

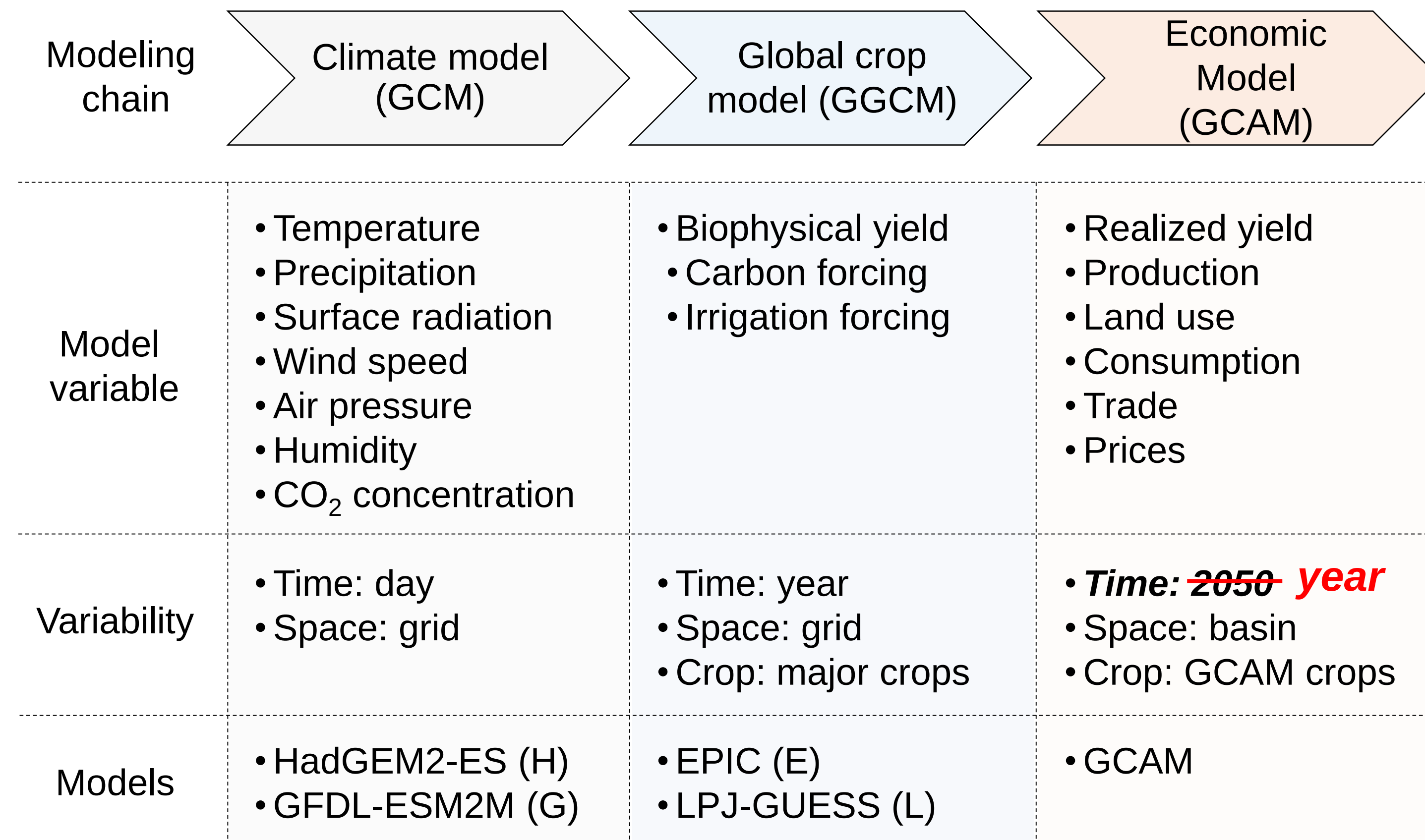
Sensitivity of agricultural economics to future climate and biophysical variability

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We run GCAM annually and separate planting and harvesting decisions to study interannual climate impacts on agriculture. We show that interannual variability in climate and biophysical shocks are transformed and transferred to crop market and magnified by endogenous market fluctuations. Improving farmer's expectations (perfect foresight) of prices and yield can significantly reduce interannual variations in market prices and consumption. Results also indicate that regional interannual variation is mediated through international trade. Net importing (food insecurity) regions are more vulnerable to climate variability.

Assessing climate impacts on agriculture

The assessment requires a combined use of climate, crop, and economic models to translate climate and biophysical shocks to changes in economic variables.



- Previous assessment focused only on one future year (2050) because
- Most economic models have a longer time-step (e.g., 5-year in GCAM)
 - Perfect foresight has been assumed in economic modeling
 - The time lag between planting and harvesting is ignored
 - Farmers can perfectly predict future climate (weather) and market
 - Convenient assumption but often times criticized
 - Underestimate variations due to endogenous market fluctuations

Objective and research questions

- Develop a modeling framework that is capable to illustrate and quantify the interannual variability of climate impacts (**Fig. 1**).
- How and to what extent variability in biophysical shocks is transferred to economic variables (**Fig. 2a**)
- How better predictions (perfect foresight) affect the results (**Fig 2b**)
- Regional heterogeneity in vulnerability to climate variability (**Fig 3**)

Separating planting & harvesting decisions in GCAM

Long history of illustrating lagged agricultural supply responses in economic literature:

- Cobweb theorem in Kaldor (1934)
- Farmers make decisions based on their expectations of prices and yield
- Suboptimal decisions lead to endogenous market fluctuations

Adaptive expectations (Nerlove, 1958):

- The expectation (x_t^E) is adaptively revised in proportion to the difference between the previous observation (x_{t-1}) and the previous expectation (x_{t-1}^E) with a constant coefficient.
- $\alpha \in [0.05, 0.3]$ in literature; $\alpha = 0.1$ was used.

$$x_t^E - x_{t-1}^E = \alpha(x_{t-1} - x_{t-1}^E); \quad x_t^E = \sum_{n=0}^{t-1} \alpha(1-\alpha)^n x_{t-1-n} + (1-\alpha)^t x_0^E$$

Interannual variability

$$\text{Annual growth rate} = \log(\text{variable}_t) - \log(\text{variable}_{t-1})$$

$$\text{Interannual variability (IV)} = SD(\text{annual growth rate}) \quad \text{Detrended \& unitless}$$

$$\text{Relative IV (RIV)} = \frac{IV_{\text{economic variable}}}{IV_{\text{biophysical yield}}} = \frac{\text{Beta coeff.}}{\text{Correlation coeff.}} \quad \text{Consistent comparison}$$

- Beta coeff.** Implies the magnitude of the interannual economics responses against biophysical yield shocks; **Correlation** implies the amount of variations being explained.
- RIV reflects the vulnerability to climate variability for a crop-region in a climate scenario.

Results

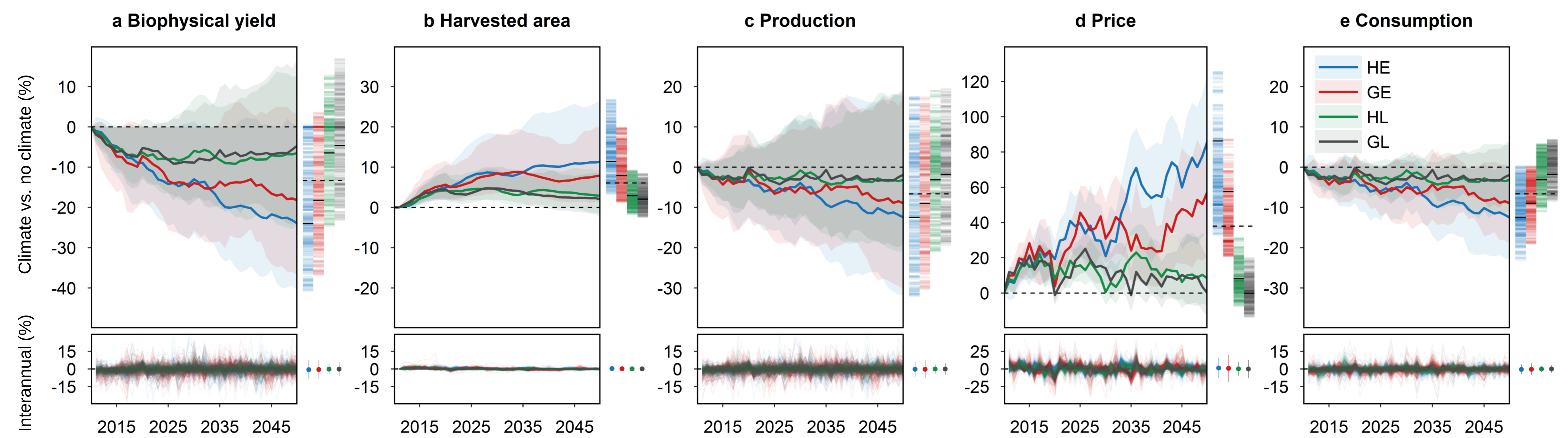


Fig. 1 | Climate impacts on biophysical yield and economic variables.

- Scenarios with higher mean or variation in biophysical shocks also show higher mean or variation in economic variables.
- Climate model contributes to interannual variation significantly more than crop model (**ANOVA**).
- Interannual variation in area is small as acreage responses are relatively rigid.
- Price has the biggest variation, particularly after planting and harvesting decisions are separated.
- Consumption has smaller variation than production due to substitutions across crops and sources (trade).

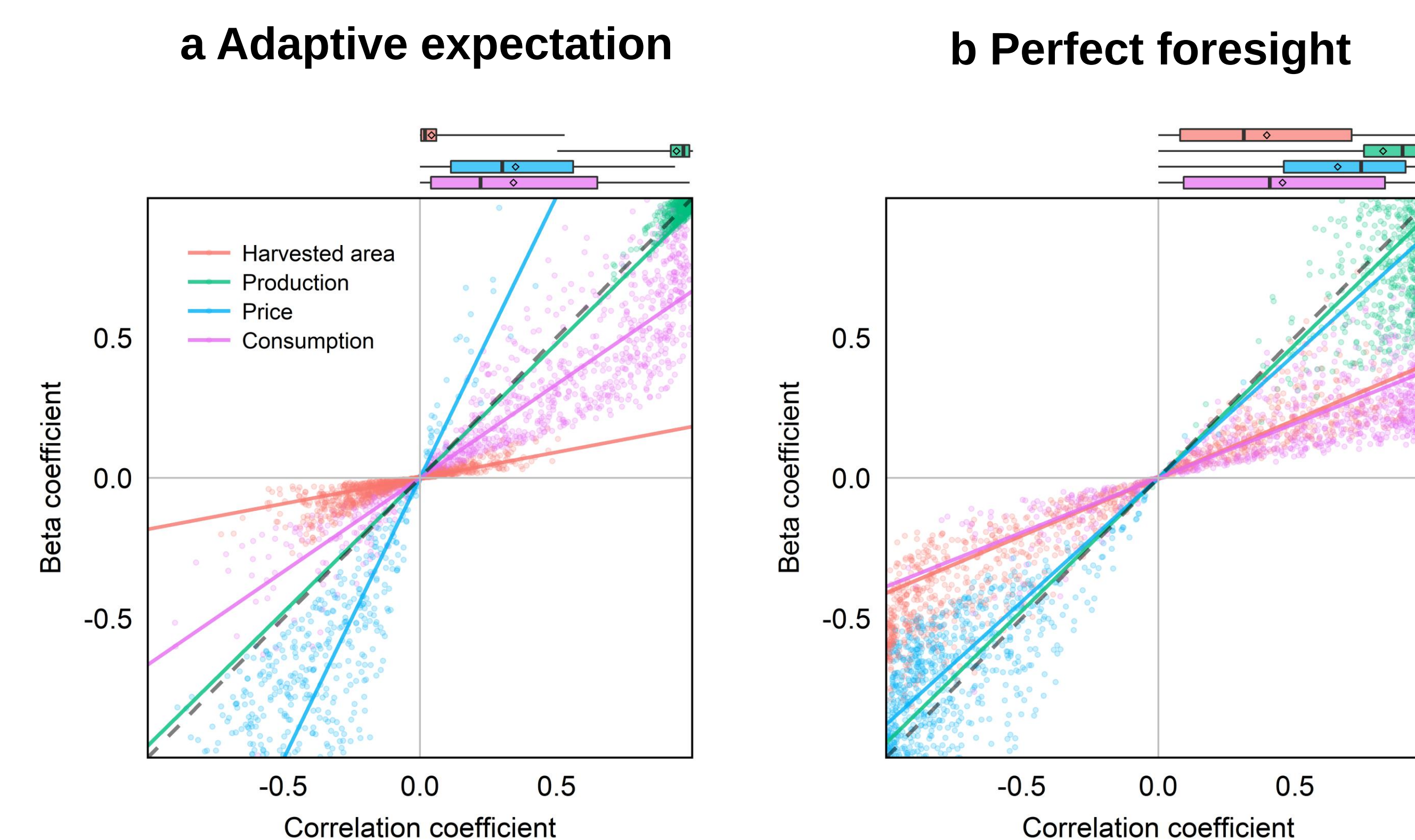


Fig. 2 | Interannual economic responses (beta coefficient) and correlations to biophysical yield shocks. Each point denotes a crop in a region and a climate scenario.

- Under adaptive expectation, crop price is more sensitive to biophysical shocks. Biophysical shocks are transferred and transformed to economic variables through different stages of nonlinear market-mediated responses in the economic system.
- Interannual variation directly explained by biophysical yield: on average 90%, 63%, 34%, 33%, and 30% in production, export, price, import, and consumption. The correlation between biophysical yield and economic variables becomes weaker when biophysical shocks are transferred from supply to demand.
- With better predictions (perfect foresight), correlation becomes stronger (no endogenous market fluctuation) while beta becomes smaller (immediate adaptations), for prices and consumption.

Fig. 3a | Relative Interannual variability of price to biophysical yield (oil crops in GE)

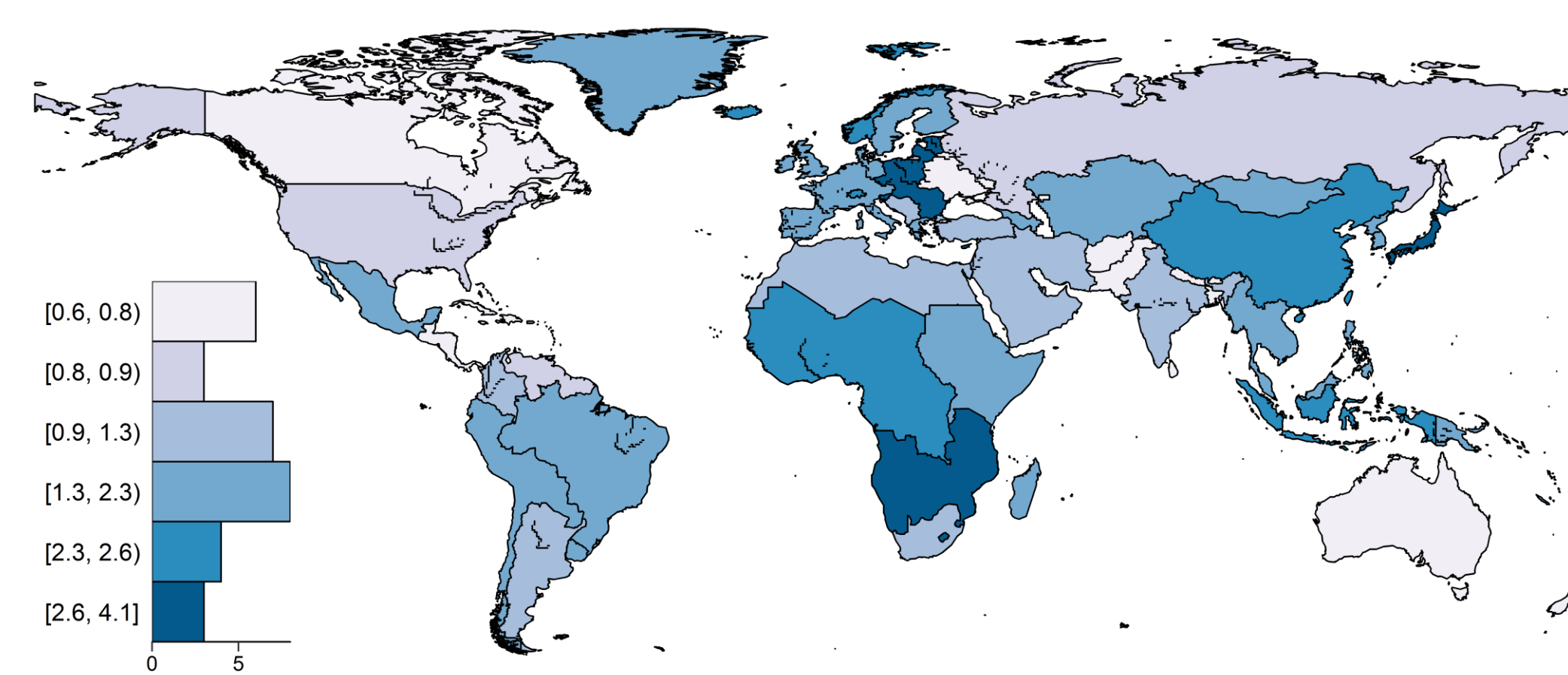
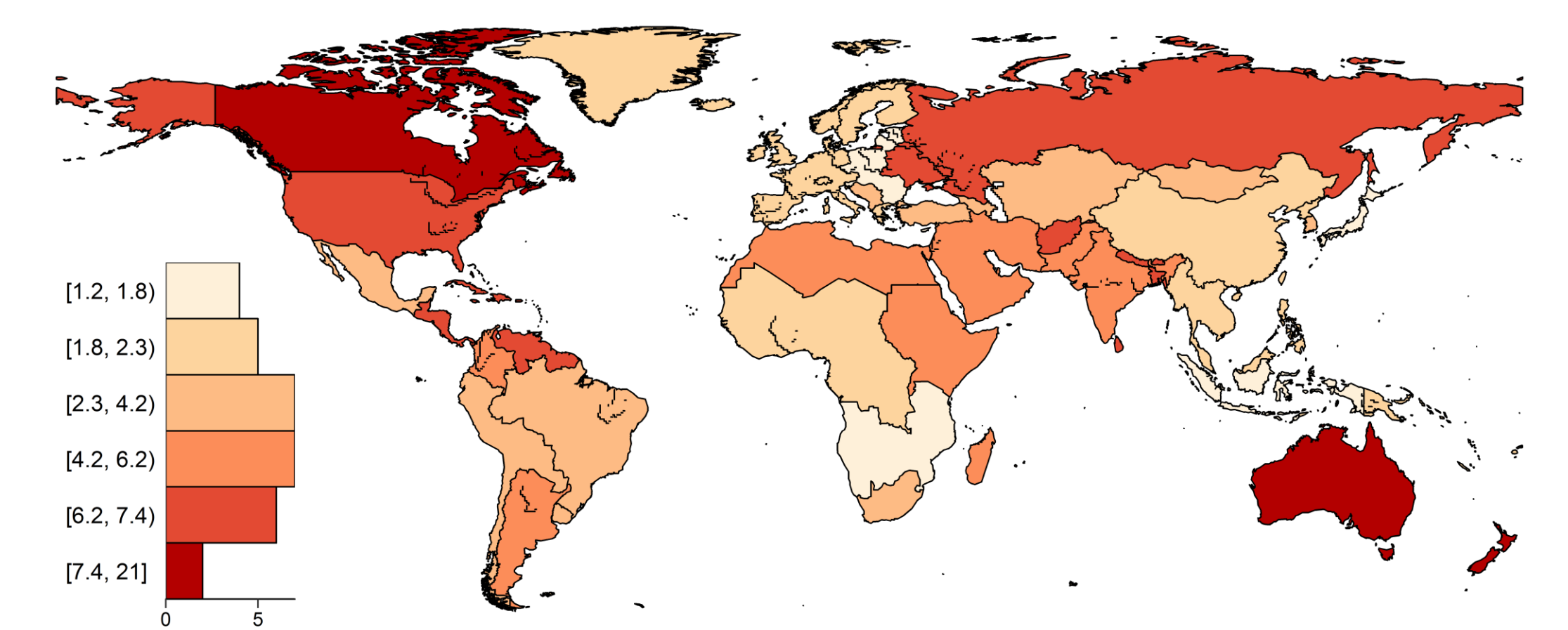


Fig. 3b | Interannual variability of biophysical shocks (oil crops in GE)



- Regions with higher variability in biophysical shocks tend to have a smaller magnifier (RIV).
- Regional interannual variation is mediated through trade.
- Net importing (food insecurity) regions are more vulnerable to climate variability.

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