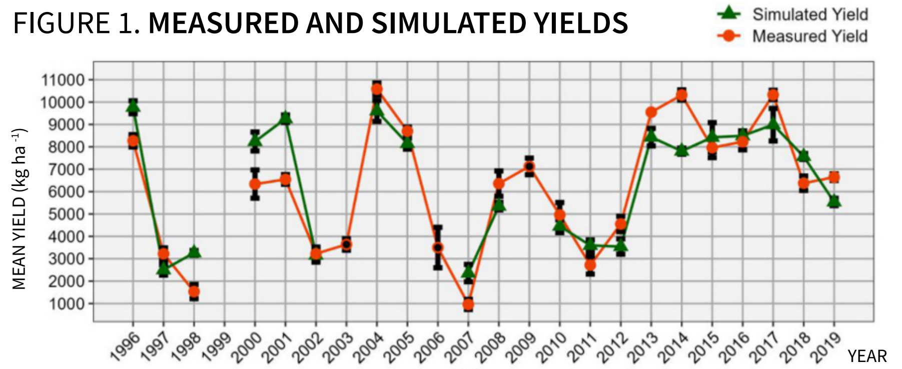
CORN MODEL RELIABLY PREDICTS THE EFFECTS OF LONG-TERM WEATHER VARIABILITY ON YIELDS

FIGURE 1. **MEASURED AND SIMULATED YIELDS**



Measured and simulated corn yields from 1996 to 2019. Bars indicate standard error of crop yields at four replicates per year. (based on Fig. 2, White et al., 2025)

Crop resilience and soil health are priorities for farmers and researchers alike. Both want to better understand how crops respond to weather conditions over long time periods. Crop simulation models are powerful tools that can help. These models mimic the complex interactions between weather, soil, and crop growth. The results provide potential outcomes of farm management and support farmer decisions.

Models are 'calibrated' to ensure the simulated results are consistent with observed data. After, they are 'validated' to ensure accurate representation of additional real-world conditions. Once validated, researchers can use models to identify how certain weather patterns may impact crop yields, including future weather conditions.

However, models differ in their complexity. For example, some models may focus on simple descriptions of growth and development for many crops. Other models have enough detail to describe differences between varieties of the same crop. Also, model simulations can suffer when data used to calibrate and validate them are missing. Information such as farmer management practice, local weather data, and soil type are not always available. This is potentially an issue when extending the simulations to field conditions outside the range of the data used to calibrate them.

Models that incorporate detailed knowledge about a single crop's physiology can solve these problems. For example, MAIZe SIMulator (MAIZSIM) is a model built explicitly for corn. It combines a detailed simulation of how soil, weather, and plant genetics' work together to affect how corn grows and how much it produces. Another strength of MAIZSIM is that it simulates weather effects by the hour. Because of these details, we have confidence that MAIZSIM is very well suited to understand how management and weather affect yield resilience. Thus, model results can inform farmers' corn management decisions.

Recently, a team of USDA researchers applied MAIZSIM to a 24-year dataset (1996-2019) at the Beltsville Farming Systems Project (FSP) in Maryland. Research at the FSP is focused on long-term farming practices for rainfed corn and other crops (**Teasdale & Cavigelli, 2017**; **Cavigelli, 2018**; **White et al., 2019**; **White et al., 2021**). The team's research[1] had two primary objectives. First, they evaluated MAIZSIM's ability to simulate the long-term corn yields measured at the FSP. Second, they used the model to identify how specific weather variables combine to influence corn yields across years.

MODEL EFFECTIVELY SIMULATES YIELD TRENDS OVER LONG PERIODS

The researchers found that simulated yields closely tracked observed yields over the 24-year period. On average, measured yields were 6408 kg/ha each year, while simulated yields averaged 6474 kg/ha each year. Thus, the model overpredicted annual yields by 51 kg/ha, a very small average error over such a long period.

The model captured general differences in yields across years caused by differences in annual weather patterns. However, it struggled to simulate years with very low or very high yields. In years with exceptionally poor corn growth, like 2007, the model predicted that the yields should be higher. In years with exceptionally good corn growth, like 2014, the model predicted that the yields should be lower. Other studies also report that simulation models are biased towards these "conservative" estimates.

In general, however, MAIZSIM successfully replicated observed FSP yield trends. The research team concluded it can be reliably used to simulate corn performance when observed field data are not available.

RAIN AND HEAT ARE PARTICULARLY IMPACTFUL DURING SPECIFIC STAGES IN CORN DEVELOPMENT

The researchers also used MAIZSIM to learn more about how certain weather variables affect corn growth. They found that both precipitation and temperature were important, especially during critical developmental stages in corn (Table 1). Specifically, the amount of precipitation falling between late vegetative and early reproductive stages including tasseling and silking had the largest effect on yields. When combined with precipitation, stress from high air temperatures during this period had nearly as large an effect. These effects are clear in Figure 2. In 2007 (a year with low yields), low precipitation and high heat stress both occurred during corn reproductive growth phases. In contrast, in 2014 (a higher-yielding year), precipitation was greater and heat stress was lower during these phases." Together, the effects of rain and heat during this critical period explained the majority (62%) of the variation in corn yields across years.

This result suggests that management practices that can buffer crops when they are most vulnerable are critical to reduce yield loss. Potential strategies include altering planting dates to avoid heat stress, selecting drought-tolerant corn varieties, or improving soil water retention. In the future, the research team plans to use MAIZSIM to determine how well such management strategies mitigate the impacts of rain and heat stress on corn yields.

FIGURE 2(A). **CUMULATIVE GROWING SEASON PRECIPITATION**

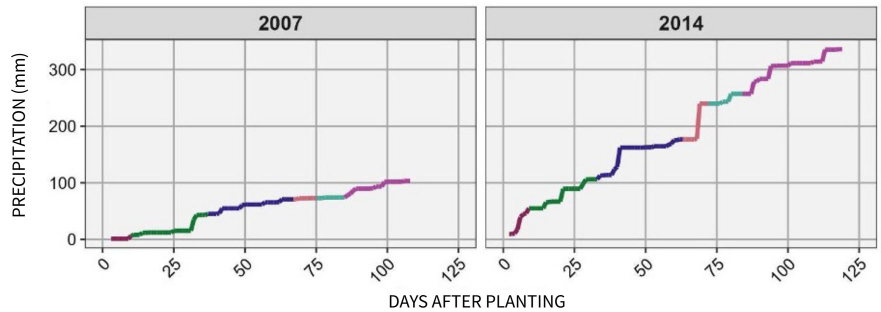
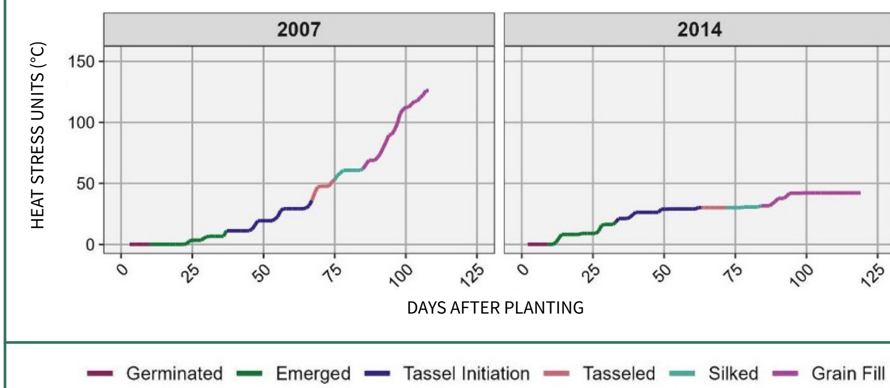


FIGURE 2(B). **CUMULATIVE GROWING SEASON HEAT STRESS UNITS**



Cumulative precipitation (A) and heat stress (B) during crop growth stages in 2007 and 2014 during the growing season. (adapted from Fig. 6 and Fig. S2, White et al., 2025)

TABLE 1	Commonality Coefficient	Percent
Rainfall during early critical period	0.11	13.0
Rainfall during late critical period	0.22	26.7
Heat stress during late critical period	0.12	13.9
Rainfall during full critical period	0.02	2.0
Rainfall during early, and heat stress during late, critical period	0.09	11.1
Rainfall and heat stress during late critical period	0.18	21.2
Rainfall and heat stress during full critical period	0.10	12.2
Total	**0.84**	**100**

Commonality coefficients (statistical measures of the effect of each listed factor on yields over the study years) and the percentage of the total yield variation over years (1996 to 2019) explained by critical period precipitation and heat stress units. The cumulative total of 0.84 indicates that 84% of the variation in yields across study years can be explained by the combination of these variables.

[1] White, K. E., Fleisher, D. H., Cavigelli, M. A., Timlin, D. J., & Schomberg, H. H. (2025). **Assessing long-term weather variability impacts on annual grain yields using a maize simulation model.** Agricultural and Forest Meteorology, 370, 110593. DOI: 10.1016/j.agrformet.2025.110593