

Forecasting Long-term Grain Supply of Low-and Middle-Income Countries

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Introduction

- Forecasting models are powerful tools for predicting food supply trajectories, helping policymakers design strategies to improve food security.**
- The world population is expected to reach 9.8 billion by 2050, with the demand for food expected to increase by 50% by 2050 (FAO, 2023; WRI, 2019).
- Previous studies have demonstrated that official forecasting released by government agencies has a significant impact on the markets and decisions on supply chains (Adjemian, 2012; Irwin et al., 1994; Isengildina et al., 2006; Isengildina-Massa et al., 2021).
- This study evaluates alternative methods to provide reliable international grain supply forecasts 10 years into the future.**

Methods

- We aim to enhance the accuracy of long-term grain supply forecasts by incorporating country-specific characteristics and employing econometric and machine learning modeling techniques.**

Decomposition of Production Forecasts

$$Prod_{i,t} = Area_{i,t} * Yield_{i,t}$$

Regression Models

$$Y_{i,t} = f(t, \theta_i) + \beta_i X_{i,t} + \alpha_i + \varepsilon_{i,t}$$

ARIMAX Models

$$Y'_{i,t} = \sum_{\tau=1}^p \phi_i Y'_{i,t-\tau} + \sum_{\tau=1}^q \varphi_i \varepsilon_{i,t-\tau} + \beta_i X_{i,t} + \alpha_i + \varepsilon_{i,t}$$

Machine Learning Models: Random Forest and Xtreme Boost Gradient

Current IFSA Model:

$$Yield_{i,t} = \beta_{1,r} t + \beta_{2,r} MA2Rev_Fert_{i,t} + \beta_{3,r} MA5Rev_Fert_{i,t} + \alpha_i + \varepsilon_{i,t}$$

$$MA2Rev_Fert_{i,t} = \frac{1}{2} \sum_{\tau=1}^2 \left(\frac{DGrainP_{i,t-\tau}}{DFertP_{i,t-\tau}} * Yield_{i,t-\tau} \right)$$

Data

- We collect production, area, prices and weather data across 78 countries from 1980 to 2021 for six major crops: corn, sorghum, millet, barley, wheat and rice.**
- Production, Area, and Yield:** We obtain production and harvested area from the USDA Foreign Agricultural Service Production, Supply and Distribution (PSD). The unit for production is millions of kilocalories (kcal), area is in hectares, and yield is in millions of kilocalories per hectare. While PSD has production data in metric tons, we convert to calories using the caloric equivalents from FAOSTAT (2024)
- Predictors:**
 - Our model specifications consider two different measures of crop prices as predictors variables in the model specifications: futures prices from the Chicago Board of Trade and local spot prices from the World Bank commodity price database.
 - Weather: Annual and monthly weather data at the country level are obtained from the Climatic Research Unit (CRU) at the University of East Anglia. CRU creates monthly country-level data by averaging monthly gridded weather data within each country. We use the cumulative precipitation (mm) and the average temperature (°C) for each month and year.

Results: Accuracy Comparison

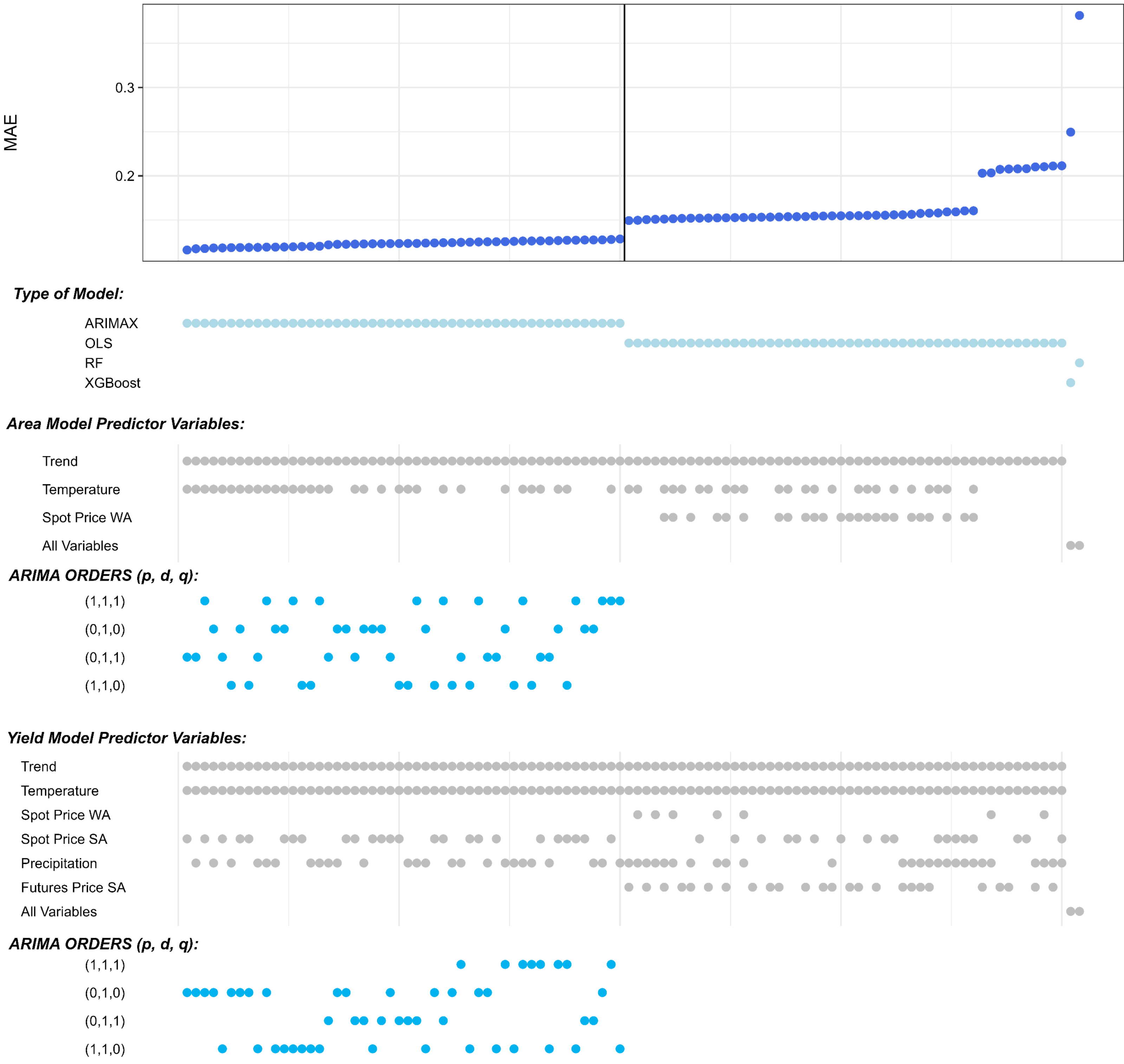


Figure A5. Accuracy Comparison: Models Specifications of Top Models

Out-of-Sample Validation Approach

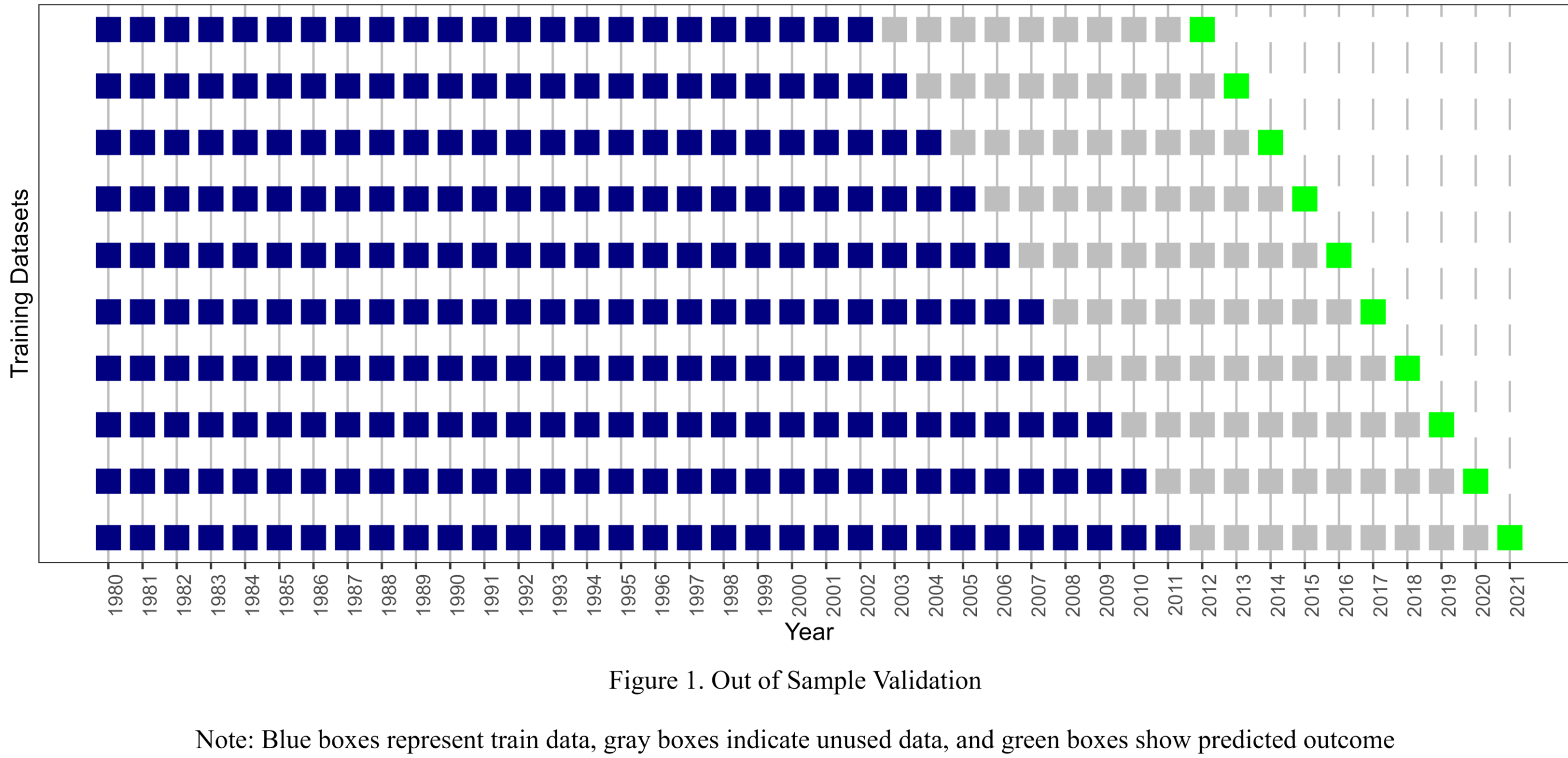


Figure 1. Out of Sample Validation

Note: Blue boxes represent train data, gray boxes indicate unused data, and green boxes show predicted outcome

Results: Production Forecasts

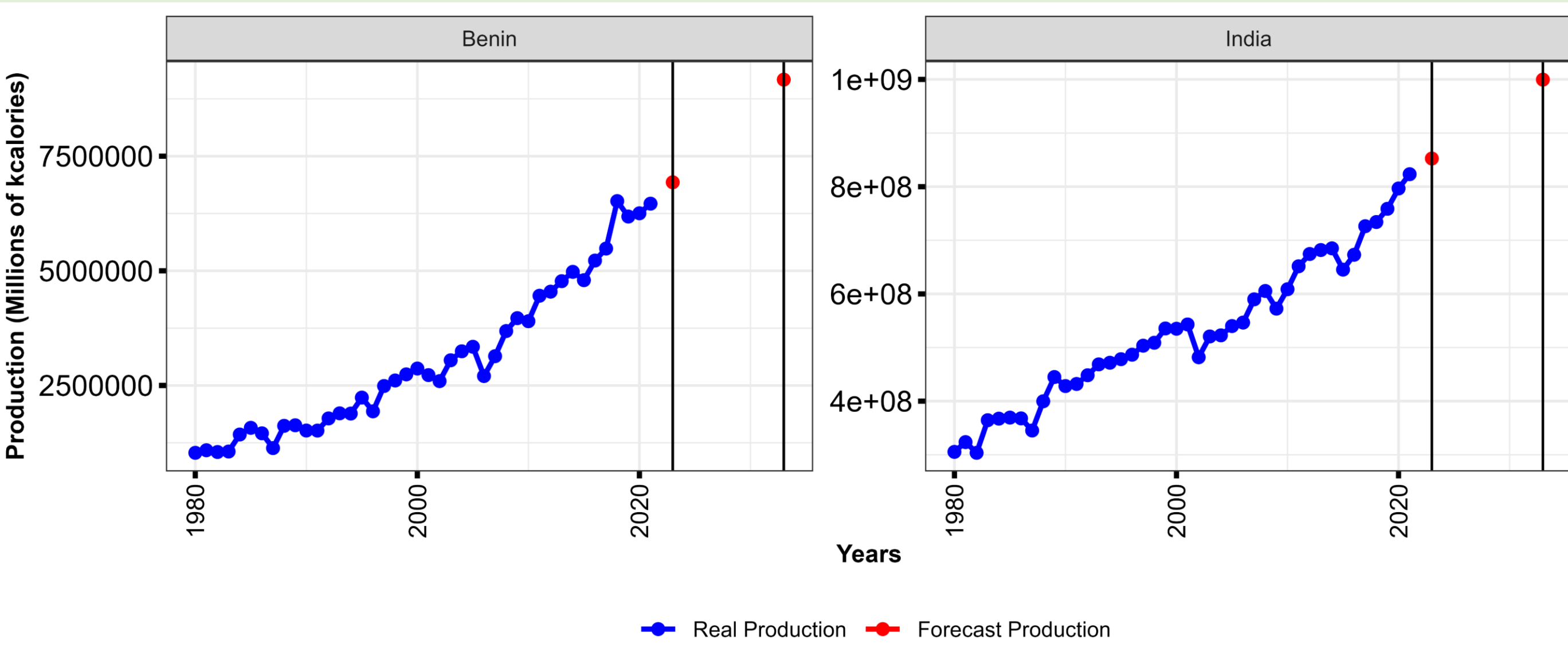


Figure 4. Forecast of 2023 and 2033

Conclusion

- The results reveal four ways to improve forecast accuracy.

- The country-specific coefficients can increase the forecast accuracy.
- Pooled coefficients reduce the number of parameters that must be estimated, while country-specific coefficients allow the model to capture more heterogeneity.
- Linear trends provide higher forecast accuracy than non-linear trends.
- The best model specifications include weather variables such as temperature.

- ARIMAX models with exogenous variables show higher accuracy than OLS, RF and XGBoost models.

- MAE of approximately 10% indicates room for further improvement, our approach represents a substantial advancement over existing methods

- By combining these grain supply forecasts with demand projections, it is possible to provide valuable insights into future food security and international trade dynamic.**