

# Redesigning Yield Map Plots for Comprehension and Usability

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*Slides: [https://alisonkleffner.github.io/presentations/SDSS\\_2023/index.html#1](https://alisonkleffner.github.io/presentations/SDSS_2023/index.html#1)*

# Outline

📊 Data Intensive Farm Management

📖 Perceptual Issues with Current Maps

📋 Redesign Process

🔮 Future Work

# Data Intensive Farm Management

# Background

- With a projected increase in future crop demand, researchers are conducting studies on crop input application to increase yield, focusing on sustainability (Tilman, Balzer, Hill, and Befort, 2011)
- Crop Input Example: Nitrogen Fertilizer
  - Nitrogen is an essential component of food production as allows plants to photosynthesize efficiently (Maheswari, Murthy, and Shanker, 2017)
  - Nearly half of the nitrogen fertilizer supplied to the field is not used by the crops (Billen, Garnier, and Lassaletta, 2013)
  - This excess nitrogen can be harmful
- Hence, research needs to be conducted on determining input rates that increase crop yield, and are also more sustainable.



# Data Intensive Farm Management (DIFM)

**Problem:** Address inefficient application of crop inputs to farm fields worldwide

**Methods:** On-Farm Precision Experimentation

- Conduct experiments using site-specific inputs
- GPS-reliant technology

## Goals

- Develop infrastructure to develop and analyze these experiments
- Find economically optimal application rate to increase profit while reducing environmental impacts.

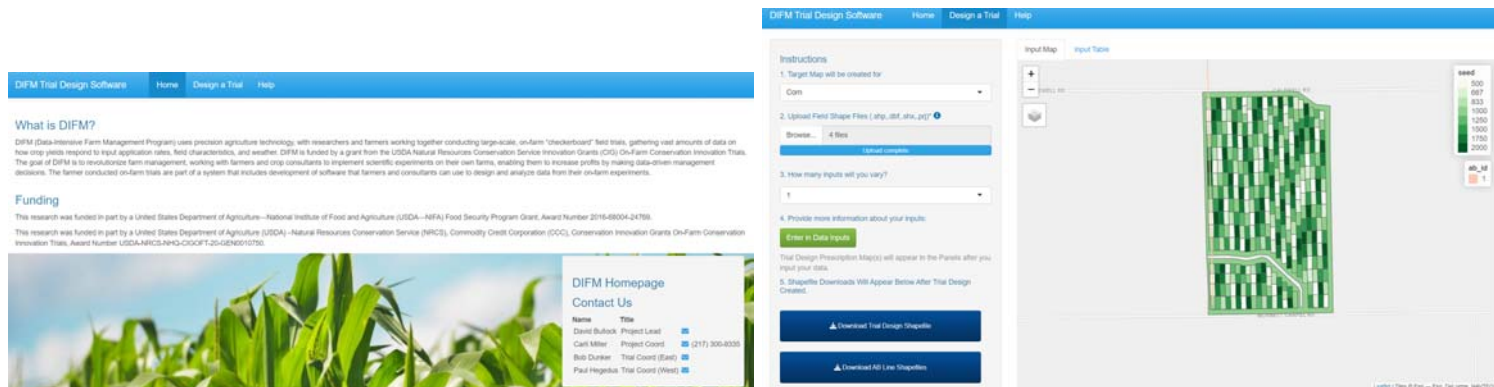
Project Website



# Trial Design

**Step 1:** Develop infrastructure to develop experiments using site-specific inputs

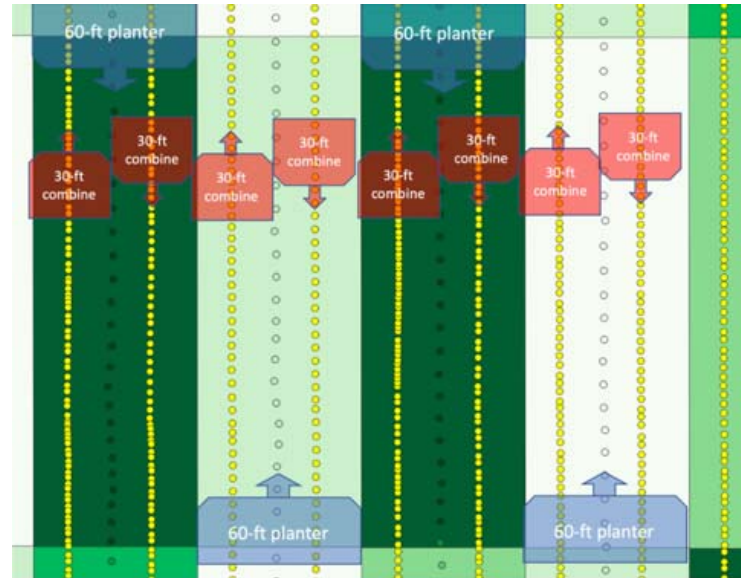
## Trial Design Tool



**Output:** shape files that can be put into a farmer's tractor that allows them to carry out the experiments

# Data Collection

**Step 2:** Conduct experiments and collect data



Examples of Data Collected:

- As-applied
- Yield
- Location of measurements

# Explain the Results

**Step 3:** Explain the optimal management decisions, accounting for various factors

**How:** create a user interface, designed around explaining machine learning output to non-experts

- Build trust in models
- Learn how crop yield responds to different input application rates, field characteristics, and weather to hopefully increase profits.

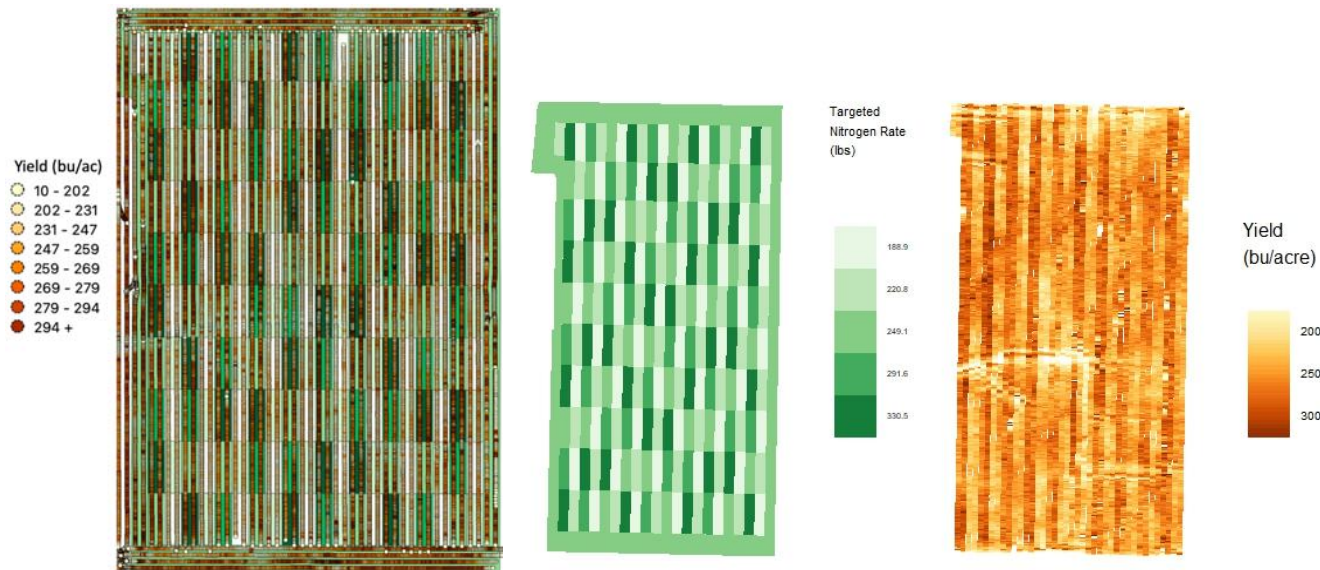
**One way to do this:** Visually explore the relationship between input application and yield through a graph

- Show the spatial correlations between the application/treatment and yield in a way that is understandable to farmers and consultants.
- Develop perceptually optimal plots that communicate this relationship.



# Current Maps

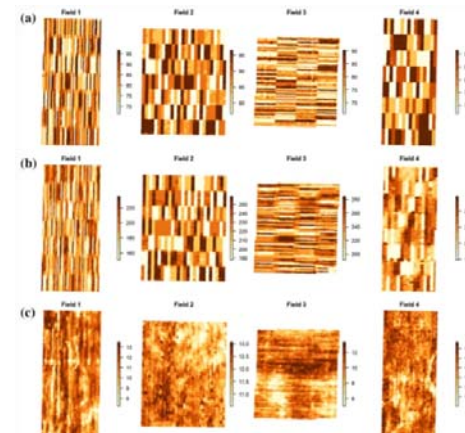
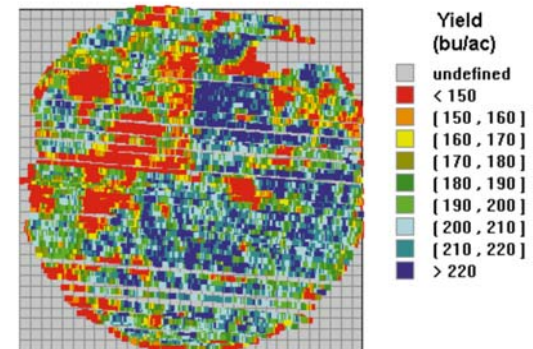
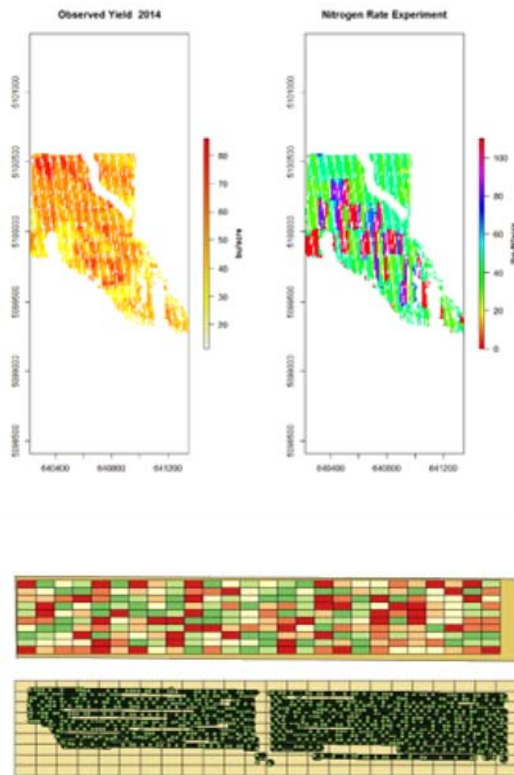
# Yield Maps Currently Used by DIFM



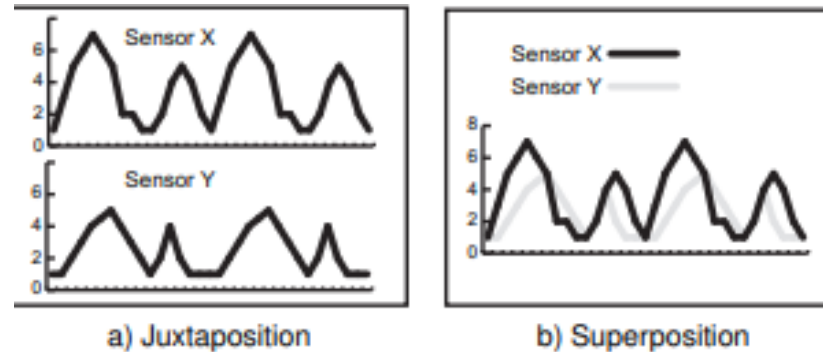
Examples of two versions of this plot currently given to farmers/crop consultants in DIFM reports

# Other Maps in the Literature

Plenty of other iterations of trial design/yield maps used in the literature. Here's some examples



# Juxtaposed vs Superimposed Graphs

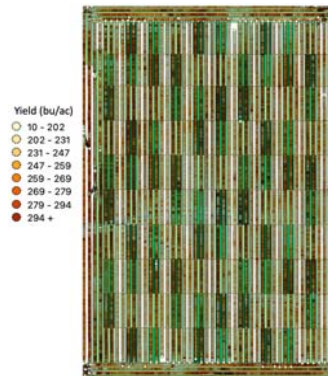


- **Juxtaposed graphs:** side by side (Gleicher, Albers, Walker, Jusufi, Hansen, and Roberts, 2011)
  - Benefits: less issues with visual clutter and easier to create
  - Drawbacks: comparative burden is placed on the user
- **Superimposed graphs:** multiple objects in same coordinate system (Gleicher, Albers, Walker, et al., 2011)
  - Benefits: Easier to compare as users can use perception rather than memory
  - Drawbacks: clutter
  - Useful when spatial location is a key component of the comparison (Wang, Haleem, Shi, Wu, Zhao, Fu, and Qu, 2018)

# Data Clutter with Superimposed Graphs

## Drawback: clutter

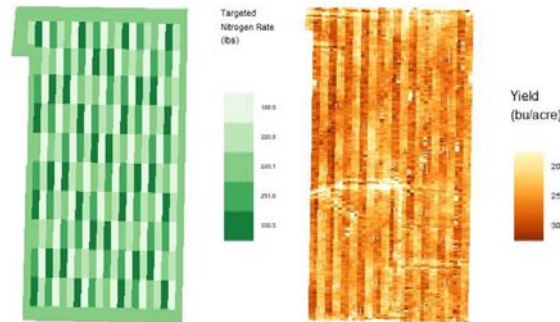
- General principle of graphical design: show data clearly (Cleveland, 1984; Gordon and Finch, 2015)
- Overlap - multiple dots on top of one another
  - Obscures true number of dots, harder to find patterns
  - Visual cues, like color, becomes partially obstructed, thereby reducing search efficiency (Bravo and Farid, 2004a; Bravo and Farid, 2004b)
  - Can overburden human perception, causing errors in performing tasks (Huang, Eades, and Hong, 2009)



# Comparative Burden with Juxtaposed Graphs

**Drawback:** Most of the comparative burden placed on users' memory

- A mental image is relied on for comparison in these scenarios, as the user moves their eyes between images (shifting focus).
  - The plot contents may not be accurately formed in working memory, leading to potential errors when deriving patterns (Vanderplas, Cook, and Hofmann, 2020; LYi, Jo, and Seo, 2021)
- Lack of visual cues for locations



# Color

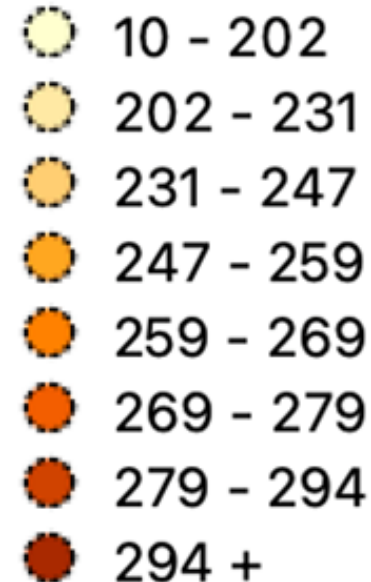
- Red-green color blindness is experienced by approximately 8% of men and 0.5% of women of Northern European ancestry.
  - Difficult to discriminate between these colors (Wong, 2011)
- Stop-Light Color Scheme
  - Yellow has a highlighting effect
  - Univariate Scale more appropriate (magnitude only)
- Same Color scheme for multiple variables
  - May cause confusion
- Rainbow Color Scheme
  - No inherent ordering of magnitude (Light and Bartlein, 2004)
  - Extremes are visually close (red and violet) (Silva, Sousa Santos, and Madeira, 2011)

# Number of Categories

Number of categorical scales should be limited to **5-7 categories** (Miller, 1956)

- Due to working memory limits (Macdonald, 1999)
  - Harder for the user to distinguish between colors and remember the meaning of colors.
- The load on the user's working memory leads to an increase in the time it takes for the user to comprehend the plot (Huang, Eades, and Hong, 2009)

## Yield (bu/ac)

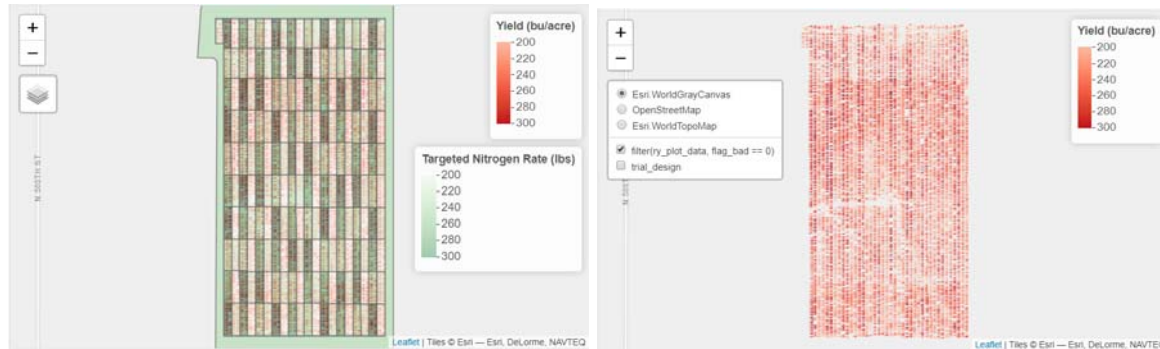


**Next:** Redesign Process



# Redesign

# Redesign: Color Blending Part 1



**Focus:** Superimpose the treatment and yield plots, while reducing the clutter

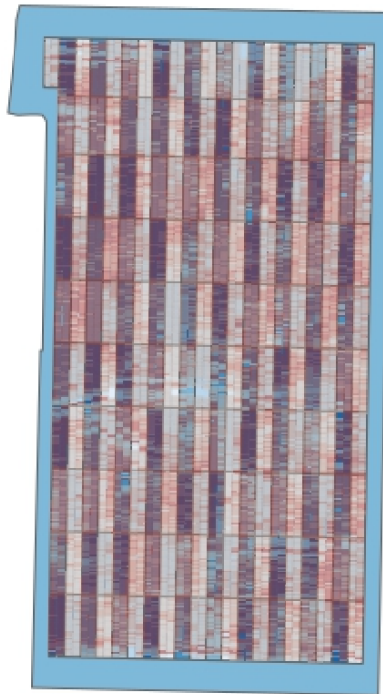
- Use of transparency to show both at same time
- Interactive plot with *leaflet* (Cheng, Karambelkar, and Xie, 2022)
  - Can add and remove trial plot layer

Work that still needs to be done:

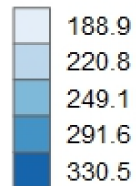
- Color needs some work
  - different color schemes

# Redesign: Color Blending Part 2

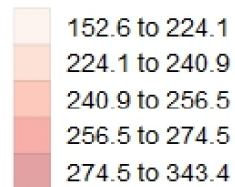
**Focus:** Color/Scales



Targeted  
Nitrogen Rate  
(lbs)



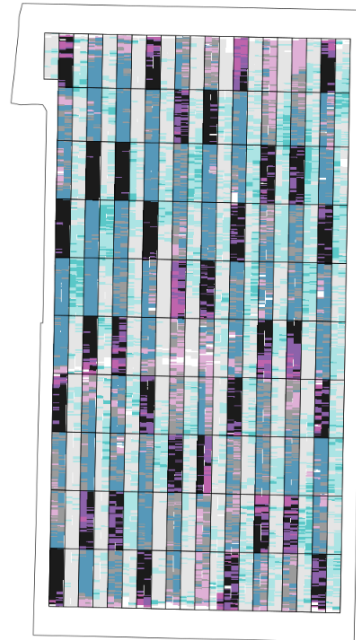
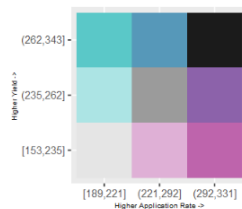
Yield (bu/ac)



- Working on blending using transparency
- Categorical Groups for both variables
  - Trial Design treatment is a factor
  - Reduce number of colors for yield
  - Use quantiles to determine categories for yield (Brewer and Pickle, 2002)

# Redesign: Bivariate Color Plot

## Alternative to color blending



- **Benefit:** relationship between the variables is most important (Elmer, 2013)
- Recommendation: 3x3 scale (Leonowicz, 2003)
  - ■ Quantiles (Biesecker, Zahnd, Brandt, Adams, and J.M, 2020)
- **Focus:** diagonal
  - Diagonal: grayscale color scheme.
  - Upper left and lower right: complementary color scheme (Strode, Morgan, Thornton, Mesev, Rau, Shortes, and Johnson, 2020)
- **Drawback:** Lose more detailed information

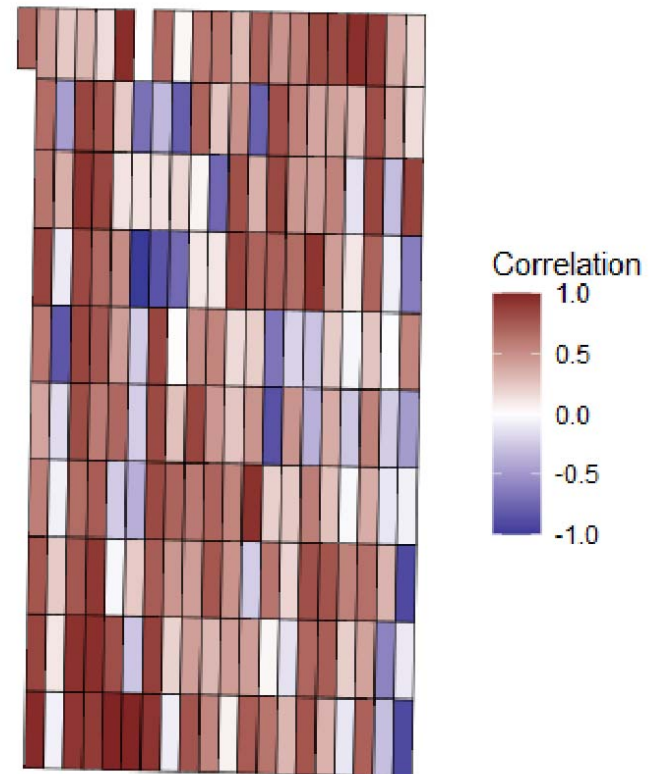
# Redesign: Correlation

## Directly encode correlations between As Applied treatments and Yield

**Benefit:** Direct statement of correlation while maintaining some spatial orientation

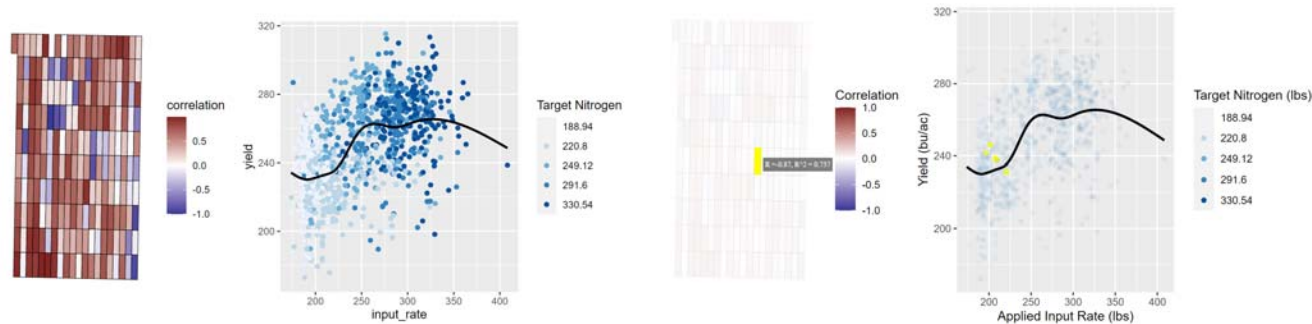
- Explicit Encoding Layout (Gleicher, Albers, Walker, et al., 2011)
  - Bivariate color scale
  - Maintain some spatial information.
- Correlations may be impacted by field location

**Drawback:** complicated to connect the displayed relationship back to the data (Gleicher, Albers, Walker, et al., 2011)



# Redesign: Correlation with Scatterplot

## Add some context back



- A standard practice to overcome weakness of decontextualization is utilizing a hybrid comparative layout (LYi et al., 2021).
  - Juxtaposed scatterplot to the correlation plot (combining the layouts of juxtaposition and explicit encoding).
- Interactivity connects the juxtaposed plots, where hovering over a trial plot in the correlation map highlights the corresponding points in the scatterplot used in the correlation calculation.

[Link](#)

# Future Work

# Conclusion/Future Work

**Next Step:** Obtain Feedback from those using the plots (farmers, crop consultants)

- Eventually do some testing between the layouts to see which farmers are reading more accurately.

**Eventually:** Develop a R Shiny app to explaining machine learning output to non-experts

- Build trust in the model predictions without requiring farmers to learn the details of statistical modeling.
- Will utilize these plots, among others
  - For example, accuracy of as applied treatment compared to trial design



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# Questions?

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