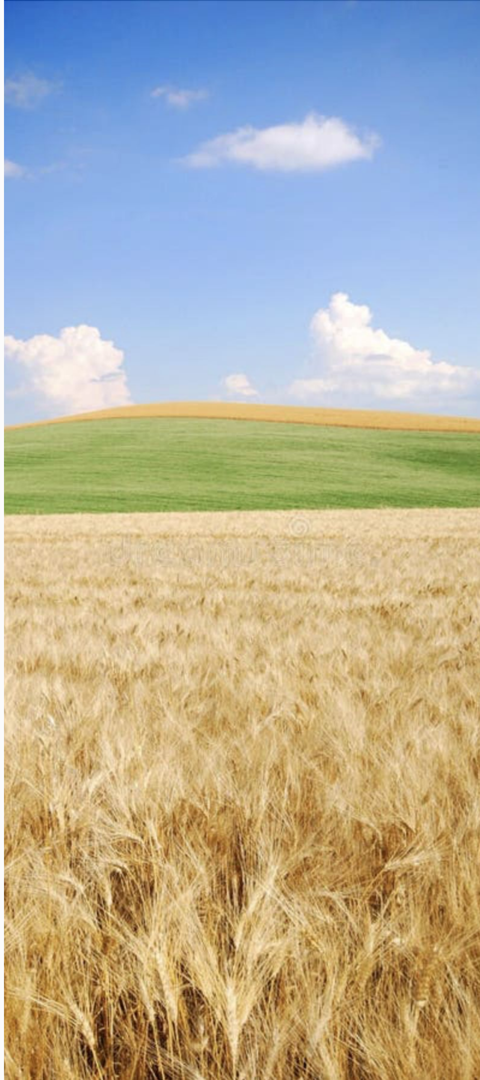
Final Project:

Climate Vulnerability Assessment for Global Agricultural Systems



Group 4: Adam Dawson, Ethan Ogrodniczuk, Julian Oldham

FRE 521D: Data Analytics in Climate, Food, and Environment

February 11, 2026

Overview

Data Sources, Description, and Pipeline

Data Sources

FAO country-level crop yield and production data (soybean, maize, wheat, rice) combined with daily weather observations from Open-Meteo for the period 2015–2023.

Description

We examine how temperature extremes and precipitation variability affect agricultural productivity, identifying crop-level sensitivity, country-level resilience, and regions at risk of climate-driven production shortfalls.

Pipeline

Raw crop and weather data are cleaned, climate variability metrics are constructed (extreme heat, GDD, precipitation variability), aggregated annually, and merged into a unified analysis-ready dataset.

Database Construction

Schema + Foundation Tables

⬇

Designed a normalized MySQL schema to store crop and climate data with appropriate primary/foreign keys, data types, and relationships.

⬇

Added a country mapping table to resolve naming inconsistencies across sources.

Ingestion + Data Quality Handling

⬇

Loaded CSV datasets into database and enforced constraints so numeric fields are stored as numeric types and missing values are NULL.

⬇

Ensured the build is reproducible (fresh database = identical results).

Weather Enrichment ETL

⬇

Built an automated pipeline to extract daily Open-Meteo weather variables for countries and load into new relational tables tied back to base schema.

⬇

Implemented production-style reliability: rate limiting, retries with backoff, logging, and idempotency .

Aggregation + Integrated Analysis

⬇

Created monthly and annual weather summaries and computed derived climate metrics (GDD, precipitation, extreme temperature days).

⬇

Produced an integrated country-year view that joins weather + crop production into an analysis-ready dataset.

Crop Yield Sensitivity: Methodology

Step 1

Exploratory Visualization

Plot crop yields against key climatic variables to identify potential trends

Step 2

Determine Model

Use correlation matrix and econometric theory to define plausible model given conditions

Step 3

Estimate Climatic Impacts on Yields

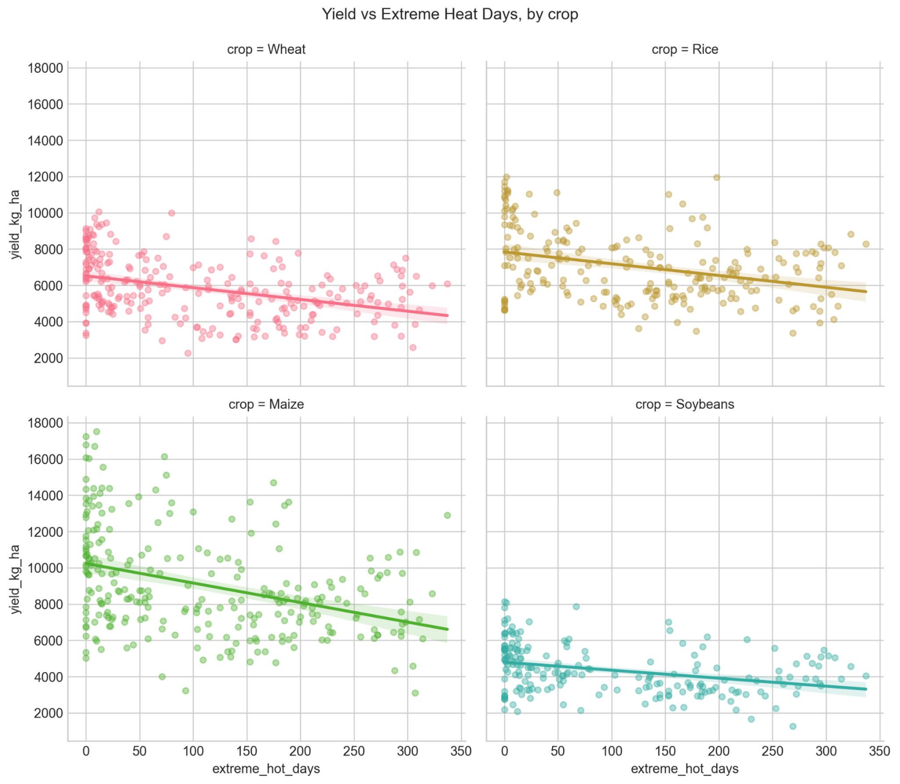
Run regressions for each crop on climate variables and key controls; rank crops by sensitivity

Step 4

Run Robustness Checks

Ensure rankings are robust across different model specifications

Crop Yield Sensitivity: Results



Crop Yield Sensitivity: Results

Rank	Crop	Extreme Hot Days
1	Soybeans	-11.979 (4.340)***
2	Maize	-0.447 (6.719)
3	Wheat	3.004 (2.759)
4	Rice	4.497 (3.379)

Rank	Crop	Daily Precip SD
1	Soybeans	-84.798 (48.493)*
2	Maize	-44.423 (57.167)
3	Wheat	-8.939 (38.092)
4	Rice	44.438 (38.917)

Two-way FE yield regressions

	Dependent variable: yield_kg_ha			
	Wheat	Rice	Maize	Soybeans
	(1)	(2)	(3)	(4)
daily_precip_sd	-8.939	44.438	-44.423	-84.798*
	(38.092)	(38.917)	(57.167)	(48.493)
extreme_hot_days	3.004	4.497	-0.447	-11.979***
	(2.759)	(3.379)	(6.719)	(4.340)
fertilizer_use_kg_ha	-3.914	-1.036	3.705	4.339
	(4.053)	(3.683)	(6.329)	(3.153)
irrigation_pct	-0.930	-3.236	-4.563	11.222
	(7.857)	(9.881)	(22.620)	(7.294)
Observations	165	117	192	124
R^2	0.765	0.905	0.701	0.724
Adjusted R^2	0.710	0.879	0.636	0.650
Residual Std. Error	936.107 (df=133)	682.417 (df=91)	1770.828 (df=157)	720.469 (df=97)
F Statistic	20.710*** (df=31; 133)	49.457*** (df=25; 91)	7.612*** (df=34; 157)	30.508*** (df=26; 97)
Note:				*p<0.1; **p<0.05; ***p<0.01

Understanding Agricultural Resilience: Methodology

Step 1

Construct Yield Resilience

Creation of yield variability measure using coefficient of variation at the country level

Step 2

Construct Climate Variability

Creation of climate variability measured using temperature based stress indicator

Step 3

Classify agricultural Systems

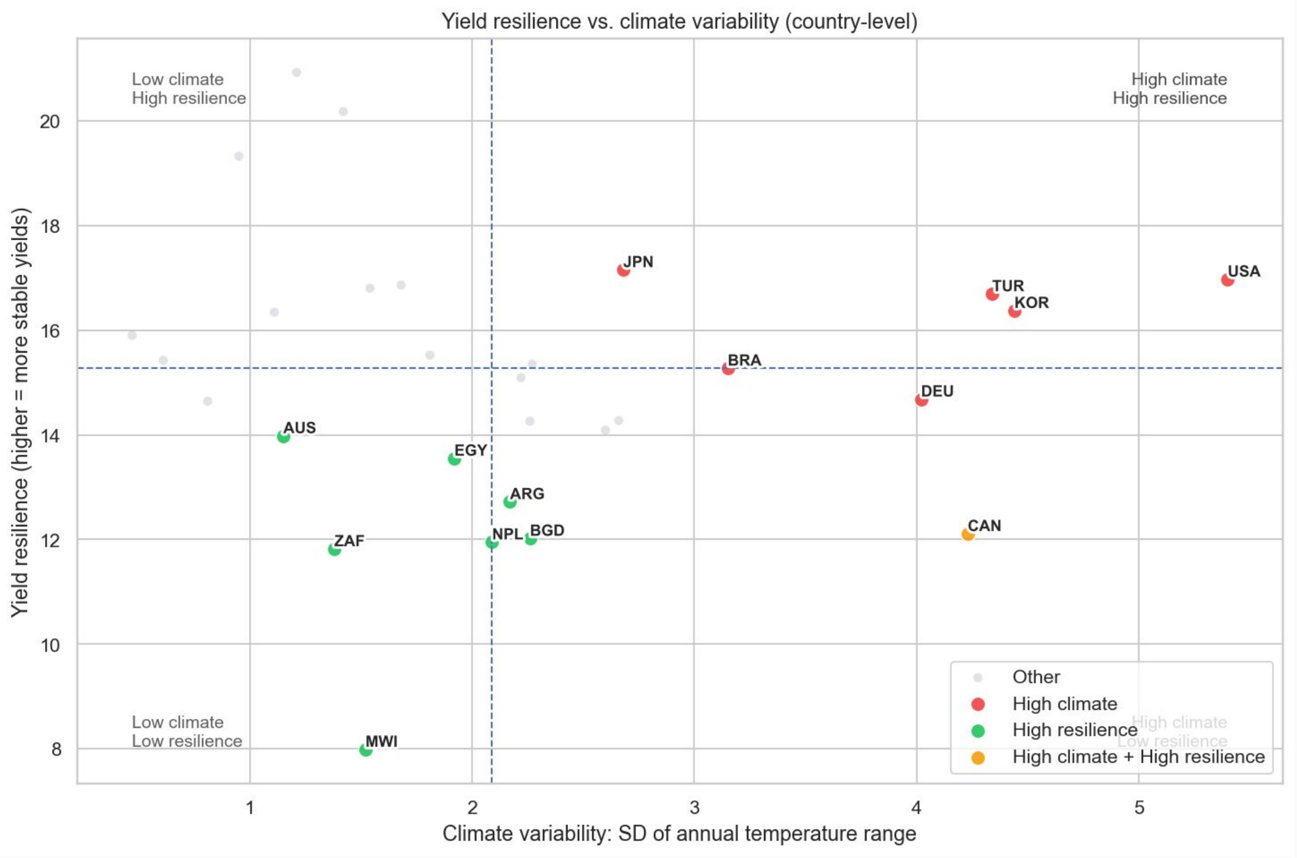
Countries classified into resilience buckets based on quartiles

Step 4

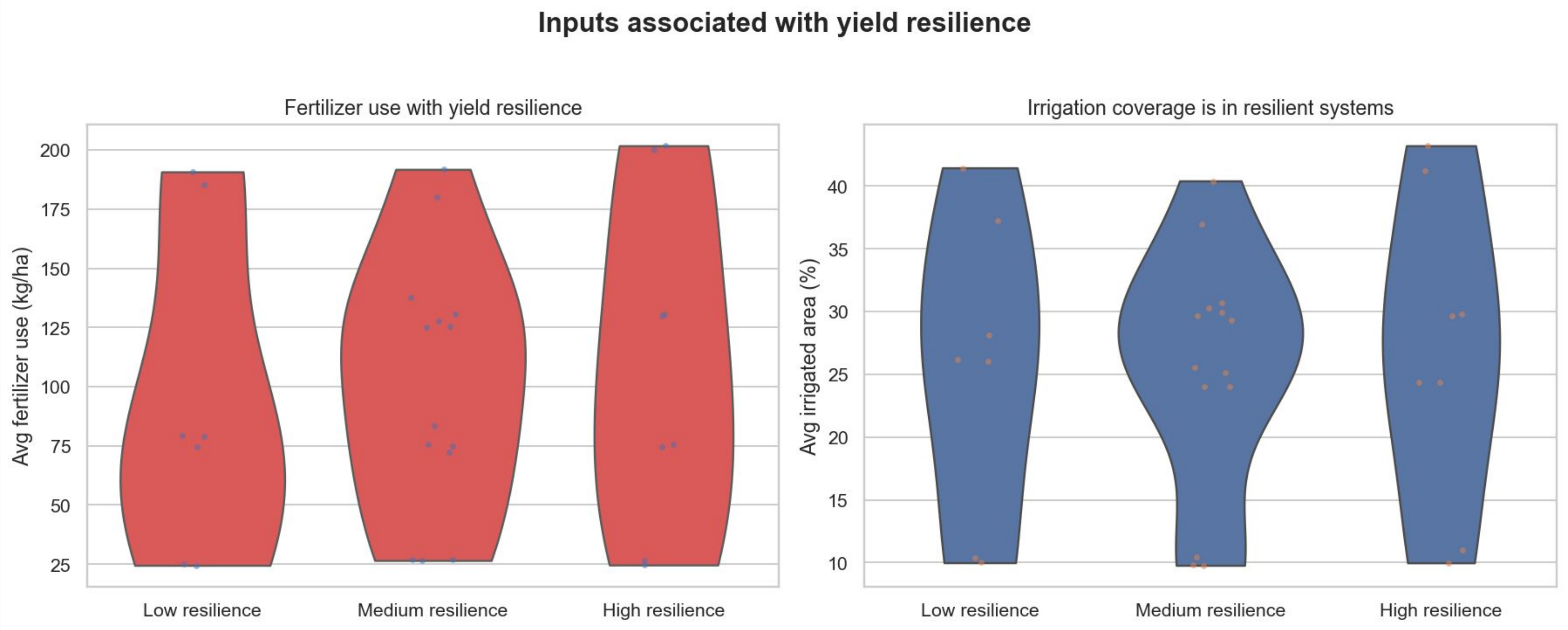
Analyze Adaptation inputs

Comparison of irrigation intensity, fertilizer use, and income group across resilience categories

Understanding Agricultural Resilience: Results



Understanding Agricultural Resilience: Results



Production Trends & Future Outlook: Methodology

Step 1

Long-Run Yield Trends

Estimate region- and crop-specific yield trends using linear time-trend regressions over the full sample period.

Step 2

Trend Classification

Classify regions as exhibiting yield growth, stagnation, or decline based on estimated trend slopes.

Step 3

Projection Framework

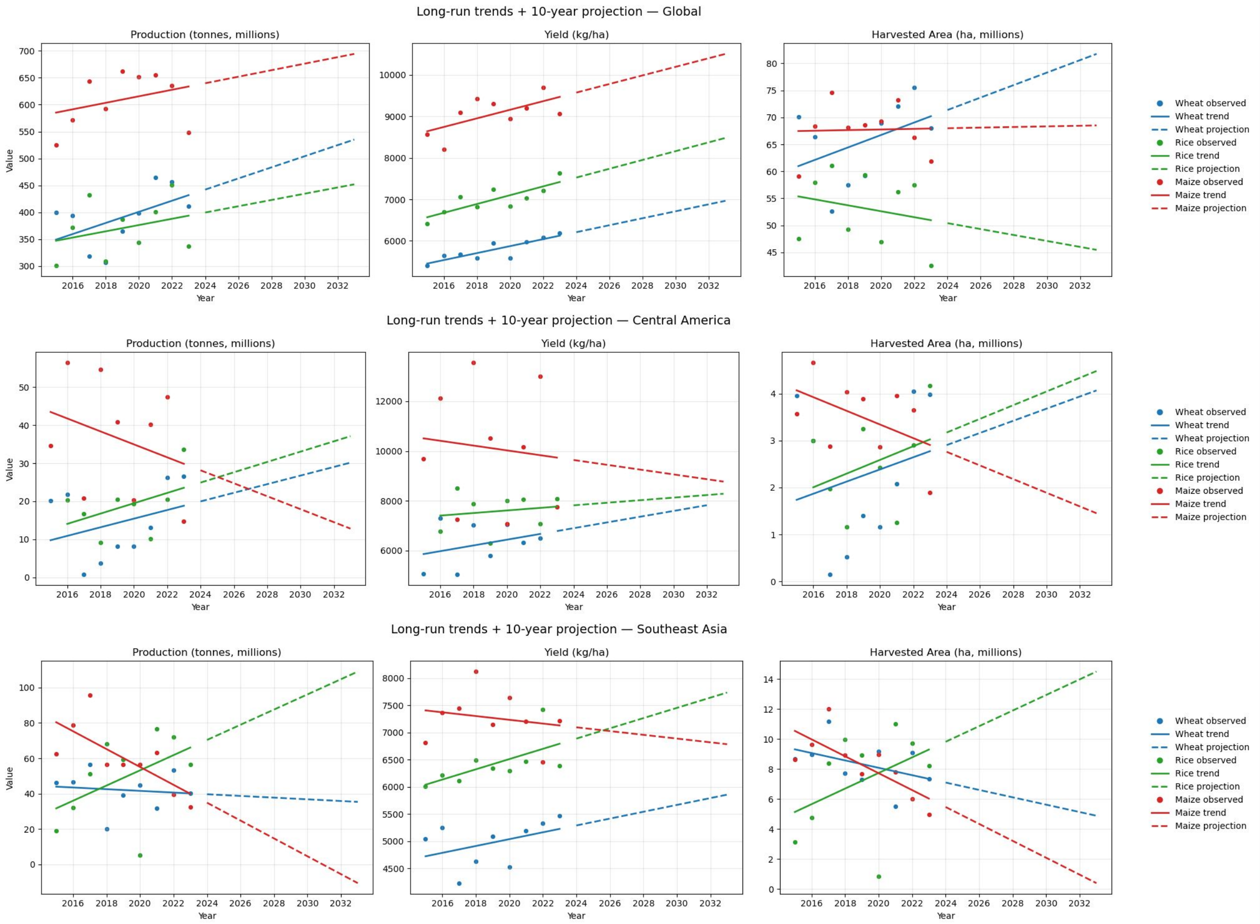
Extrapolate observed trends forward under a continuation-of-trends assumption to assess future yield trajectories.

Step 4

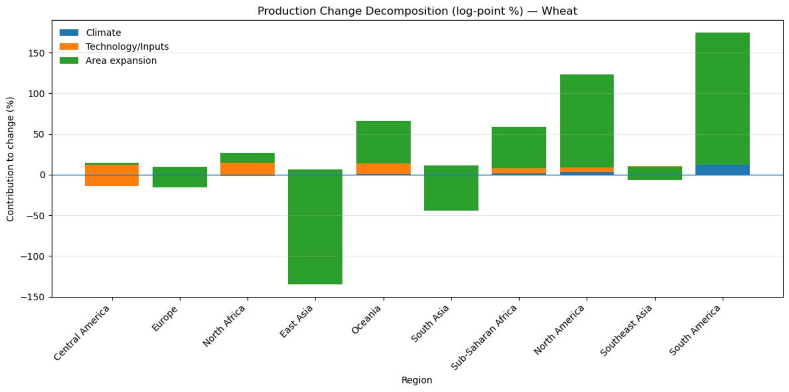
Production Risk Identification

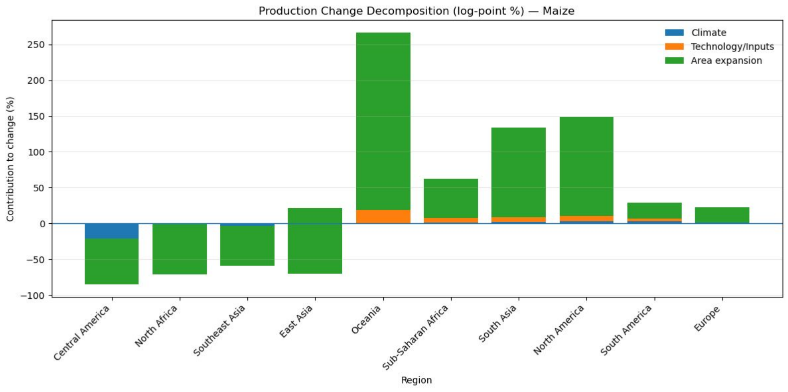
Identify regions at elevated risk of future production shortfalls by comparing projected yields to recent production baselines.

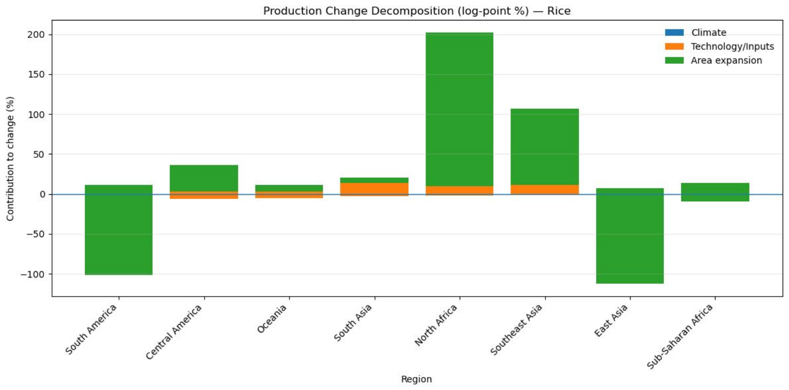
Production Trends & Future Outlook: Results



Production Trends & Future Outlook: Results







Limitations

Short Climate Time-Series

- Weather data spans only 9 years, limiting variation and causal inference.
- Trend projections rely on relatively short historical windows.

Measurement & Model Constraints

- Weather data drawn from country centroids may not reflect crop-specific growing regions.
- TWFE specification removes substantial variation; small sample size may affect robustness.

Economic Drivers Not Fully Modelled

- Commodity prices not incorporated into resilience classification.
- Yield fluctuations may reflect market responses rather than purely climatic effects.

Policy Implications

Invest in Heat-Resilient Crop Development

- Prioritize breeding and deployment of heat-tolerant soybean varieties.
- Target adaptation funding toward crops most sensitive to extreme heat stress.

Establish Trend-Based Early Warning Systems

- Monitor sustained regional yield declines using data-driven thresholds.
- Enable preemptive infrastructure and adaptation investments before production shortfalls emerge.

Strengthen Input & Adaptation Strategies

- Expand access to irrigation, improved seeds, and climate-smart inputs.
- Focus resilience policy on regions where technological inputs can offset climatic stress.

Thank you!

Questions?

Group 4: Adam Dawson, Ethan Ogrodniczuk, Julian Oldham

FRE 521D: Data Analytics in Climate, Food, and Environment

February 11, 2026