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BUILDING AN OBJECTIVE SEASONAL FORECASTING SYSTEM FOR U.S. CORN AND SOYBEAN YIELDS

Allocation: Blue Waters Professor/250 Knh
PI: Kaiyu Guan[1]
Co-PIs: Jian Peng[1], Chongya Jiang[1], Bin Peng[1], Sibo Wang[1]

[1]University of Illinois at Urbana–Champaign

EXECUTIVE SUMMARY

Despite significant advances in both seasonal climate prediction and satellite remote sensing, the produced data have not been fully used in crop yield forecasting at the regional scale, compared to survey-based approaches. In this project, the research team built a seasonal forecasting system for U.S. corn (maize) and soybean yield by bridging the most advanced seasonal climate prediction products from the National Centers for Environmental Prediction (NCEP) and satellite remote sensing within a statistical crop modeling framework. The researchers then evaluated the benefits of using seasonal climate prediction and satellite remote sensing data in forecasting U.S. corn and soybean yield at both national and county levels. They found they could not achieve a better forecasting performance than the official survey-based forecast from the United States Department of Agriculture (USDA) until they used both climate and remote sensing observations in their model. Compared with using historical climate information for the unknown future in each growing season, using climate predictions from NCEP gave better forecasting performance once the team corrected the bias in the seasonal climate prediction products. Using the climate–remote sensing combined model and bias-corrected climate prediction from NCEP, the researchers achieved a better forecasting performance than the USDA forecast. The team's system will be useful for stakeholders in the agriculture industry and commodity markets.

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RESEARCH CHALLENGE

More frequent extreme events and ongoing climate change puts food production at a higher risk [1–4]. Seasonal forecast of agricultural production thus becomes increasingly more important for early warning of food security issues, supply chain planning for the agriculture industry, and market prediction [5–7]. Although many countries and regions around the world have their own operational crop yield forecasting systems with varied modeling and data configurations, using combined seasonal climate prediction and remote-sensing data for crop yield prediction at large scales is still rare.

METHODS & CODES

The research team built a seasonal forecasting system for U.S. corn and soybean yield by bridging the North American multi-model ensemble (NMME) seasonal climate prediction products [8] and satellite remote sensing within a statistical crop modeling framework. The seasonal climate prediction products were first bias-corrected and spatially downscaled to 4 km using the percentile mapping algorithm and then aggregated to the county level. Multiple remote-sensing products were used in this system, including the MODIS NDVI, EVI, NIRv, LST, and OCO-2/TROPOMI SIF products. Both traditional statistical regression and machine learning algorithms were used to build the yield prediction models. The model performances were evaluated using the out-of-sample validation method. The crop yield forecasting performances were benchmarked with that from USDA World Agricultural Supply and Demand Estimates (WASDE) reports.

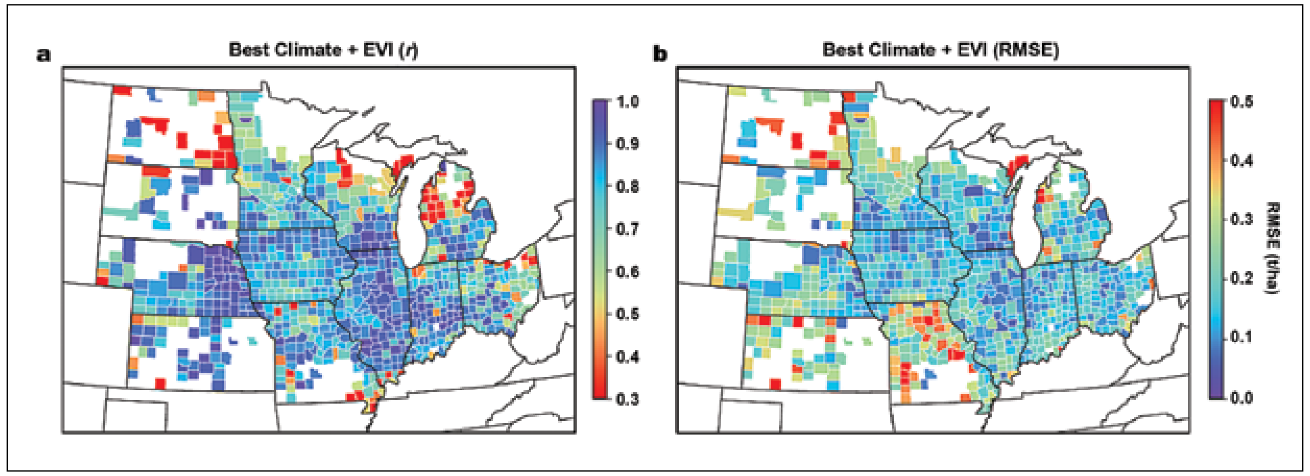

Figure 1: (a) Temporal correlation between actual yield and yield predicted by the "Best Climate + EVI" model and (b) its median prediction root mean square error (RMSE) from 2003 to 2016 at each county. Counties with yield observations of fewer than five years over the evaluation period are not shown.

RESULTS & IMPACT

The research group demonstrated that incorporating satellite information significantly improved the yield forecasting performance, compared with other climate-only models using monthly air temperature, precipitation, and vapor pressure deficit. The bias-corrected climate prediction from NMME showed better yield forecasting performance than the historical climate ensemble. Among the remote-sensing features, using NIRv and EVI can generally have better yield prediction performances. The multi-model ensemble approach can lead to the best yield prediction performance. Finally, the team's yield forecast outperformed the WASDE reports released by the USDA.

WHY BLUE WATERS

Blue Waters was essential for this research because of the need to run ensemble models (more than 200 ensembles for prediction at each time) at a regular updating frequency. The computational and storage requirements can only be fulfilled by using Blue Waters.

PUBLICATIONS & DATA SETS

B. Peng, K. Guan, M. Pan, and Y. Li, "Benefits of seasonal climate prediction and satellite data for forecasting U.S. maize yield," *Geophys. Res. Lett.*, vol. 45, pp. 9662–9671, 2018.

Y. Li *et al.*, "Toward building a transparent statistical model for improving crop yield prediction: Modeling rainfed corn in the U.S.," *Field Crops Res.*, vol. 234, pp. 55–65, 2019.