Assessing the Financial Impacts from Drought and Heat Induced Crop Losses

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1. Motivation

Context

- While crop production and yield impacts of climate change have been widely assessed[1], their financial and economic implications are poorly understood.
- This matters because, beyond being a key component of food security, crop production is a vehicle of economy, and farmers rely on it as a crucial source of income.
- Agricultural production is highly susceptible to predictable shocks[2], such as climate events and supply chain disruptions. These vulnerabilities can have far-reaching consequences, impacting regional and global economies as well as financial markets.

Research objectives

- Provide an estimate of future climate driven financial risks from agricultural losses on national level using a statistical model based on heat and water stress.
- Attribute losses to top emitting countries and carbon majors.

2. Data & Methods

- Statistical model (panel regression) with climate variables as independent predictors, controlling for fixed effects (country and time trend)[3]:

$$y_{it} = \sum_{n=1}^{n} \beta_n f_n X_{nitg} + \lambda_i + \alpha_{it} + \epsilon_{it}$$

y_{it}: Crop yield for grid i and year t
β_n: Regression coefficients
$f(.)$: Cubic expansions on growing season daily time series of climate variables
X_{nitg}: n^{th} independent mean growing season climate variable for country i and year t
λ_i : Fixed effect for time-invariant differences between countries
α_{it}: Fixed effect for country-specific time trend

- Yield impact (*dy*) caused by climate variables *X*:

$$dy_{it} = \sum_{n=1}^{n} \beta_n f_n X_{nitg,fut} - \sum_{n=1}^{n} \beta_n f_n X_{nitg,base}$$

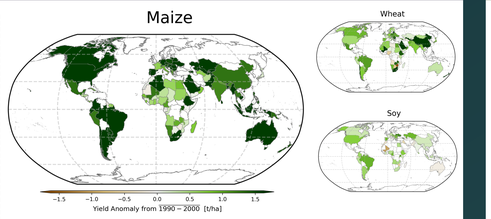
- Corresponding production (*dp*) impact for country *c*:

$$dp_{ct} = dy_{ct} y_{ct} HA_{ct}$$

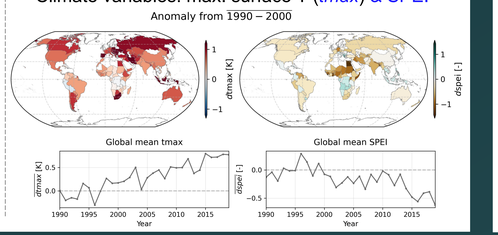
- Abs. (*de*) & GDP-weighted (*degdp*) economic impact[4]:

$$de_{ct} = dp_{ct} \cdot \text{producer\_price} \qquad degdp_{ct} = \frac{de_{ct}}{GDP_{ct}}$$

- Data: ISIMIP3a (hist, 2007-2019), ISIMIP3b (SSP), NGFS scenarios, FAO (crop yield & production).

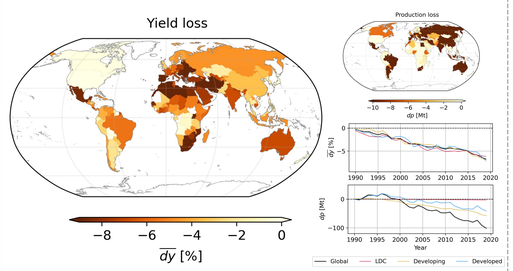


- Climate variables: max. surface T (*tmax*) & SPEI



3. Crop Yield & Production Losses

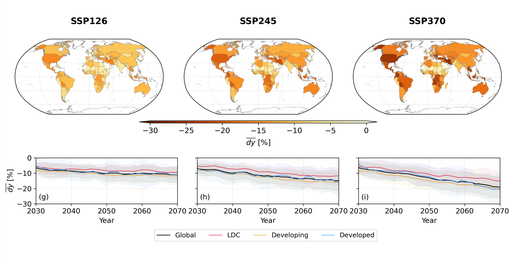
Historical



**All figures show values for all crops combined unless otherwise indicated*

- Heat and drought-related yield losses are most severe in the poorest regions, although their production losses are significantly smaller compared to wealthier countries.

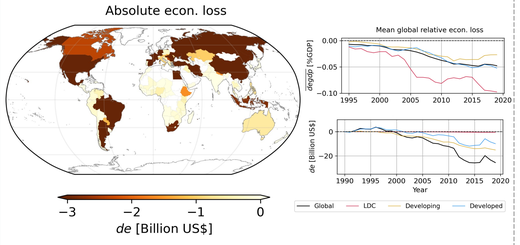
SSP Projection



- By 2070, the global average yield impact difference between SSP1 and SSP3 is projected to be 7.4%, equivalent to a difference of 207 million tonnes of crops (maize, soy, and wheat) between the two pathways.

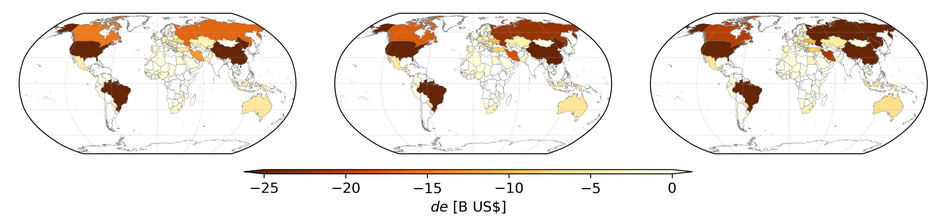
4. Financial Losses

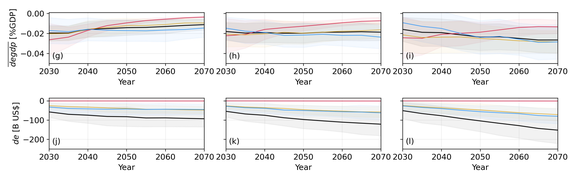
Historical



- Wealthier countries experienced the largest economic losses from heat and drought-induced crop losses.
- However, as a percent of GDP, poorer countries are disproportionately impacted by these financial losses.

Future Projections





- Under SSP3, global economic losses from heat and drought-induced crop losses could reach up to 150 billion US$ by 2070.
- Following a sustainable pathway (SSP1) could save approximately 50 billion US$, with wealthier countries experiencing the largest saving.

5. Attributable Financial Losses

- Estimate attributable economic impact of warming induced by emissions from group of emitters (E_e):

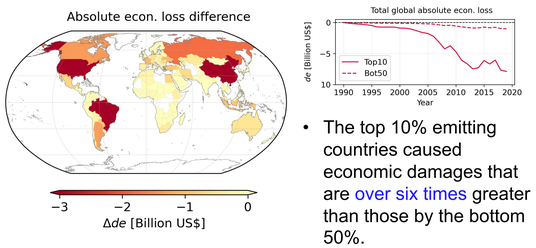
$$\Delta Tmax_{ie} = E_e \cdot \Phi_i \cdot rTCRE$$

$$\Phi_i = \frac{\Delta Tmax_{ig}}{\Delta T_i}$$

$$\Delta Y_{ite} = \beta_T\left(T_{it,base} + \Delta Tmax_{ie}\right) - \beta_T\left(T_{it,base}\right)$$

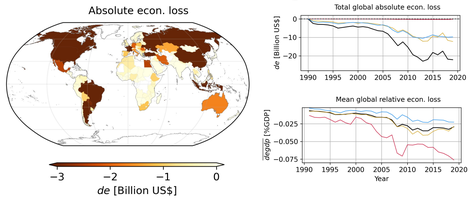
- Considers only temperature-related impacts, making the economic impact estimates more conservative.

Top emitters



- The top 10% emitting countries caused economic damages that are over six times greater than those by the bottom 50%.

Carbon Majors



- The financial losses incurred by the Carbon Majors are greater than the top 10% emitting countries combined.

6. Summary

- **We develop a statistical model to assess the impact of heat and drought on crop yield, and estimated the resulting economic losses.**
- **The world's poorest regions suffer the most severe heat- and drought-related yield losses, despite having much smaller overall production losses than wealthier regions.**
- **As a percent of GDP, less-developed countries experience the highest economic losses, despite their absolute losses in US dollars being much smaller than those of developed countries.**
- **The world stands to save approximately 50 billion US$ annually by 2070 when following a sustainable development pathway (SSP1) compared to one where regional rivalry dominates (SSP3).**
- **The top 10% of emitting countries caused over six times the economic damage of the bottom 50%, yet this pales in comparison to the damages attributed to Carbon Majors (~20 billion US$ annually).**

7. Plans

- Conduct comparative analyses with process-based crop models.
- Explore alternative climate predictors (e.g., soil moisture) and assess potential regional discrepancies of modelled yield and economic impacts.
- Explore the inclusion of governance and socio-economic indicators as independent predictors (e.g., the human development index [HDI]).
- Conduct in-depth case studies of specific countries or regions that exhibit high vulnerability to heat and drought-induced crop losses.

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