Crop Production Function Estimation using High Resolution Observation Data

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Background

- Successful input variable-rate application (VRA) recommendations of precision agriculture rely greatly on the accurate estimation of crop yield responses to input.
- Crop responses can vary widely across different parts of the field, due to the variability in soil, water, slope, and other kind of growing conditions.
- Many agronomic studies have established crop yield responses to various factors separately based on controlled experiments.
- But obtaining a reliable function which models crop responses to multiple factors simultaneously is still a challenging task due to the limitation in multiple-factor experimental data.

Research Objective

- With the widespread use of information and computer technologies, modern agriculture has entered the era of "Big Data". Producers have accumulated large volumes of high resolution production data from the yield monitors, inputs application sensors, field imageries, etc.
- Those observation-based data, though having less randomness and higher measurement errors comparing to experimental data, are featured by much larger sample sizes and lower costs.
- The objectives of this study are to:

(1) explore the feasibility of using the observational production data and empirical regression model to estimate the micro-level crop production function of multiple growing factors; and

(2) develop the variable-rate application (VRA) prediction algorithm based on the estimated production function to convert data into precision farming decisions for producers.

Empirical Model

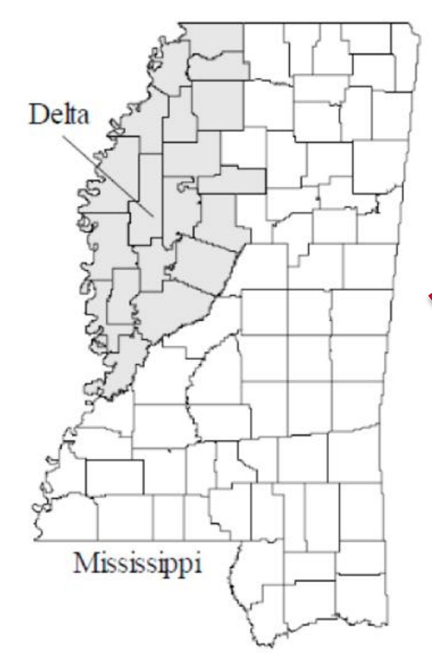
- Specify the micro-level crop production function:

$$yield = f(fertilizer, seed, soil, precipitation, temperature)$$

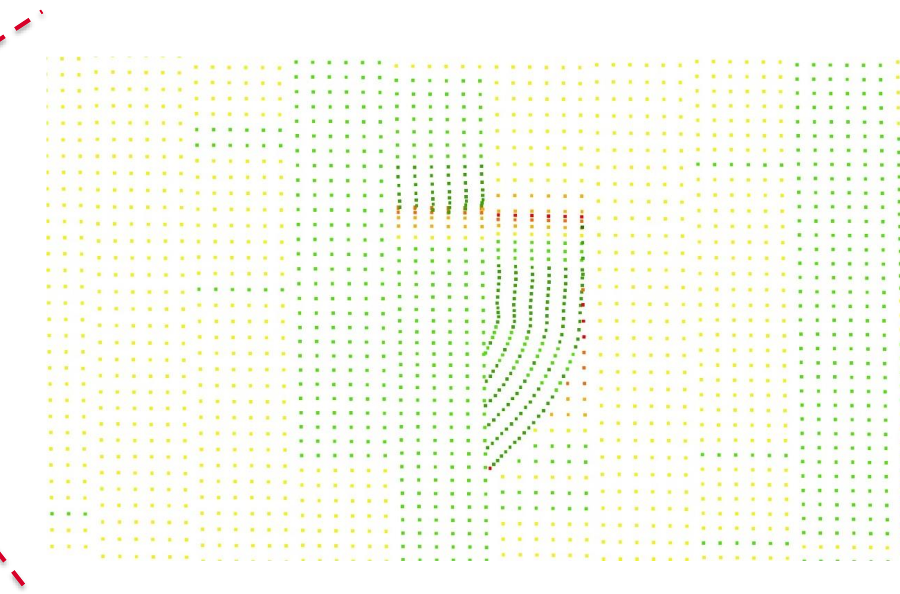
- Two inputs (fertilizer and seed) follow the quadratic functional form.
- Three growing factors (soil type, precipitation, and temperature) are measured in discrete categories.
- Full interactions between inputs and factors are captured.
- Spatially correlated omitted growing conditions (soil pH, organic matters, etc.) are accounted for by spatial error model.

Observation Data

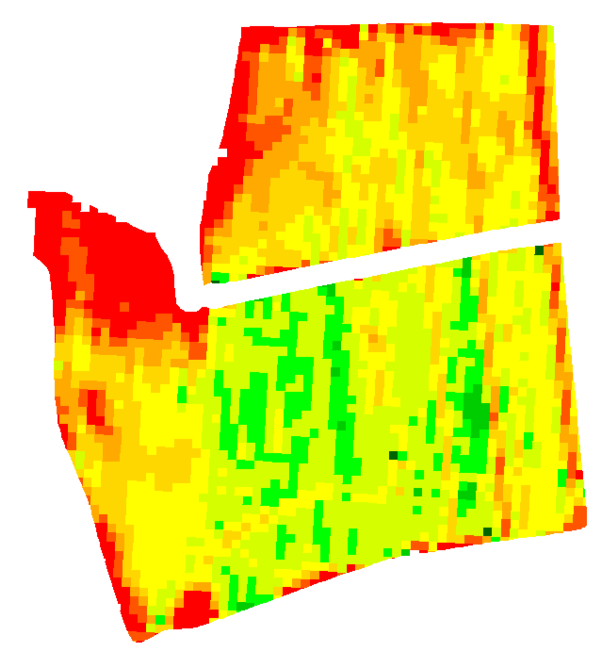
- Data source 1: Production data (corn)



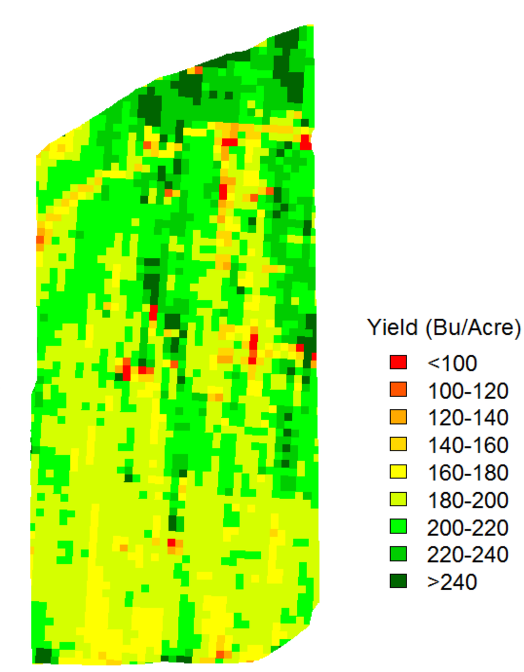
Cooperating Mississippi farms, 87 corn fields from 6 years' history



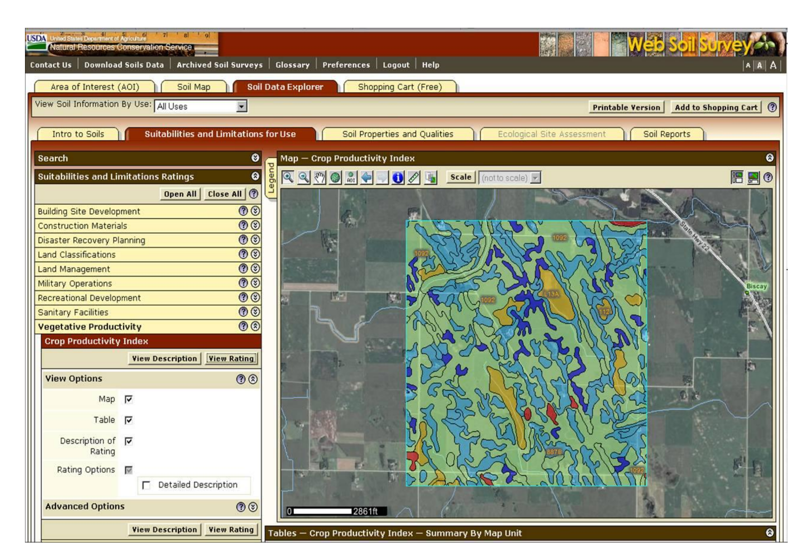
Part of the original yield monitor data: Each point represents a recorded yield value collected from the header of combine, with point distance around 1 meter.



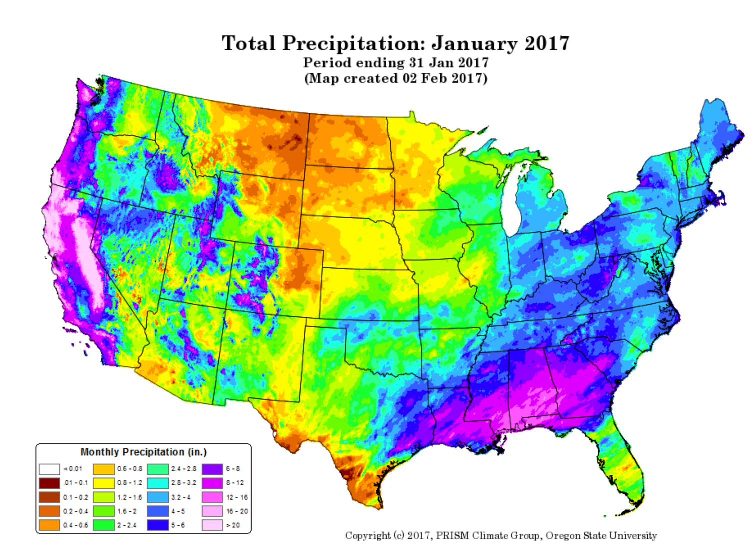
aggregate into 10-meter grids; a total of 405,128 grids for the sample



- Data source 2: Public soil and weather data



USDA SSURGO Web Soil Survey Data



PRISM Climate Data

Results

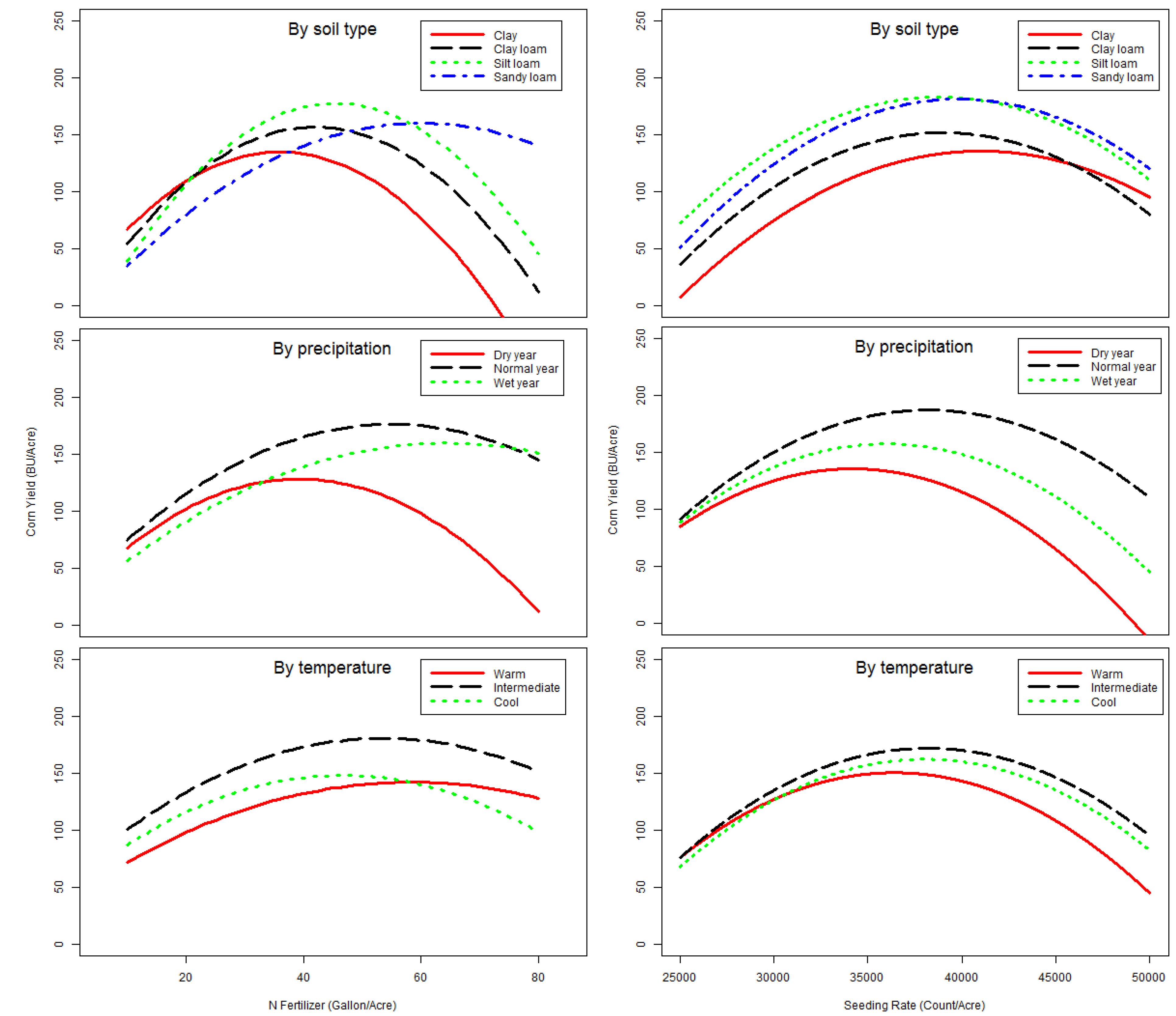


Figure: Estimated corn yield response to input (left: N fertilizer, right: seeding rate), and variability of the response across growing factors (soil type, precipitation and temperature)

- Complex nonlinear effects and interactions of yield-determining factors.
- Optimal input levels vary across space (by soil type) and over time (by precipitation and temperature).
- Foundation to generate grid-level VRA recommendations of N fertilizer and seeding rate: In-sample simulations show an 20.7% profitability increase on average comparing with existing practices

Conclusions

- It is feasible to estimate crop production functions by utilizing empirical econometric models and grid-level production data.
- The empirical estimation provides a data-driven algorithm to obtain VRA prescriptions that can considerably improve profitability of farming.
- This method has great potential in the near future with the fast accumulation and improving quality of farming production data.