What does pre-planting soil moisture tell us about final corn yields?

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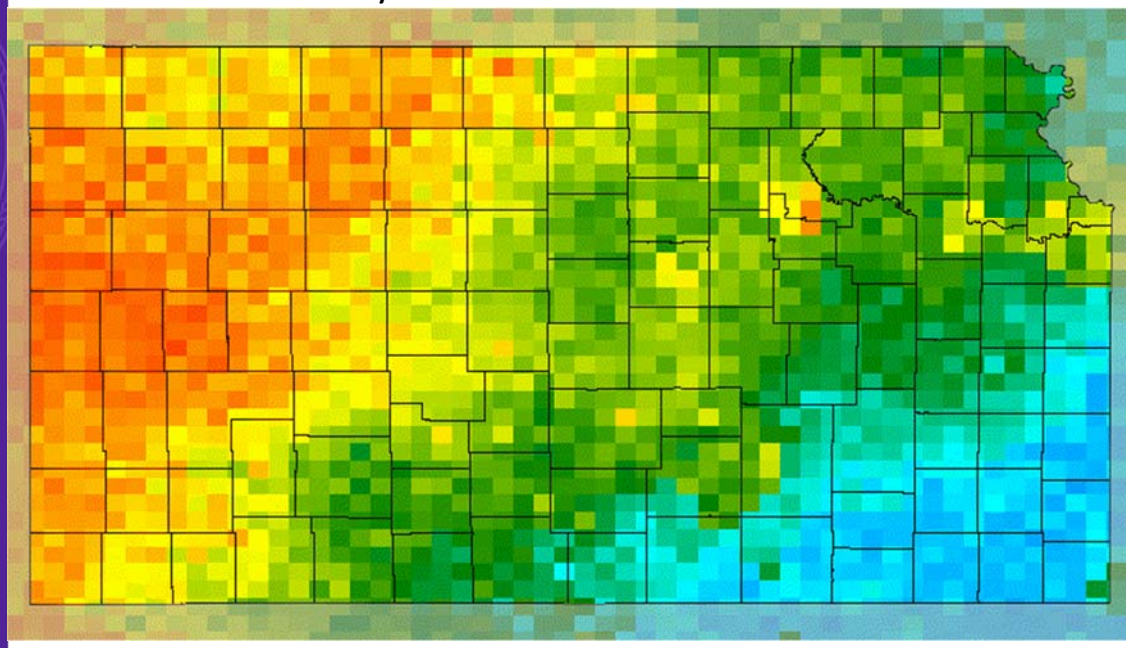
Daily Soil Moisture

January 1st to March 15th, 2021



Data source: NASA-USDA Enhanced SMAP

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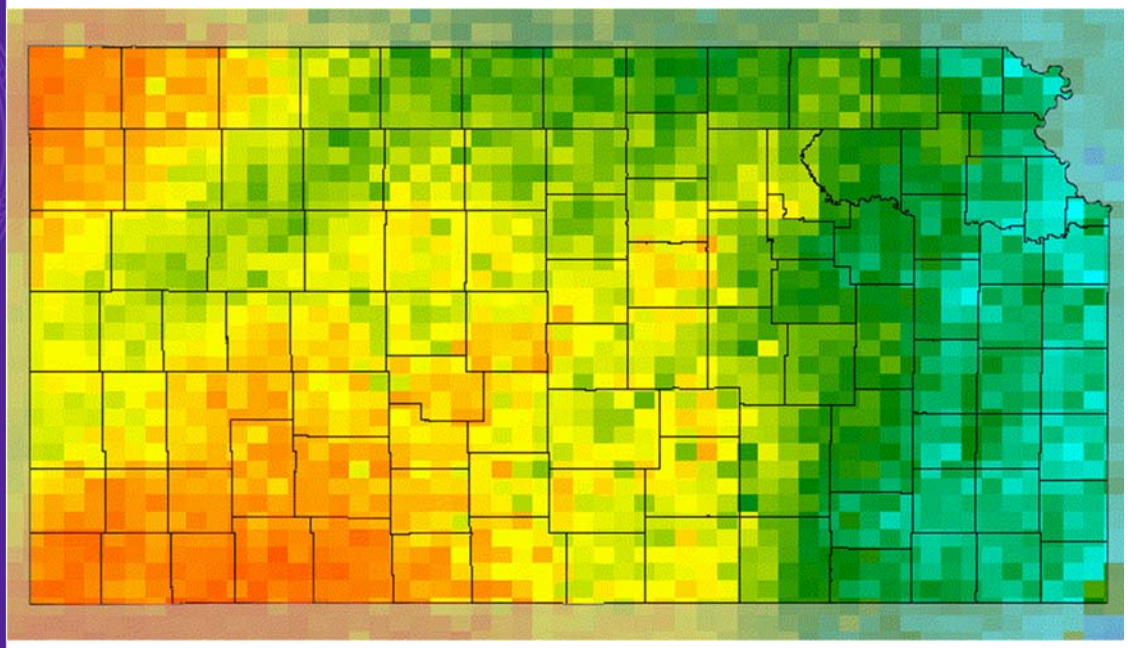

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Are decisions made based on early season soil moisture information supported by measurable impacts on corn yields?

Data Sources

Yield Data: USDA Risk Management Agency (1990-2022)	Precise county yield records Ability to control for irrigation status
Soil Moisture Data: NASA SPoRT-LIS (1km^2 daily measurements)	High-resolution standardized moisture data Longer time series than alternatives
Planting dates: Deines et al. (2023) estimate county-level dates	Vary year-to-year Use 30 days before 10% of corn planted

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Methods: Scaling Soil Moisture Data to the County Level

Step 1

Create crop masks

- Used USDA NASS CDL (2002–2021)
- Kept grid cells that grew corn, wheat, or soybeans in ≥ 50% years
- Output: binary map of "consistently cropped" land

Step 2

Apply to soil moisture

- Converted volumetric SM to RSM
- Multiplied by crop mask → keeps only relevant cropland pixels

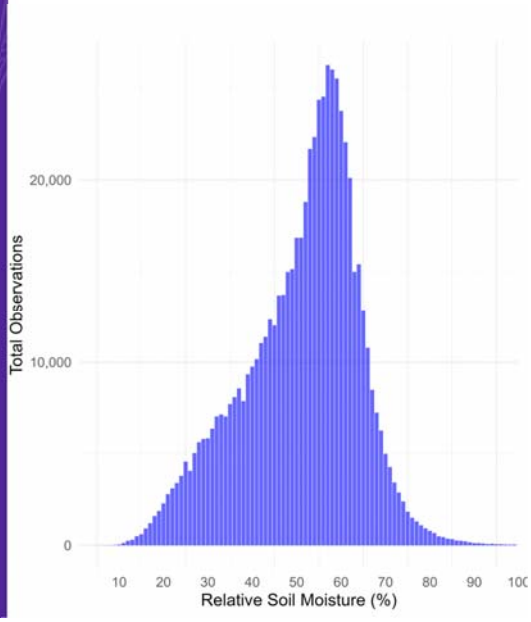
Step 3

Aggregate to counties

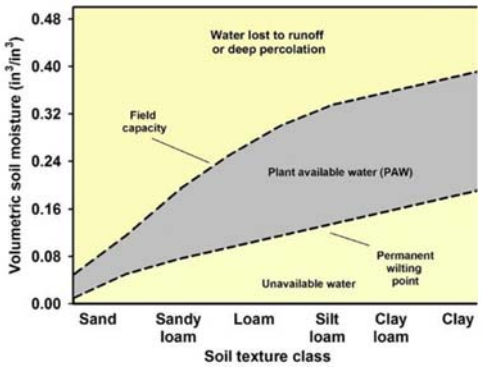
- Used spatially-weighted median to account for partial grid cell overlap w/ counties
  - Example: grid cell 50% in county = 50% weight

Relative Soil Moisture (RSM) Data

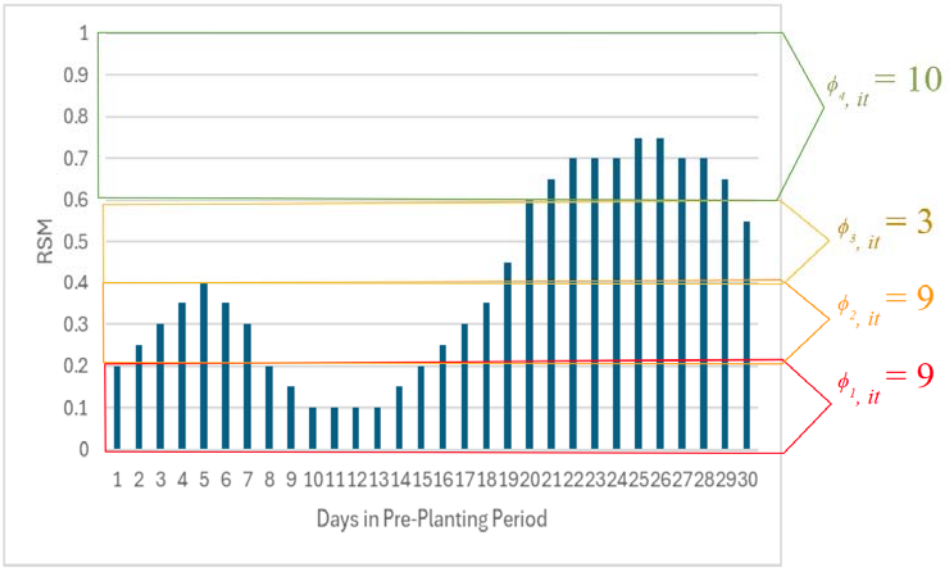
$$Relative\ soil\ moisture = \frac{Volumetric\ soil\ moisture\ -\ wilting\ point}{Saturation\ -\ wilting\ point}$$



- Interpretation:
  - 0 = wilting point
  - 1 = saturation
- Stress thresholds:
  - Below 0.2: drought conditions
  - Above 0.8: excess moisture stress



Methodology: Non-Parametric Soil Moisture Exposure Model



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Specifying Exposure Bins

Why Bin Selection Matters:

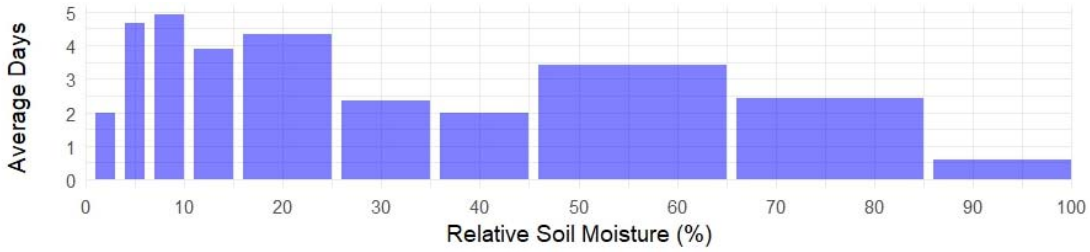
- Too many bins/regressors may cause **overfitting** (Schwarz, 1978).
- Too few bins may overlook important **nonlinear effects**.

Bin Definition and Calculation:

- Grouped into **100 bins**, each representing a 1% increment of Relative Soil Moisture (RSM).

Data-Driven Bin Selection Process:

- K-fold cross validation procedure.



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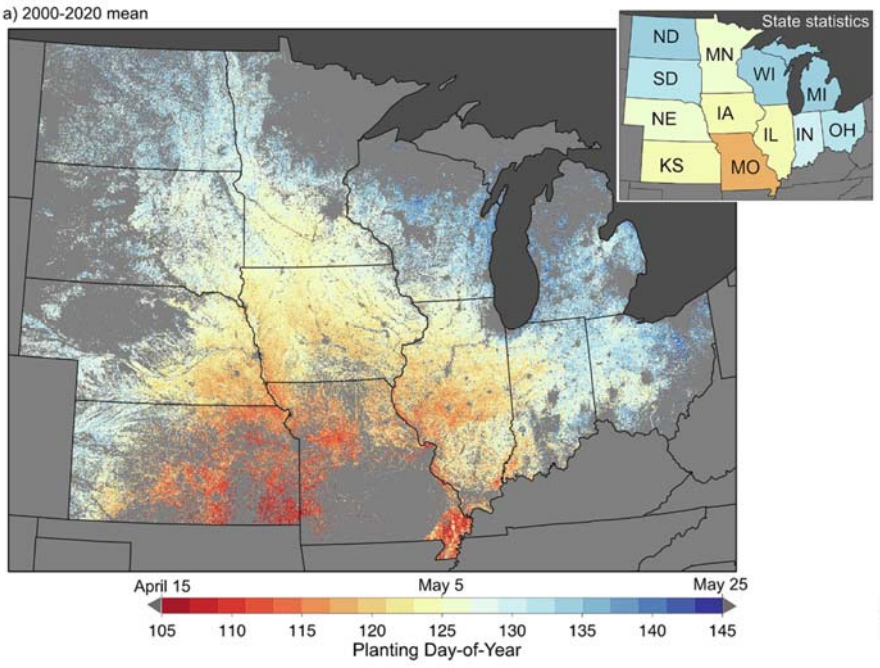
"Early Season" Definition

- **Use dates from Deines et al. (2023).**
- **30 days prior to the date when 10% of the corn crop is planted.**



Regression Model Specification

$$\ln y_{it} = \sum_k \beta_k \phi_{k,it} + z_{it}\delta + c_i + \varepsilon_{it}$$

Where:

$\boldsymbol{ln\, y_{it}}$: natural logarithm of yield for county *i* in year *t*

$\boldsymbol{\phi_{k,it}}$: number of days county *i* in year *t* was exposed to relative soil moisture within bin *k*

$\boldsymbol{(\beta_k)}$: marginal impact of one additional day of exposure to relative soil moisture in bin *k*

$\boldsymbol{z_{it}}$ *:* control variables, such as a quadratic time trend (*t* and t^2) to account for technological change.

$\boldsymbol{(c_i)}$: county fixed-effects to control for unobserved heterogeneity

Finally, we expect moisture conditions to be correlated in adjacent counties, so we allow the error terms (ε_{it}) to be spatially correlated using Conley standard errors (Conley 1999).

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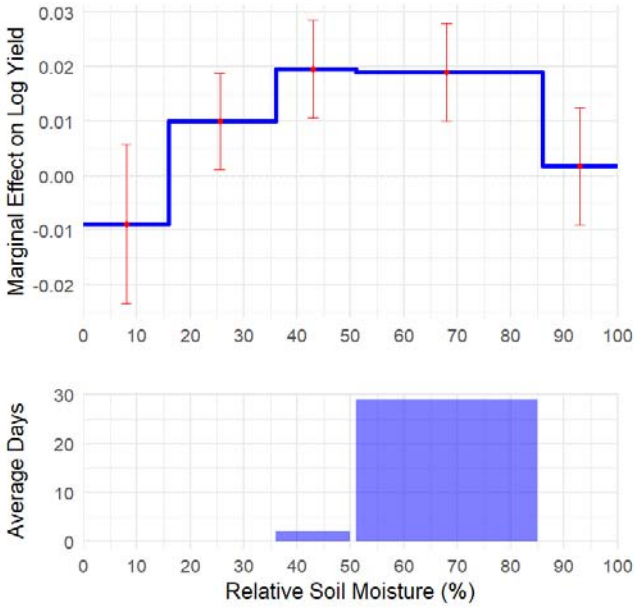
Results: National Model

What Do the Coefficients Mean?

- Each coefficient represents the effect of one additional day spent within a specific soil moisture bin.

Overall Insight:

- Exposure to very low soil moisture (1–15%) reduces yields.
  - An additional day reduces yield by 1%.
- Typical, intermediate levels increase yields (16-85%).
- Evidence that high soil moisture levels may be detrimental.



Results: National Model

Variable	Estimate	Standard Error	t Value	p Value	Significance
SM 1-15%	-0.0088	0.0075	-1.1746	0.240	
SM 16-35%	0.0100	0.0045	2.2111	0.027	*
SM 36-50%	0.0196	0.0046	4.2949	<0.001	***
SM 51-85%	0.0190	0.0046	4.1532	<0.001	***
SM 86-100%	0.0018	0.0055	0.3248	0.745	
time	0.0097	0.0015	6.2339	<0.001	***
$time^2$	0.0007	0.0001	11.4042	<0.001	***
Observations	21495				
Adj. R-squared	0.5535				
Standard-errors	Conley (50km)				
Fixed effects	County: 0				
RMSE	0.37566				

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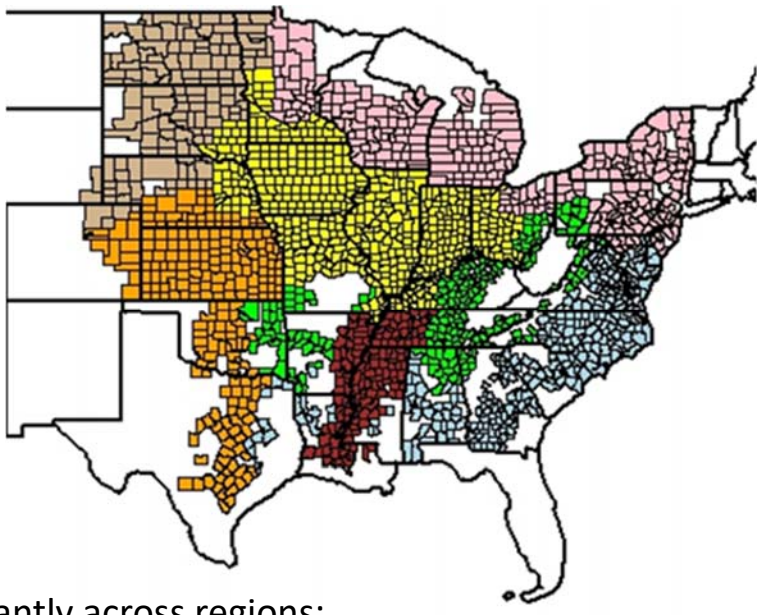
Key Findings: Spatial Heterogeneity



- USDA Economic Research Service (ERS) Farm Resource Regions
  - Robustness checks
- Effects vary significantly across regions:
  - High rainfall areas benefit from drier early season conditions
  - Drought-prone areas suffer from dry conditions

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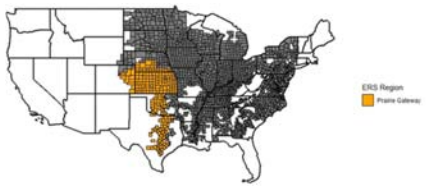
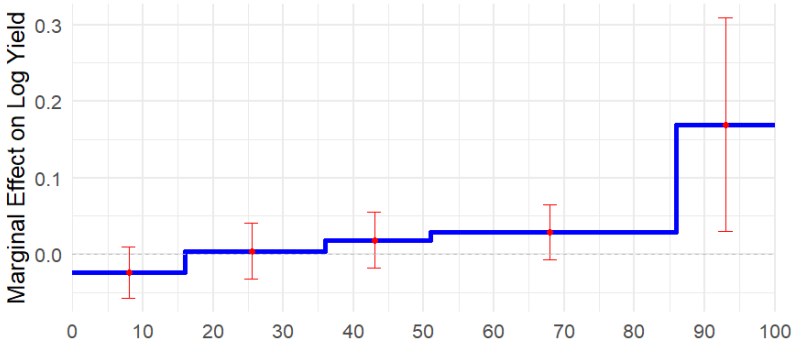
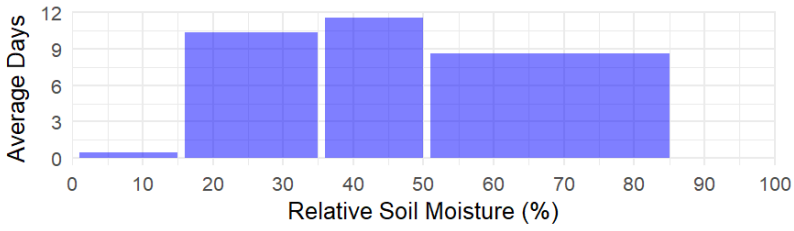
Prairie Gateway







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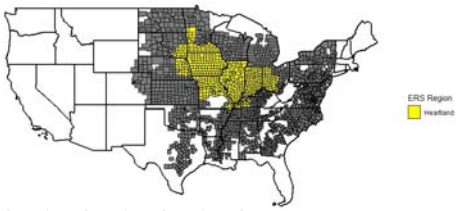
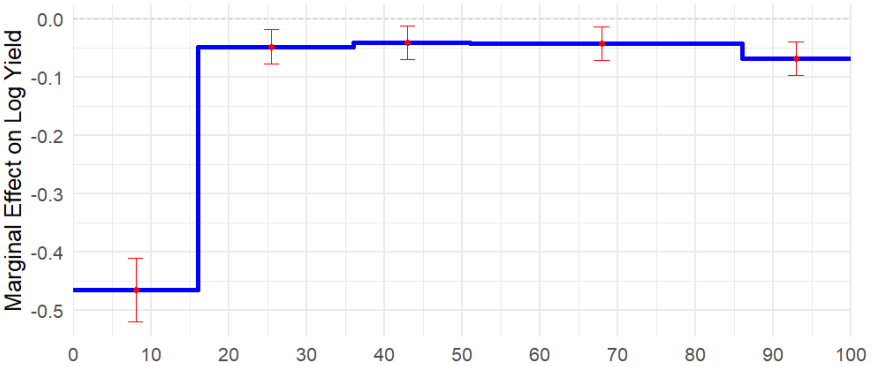
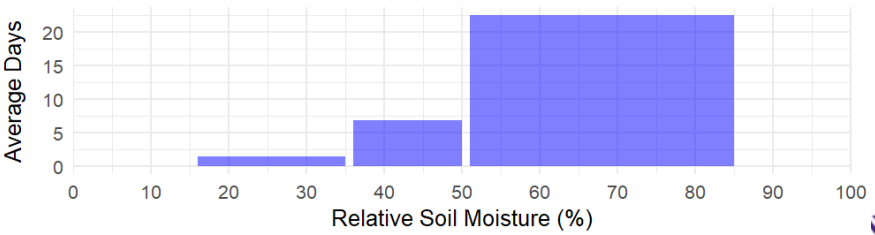
Heartland







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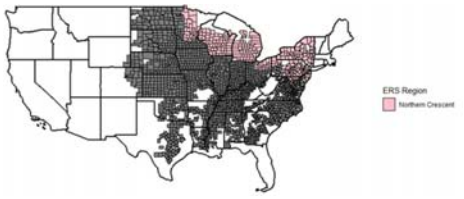
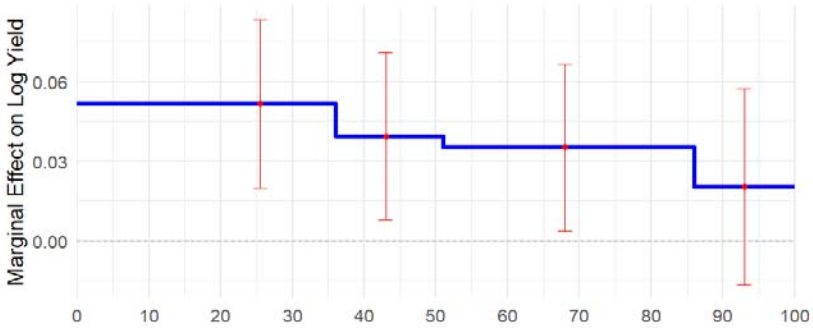
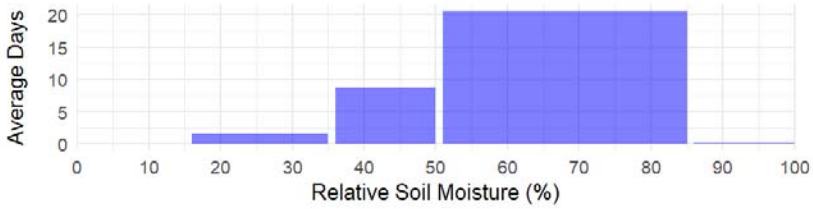
Northern Crescent







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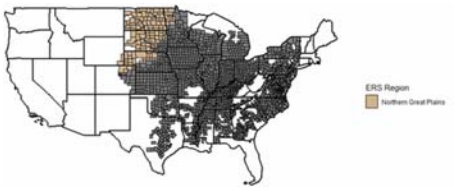
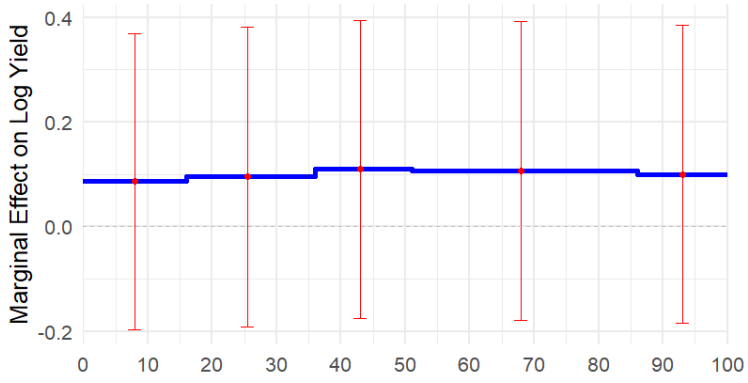
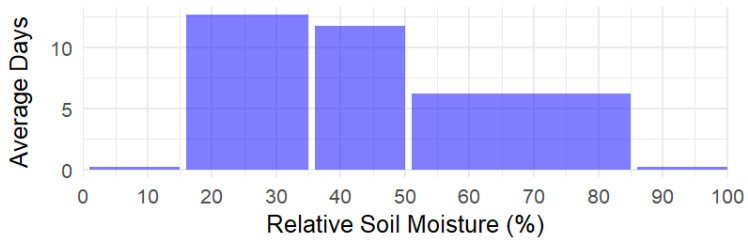
Northern Great Plains







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Summary and Contributions

Key Findings:

- Strong evidence of a nonlinear relationship between early season soil moisture and yield outcomes.
- Clear indication of regional heterogeneity
- Demonstrated method's effectiveness in capturing critical moisture thresholds without imposing restrictive assumptions.

So What?

- As more data becomes available, we can better predict differences between local and national production.
- Accurate models facilitate better marketing and planting decisions going forward.

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Thank you!

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