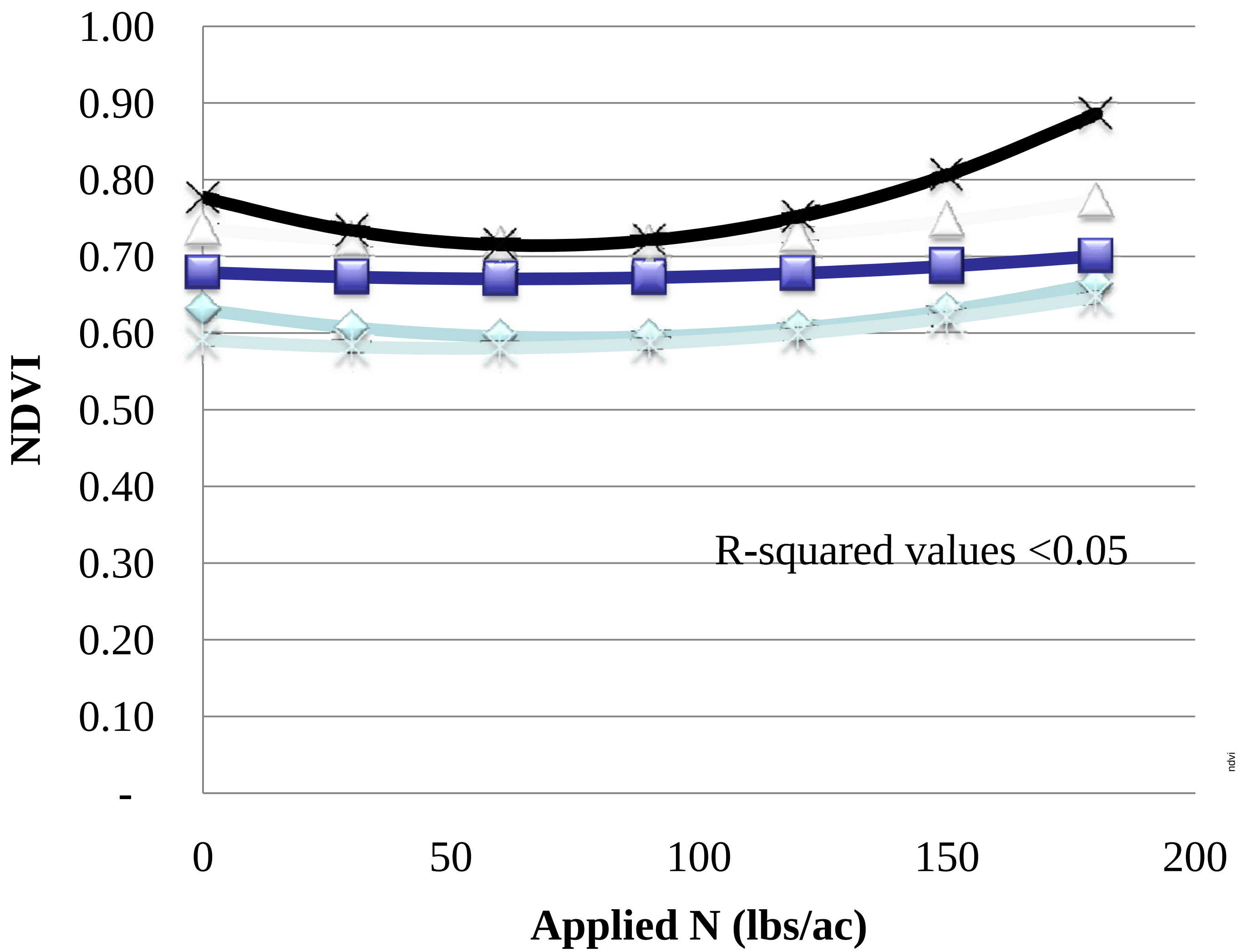
Correlation: N and NDVI by Time

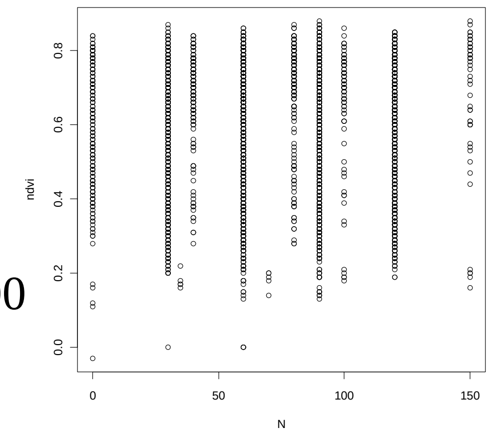
Pearson Correlation Coefficient applies only to linear relationship

Bolded numbers are significant at 90% level
WAP8 and WAP9 become significant at 89 and 88% levels

	N	WAP6	WAP7	WAP8	WAP9	<=WAP10
N	1	0.49	**0.73**	0.66	0.65	**0.83**
WAP6		1	**0.95**	**0.98**	**0.98**	**0.89**
WAP7			1	**0.99**	**0.99**	**0.99**
WAP8				1	**1.00**	**0.97**
WAP9					1	**0.96**
WAP<=10						1

NDVI and Nitrogen by Time





Algorithms

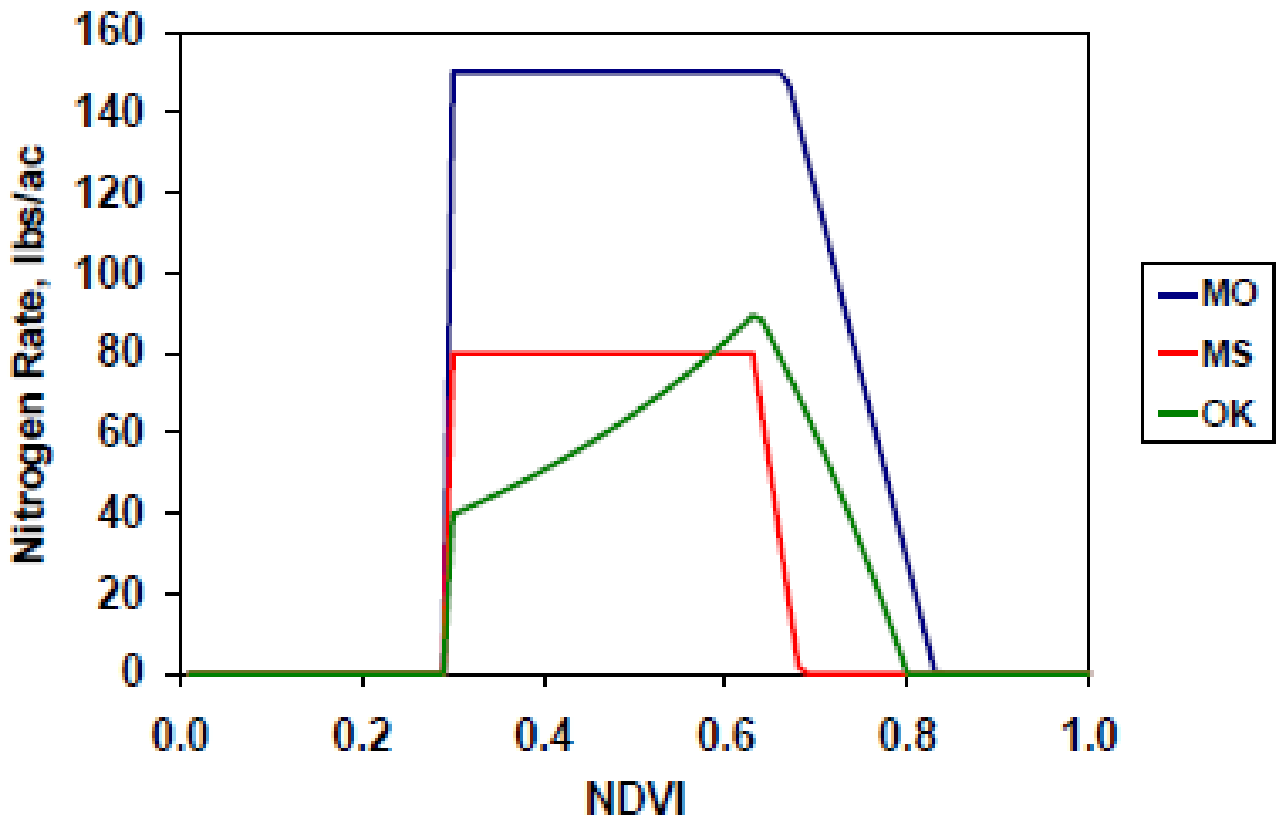
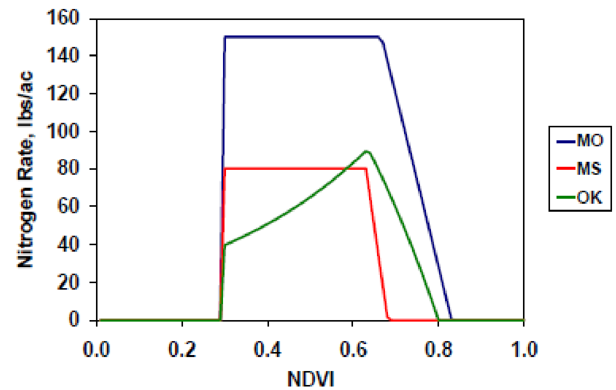


Figure 10. Variable nitrogen prescriptions developed by Missouri (MO), Mississippi (MS), and Oklahoma (OK).

Source: Randy Taylor, Oklahoma State University

Histogram of NDVI Values

Algorithm can be "hard bounded" by 0.2 and 0.8



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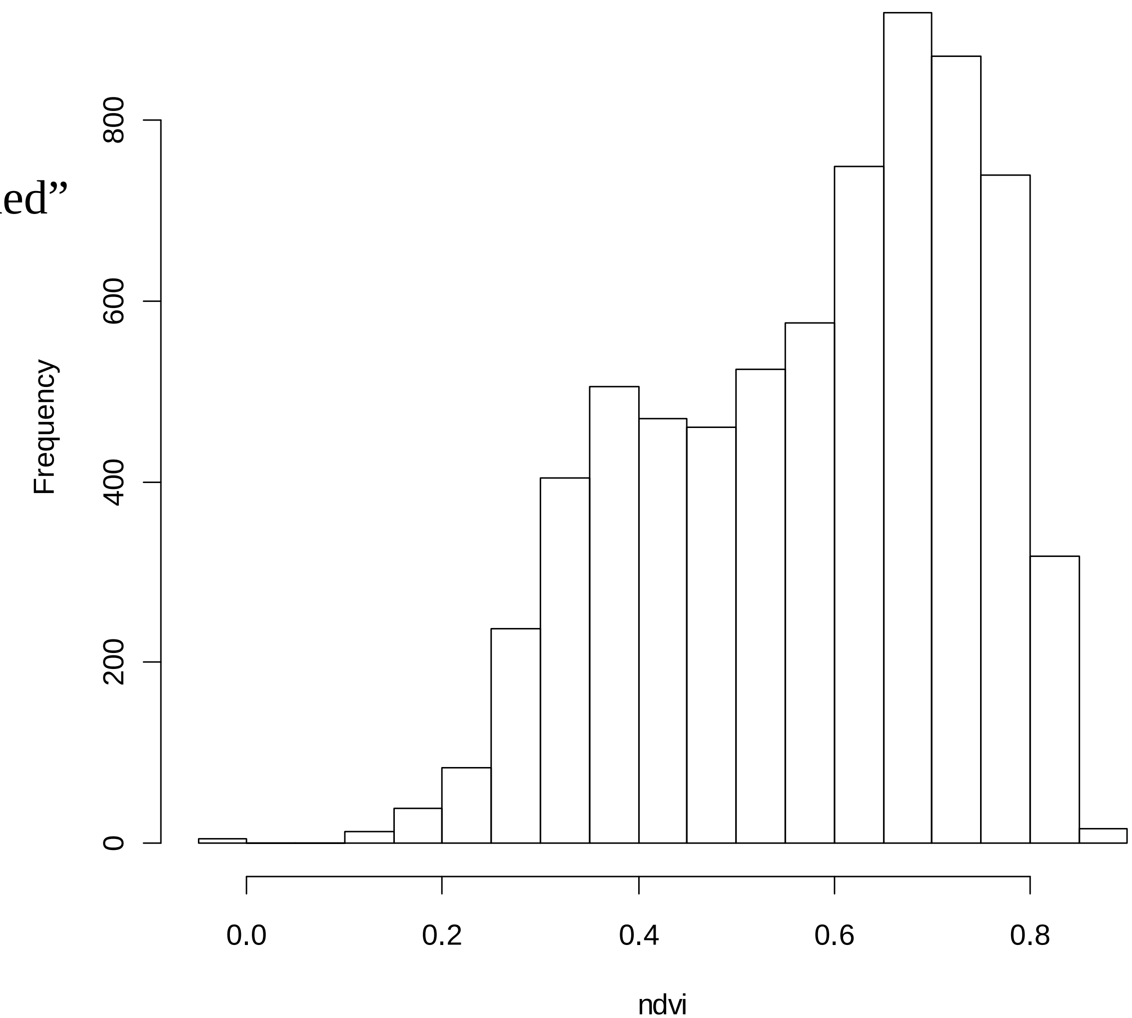
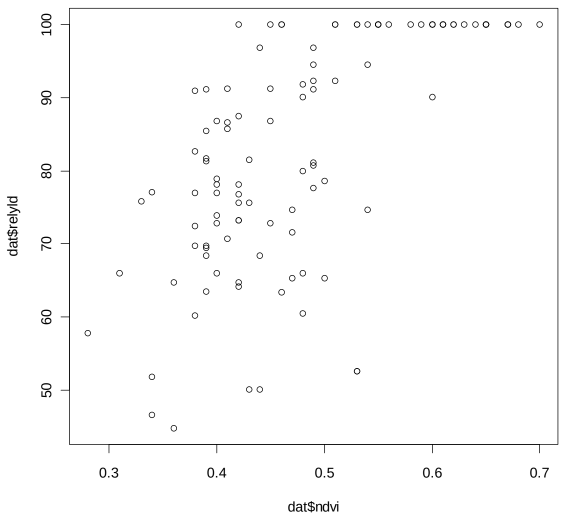
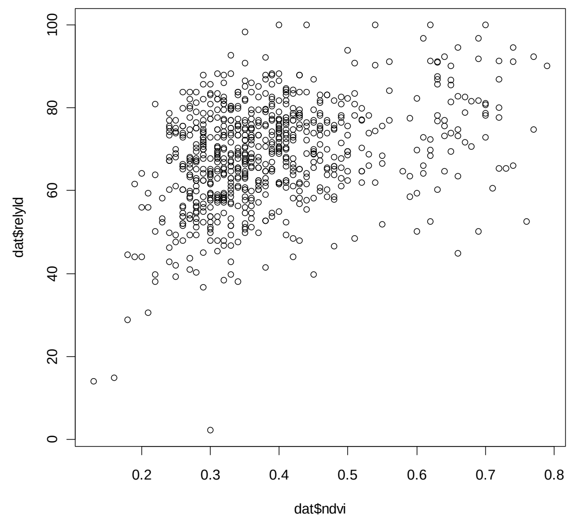


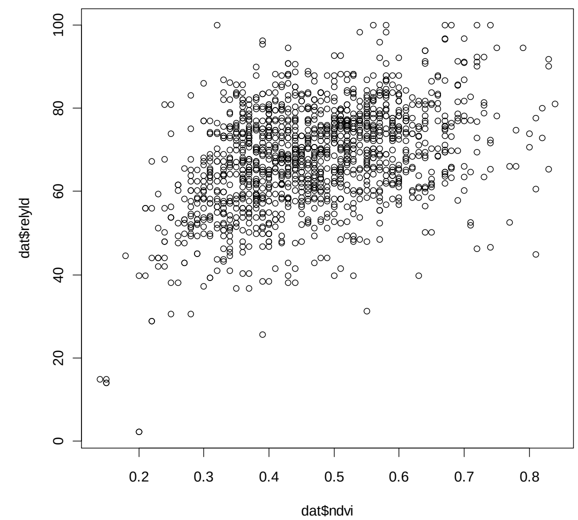
Yield potential as function of NDVI by WAP



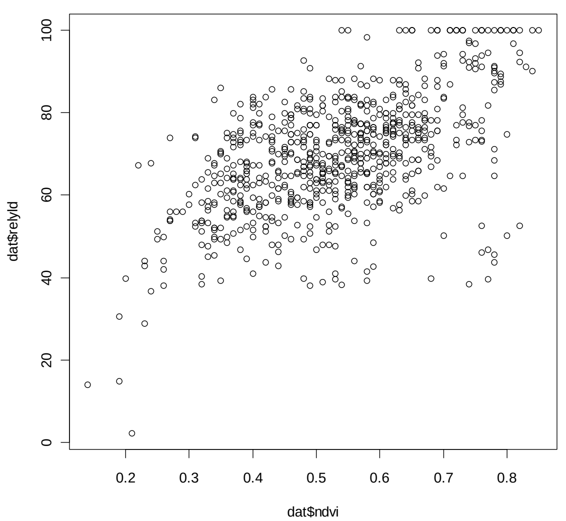
WAP=5



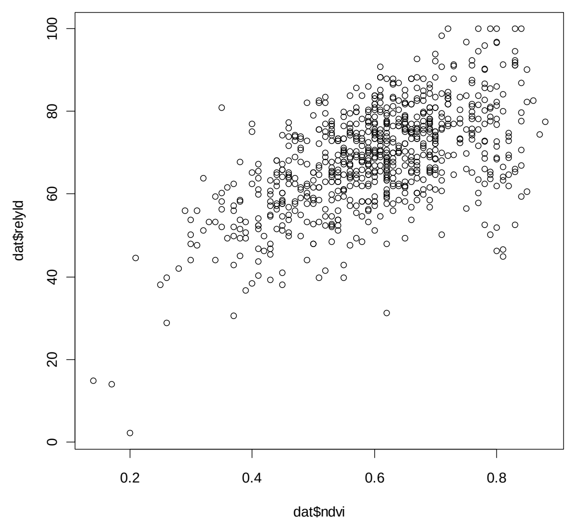
WAP=6



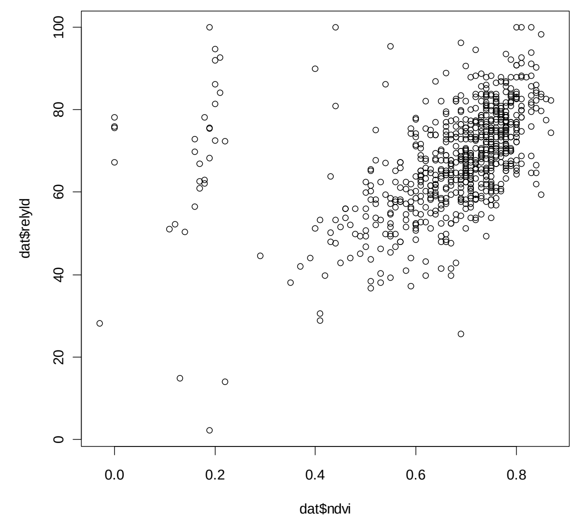
WAP=7



WAP=8

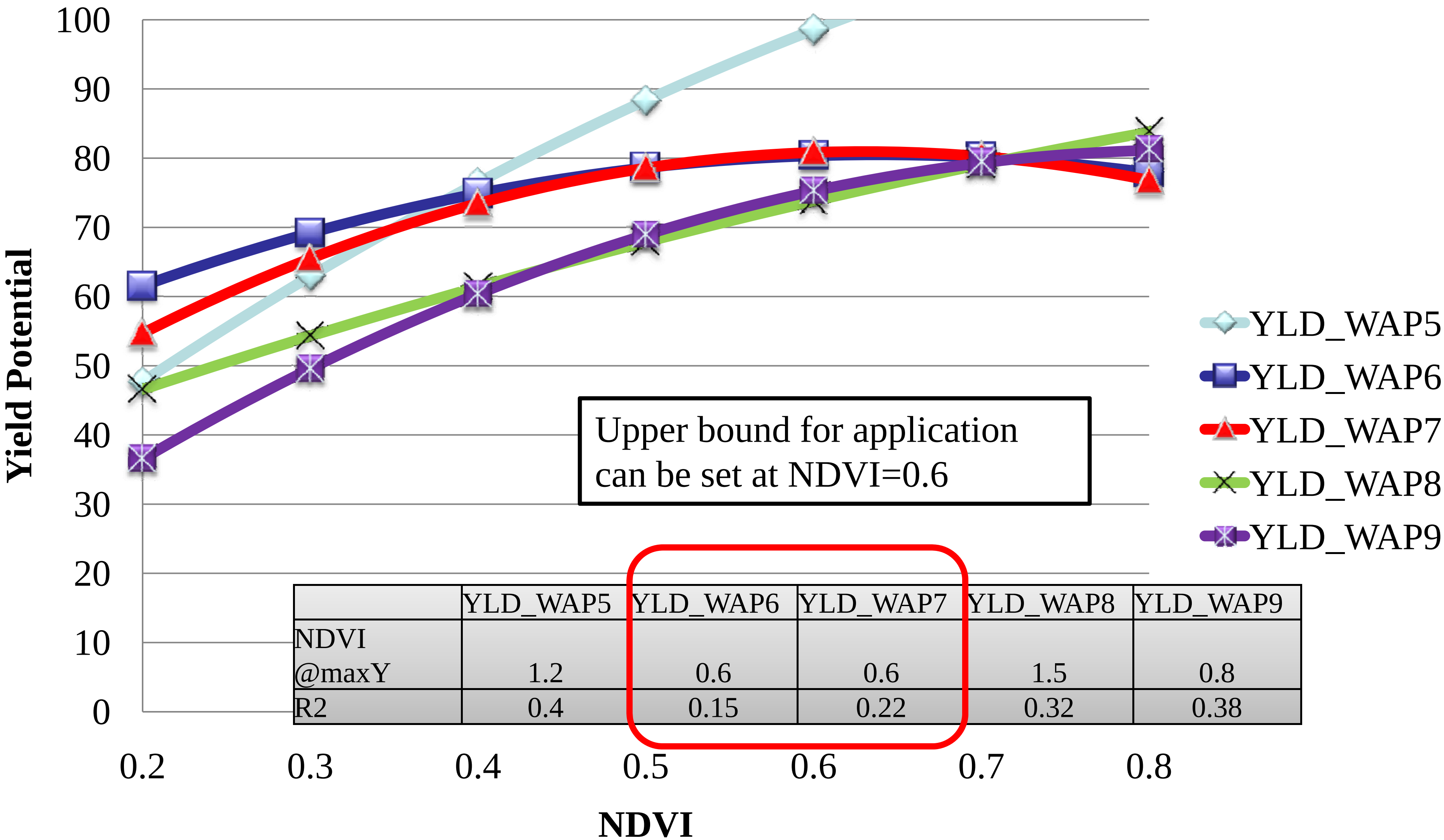


WAP=9



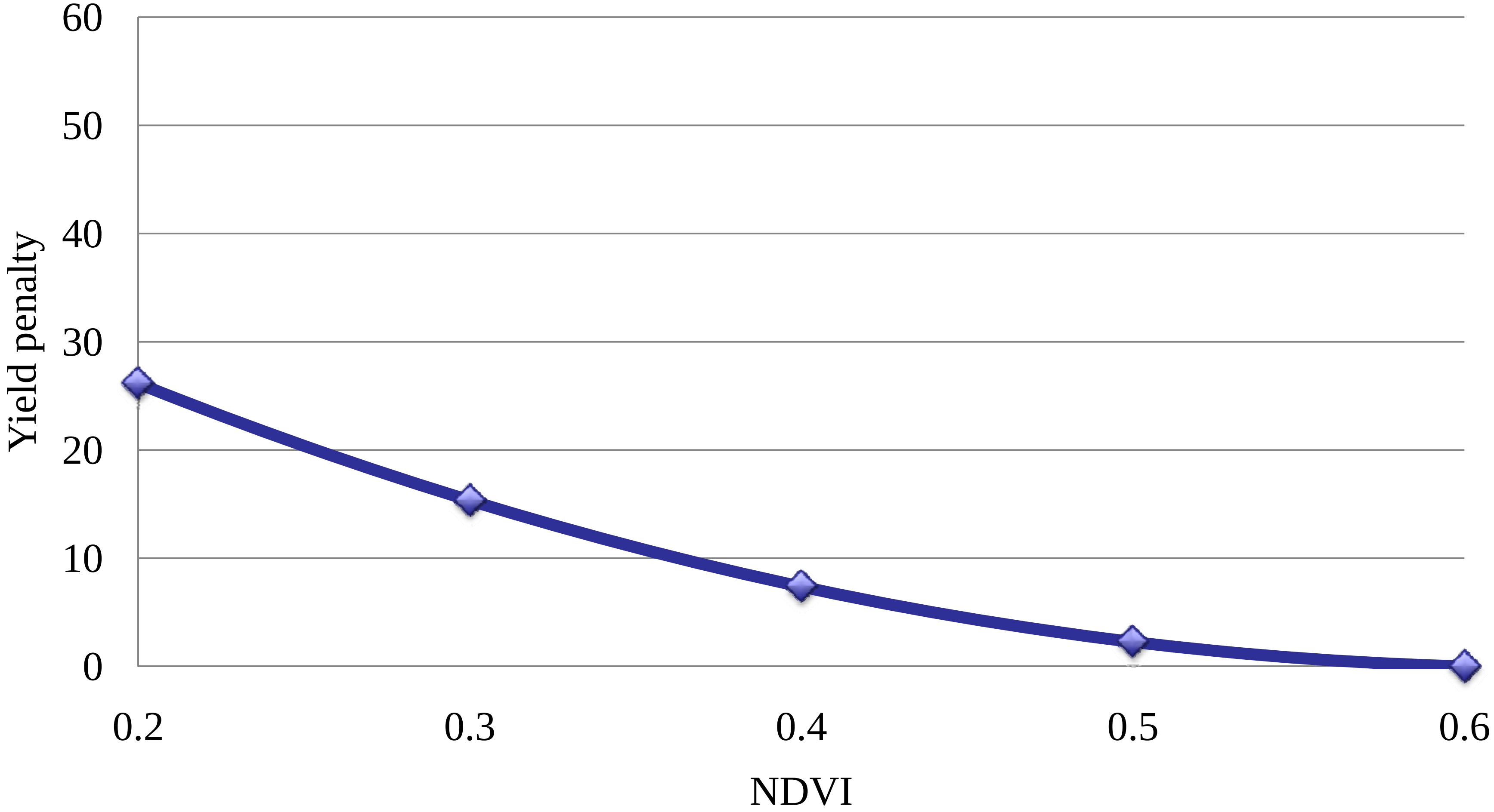
WAP=10

Yield as Function of NDVI by WAP



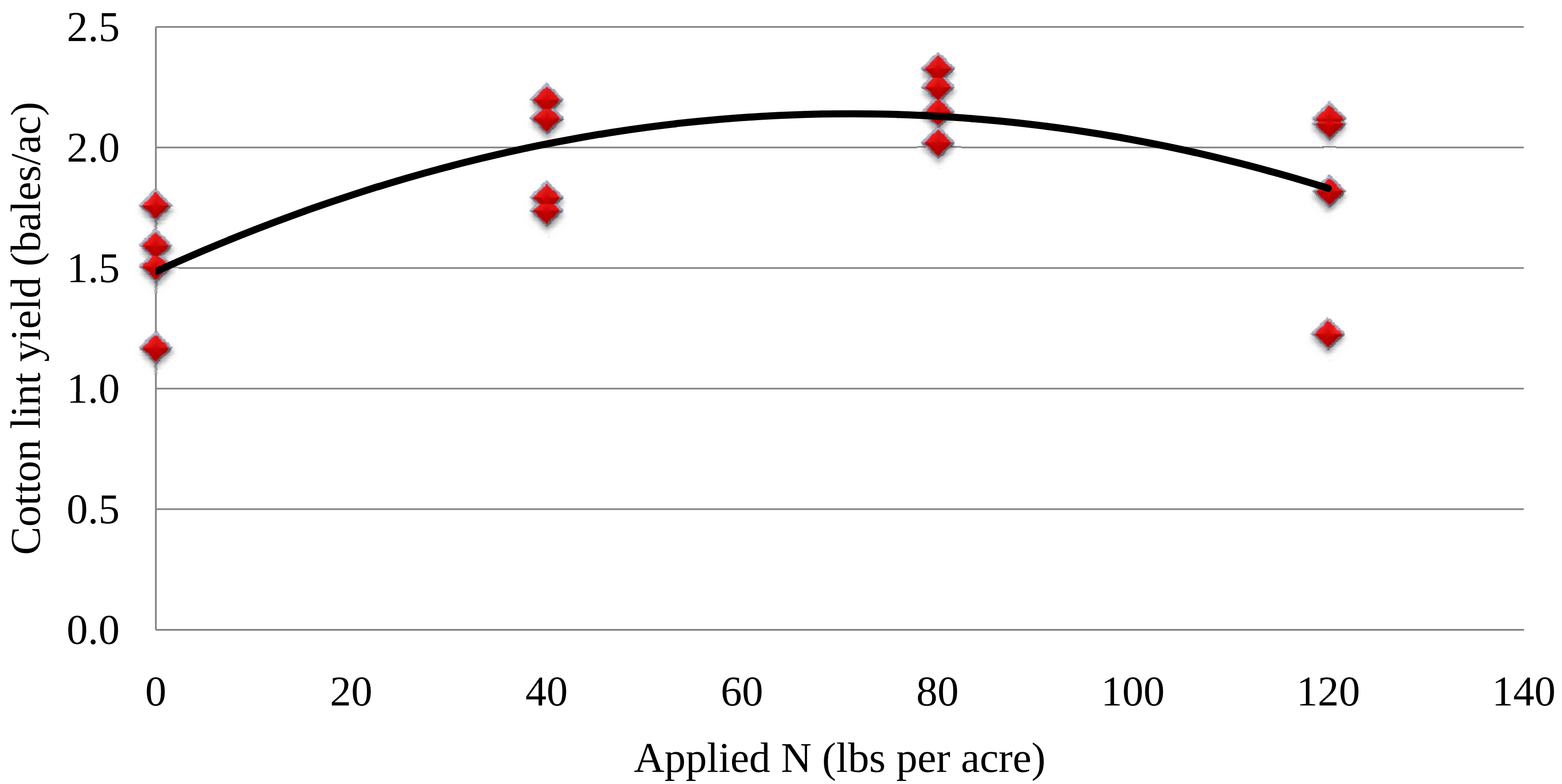
	YLD_WAP5	YLD_WAP6	YLD_WAP7	YLD_WAP8	YLD_WAP9
NDVI @maxY	1.2	0.6	0.6	1.5	0.8
R2	0.4	0.15	0.22	0.32	0.38

Yield Penalty as Function of NDVI: WAP=7

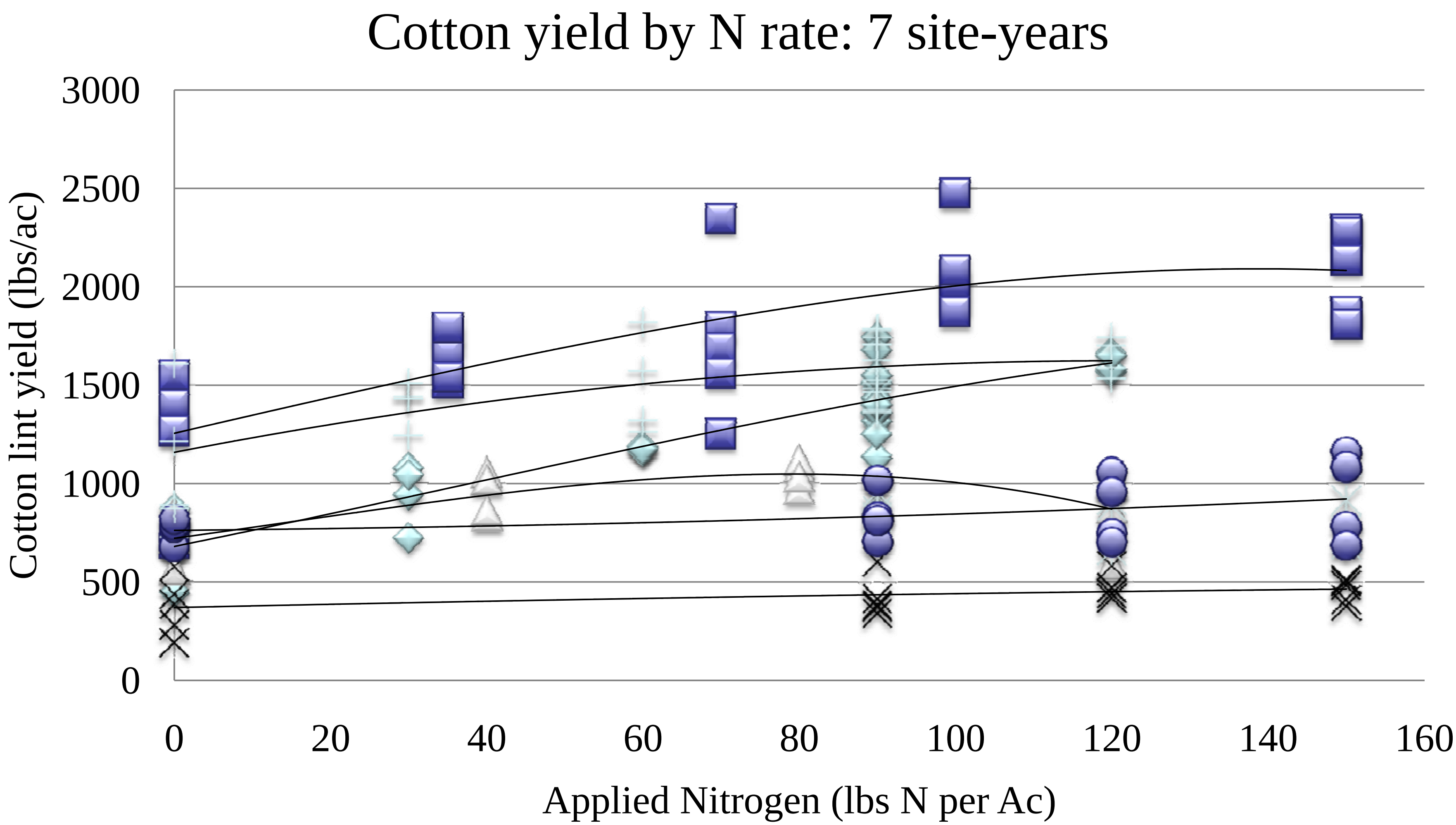


Classic Cotton Lint Response to Applied N

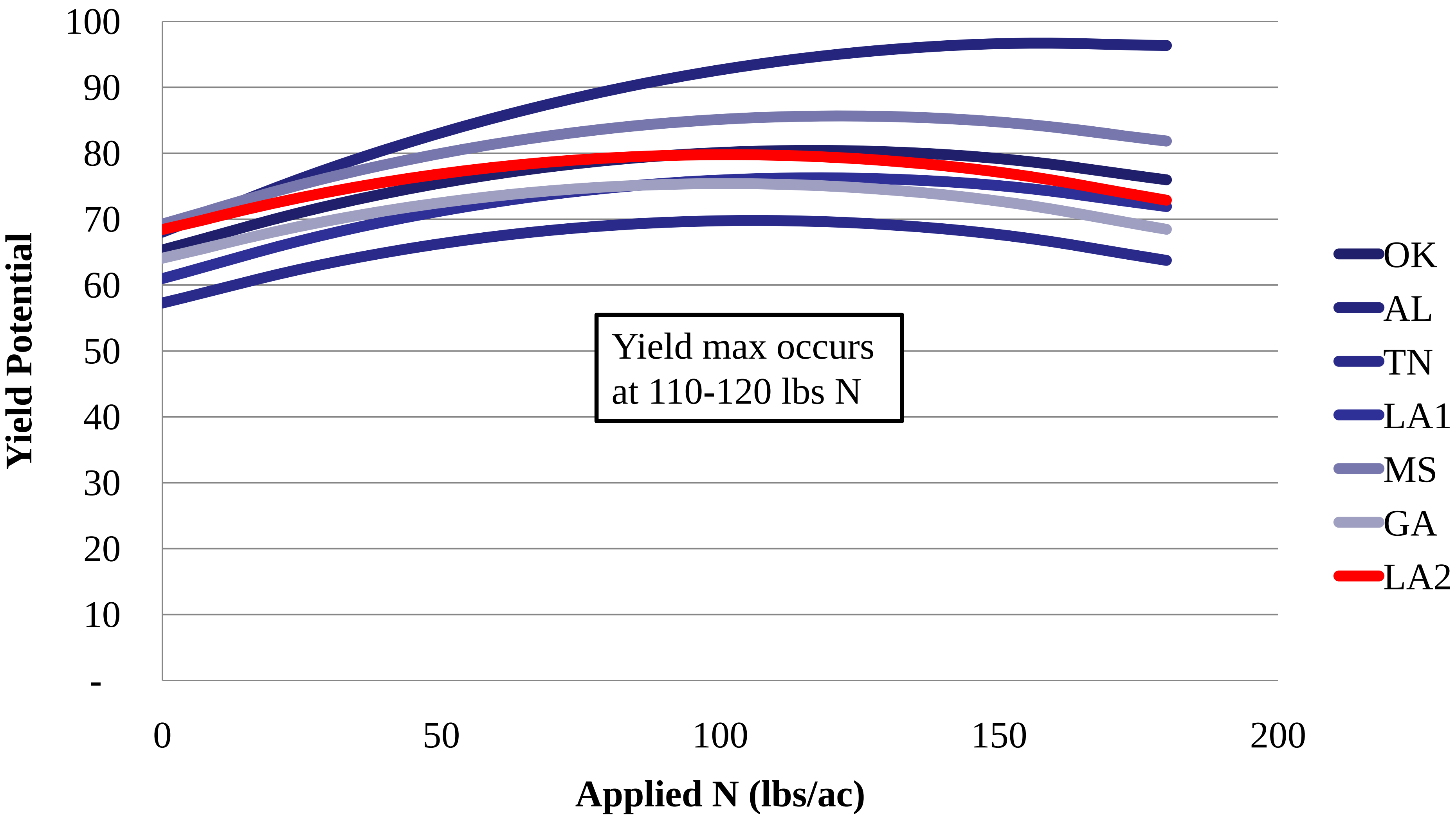
- In theory, quadratic without plateau



Data is 'messy' and 'all over the place'



Yield Potential by N Rate



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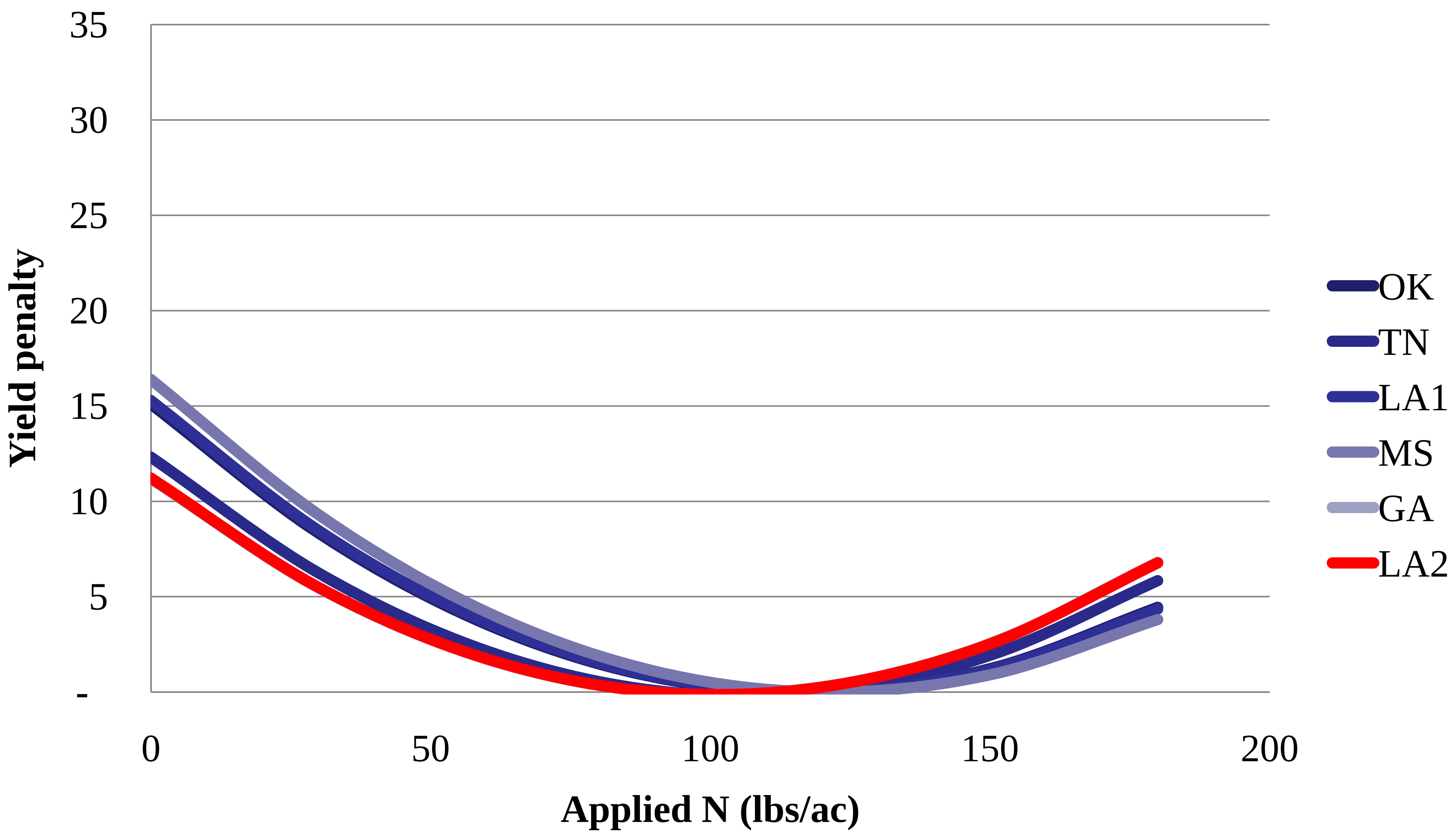
Yield Penalty by N Rate



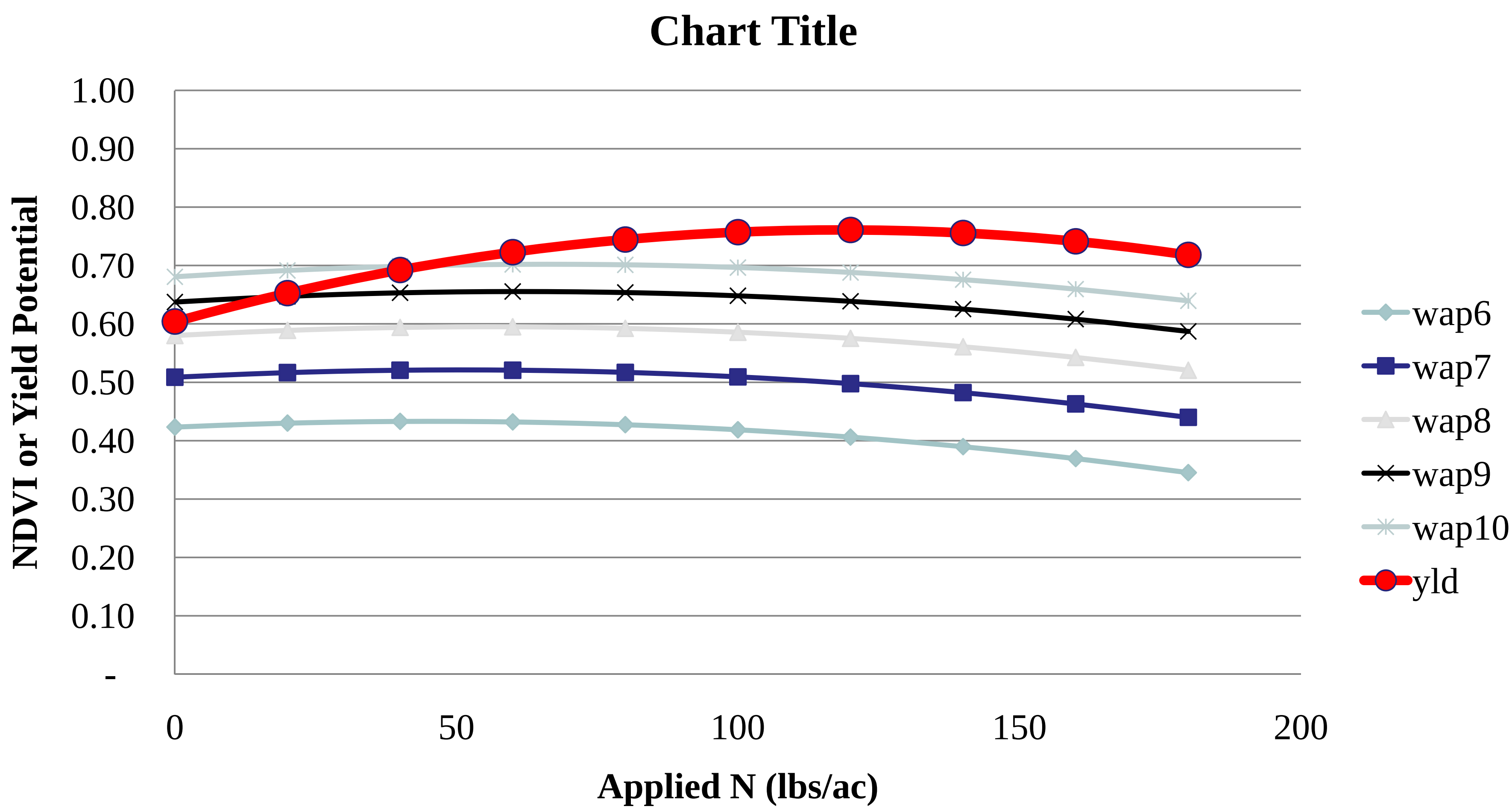
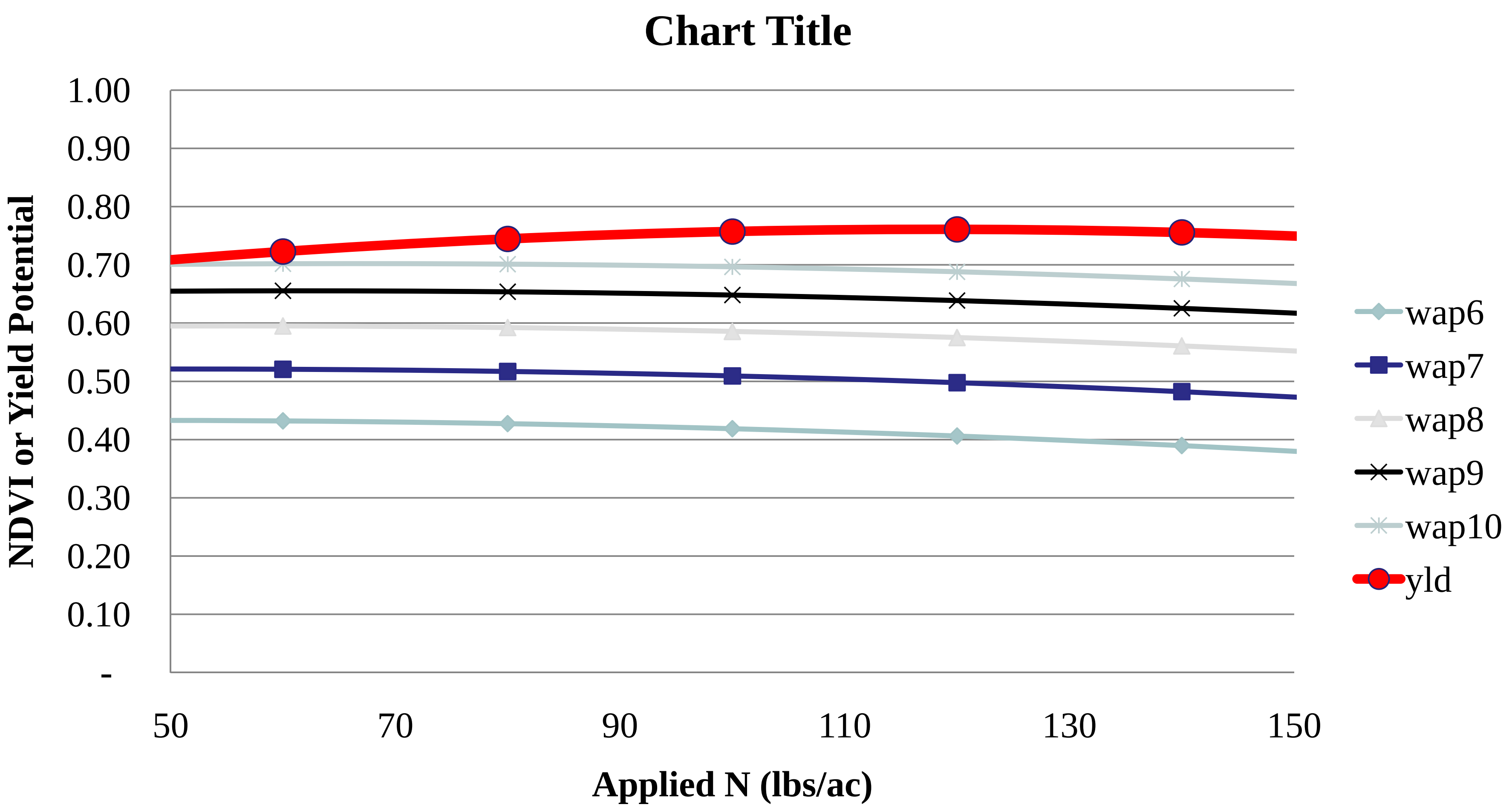


Chart Title
NDVI or Yield Potential
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
-
0
50
100
150
200
Applied N (lbs/ac)
wap6
wap7
wap8
wap9
wap10
yld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1.00
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70
90
110
130
150
Applied N (lbs/ac)
wap6
wap7
wap8
wap9
wap10
yld

Practical Implications

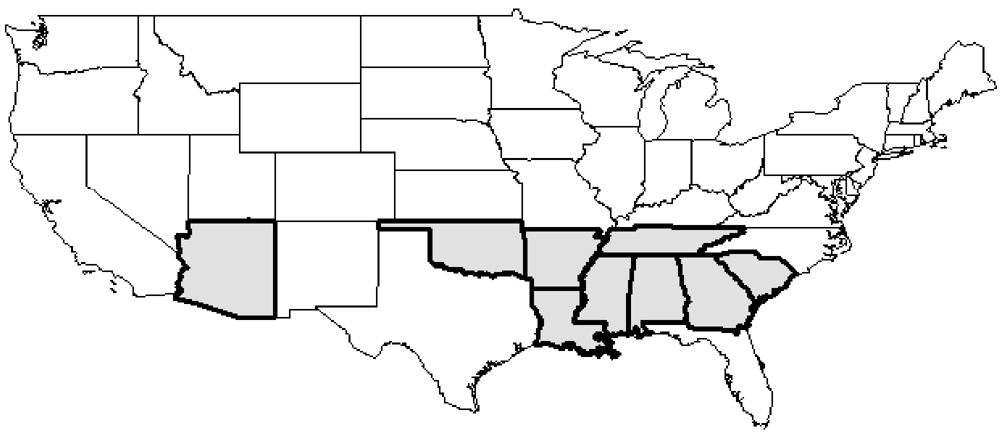
- Lower bound = 0.2
- Upper bound = 0.6
- Difficult to predict total on-the-go applied product
  - Need to take extra product to field
- Some applicators not capable of abruptly varying rates

Limitations

- Cotton is a perennial grown as summer annual
  - Cotton is a tree
- Need more data!
  - Locations, years, varieties
  - DAP/GDD60 of measurements
  - Variables: canopy height, time of day
- Profit maximization has not been evaluated
- Heat unit accumulation metrics
  - Use of GDD60 needs to be revisited

Acknowledgements

- Funding from Cotton Inc.
- Collaborators in 9 states



State	**PI**
Alabama	Kip Balkcom
Arizona	Ed Barnes
Arizona	Pedro Andrade-Sanchez
Arkansas	Tom Barber
Georgia	George Velidis
Lousiana	Brenda Tubana
Mississippi	Jac Varco
Mississippi	Yufeng
Oklahoma	Randy Taylor
South Carolina	Phil Bauer
Tennessee	John Wilkerson

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Correlation: Yield and GDD60

Pearson Correlation Coefficient applies only to linear relationship

	YLD	300 GDD60	600 GDD60	900 GDD60	1200 GDD60	1500 GDD60	1800 GDD60	2100 GDD60	2400 GDD60	2700 GDD60
YLD	1	-0.32	-0.25	-0.15	-0.02	0.16	0.37	0.60	0.80	0.92
300 GDD60		1	1.00	0.98	0.95	0.89	0.76	0.57	0.32	0.07
600 GDD60			1	1.00	0.97	0.92	0.81	0.63	0.39	0.15
900 GDD60				1	0.99	0.95	0.86	0.70	0.48	0.25
1200 GDD60					1	0.99	0.92	0.79	0.59	0.37
1500 GDD60						1	0.98	0.88	0.72	0.53
1800 GDD60							1	0.97	0.86	0.70
2100 GDD60								1	0.96	0.86
2400 GDD60									1	0.97
2700 GDD60										1