

Bayesian Forecasting of Spatio-Temporal Dependencies in Crop Yields: A Time-Varying Conditional Copula Approach with Extreme Weather Effects

Marie Michaelides^{a*}, Mélina Mailhot^a, Yongkun Li^a

^a Department of Mathematics and Statistics, Concordia University, Montréal, Canada

*Corresponding author marie.michaelides@concordia.ca

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Abstract

In this paper, we propose a novel forecasting model for crop yields that explicitly accounts for spatio-temporal dependence as well as the impact of extreme weather and climatic events. The marginal crop yield distributions are modeled using Bayesian Structural Time Series (BSTS), incorporating exogenous climatic risk factors. To capture the dynamic dependence structure between regions, we fit a time-varying conditional copula model to the residuals of the BSTS. In this copula framework, the dependence parameter evolves over time following a dynamic time series model, influenced by weather or climatic covariates. A key innovation of our approach lies in the treatment of these exogenous covariates: rather than assuming them as observed values, we model them using dynamic Generalized Extreme Value (GEV) models, where the location parameter follows a time series process to capture long-term trends and persistence in extreme weather events. To enhance scalability, we integrate a Partitioning Around Medoids (PAM) clustering algorithm, facilitating the extension of our model to higher-dimensional settings while maintaining computational efficiency. By combining these components, our model produces crop yield forecasts that reflect not only the spatio-temporal dependence of yields but also the evolving influence of extreme climatic events. These results are particularly relevant for agricultural insurers, policymakers, and stakeholders seeking robust risk assessment tools in the face of climate change.

keywords: spatio-temporal dependence, conditional copula, bayesian modelling, extreme weather events