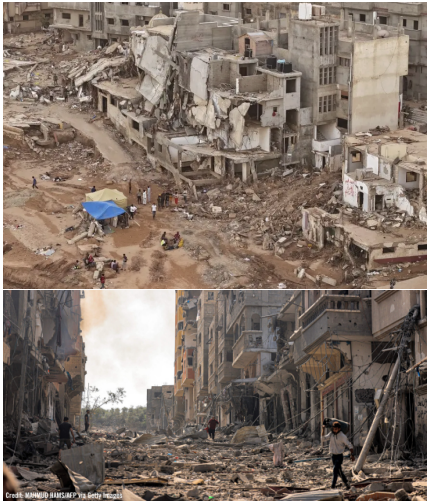
Navigating Uncertainty:

Climate Variability, Armed Conflict, and Predicting Vulnerable Futures

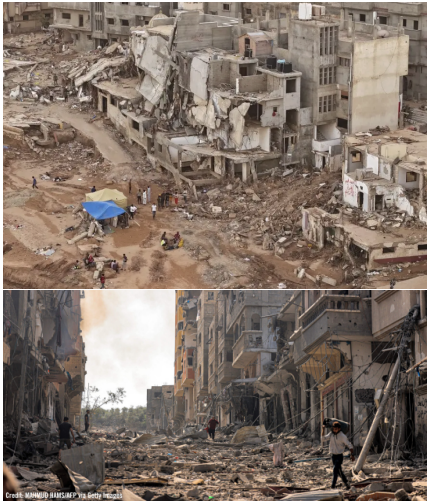
Paola Vesco

IAERE Keynote Lecture, 21 February 2025

Climate and conflict impacts



Climate and conflict impacts

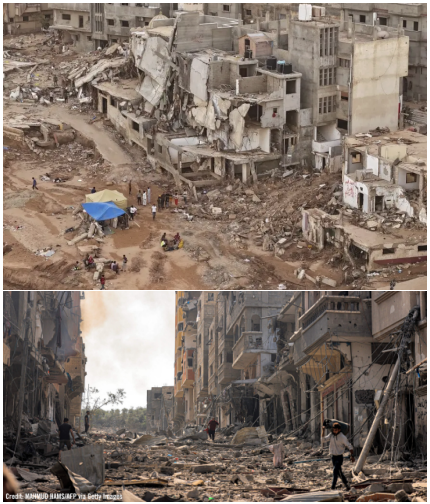


- Flood, Lybia, September 2023

- War, Gaza, 2024

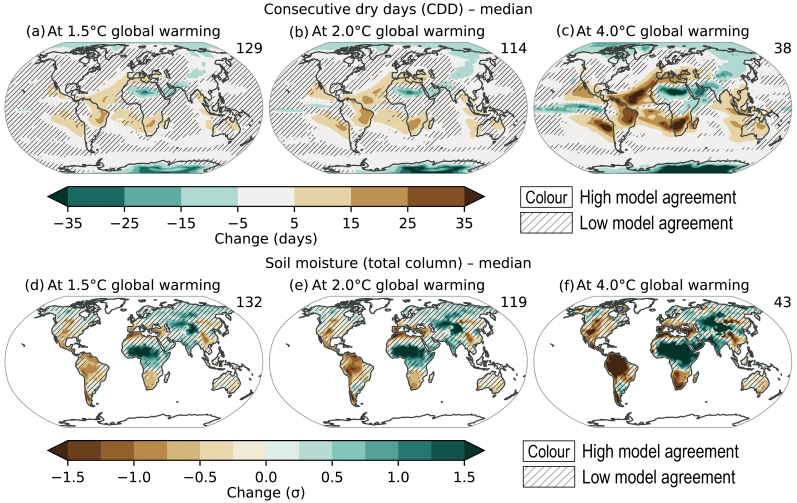
Climate extremes and armed conflicts:
trends and impacts

Climate and conflict impacts



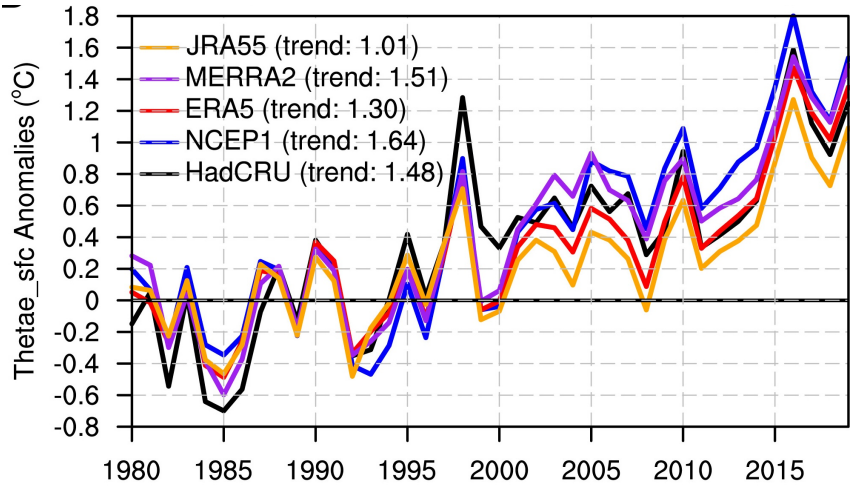
- 3.3 billion people directly affected by climate-related disasters (Donatti et al., 2024)
- 154,000 people were killed *directly* by armed conflict in 2023 (Davies et al., 2024)
- In 2023, ~2 billion children lived in a conflict-affected country (Østby and Rustad, 2024)

Frequency of extreme weather events



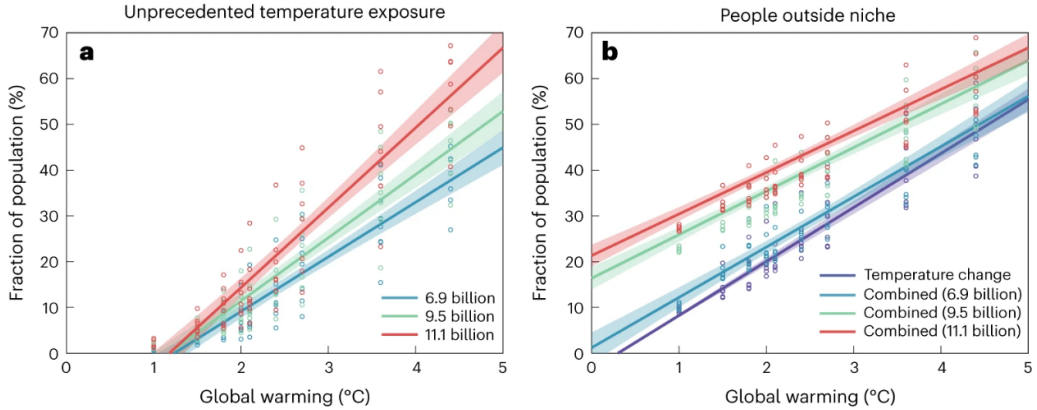
IPCC (2021)

Frequency of extreme weather events



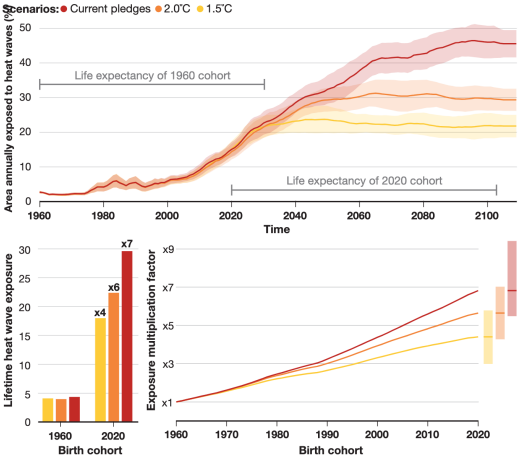
Song et al. (2021), *PNAS*

Exposure to climate extremes



Lenton et al. (2023), *Nature Sustainability*

Exposure to climate extremes



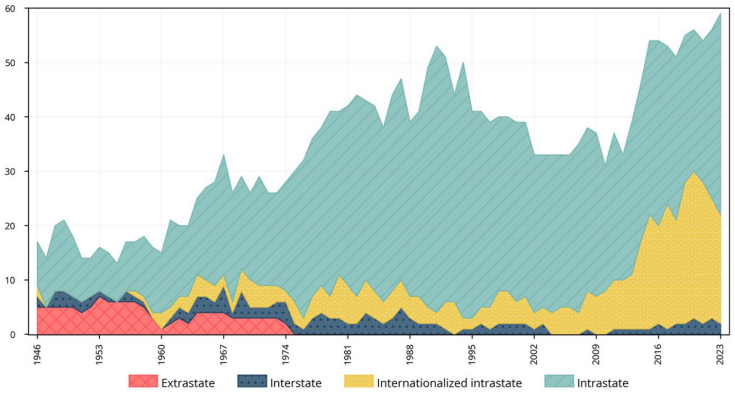
A child born in 2020 will experience seven times more heat waves than a person born in 1960. Thiery et al. (2021), *Science Advances*

The cost of extreme events

Climate-change attributed costs of 185 extreme weather events from 2000 to 2019 estimated to total 2.86, trillion USD, averaging 143 billion annually or 16.3 million per **hour**.

Newman and Noy, 2023, *Nature Communications*.

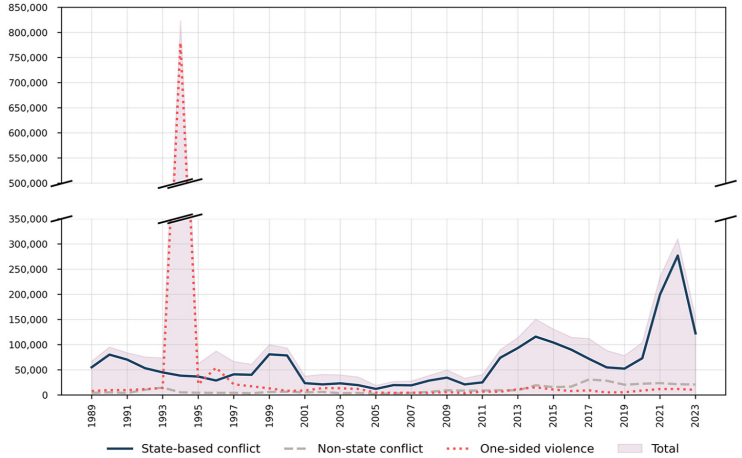
Trends in armed conflict



Davies et al. (2024), *Journal of Peace Research*

- 59 state-based armed conflicts in 2023, highest level ever recorded by the UCDP

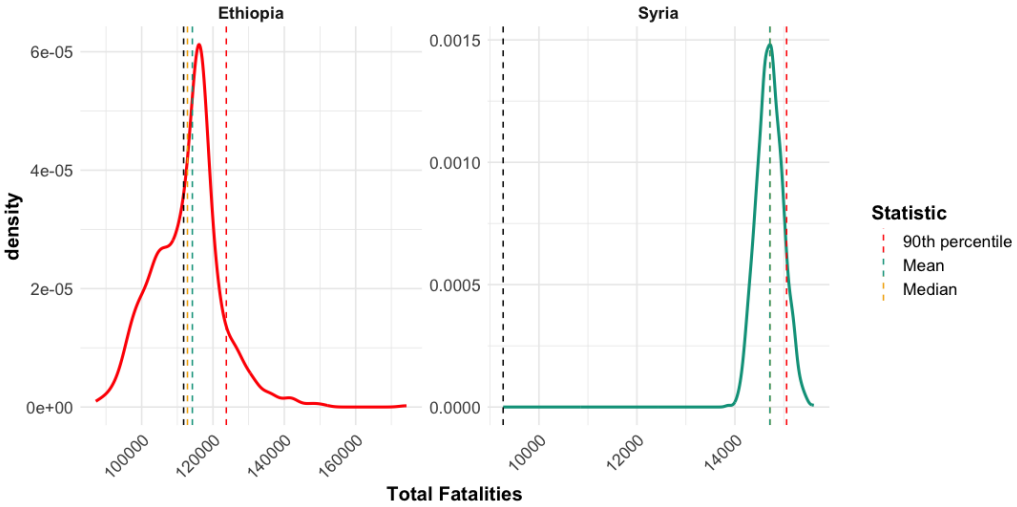
Trends in armed conflict



Davies et al. (2024), *Journal of Peace Research*

- Fatalities from organized violence decreased from 310,000 in 2022 to 154,000
- One of the highest numbers since Rwandan genocide

Conflict deaths are under-estimated



Vesco et al. (2025), *Journal of Conflict Resolution* (under review)

The cost of conflict

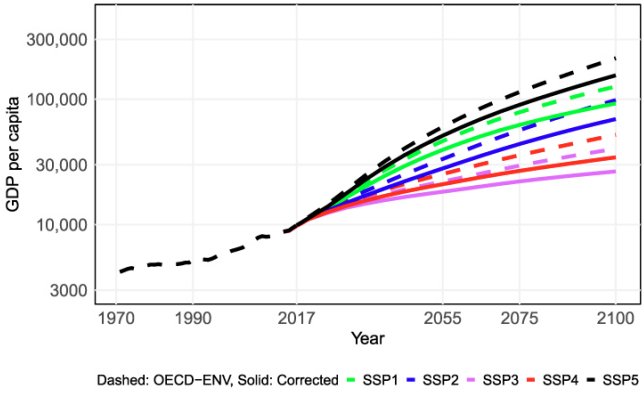
The macro-level effect of conflict on economic growth ranges from about 1% of GDP per year of conflict to 12% relative to the counterfactual

Collier, 1999; Gates et al., 2012; Mueller and Tobias, 2016; De Groot et al., 2022

Projected costs of conflict

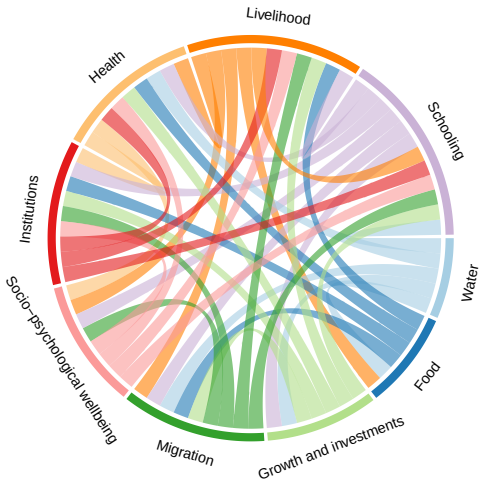
When correcting for conflict, GDP is 25% lower on average by the end of the century

Petrova et al., 2023



(d) Dellink et al. (2017) original and corrected projections

The *human* cost of conflict

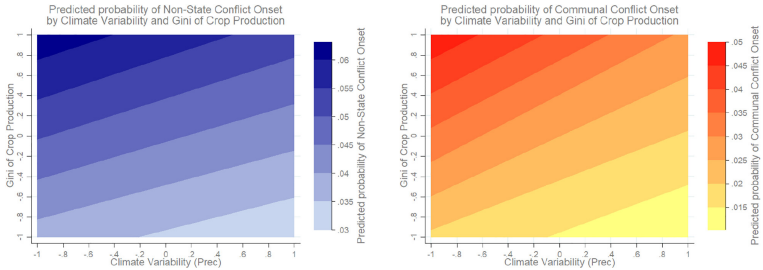


Vesco et al. (2025), *World Development*

Conflict risks can be amplified by climate variability

- Climate variability has increased the risk of conflict albeit indirectly and conditionally (Mach et al., 2019, *Nature*)
- Empirical results are highly sensitive to model specifications (Vesco et al., 2020, *Ecological Economics*)

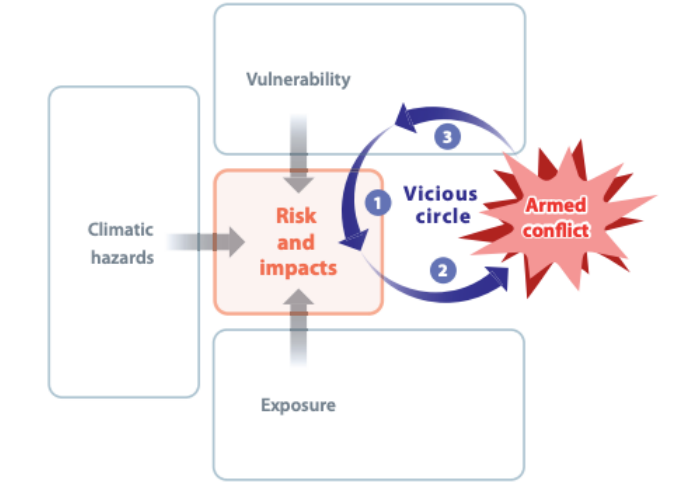
Climate-conflict linkages are complex



Vesco et al. (2021) *Journal of Peace Research*

Combined, climate variability and crop production variations increase the risk of conflict outbreaks

Conflict and climate impacts: a vicious circle

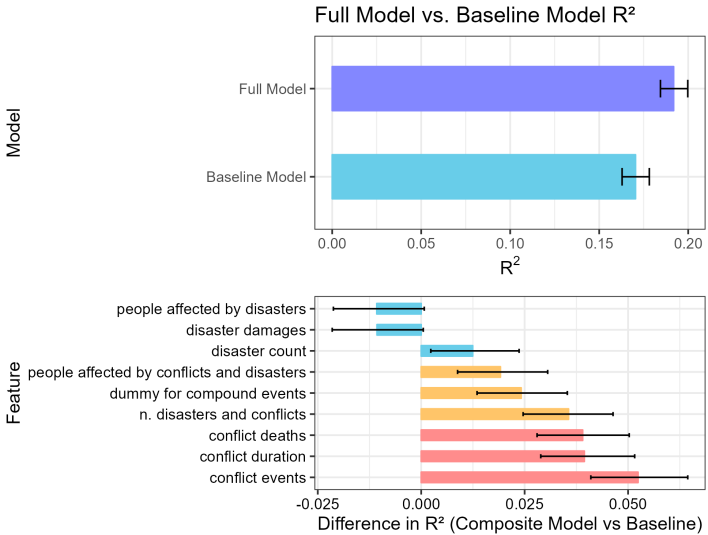


Armed conflict and climate impacts can give rise to a vicious circle of vulnerability and heightened risks

Buhaug and von Uexkull (2021) *Annual Review of Environment and Resources*

Conflict and climate impacts compound

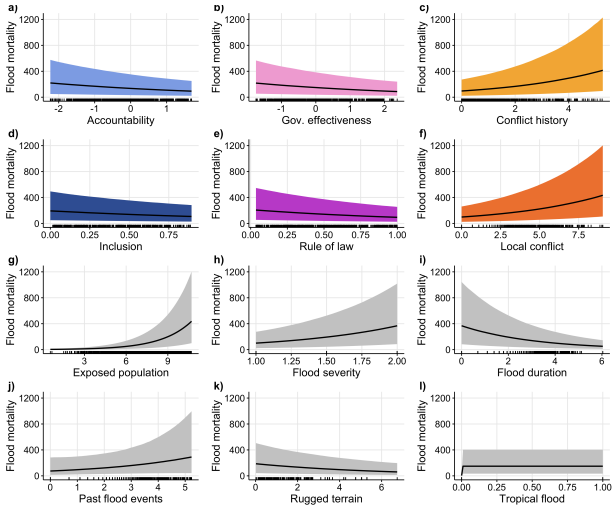
- Conflict increases vulnerability to climate extremes (D'Angeli and Vesco, *in progress*)



Armed conflicts worsen climate impacts

- Conflict and poor governance exacerbate flood mortality

  (Vesco et al., *Under Review, Nature Communications*)



Armed conflict exacerbates vulnerability

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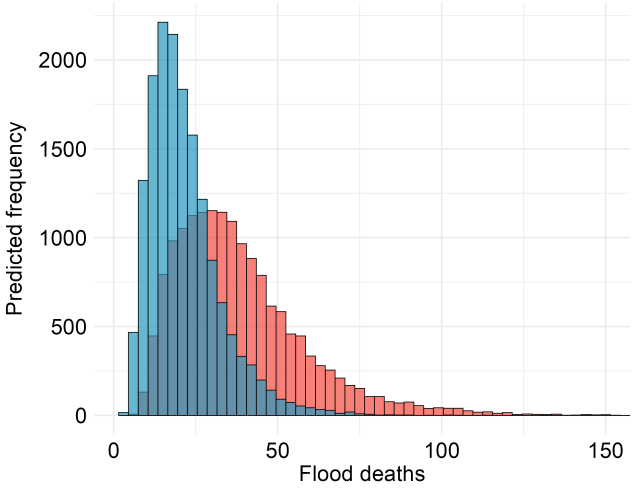
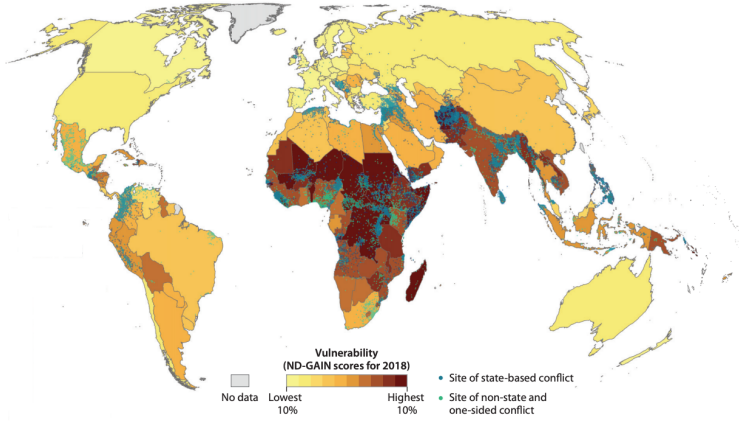


Climate and conflict effects compound

- The few confirmed famines during the 2009–2018 period coincided with both conflict and drought (Anderson et al., 2021, *Nature Food)*
- The Nargis flood that hit Myanmar in 2008 increased food insecurity by 7–18%.
- This effect goes up by 61–106% for every one SD increase in conflict.

  (Rogall, Rudolfsen and Vesco, *in progress*)

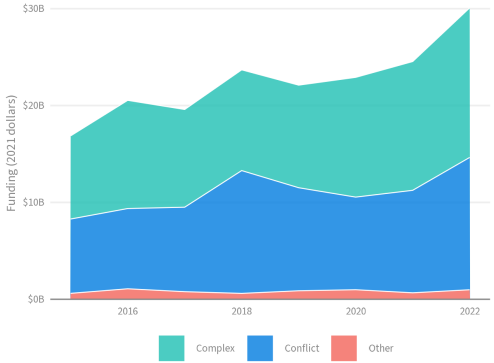
Some countries are and will be disproportionately affected by armed conflict and climate impacts.



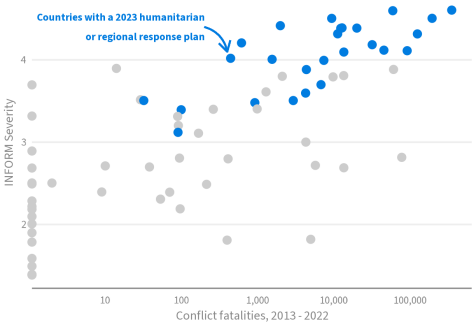
Buhaug and von Uexkull (2021) *Annual Review of Environment and Resources*; Vestby et al., 2024 *PNAS*

Humanitarian needs

Humanitarian funding, 2021 dollars, 2015 to 2022



Severity of humanitarian conditions and intensity of conflict



Caldwell and Vesco (2025, preliminary)

Forecasting conflict and its impacts: Anticipatory action and scientific relevance

Anticipatory action

- ”By acting early, we can prevent [crises] from turning into full-blown catastrophes” A. Guterres, UN Secretary-General, 2021
- Anticipatory action is needed to minimise the impact of the shock before needs are realized (Anticipation Hub, 2022).

Predictions are *needed* for conflict prevention

Figure 5. Prevented Loss in High-Risk Countries

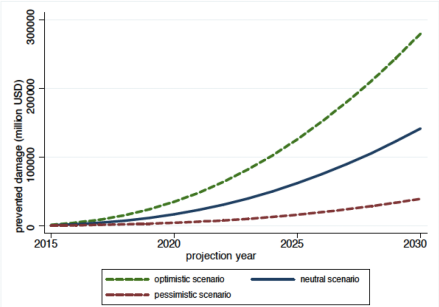
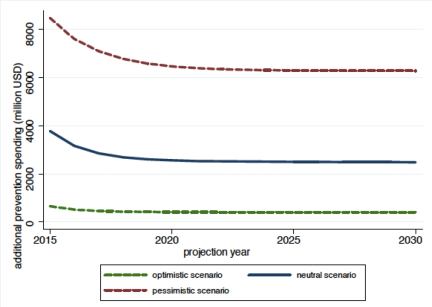


Figure 7. Total Yearly Costs of Prevention



Annual prevented damage (left) dwarfs the annual costs of prevention (right) (Mueller, 2017, World Bank)

The ‘business case’ for prevention

Table 3. The Business Case for Prevention

Spending, damages, and costs are all in US$ millon per year

	scenario		
	optimistic	neutral	pessimistic
prevented damage	68736	34251	9377
saved costs	1523	1176	698
additional cost	-352	-2118	-5247
net savings per year	**69907**	**33309**	**4828**

Net savings per year close to 5bn US$ even under pessimistic scenario (Mueller, 2017, World Bank)

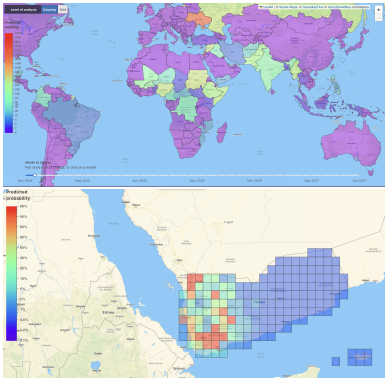
Predictions are *academically* useful

True predictions are not only politically impactful but academically useful:

- Predictions are **unavoidable:** Policy analysis requires predictions about future consequences (Gleditsch, 2022)
- Predictions are **useful**: they provide insights into key drivers of outcomes (Ward, 2010; Lo et al., 2015; Colaresi and Mahmood, 2017; Vesco et al., 2022)
- Forcing us to predict to common specified problems and the same data can foster inter-disciplinary **dialogues** and greater transparency (Gleditsch, 2022; Vesco et al., 2022; Hegre et al., 2022; Hegre et al., Forthcoming)

An **open-source AI-driven platform providing monthly forecasts for the likelihood and severity of armed conflicts worldwide**, up to three years ahead.

Developed by a research consortium led by **PRIO and Uppsala University**, we pool the expertise of renowned researchers across the world to deliver actionable **insights that empower early action** for preparedness and mitigation or armed conflicts and their adverse humanitarian impacts.



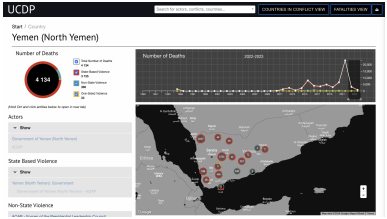
Predicted n. fatalities (top) and probability of fatal state-based conflict (bottom) in December 2024

An innovative **conflict early-warning system** leveraging cutting-edge technology.

- **Country and Local Coverage:** Global forecasts at the country-level, and sub-national forecasts at a 0.5° (∼ 55 sq.km) grid level for Africa and the Middle East.
- **Monthly Updates, Up to 3 Years Ahead:** Forecasts for the likelihood and severity of armed conflict 1 to 36 months ahead, updated monthly.
- **Empowering Early Action:** Empowering **humanitarian actors and stakeholders to minimize human suffering** through early warning for early action.

VIEWS: What We Predict

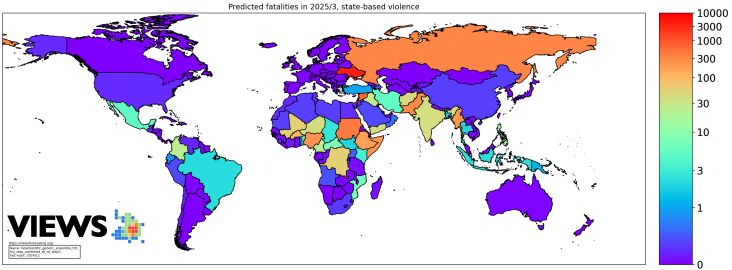
We predict the **probability and number of fatalities in state-based armed conflict** – per the UCDP definition. We capture conflicts that involve:



UCDP records of armed conflict in Yemen over 2022-2023.
Source: `https://ucdp.uu.se`.

- Fatal use of armed force, resulting in at least 25 deaths per country and year
- An incompatibility over government or territory
- At least one **governmental actor**, affiliated with the 'party controlling the capital of the state'

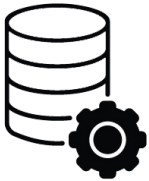
Our current predictions



Country-level forecasts for ME for March 2025. Based on input data up to December 2024.

- We predict relative stability in the short term and a de-escalation in Israel-Palestine
- … but an escalation in the medium-long term in the MENA region

What Data Is the Model Trained On?

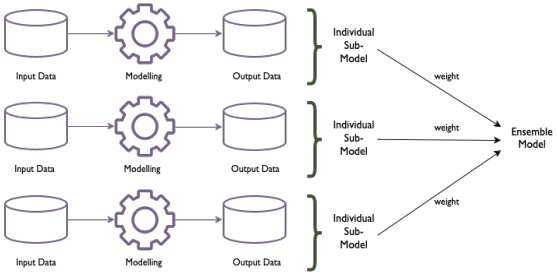


The Data Informing the Models

- An extensive suite of open-source input data variables, covering 1990 onwards
  - Carefully selected based on decades of peace and conflict research
  - Drawn directly from the original data providers, and/or created by means of processing/transforming the original data
  - 200+ unique predictors at the country level; 100+ at the grid level
- Updated *at least* annually; conflict and media data monthly

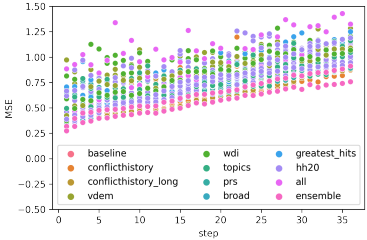
How Are the Forecasts Generated?

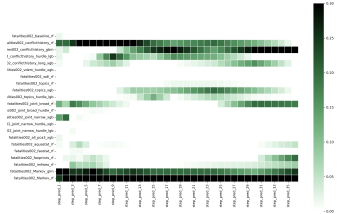
1. **Organize Features:** Data on similar themes are grouped together into sets of predictors ('feature sets')
2. **Create Sub-Models:** Feature sets are combined with advanced machine learning techniques into 'sub-models'
3. **Ensembling:** The sub-models are combined into ensembles that are updated monthly



⚠ *No models are perfect; an ensemble evens out errors from each sub-model and focuses on their core contributions*

Ensembling





Use of Ensembles of Models That Perform Well But Are Reasonably Diverse:

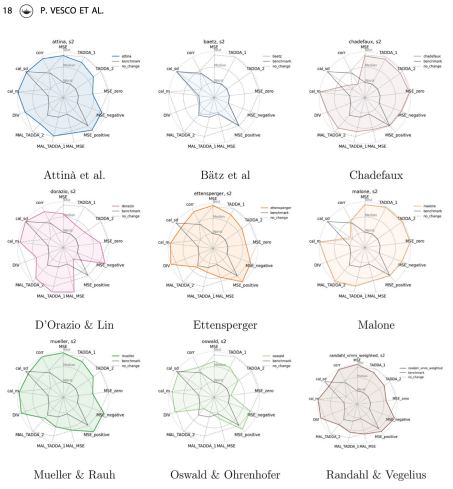
- 'Wisdom of the crowd' – most wise when diverse and competent
- Ensembling safeguards against overfitting
  - But can be over-fit to calibration partition
- Country-level sub-model weights trained using a genetic algorithm; grid-level weights using a simple average
- Optimizing on Mean Squared Error (MSE) of predictions across all cases

What Constitutes a Good Prediction?

Models perform differently on different evaluation metrics.

Main Metric: Mean Squared Error (MSE)

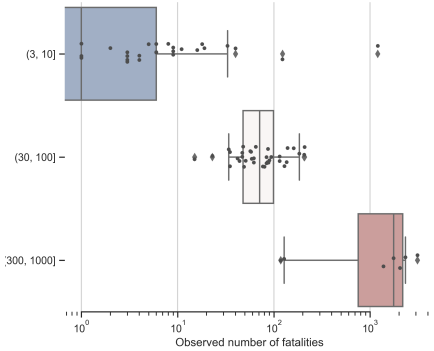
- The square of the difference between what we predict and what actually happened
- Favors well-calibrated models



Vesco et al. (2022) *International Interactions*

How Well Does the VIEWS Model Predict Overall?

Out-of-Sample MSLE at Country Level Between .25 and .75



How many were killed per country if we predict the following 12 months into the future?

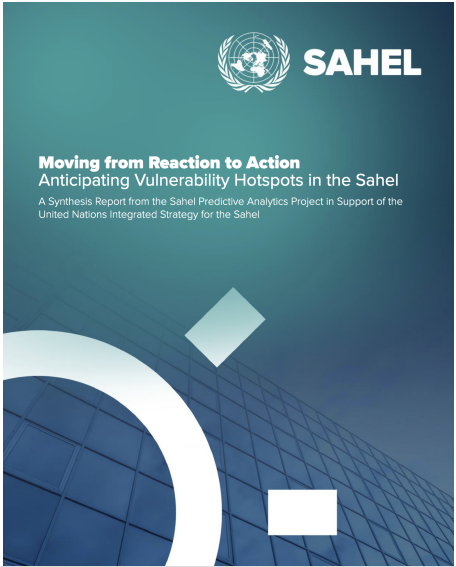
- 3–10 fatalities:
  - 50% are 1 or higher, median observation is 1, and 95% are below 30
- 30–100 fatalities:
  - 90% are between 30 and 200
- 300–1000 fatalities:
  - all are above 100, and 90% are above 800

Read more: Forecasting Fatalities (Hegre et al. 2022) (Model: *fatalities001)*

Predictions have impact

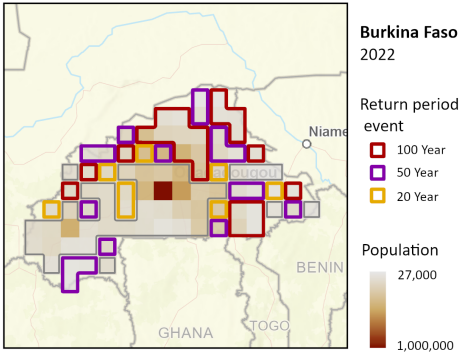
Quantitative, Cross-National Forecasts as a Complement to In-Depth Qualitative Assessments

- Relevant for anticipatory action and humanitarian reliefs
- Integration of VIEWS forecasts to internal data dashboards helps allocation of resources
- Financing mechanisms can disburse funds before disasters materialize



Simulated payouts 2022, thresholds from 1989–2020, Burkina Faso

FAO financing mechanism integrating conflict risks to release early disbursement of funds



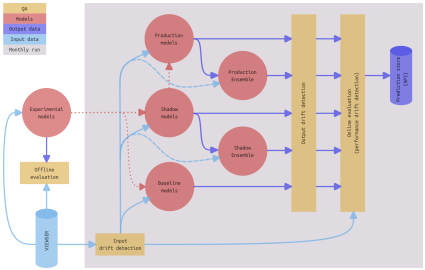
- Conflict index supporting a disaster risk financing mechanism for Burkina Faso

AI for peace:
new opportunities

AI potential to boost predictions

- Help handling uncertainty and missingness in input data: Bayesian models, Variational Autoencoders (VAEs), Conformal Predictions
- Capture complex spatio-temporal dynamics: CNNs, LSTMs, Transformers
- Monitor real-time and extract information from large text corpora: Large Language Models (GPT, BERT), Retrieval-Augmented Generation (RAG)

AI potential to boost predictions II



- Model interactions and inter-dependencies at the actor level: Reinforcement Learning (RL), Agent based models, crowd-sourcing of a pool of human forecasts
- Increase precision in forecasts of challenging distributions: Mixture of Experts (MOE), Monte Carlo Tree Search (MCTS)
- Build trust in AI for decision making: Auditable workflows, Explainable AI, human-in-the-loop systems

Concluding remarks

- Advances in AI, computational resources and data granularity offers unprecedented opportunities for accurate predictions
- Inter-disciplinary collaborations, such as through commonly defined competitions, can boost our collective knowledge to solve wicked problems
- Scientists have the means to be ‘honest brokers’ (Van Vuuren, 2015)

Thank You!

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Predicting Continuous Conflict *vs* New Conflict

But... predicting *new* conflict or sudden (de-)escalation is hard!

[controls=play, step, stop,buttonsize=1em, width=9cm]2Figures/GIFs/Yemen/Yemen$_{a}$*ctuals*—*forecasts*$_{2}$02304 — 202410120

Illustration of how the model reacts to changes in fatalities over time. The grey bars show actual fatalities from state-based conflict (UCDP GED 23.1; Candidate 24.0.1-24.0.10). The blue lines show the monthly forecasts produced using that data, combined with other predictors, between May 2023 – Oct 2024.

- Within the model, there is a lag between peak in violence and changes in predictions
- The model reflects changes in fatalities over the next month(s)
- The model can only react when data changes: lags in data access means lags in conflict alerts – no matter how good the model is
- Investments in large data collection efforts are crucial for powering data-driven models