# Food security beyond borders: how crop imports affect drought risk of conflict-affected countries

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## Abstract

Drought events can disrupt food security and increase the risk of violent conflicts. In an interconnected global food system, countries rely on both local food production and imports to meet domestic demand. When assessing the impact of drought risk on national food security, however, imported crops are often overlooked. This study incorporates international crop trade information to understand the role of crop imports in the drought risk profile of countries. We focus on conflict-affected countries due to their reliance on food imports, and particular vulnerability to the impacts of drought events and their corresponding cascading effects. We develop a framework to quantify drought risk associated with domestic production and imports of crops (i.e. composite drought risk) by combining gridded drought risk data with crop production and trade for 23 countries. Our findings show that most conflict-affected countries face drought risk primarily through domestic production, as most consumed calories are produced locally. Nevertheless, including crop imports alters the composite drought risk profiles considerably (>10%) in 14 countries, with Middle Eastern and North African countries showing 40-50% reduction. Crop imports also introduce an additional source of high drought risk, accounting for over 10% of high drought risk in 18 countries and amounting to 90% in some cases. Furthermore, we identify critical trade connections that expose countries to concentrated drought risks from specific trading partners. We demonstrate the need to incorporate both domestic and import-related drought risks in food security assessments, and we suggest potential strategies based on countries' composite drought risk profiles for drought resilient food security.

## 1. Introduction

Food security is not only fundamental for human well-being and development, but also for societal stability, with disruptions potentially leading to multiple societal impacts. Food insecurity has been shown to increase social unrest (Bellemare, 2015) and impacts on health (Gundersen & Ziliak, 2018; Martin et al., 2016). Links between food security and violent conflict have been observed across multiple scales, from individual to global levels (Brück & d'Errico, 2019; Martin-Shields & Stojetz, 2019). Drivers of food insecurity are complex, spanning climatic, socio-economic and political factors (Bowen et al., 2021; FSIN, 2024; Jagermeyr et al., 2020; Lin et al., 2023; Mottaleb et al., 2022). Extreme weather events, such as droughts, can undermine food security by damaging crops, reducing production and cascading to food shortages and price increases (Christian et al., 2020; Hasegawa et al., 2021; Mach et al., 2019; Talebian et al., 2024).

Traditional studies on climate-conflict relations focus mainly on climate variables, but the impacts of hydrometeorological variables and extreme weather events like droughts are particularly critical in conflict-affected countries (Dahm et al., 2023). This is due to interactions with existing violent conflicts (Martin-Shields & Stojetz, 2019; Von Uexkull et al., 2016), dependency on rainfed agriculture (Von Uexkull, 2014) and limited coping mechanisms (FSIN, 2024; Holleman et al., 2017; Jaramillo et al., 2023). Potential cascading impacts of drought in conflict-affected areas include increased food insecurity, higher number of internal displacements, and more conflicts (Adaawen et al., 2019; Anderson et al., 2021; Sardo et al., 2023).

Drought risk in the context of food security has been primarily assessed for domestic crop production (Hagenlocher et al., 2019; Hameed et al., 2020; Kogan et al., 2019; Vogt et al., 2018). This focus often overlooks the drought risks associated with imported crops (Ercin et al., 2021), leading to potentially inaccurate estimates of a country's drought risk exposure. Food systems are globally interconnected through international trade, which increases countries' dependencies on food imports, especially in developing countries (Bren D'Amour et al., 2016; Kummu et al., 2020; Puma et al., 2015). While crop trading can mitigate the impacts of local droughts (Dall'Erba et al., 2021), disruptions in crop imports, caused by remote droughts, geopolitical conflicts or other events, can hinder food security in importing countries. This is particularly true for the Global South and conflict-affected countries, which are often net food importers (Bren D'Amour et al., 2020; Burkholz & Schweitzer, 2019; Calì, 2014; Talebian et al., 2024). For example, studies have linked the 2011 droughts in Russia and Ukraine to a global wheat shortage and price hikes, and subsequently to (at least partially) the occurrence of the Arab Spring (Johnstone & Mazo, 2011; Soffiantini, 2020; Sternberg, 2012).

Under climate change, concurrent droughts and simultaneous crop failures are projected to become more common, increasing risks to the global food system through disruptions in trade connections (Gaupp et al., 2019; Goulart et al., 2023; Hamed et al., 2025; Qi et al., 2022). Recent studies found vulnerabilities in the EU's food imports to climate-related risks in exporting countries, and an expected rise in remote drought risk due to climate change (Brás et al., 2019; Ercin et al., 2021). Therefore, there is growing recognition of the need for countries to assess drought risk both domestically and abroad.

This study quantifies the drought risk for food security in 23 conflict-affected countries, considering both domestic crop production and imports. We develop a framework that quantifies drought risks for agricultural production regions globally and links them to countries' domestic crop production and to their imports. We apply the framework to assess changes in drought risk profiles in countries due to crop imports, to identify critical trade connections between crop-country combinations, and to discuss potential strategies for countries to reduce their composite drought risks.

## 2. Data and methods

### 2.1 Conflict-affected countries selection

The data used for conflict-affected countries was obtained from the Georeferenced Event Dataset (GED) version 24.1 from the Uppsala Conflict Data Program (Davies et al., 2023). It covers individual events of organized violence at a local scale (such as a village or town) and at a daily temporal scale globally over the 1980-2023 period.

The selection of conflict-affected countries aimed to reflect countries that had chronic issues with violent conflicts in the recent past and that might struggle to cope with the impacts of drought events. We excluded countries classified as high income in the World Banks's classification of countries by income (Ceriani & Verme, 2016) and we limited the analysis to the time period between 2000 and 2020 to balance data availability and current day relevance. The selection of conflict-affected countries required calculating conflict years for a given country, which followed two conditions: an absolute threshold requiring a minimum of 100 conflict-related fatalities and a relative threshold of at least 1 conflict-related fatality per 100,000 population (adapted from World Bank, 2020). All types of conflicts documented in the GED were considered: state-based conflicts, non-state conflicts and one-sided violence. Conflict-affected countries were defined as countries that presented at least 5 non-consecutive conflict years over the study period. 23 countries were selected as conflict-affected countries (see Table 1).

### 2.2 Framework to connect drought risk to domestic and imported crops

We developed a framework to assess the drought risk of crops consumed in a given country, considering both domestic production and imports, which we refer to as composite drought risk. The framework requires national data on crop production and trade, and gridded data on crop production and drought risk, which are processed and then combined. The specific data and steps are described below.

#### *2.2.1 Crop production and trade*

National crop production and trade data were obtained from the food and agricultural trade matrix database from the Food and Agriculture Organization of the United Nations (FAO, 2024). Besides data on yearly crop production data, the trade matrix also offers annual data on imports and exports for food and agricultural commodities, covering bilateral trade between countries over the 1986-2022 period. The following staple crops were considered in our analysis: barley, cassava, maize, millet, plantains, potatoes, rice, sorghum, soybeans, sweet potatoes and wheat.

For a uniform comparison of food energy content between different crops, crop data was converted from tons to calories using caloric density values from the FAO. To account for domestic crop consumption, we subtracted total exports from the total national production.

We also used a global gridded dataset providing crop production data at a high spatial resolution. This dataset is produced by the global process-based crop model ACEA (Mialyk et al., 2024) and offers annual simulated production for 175 crops from 1990 to 2019, at a 5-arcminute spatial resolution. It differentiates between rainfed and irrigated production systems. We converted crop production values in each grid cell into relative production values, representing the percentage of local production with respect to the country's national production for a given crop.

### *2.2.2 Drought risk categories*

For assessing drought risk that is relevant to food security, we use a global gridded dataset designed for agricultural systems (Meza et al., 2020). The dataset provides drought risk information for irrigated and rainfed agricultural systems at a 0.5° spatial resolution and averaged between 1980-2016. Drought risk for each system is based on hazards, exposure, and vulnerability indicators, all normalised and unitless. The agricultural focus supports the connection between drought risk and food security: drought hazards are derived from climate data, exposure from crop information, and vulnerability from agriculture-relevant socioecological indicators. Details on the data are available on Meza et al., 2020.

We convert drought risk data into categories for easier comparison and interpretation. First, we combined the rainfed and irrigated drought risk data based on their weighted harvest areas to obtain the combined drought risk (also unitless). It was then categorised into five discrete classes based on equal intervals between the 5th and 95th percentiles of the risk distribution and classified from very low to very high. The data was then downscaled to match the spatial resolution of the crop production data.

### *2.2.3 Composite drought risk calculation*

We combined drought risk and crop production datasets so that each grid cell has information on both the relative production for a given crop and the corresponding drought risk category. We allocated national domestic crop production based on each grid cell's relative domestic production share for the specific crop. Total crop imports from each specific partner were allocated based on the relative production shares within the country of origin's grid cells (Figure 1). The composite drought risk of a given country was calculated by aggregating the calories from domestic crop production and imports for each drought risk category separately. Knowing the origin of drought risk helps understand the contributing factors to the composite drought risk profile of individual countries. They can also support the development of different strategies for both domestic production and international trade to reduce composite drought risk.

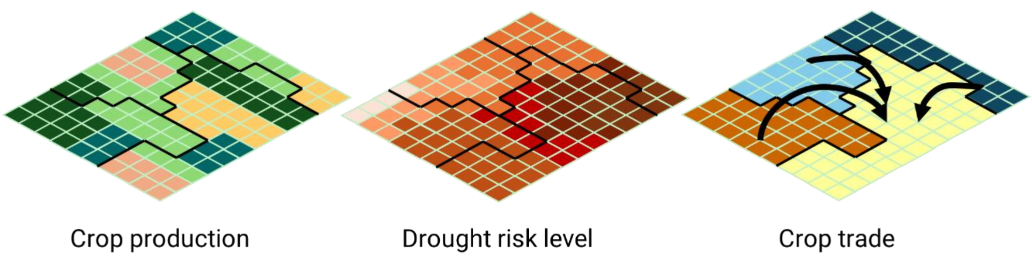

*Figure 1. Composite drought risk method description. Colours represent different crop types on left panel, drought risk level on middle panel, and countries on right panel. Black borders indicate country borders and black arrows the direction of crop trade.*

### *2.2.4 Bilateral trade connections*

The framework also quantifies the drought risk of individual bilateral trades, which enables the identification of potential external vulnerabilities to a country's food security. We defined critical trade connections as those in which at least 10% of a country's total caloric intake for a specific crop is sourced from high or very high drought risk regions from a single partner country. The 10% threshold is chosen for scalability and realism (Bren D'Amour et al., 2016). We then determined the number of critical trade connections affecting each conflict-affected country. Identifying critical trade connections can support trade policies aimed at trade diversification.

## 3. Results

### *3.1 Domestic crop production and imports in conflict-affected countries*

16 out of 23 countries, mainly located in Eastern, Middle, and Western Africa, source most of their calories from domestic production, with most countries importing less than 10% of the domestic production (Table 1). However, seven countries import more calories than they produce domestically. They are mainly from the Middle East (6.52 average import/domestic ratio) and Northern Africa (5.73 ratio), with Lebanon (17.91) and Libya (14.64) showing the highest ratios among all countries analysed. Latin America (Colombia and Mexico) also imports more than it produces, but at lower ratios (2.10). Southeast Asia shows in general low imports (0.14 ratio), but countries like Pakistan and Sri Lanka import the equivalence of 43 and 44% of their domestic production, respectively. In Southeast Asia, Philippines show an import/domestic ratio of 0.27 while Myanmar does not engage in trade.

***Table 1.*** *Crop production and import dependency in conflict-affected countries. Selected countries, domestic crop production (kcal), crop imports (kcal).*

| Region | Country | Domestic production (billions kcal) | Crop imports (billions kcal) | Import/Domestic Ratio |
|---|---|---|---|---|
| Eastern Africa | Burundi | 271 | 58 | 0.2 |
| | Uganda | 1911 | 239 | 0.1 |
| Latin America | Colombia | 1945 | 4349 | 2.2 |
| | Mexico | 12631 | 24747 | 2.0 |
| Middle Africa | Central African Republic | 170 | 2 | 0.0 |
| | Cameroon | 1463 | 165 | 0.1 |
| | Democratic Republic of the Congo | 3773 | 194 | 0.1 |
| Middle East | Iraq | 1386 | 412 | 0.3 |
| | Lebanon | 54 | 972 | 17.9 |

| | | | | |
|---|---|---|---|---|
| | Syria | 1510 | 2917 | 1.9 |
| | Yemen | 200 | 1186 | 5.9 |
| Northern Africa | Algeria | 1253 | 2917 | 2.3 |
| | Libya | 79 | 1154 | 14.6 |
| | Sudan | 2077 | 464 | 0.2 |
| South Asia | Afghanistan | 1704 | 312 | 0.2 |
| | Nepal | 3037 | 742 | 0.2 |
| | Pakistan | 12661 | 5435 | 0.4 |
| | Sri Lanka | 1417 | 629 | 0.4 |
| Southeast Asia | Myanmar | 11140 | 163 | 0.0 |
| | Philippines | 8507 | 2264 | 0.3 |
| Western Africa | Mali | 2093 | 89 | 0.0 |
| | Niger | 1522 | 38 | 0.0 |
| | Nigeria | 16743 | 1211 | 0.1 |

### *3.2 Drought risk in domestic crop production*

Coupling domestic crop production with corresponding drought risk levels indicates that 16 countries have at least 30% of their domestic crop production affected by high or very high drought risk (Table 2). Furthermore, 11 of these countries have over 50% of their domestic crop production in areas with high or very high drought levels. Yemen (99.7%), Pakistan (97.5%), Iraq (91.9%), Afghanistan (91.8%), Sudan (87.4%), Libya (86.6%), and Sri Lanka (80.9%) face the highest domestic risk, with over three-quarters of their total production in high or very high drought risk level areas. Conversely, countries like Nigeria (2.2%), Central African Republic (2.6%), Myanmar (5.9%), Uganda (8.3%) and Cameroon (10.9%) present the lowest drought risk in domestic crop production. Regional analysis indicates the Middle East and North Africa as regions with the highest relative production in high and very high risk (average of 83.7%), while Eastern, Middle, and Western Africa display the lowest contributions from high and very high drought risk in their domestic crop production (17.3% on average).

***Table 2.*** *Percentage of domestic production under different drought risk categories. Drought risk categories range from Very Low to Very High.*

| **Region** | **Country** | **Relative domestic production per risk category (%)** | | | | |
|---|---|---|---|---|---|---|
| | | **Very Low** | **Low** | **Medium** | **High** | **Very High** |
| South Asia | Afghanistan | 4 | 2 | 2 | 4 | 88 |
| South Asia | Pakistan | 0 | 0 | 2 | 13 | 85 |
| Northern Africa | Sudan | 0 | 8 | 4 | 5 | 83 |
| Middle East | Iraq | 1 | 2 | 5 | 13 | 79 |
| South Asia | Sri Lanka | 0 | 10 | 9 | 17 | 64 |
| Northern Africa | Libya | 0 | 1 | 13 | 24 | 63 |
| Middle East | Lebanon | 0 | 19 | 12 | 12 | 57 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Middle East | Yemen | 0 | 0 | 0 | 47 | 53 |
| Middle East | Syria | 0 | 2 | 21 | 25 | 52 |
| Northern Africa | Algeria | 3 | 8 | 15 | 33 | 42 |
| Latin America | Mexico | 28 | 14 | 10 | 14 | 35 |
| South Asia | Nepal | 12 | 18 | 23 | 15 | 32 |
| Western Africa | Mali | 41 | 20 | 6 | 3 | 31 |
| Western Africa | Niger | 15 | 23 | 12 | 30 | 20 |
| Southeast Asia | Philippines | 6 | 25 | 23 | 26 | 20 |
| Eastern Africa | Burundi | 15 | 27 | 43 | 3 | 12 |
| Latin America | Colombia | 46 | 15 | 7 | 20 | 11 |
| Middle Africa | Cameroon | 68 | 14 | 8 | 2 | 9 |
| Southeast Asia | Myanmar | 43 | 45 | 7 | 3 | 3 |
| Middle Africa | Central African Republic | 97 | 0 | 1 | 1 | 2 |
| Middle Africa | Democratic Republic of the Congo | 32 | 10 | 41 | 15 | 2 |
| Eastern Africa | Uganda | 14 | 53 | 25 | 8 | 1 |
| Western Africa | Nigeria | 70 | 24 | 4 | 2 | 0 |

### *3.3 Import-related drought risk implications*

Beyond analysing the drought risks in domestic production, we also include imported crops and their corresponding drought risk to quantify the changes in the composite drought risk that countries may face by engaging in international trade (Figure 2a). 14 out of 23 countries exhibit a shift of at least 10% in their drought risk profile when including crop imports: risk decreases for 9 countries and increases for 5. Countries with large shares of domestic production in high and very high drought risk areas considerably decrease their composite drought risk by importing crops, up to 40%-50% in case of Yemen and Libya. Countries with little domestic crop production in high and very high risk areas experience mild increases in their composite drought risk due to crop imports.

Figure 2b presents the share of total crop calories sourced from high and very high drought risk areas, distinguishing between domestic production and imports. For the majority of conflict-affected countries (17) the main source of high and very high drought risk originates from domestic production. Among the highest-risk countries (Afghanistan, Sudan, Iraq, Pakistan and Sri Lanka), drought risk is dominated by domestic production, making up over 80% of the combined high and very high drought risk levels, and over 50% of the composite drought risk. Nevertheless, import-related drought are still a risk factor as they account in 18 out of 23 countries for at least 10% of their high and very high drought risk. Countries like Lebanon, Libya, Yemen, Syria, Mexico, Colombia and Algeria have over 50% of their high and very high drought risk from imported crops. Despite the risk-reduction effects of imports observed for many of these countries, a high dependency on crop imports indicates their food security remains vulnerable to droughts beyond their borders. The countries in the bottom of the figures present little drought risk from both domestic and imported sources.

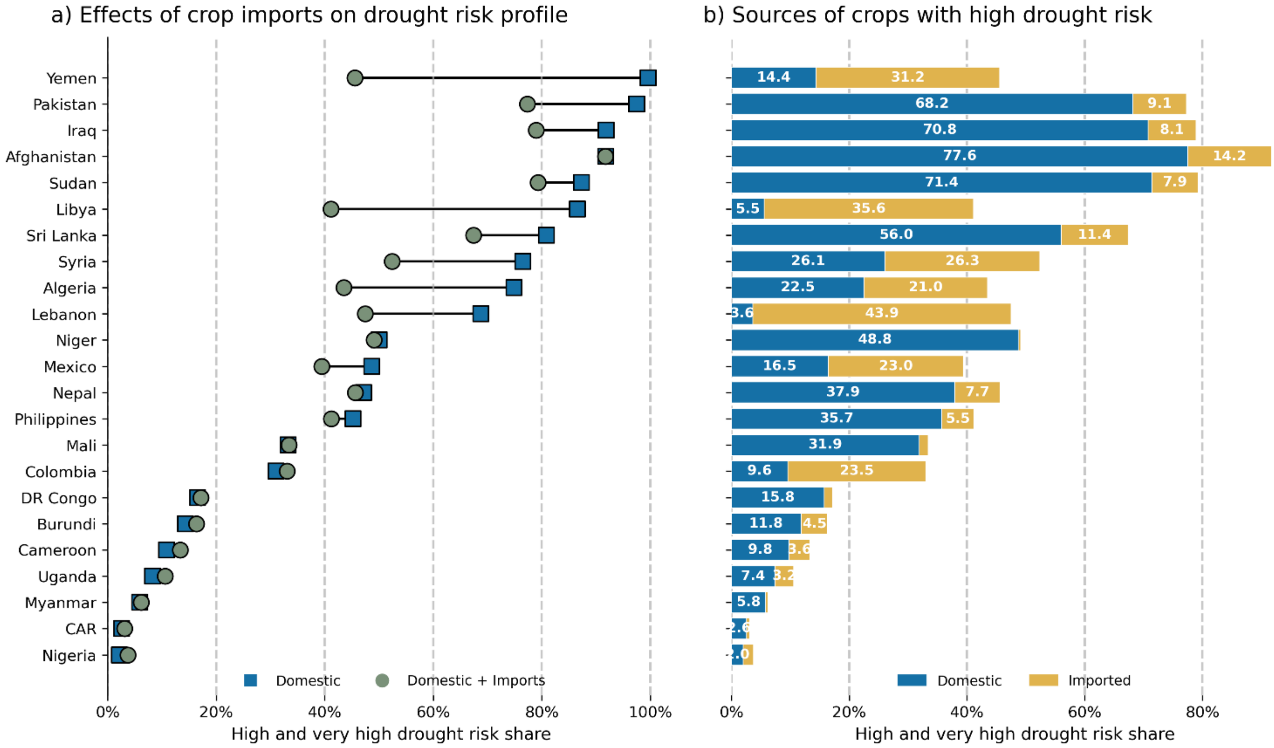


***Figure 2.*** *a) Comparison of drought risk profiles in conflict-affected countries considering domestic production only and including crop imports. Blue squares represent domestic production only, while green circles include imports. b) Composition of high and very high drought risk by source. Bars represent the percentage of total calories derived from high and very drought risk areas, subdivided into domestic production (blue) and imports (golden).*

### *3.4 Drought risk profiles of conflict-affected countries*

Figure 3 maps each conflict-affected country's domestic drought against their import dependency, clustering countries with similar profiles. In cluster 1, Afghanistan, Sudan, Iraq, Pakistan, and Sri Lanka display high drought risk in domestic production (>80%) and low import dependency (<40%). On the left side of the figure, cluster 2, with Niger, Mali, Nepal and Philippines, indicates moderate drought risk in domestic production (approximately 50%) and low dependency on crop imports (<25%). In cluster 3, Central African Republic (CAR), Nigeria, Myanmar, Uganda, and Cameroon, Democratic Republic of the Congo (DR Congo) and Burundi, demonstrate both low drought risk in domestic production and limited import dependency, representing the most drought-resilient profile overall. Countries in cluster 4 (Yemen, Libya, Syria, and Algeria) face both high drought risk in domestic production (>60%) and high import dependency (>60%). Colombia and Mexico, cluster 5, reveal drought risk in domestic production between 30% and 50%, and high import dependency (>60%). Mexico slightly reduces its drought risk with imports, Colombia slightly increases its drought risk. Top clusters show a higher risk in domestic production than in crop imports (red dots), while bottom clusters indicate the opposite (blue dots).

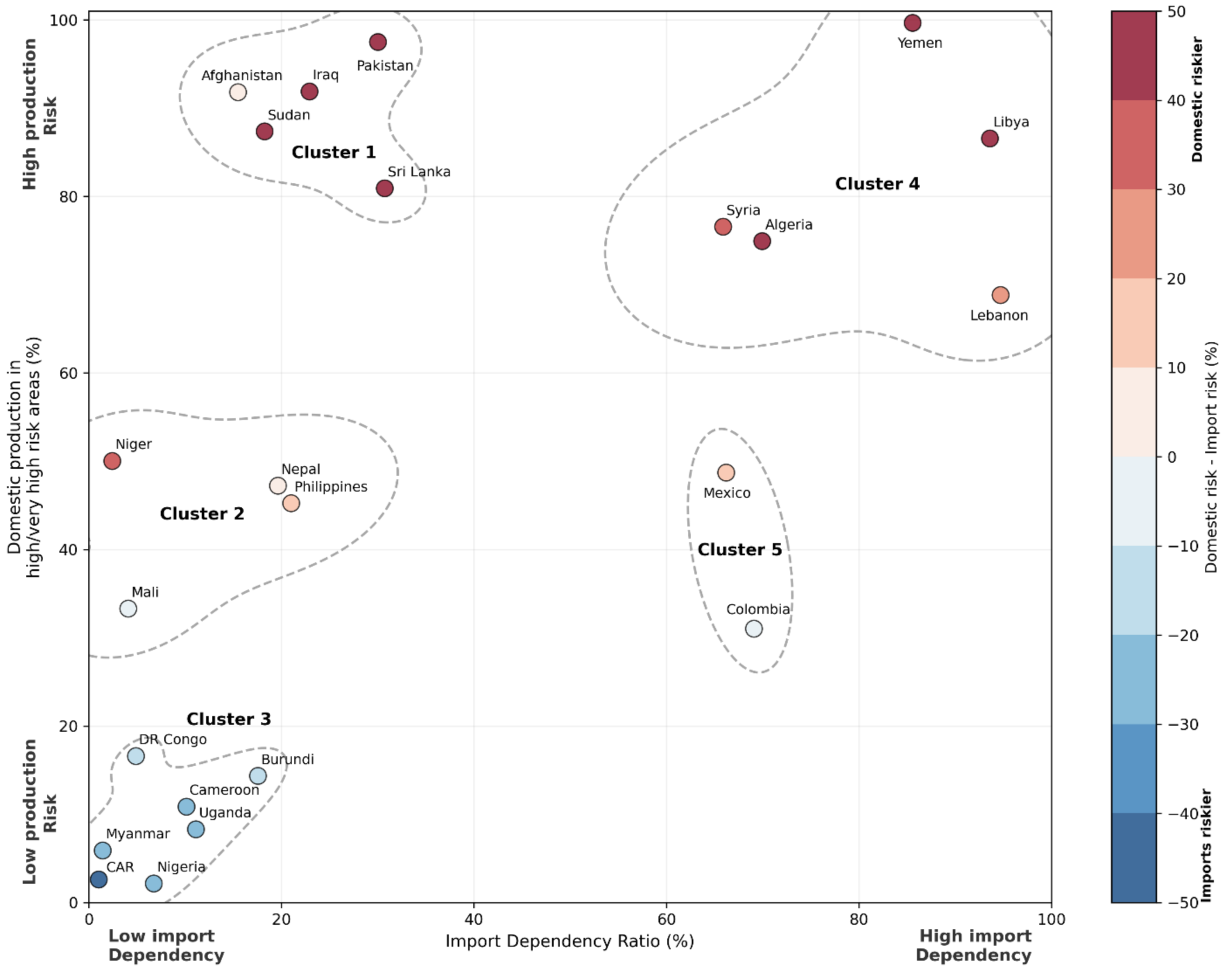


***Figure 3.*** *Drought risk profiles of conflict-affected countries across domestic and import-related risk exposure. Colours indicate the risk differential between domestic production and imports (red indicating domestic risk exceeds imported risk and blue vice versa). Dashed contour lines represent clusters of countries with similar risk profiles.*

### *3.5 Critical trade connections*

We identify critical trade connections between crop-country combinations. Their total count provides an estimate of the number of external vulnerabilities to a country's food security. All conflict-affected countries exhibit at least one critical trade connection, with Lebanon, Algeria, Sudan and Libya showing the highest numbers (Figure 4a), suggesting broader risk sources to their food security. We can also investigate the individual critical trade connections to a country to understand specific vulnerabilities, such as crops and partner countries. For example, Lebanon imports over 90% of its rice consumption from areas facing high or very high drought risk in Russia (Figure 4b), indicating a concentrated risk to drought events in Russia. Diversifying import partners could reduce the risk of rice shortages.

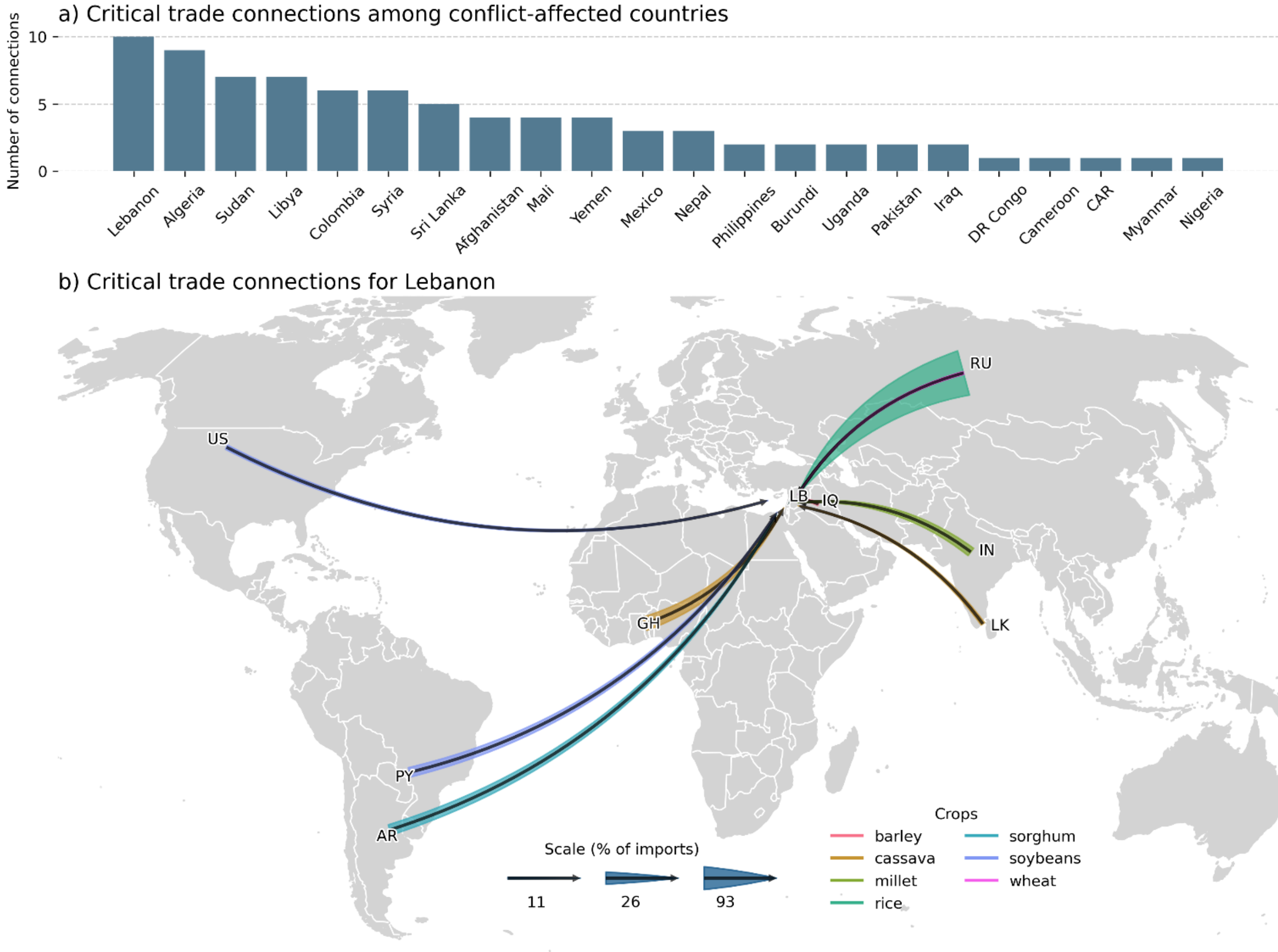


***Figure 4.*** *a) Number of critical trade connections among conflict-affected countries. b) Visual demonstration of the critical trade connections for Lebanon. Colours indicate the type of crop, and the width of the connecting arrows represent the magnitude of the trade connection (%). Acronyms indicate each country's name.*

## 4. Discussion

Drought events can exacerbate both food insecurity and conflicts, which are on their own mutually reinforcing (Jaramillo et al., 2023; C. Sova et al., 2023; Tschunkert & Delgado, 2022). In an interconnected global food system, many countries depend on food imports, potentially mitigating domestic drought vulnerability but making them vulnerable to droughts outside of their borders. This study incorporates international crop trade information into drought risk assessment to understand the role of crop imports in the drought risk profile of conflict-affected countries, and to identify critical trade connections that may amplify food insecurity.

### 4.1 Crop imports matter for drought risk assessment

Domestic production is the primary driver of drought risk to crop consumption in most conflict-affected countries, largely because the majority of their calories are sourced domestically. However, crop imports are still relevant for many countries as they shift composite drought risk considerably: at least 10% changes in 14 out of 23 countries, and up to 40-50% reductions in Middle Eastern and North African countries. Crop imports also introduce drought risk from trading partners, accounting for at least 10% of high drought risk in 18 countries, and reaching approximately 90% in cases like Lebanon and Libya. Other studies documented approximate results by analysing vulnerabilities to remote disruptions and shocks in similar regions (Bren D'Amour et al., 2016; Burkholz & Schweitzer, 2019).

Recent studies found that climate-related hazards in exporting regions, like droughts, matters when assessing importing countries' food security (Brás et al., 2019; Ercin et al., 2021). Our results reinforce these findings by showing that the inclusion of crop imports alters drought risk profiles in many conflict-affected countries. Since food security forms an important mediating variable in climate-conflict pathways, we argue that studies focusing solely on domestic drought risk can present an incomplete picture of the dynamics between climate, food security and violent conflict.

## 4.2 Potential strategies based on composite drought risk profiles

The findings of this study have policy making implications and can be used to support tailored strategies to countries in different circumstances. Countries that have high domestic production risk but have low import dependency (e.g., Afghanistan and Sudan from cluster 1 in Figure 4) can improve domestic crop production e.g., through improved water management, or shifting to more drought-resistant crop varieties and types (Mustafa et al., 2019; Talebian et al., 2024). Such countries can also explore opportunities to increase crop imports from low drought risk regions or pursue internal cooperation (Kuhla et al., 2024), such as regional trade agreements with grain reserves (Kornher & Kalkuhl, 2016). Countries with both high domestic risk and high import dependency (e.g., Yemen, Libya, cluster 4) can combine efforts to reduce domestic vulnerability with actions to diversify imports. Some of these countries face arid desert conditions that limit domestic agriculture expansion (Bren D'Amour et al., 2016), and focus should be in diversifying towards trade partners in low-drought risk areas (Aguiar et al., 2020). Critical trade connection can help identify the riskiest import partners. Countries with low domestic drought risk but high import dependence (cluster 5) can expand their low drought risk crop production areas, or diversify imports to lower risk areas. Countries with the lowest composite drought risk and low import dependency (cluster 3) can maintain their current approach to domestic crop production, while monitoring for potential changes in demand or climate conditions. This latter group of countries, however, may play a mitigating role in reducing drought risk exposure in other countries: if they expand their domestic production and export additional production under low drought risk, they may pre-empt the need to produce those crops in high drought risk countries that import from them (Hogeboom, 2020). A readily available strategy for all countries is to identify their main drought risk vulnerabilities domestically and remotely. Mapping vulnerabilities and critical trade connections helps to better direct resources towards monitoring and anticipating drought conditions in key domestic or external areas (Busker et al., 2023; Funk et al., 2019).

## 4.3 Limitations and future research

Our study focused solely on the drought aspect of food security. However, food security is a complex topic with multiple drivers and interactions, including other climate hazards, conflicts, displacement and economic drivers (FSIN, 2024). While the drought risk data accounts for crop-specific water requirements in its calculations (Meza et al., 2020), the final risk values are aggregated across all crops within each grid cell, which may not fully capture the specific drought vulnerabilities of individual crop types (Dietz et al., 2021). International food trade is both complex and data sensitive. While the most comprehensive public database for food trade, the FAO trade matrix does not have data for all countries and trade flows, possibly due to countries not disclosing their trade partnerships, limiting the number of countries included in the analysis. Additionally, drought risk, crop production and crop trade data are averages of past time periods, which may not reflect future conditions under climate change. Our analysis also does not account for indirect effects such as the role of intermediate countries in trade and food processing, which exclude other potential trade chain disruptions (Burkholz & Schweitzer, 2019).

Besides including import-related drought risk, future research could also account for changes in future drought risk (Qi et al., 2022), crop production and consumption (Lehtonen et al., 2021), and trade policies (Wu et al., 2024). Storyline approaches can explore these scenarios through specific event sequences and quantifying cascading effects (Goulart et al., 2021; van den Hurk et al., 2023). Studies could also consider water footprint to include virtual water trading, which accounts for intermediaries between crop producing and consuming regions (Hogeboom, 2020). Additionally, future studies could explore interannual variability of droughts and crop trades, or investigate the potential uses and benefits of early warning systems (such as seasonal weather forecasts) combined with our method.

## 5. Conclusions

This study investigates drought risk to crop consumption in 23 conflict-affected countries, considering both domestic production and imports. While domestic production accounts for the majority of composite drought risk, crop imports both alter the drought risk profiles in most countries and add considerable sources of high drought risk from remote areas. Food security assessment studies should therefore incorporate both domestic and remote drought risks, particularly in the climate-conflict research area. We propose a method to identify critical trade connections between country-crop combinations to support targeted actions, and suggest ways to use this information in strategies to reduce the risk of droughts and improve food security in conflict-affected countries.

## Code availability

The code used in this study is available at https://github.com/dumontgoulart/crop_imports_drought_risk.

## Data availability

The drought risk dataset is available at (Meza et al., 2020). Crop yield data is available at (Mialyk et al., 2024). The drought risk data produced in this study for conflict-affected countries, including national crop production and imports, is available at https://github.com/dumontgoulart/crop_imports_drought_risk.

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## References

Adaawen, S., Rademacher-Schulz, C., Schraven, B., & Segadlo, N. (2019). *Drought, migration, and conflict in sub-Saharan Africa: what are the links and policy options? 2*, 15–31. https://doi.org/10.1016/B978-0-12-814820-4.00002-X

Aguiar, S., Texeira, M., Garibaldi, L. A., & Jobbágy, E. G. (2020). Global changes in crop diversity: Trade rather than production enriches supply. *Global Food Security*, *26*, 100385. https://doi.org/10.1016/J.GFS.2020.100385

Anderson, W., Taylor, C., McDermid, S., Ilboudo-Nébié, E., Seager, R., Schlenker, W., Cottier, F., de Sherbinin, A., Mendeloff, D., & Markey, K. (2021). Violent conflict exacerbated drought-related food insecurity between 2009 and 2019 in sub-Saharan Africa. *Nature Food 2021 2:8*, *2*(8), 603–615. https://doi.org/10.1038/s43016-021-00327-4

Bellemare, M. F. (2015). Rising Food Prices, Food Price Volatility, and Social Unrest. *American Journal of Agricultural Economics*, *97*(1), 1–21. https://doi.org/10.1093/AJAE/AAU038

Bowen, S., Elliott, S., & Hardison-Moody, A. (2021). The structural roots of food insecurity: How racism is a fundamental cause of food insecurity. *Sociology Compass*, *15*(7), e12846. https://doi.org/10.1111/SOC4.12846

Brás, T. A., Jägermeyr, J., & Seixas, J. (2019). Exposure of the EU-28 food imports to extreme weather disasters in exporting countries. *Food Security*, *11*(6), 1373–1393. https://doi.org/10.1007/S12571-019-00975-2/FIGURES/6

Bren D'Amour, C., Bren D'Amour, C., Bren D'Amour, C., & Anderson, W. (2020). International trade and the stability of food supplies in the Global South. *Environmental Research Letters*, *15*(7), 074005. https://doi.org/10.1088/1748-9326/AB832F

Bren D'Amour, C., Wenz, L., Kalkuhl, M., Christoph Steckel, J., & Creutzig, F. (2016). Teleconnected food supply shocks. *Environmental Research Letters*, *11*(3), 035007. https://doi.org/10.1088/1748-9326/11/3/035007

Brück, T., & d'Errico, M. (2019). Reprint of: Food security and violent conflict: Introduction to the special issue. *World Development*, *119*, 145–149. https://doi.org/10.1016/J.WORLDDEV.2019.04.006

Burkholz, R., & Schweitzer, F. (2019). International crop trade networks: the impact of shocks and cascades. *Environmental Research Letters*, *14*(11), 114013. https://doi.org/10.1088/1748-9326/AB4864

Busker, T., de Moel, H., van den Hurk, B., & Aerts, J. C. J. H. (2023). Impact-based seasonal rainfall forecasting to trigger early action for droughts. *Science of The Total Environment*, *898*, 165506. https://doi.org/10.1016/J.SCITOTENV.2023.165506

Calì, M. (2014). Trading Away from Conflict: Using Trade to Increase Resilience in Fragile States. In *Trading Away from Conflict: Using Trade to Increase Resilience in Fragile States*. https://doi.org/10.1596/978-1-4648-0308-6

Ceriani, L., & Verme, P. (2016). The World Bank's Classification of Countries by Income. *Journal of Development Studies*, *50*(11), 1510–1522. https://doi.org/10.1080/00220388.2014.951037

Christian, J. I., Basara, J. B., Hunt, E. D., Otkin, J. A., & Xiao, X. (2020). Flash drought development and cascading impacts associated with the 2010 Russian heatwave. *Environmental Research Letters*, *15*(9), 094078. https://doi.org/10.1088/1748-9326/AB9FAF

Dahm, R., Meijer, K., Kuneman, E., & van Schaik, L. (2023). What climate? The different meaning of climate indicators in violent conflict studies. *Climatic Change*, *176*(11), 1–23. https://doi.org/10.1007/S10584-023-03617-X/FIGURES/2

Dall'Erba, S., Chen, Z., & Nava, N. J. (2021). U.S. Interstate Trade Will Mitigate the Negative Impact of Climate Change on Crop Profit. *American Journal of Agricultural Economics*, *103*(5), 1720–1741. https://doi.org/10.1111/AJAE.12204

Davies, S., Pettersson, T., & Öberg, M. (2023). Organized violence 1989–2022, and the return of conflict between states. *Journal of Peace Research*, *60*(4), 691–708. https://doi.org/10.1177/00223433231185169/ASSET/805FB54C-9DC7-42DB-B7FA-D236FBD75470/ASSETS/IMAGES/LARGE/10.1177_00223433231185169-FIG6.JPG

Dietz, K. J., Zörb, C., & Geilfus, C. M. (2021). Drought and crop yield. *Plant Biology*, *23*(6), 881–893. https://doi.org/10.1111/PLB.13304

Ercin, E., Veldkamp, T. I. E., & Hunink, J. (2021). Cross-border climate vulnerabilities of the European Union to drought. *Nature Communications 2021 12:1*, *12*(1), 1–10. https://doi.org/10.1038/s41467-021-23584-0

FAO. (2024). *FAOSTAT TM Trade Matrix Database*. FAO. https://www.fao.org/faostat/en/#data/TCL

FSIN. (2024). *Global Report on Food Crises (GRFC) 2024*. https://www.fsinplatform.org/report/global-report-food-crises-2024

Funk, C., Shukla, S., Thiaw, W. M., Rowland, J., Hoell, A., Mcnally, A., Husak, G., Novella, N., Budde, M., Peters-Lidard, C., Adoum, A., Galu, G., Korecha, D., Magadzire, T., Rodriguez, M., Robjhon, M., Bekele, E., Arsenault, K., Peterson, P., … Verdin, J. (2019). Recognizing the Famine Early Warning Systems Network: Over 30 Years of Drought Early Warning Science Advances and Partnerships Promoting Global Food Security. *Bulletin of the American Meteorological Society*, *100*(6), 1011–1027. https://doi.org/10.1175/BAMS-D-17-0233.1

Gaupp, F., Hall, J., Hochrainer-Stigler, S., & Dadson, S. (2019). Changing risks of simultaneous global breadbasket failure. *Nature Climate Change 2019 10:1*, *10*(1), 54–57. https://doi.org/10.1038/s41558-019-0600-z

Goulart, H. M. D., Van Der Wiel, K., Folberth, C., Balkovic, J., & Van Den Hurk, B. (2021). Storylines of weather-induced crop failure events under climate change. *Earth System Dynamics*, *12*(4), 1503–1527. https://doi.org/10.5194/ESD-12-1503-2021

Goulart, H. M. D., van der Wiel, K., Folberth, C., Boere, E., & van den Hurk, B. (2023). Increase of Simultaneous Soybean Failures Due To Climate Change. *Earth's Future*, *11*(4), e2022EF003106. https://doi.org/10.1029/2022EF003106

Gundersen, C., & Ziliak, J. P. (2018). Food Insecurity Research in the United States: Where We Have Been and Where We Need to Go. *Applied Economic Perspectives and Policy*, *40*(1), 119–135. https://doi.org/10.1093/AEPP/PPX058

Hagenlocher, M., Meza, I., Anderson, C. C., Min, A., Renaud, F. G., Walz, Y., Siebert, S., & Sebesvari, Z. (2019). Drought vulnerability and risk assessments: state of the art, persistent gaps, and research agenda. *Environmental Research Letters*, *14*(8), 083002. https://doi.org/10.1088/1748-9326/AB225D

Hamed, R., Lesk, C., Shepherd, T. G., Goulart, H. M. D., van Garderen, L., van den Hurk, B., & Coumou, D. (2025). One-third of the global soybean production failure in 2012 is attributable to climate change. *Communications Earth & Environment 2025 6:1*, *6*(1), 1–9. https://doi.org/10.1038/s43247-025-02171-x

Hameed, M., Ahmadalipour, A., & Moradkhani, H. (2020). Drought and food security in the middle east: An analytical framework. *Agricultural and Forest Meteorology*, *281*, 107816. https://doi.org/10.1016/J.AGRFORMET.2019.107816

Hasegawa, T., Sakurai, G., Fujimori, S., Takahashi, K., Hijioka, Y., & Masui, T. (2021). Extreme climate events increase risk of global food insecurity and adaptation needs. *Nature Food 2021 2:8*, *2*(8), 587–595. https://doi.org/10.1038/s43016-021-00335-4

Hogeboom, R. J. (2020). The Water Footprint Concept and Water's Grand Environmental Challenges. *One Earth*, *2*(3), 218–222. https://doi.org/10.1016/j.oneear.2020.02.010

Holleman, C., Jackson, J., Sánchez, M. V., & Vos, R. (2017). *Sowing the seeds of peace for food security. Disentangling the nexus between conflict, food security and peace*. https://ageconsearch.umn.edu/record/296657

Jagermeyr, J., Robock, A., Elliott, J., Muller, C., Xia, L., Khabarov, N., Folberth, C., Schmid, E., Liu, W., Zabel, F., Rabin, S. S., Puma, M. J., Heslin, A., Franke, J., Foster, I., Asseng, S., Bardeen, C. G., Toon, O. B., & Rosenzweig, C. (2020). A regional nuclear conflict would compromise global food security. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(13), 7071–7081. https://doi.org/10.1073/PNAS.1919049117/SUPPL_FILE/PNAS.1919049117.SAPP.PDF

Jaramillo, L., Cebotari, A., Diallo, Y., Gupta, R., & Koshima, Y. (2023). *Climate challenges in fragile and conflict-affected states*. https://books.google.com/books?hl=en&lr=&id=j2_VEAAAQBAJ&oi=fnd&pg=PP1&dq=Climate+Challenges+in+Fragile+and+Conflict-Affected+States+By+Laura+Jaramill&ots=Q0oNR7E9ZN&sig=qV6NwBwT2BE0mrM2lkzjT9aSbSs

van den Hurk, B., Baldissera Pacchetti, M., Boere, E., Ciullo, A., Coulter, L., Dessai, S., Ercin, E., Goulart, H. M. D., Hamed, R., Hochrainer-Stigler, S., Koks, E., Kubiczek, P., Levermann, A., Mechler, R., van

Meersbergen, M., Mester, B., Middelanis, R., Minderhoud, K., Mysiak, J., ... Witpas, K. (2023). Climate impact storylines for assessing socio-economic responses to remote events. *Climate Risk Management*, *40*, 100500. https://doi.org/10.1016/J.CRM.2023.100500

Johnstone, S., & Mazo, J. (2011). Global warming and the Arab spring. *Survival*, *53*(2), 11–17. https://doi.org/10.1080/00396338.2011.571006/ASSET//CMS/ASSET/5F5B0984-69EB-4AE4-898E-ABEF2C372D63/00396338.2011.571006.FP.PNG

Kogan, F., Guo, W., & Yang, W. (2019). Drought and food security prediction from NOAA new generation of operational satellites. *Geomatics, Natural Hazards and Risk*, *10*(1), 651–666. https://doi.org/10.1080/19475705.2018.1541257

Kornher, L., & Kalkuhl, M. (2016). The costs and benefits of regional cooperation on grain reserves: The case of ECOWAS. *Food Price Volatility and Its Implications for Food Security and Policy*, 353–384. https://doi.org/10.1007/978-3-319-28201-5_15/TABLES/8

Kuhla, K., Puma, M. J., & Otto, C. (2024). International cooperation was key to stabilize wheat prices after the Russian Invasion of Ukraine. *Communications Earth & Environment 2024 5:1*, *5*(1), 1–15. https://doi.org/10.1038/s43247-024-01638-7

Kummu, M., Kinnunen, P., Lehikoinen, E., Porkka, M., Queiroz, C., Röös, E., Troell, M., & Weil, C. (2020). Interplay of trade and food system resilience: Gains on supply diversity over time at the cost of trade independency. *Global Food Security*, *24*, 100360. https://doi.org/10.1016/J.GFS.2020.100360

Lehtonen, H. S., Aakkula, J., Fronzek, S., Helin, J., Hildén, M., Huttunen, S., Kaljonen, M., Niemi, J., Palosuo, T., Pirttioja, N., Rikkonen, P., Varho, V., & Carter, T. R. (2021). Shared socioeconomic pathways for climate change research in Finland: co-developing extended SSP narratives for agriculture. *Regional Environmental Change*, *21*(1), 1–16. https://doi.org/10.1007/S10113-020-01734-2/TABLES/2

Lin, F., Li, X., Jia, N., Feng, F., Huang, H., Huang, J., Fan, S., Ciais, P., & Song, X. P. (2023). The impact of Russia-Ukraine conflict on global food security. *Global Food Security*, *36*, 100661. https://doi.org/10.1016/J.GFS.2022.100661

Mach, K. J., Kraan, C. M., Adger, W. N., Buhaug, H., Burke, M., Fearon, J. D., Field, C. B., Hendrix, C. S., Maystadt, J. F., O'Loughlin, J., Roessler, P., Scheffran, J., Schultz, K. A., & von Uexkull, N. (2019). Climate as a risk factor for armed conflict. *Nature 2019 571:7764*, *571*(7764), 193–197. https://doi.org/10.1038/s41586-019-1300-6

Martin, M. S., Maddocks, E., Chen, Y., Gilman, S. E., & Colman, I. (2016). Food insecurity and mental illness: disproportionate impacts in the context of perceived stress and social isolation. *Public Health*, *132*, 86–91. https://doi.org/10.1016/J.PUHE.2015.11.014

Martin-Shields, C. P., & Stojetz, W. (2019). Food security and conflict: Empirical challenges and future opportunities for research and policy making on food security and conflict. *World Development*, *119*, 150–164. https://doi.org/10.1016/J.WORLDDEV.2018.07.011

Meza, I., Siebert, S., Döll, P., Kusche, J., Herbert, C., Rezaei, E. E., Nouri, H., Gerdener, H., Popat, E., Frischen, J., Naumann, G., Vogt, J. V., Walz, Y., Sebesvari, Z., & Hagenlocher, M. (2020). Global-scale drought risk assessment for agricultural systems. *Natural Hazards and Earth System Sciences*, *20*(2), 695–712. https://doi.org/10.5194/NHESS-20-695-2020

Mialyk, O., Schyns, J. F., Booij, M. J., Su, H., Hogeboom, R. J., & Berger, M. (2024). Water footprints and crop water use of 175 individual crops for 1990–2019 simulated with a global crop model. *Scientific Data 2024 11:1*, *11*(1), 1–16. https://doi.org/10.1038/s41597-024-03051-3

Mottaleb, K. A., Kruseman, G., & Snapp, S. (2022). Potential impacts of Ukraine-Russia armed conflict on global wheat food security: A quantitative exploration. *Global Food Security*, *35*, 100659. https://doi.org/10.1016/J.GFS.2022.100659

Mustafa, M. A., Mayes, S., & Massawe, F. (2019). Crop Diversification Through a Wider Use of Underutilised Crops: A Strategy to Ensure Food and Nutrition Security in the Face of Climate Change. *Sustainable Solutions for Food Security: Combating Climate Change by Adaptation*, 125–149. https://doi.org/10.1007/978-3-319-77878-5_7

Puma, M. J., Bose, S., Chon, S. Y., & Cook, B. I. (2015). Assessing the evolving fragility of the global food system. *Environmental Research Letters*, *10*(2), 024007. https://doi.org/10.1088/1748-9326/10/2/024007

Qi, W., Feng, L., Yang, H., & Liu, J. (2022). Increasing Concurrent Drought Probability in Global Main Crop Production Countries. *Geophysical Research Letters*, *49*(6), e2021GL097060. https://doi.org/10.1029/2021GL097060

Sardo, M., Epifani, I., D'Odorico, P., Galli, N., & Rulli, M. C. (2023). Exploring the water–food nexus reveals the interlinkages with urban human conflicts in Central America. *Nature Water 2023 1:4*, *1*(4), 348–358. https://doi.org/10.1038/s44221-023-00053-0

Soffiantini, G. (2020). Food insecurity and political instability during the Arab Spring. *Global Food Security*, *26*, 100400. https://doi.org/10.1016/J.GFS.2020.100400

Sova, C., Fountain, G., Zembilci, E., & Carr, T. (2023). *Dangerously Hungry: The Link Between Food Insecurity and Conflict*.

Sternberg, T. (2012). Chinese drought, bread and the Arab Spring. *Applied Geography*, *34*, 519–524. https://doi.org/10.1016/J.APGEOG.2012.02.004

Talebian, S., Lager, F., Harris, K., & Cole, M. (2024). *Solutions for managing food security risks in a rapidly changing geopolitical landscape*. https://doi.org/10.51414/SEI2024.044

Tschunkert, K., & Delgado, C. (2022). *Food Systems in Conflict and Peacebuilding Settings: Ways Forward*. https://doi.org/10.55163/SSKG9519

Vogt, J. V, Naumann, G., Masante, D., Spinoni, J., Cammalleri, C., Erian, W., Pischke, F., Pulwarty, R., & Barbosa, P. (2018). Drought Risk Assessment. A conceptual Framework. In *publications.jrc.ec.europa.eu*. https://doi.org/10.2760/057223

Von Uexkull, N. (2014). Sustained drought, vulnerability and civil conflict in Sub-Saharan Africa. *Political Geography*, *43*, 16–26. https://doi.org/10.1016/J.POLGEO.2014.10.003

Von Uexkull, N., Croicu, M., Fjelde, H., & Buhaug, H. (2016). Civil conflict sensitivity to growing-season drought. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(44), 12391–12396. https://doi.org/10.1073/PNAS.1607542113/SUPPL_FILE/PNAS.201607542SI.PDF

World Bank. (2020). *World Bank Group Strategy for Fragility, Conflict, and Violence 2020–2025*. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/844591582815510521/world-bank-group-strategy-for-fragility-conflict-and-violence-2020-2025

Wu, D., Chen, J., Xiong, L., Lee, J. H., Kim, J. S., & Moon, H. T. (2024). Assessing global drought conditions under climate change: A comparison of stationary and non-stationary approaches and identification of hotspot regions. *Journal of Hydrology*, *640*, 131663. https://doi.org/10.1016/J.JHYDROL.2024.131663