International cooperation could help avert a major food crisis due to the Russian invasion of Ukraine

Kilian Kuhla
Potsdam Institute for Climate Impact Research https://orcid.org/0000-0002-8698-1246

Michael Puma (mjp38@columbia.edu)
Columbia University https://orcid.org/0000-0002-4255-8454

Jacob Schewe
Potsdam Institute for Climate Impact Research https://orcid.org/0000-0001-9455-4159

Patryk Kubiczek
Potsdam Institute for Climate Impact Research https://orcid.org/0000-0002-4979-9496

Christian Otto
Potsdam Institute for Climate Impact Research https://orcid.org/0000-0001-5500-6774

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Abstract

The Russian invasion of Ukraine is a major threat to the global food system. We explore multiple scenarios for global annual wheat prices and country supplies, finding that prices could spike by up to 65%, exceeding the price spikes of the two recent world food price crises in 2007/08 and 2010/11 if the war escalates any further and national policy makers react uncoordinatedly and unilaterally. International cooperation and leadership are urgently needed to help coordinate an effective international response.

Full Text

Together, Russia and Ukraine produce more than one-third of the wheat traded in international markets[1]. Both countries grow a substantial amount of their wheat on the highly fertile black earth soils of the Black Sea region[2]. The Russian invasion of Ukraine triggered sharp increases in global food prices, sparking concern that food-supply disruptions will spread globally. To mitigate these global impacts, policymakers and other agricultural stakeholders must understand the scope and magnitude of potential disruptions.

Systemic modeling of global food system stability

To demonstrate the type of actionable information and understanding of systemic risks that policymakers and strategists need to stabilize the global food system, we present a set of scenarios for wheat – one of the most important food crops grown in the Black Sea region – and estimate price and supply changes for each scenario. We focus on three scenarios that capture the essence of how the war could impact production, disrupt international trade by export restrictions, and increase fertilizer price levels.

Key metrics

Combining an analysis of the global wheat supply network[3] with a global agricultural commodity price model including storage[4] allows us to consider two key metrics for food security risks. On the one hand, *impaired supply* describes the reduction in supply resulting from production anomalies and export restrictions that countries have to cope with by either tapping into their reserves, filing additional demand requests to non-failing suppliers or, as a last resort, reducing their consumption. In essence, impaired supply provides an indication of how much the current global distribution of wheat would be changed. On the other hand, *world market (WM) price hikes* impact consumers, especially the urban poor in low-income countries that have little means to insulate their domestic consumers from price volatility at world markets (e.g., costly strategic reserves).

Scenarios

All scenarios are designed to help identify the risks to global food security arising from the Russian invasion of Ukraine in February 2022 and the associated escalation of the Russo-Ukrainian War during the international wheat trade year (TY) ‘22 from July 2022 to June 2023. In the most optimistic scenario, *Stalemate*, we assume that the war in Ukraine reaches a stalemate by July 2022 and that the fighting will

not expand beyond the currently contested areas of Ukraine (mostly situated to the east of the Dnieper river). Following the recent estimates of Ukraine's main agricultural organization, the upcoming winter wheat harvest will be reduced by 36% compared to the period 2019-2021[5], because of limited capacity to fertilize fields during March and April and harvesting will likely not take place as usual due to fighting, shortages of fuel, machinery and field workers, and the clearing of mined fields. Further, because its Black Sea ports are blocked, Ukraine must primarily rely on transportation of wheat by rail and road through its western borders, which comes with major logistical challenges and may, even under optimistic assumptions, reduce its export capacity by one-third[6]. Finally, export restrictions – already issued in India, Serbia, and Afghanistan – remain active until the end of TY '22. These restrictions result in a substantial hike of the WM price that increases in TY '22 by 26% compared to TY '21 (Fig. 1). To interpret these changes, it is important to keep in mind that we only model annual WM price anomalies, and that short-term and regional price hikes can be significantly higher. In April 2022, for instance, the monthly WM price for wheat already exceeded its peak level of the 2007/08 food crisis[7]. Further, Ukraine (-40% supply reduction) and countries with strong import dependencies on Ukraine, such as Bhutan (-41%), Montenegro (-37%), Macedonia (-18%), Central African Republic (-14%), and Lebanon (-13%), are stripped of a significant amount of their usual supply. Importantly, Ukraine and Lebanon are not able to buffer these failures by their reserves.

The next scenario that we consider is focused on an escalation of protectionism. Already the current price hikes pose a substantial risk to food security for import-dependent developing countries in Africa and Asia. Still struggling with the economic downturns of the compounding COVID-19 pandemic, these countries often have little means to support their vulnerable low-income populations[8]. Thus, there is a risk that some countries may issue unilateral protectionist policies such as export restrictions in an attempt to improve food security domestically. During the last two recent food crises, extensive use of such beggar-thy-neighbor" policies substantially deteriorated food security globally[9]. We therefore include an *International Agitation* scenario for which we assume that countries that have imposed export restrictions during at least one of the last two food crises would do so now, in addition to the countries already having import restrictions in place. Importantly, Russian export restrictions result in a 25% export decline in TY '22 compared to the baseline period 2019-21. These restrictions are implemented in an effort to i) compensate domestic consumers for price inflation partially driven by Western sanctions and/or ii) to keep WM prices high, leveraging the risk of widespread food insecurity and social instability (especially in Africa and Asia) as well as potential migration flows to put pressure on the Western Alliance[10].

Under this *International Agitation* scenario, the significant reduction in grain available on the global market by Ukraine and Russia has widespread consequences; many import-dependent low- and middle-income countries in North- and Sub-Saharan Africa as well as West- and South-East Asia and North Africa and the Middle East are stripped of more than one fourth of their annual wheat supply. In many of the affected countries, reserves are insufficient to buffer the impaired supply, so these countries would have to find alternative suppliers. The WM price hike reaches almost the level of the 2007/08 food crisis (+55% compared to TY '21), which could be difficult for poorer countries that may be outbid by rich importers –

potentially forcing poorer countries to reduce consumption. Russian export restrictions mainly affect African countries like Kenya (-25%) and Congo (-18%) as well as West Asian countries, such as Georgia (-22%) and Oman (-17%), whereas Ukrainian supply failures mainly affect countries in South-East Asia, such as Indonesia (-27%) and Thailand (-21%), as well as countries of the Middle East and North Africa such as Lebanon (-18%) and Libya (-13%) (cf. supplementary Fig. S1). Egypt and Tunisia (each -13%) strongly depend upon wheat imports from both conflict parties. A comparison with a scenario where the conflict escalates locally but international cooperation can avoid the widespread and spiraling export restrictions of the previous crises (i.e., the *Persistent War* scenario in supplementary Fig. S1) reveals that, in the *International Agitation* scenario, export restrictions issued by Argentina as a key exporter cause supply deficits spreading across South America; Brazil, followed by Chile, are the most severely affected, which further aggravates supply failures in South-East Asia. In addition, withheld wheat exports from Kazakhstan trigger impaired supply in parts of Central Asia.

Our final scenario is focused on multiple breadbasket failure as it was a main driver of both preceding crises in 2007/08 and 2010/11[4]. Reports on unusual autumn floods in China, the recent heatwave in India, and drier-than-usual conditions in France and US Central Plains raised concerns that in TY ’22 weather-induced production failures in these main production regions could compound the war- and policy-induced production and supply failures, thereby aggravating the developing food security crisis[11]. In this *Compound Events* scenario, we assess these risks by deriving production anomalies from USDA’s May production estimates for TY ’22 and overlaying them with the *International Agitation* scenario. We find that forecasted weather-induced production anomalies are positive on a global level reducing the global production loss to 0.02% (down from 1.36% in the *International Agitation* scenario). In several strongly import-dependent countries such as Egypt and Tunisia, better-than-usual local harvests mitigate war-induced supply failures by -9% and -8%, respectively, compared to -13% for both countries in the *International Agitation* scenario. Thus, the world might be spared from a worst case superposition of breadbasket and war-induced production and supply failures for wheat. Nevertheless, the amount of grain that is not affected by export restriction and thus available for international trade is decreased compared to the *International Agitation* scenario, mainly due to the forecasted production failure in the US (Fig.1 and supplementary Tab. 2). Further, the WM price increase even exceeds the price increase during the 2007/08 food crisis (+65% compared to +59%) and would thus be the most severe wheat price increase since the oil crises in the 1970s.

Already before the war, the price of synthetic fertilizer had doubled compared to its long-term average amid the high prices of natural gas[12]. Since Russia is one of the world’s top suppliers of all three main types of synthetic fertilizer[1], sanctions imposed on Russia may further drive up fertilizer prices over the TY ‘22. In our scenario analysis, we account for the direct impact of an up to threefold increase in fertilizer prices on production prices. We find that a threefold increase in fertilizer input prices, would raise the annual WM wheat price by 29% (compared to TY ‘21), and is therefore a stronger WM price driver than the production declines in Ukraine assumed in the Stalemate scenario (supplementary Fig. S2). Notably,

this estimate provides a lower bound for the impact of fertilizer price increases on WM prices, because it neglects indirect effects such as yield reductions due to lower fertilizer use.

Humanitarian needs

Based on our analyses, the war could undermine global food security to an extent comparable to the two preceding crises. Back then, price spikes triggered social unrest and uprisings in import-dependent, developing countries with small or volatile domestic production and large low-income populations (mainly in Africa and South-East Asia) and may have contributed to the Arab Spring and the Syrian Civil War[13]. The current crisis is unfolding at a time when many developing economies have not yet recovered from the COVID-19 pandemic, which financially constrains their response options. Further, countries in the Horn of Africa such as Ethiopia and Kenya are additionally affected by a severe drought threatening the food security of 13 million people[14]. Also, Lebanon, Libya, and Tunisia – the three countries in Northern Africa that would be most severely affected by an Ukrainian export failure – already have to cope with multiple overlapping crises[15]. All three are facing political instability aggravated by economic crises, while Lebanon and Libya have to handle large refugee inflows from Syria and Sub-Saharan Africa, respectively.

The severity and complex multi-dimensional structure of the developing crisis require immediate and coordinated action by key food producing-countries and international institutions. Efforts must be focused on addressing both urgent humanitarian needs and the rapid, short-term structural changes in global supply and trade. The centerpiece for humanitarian activities around food assistance is the World Food Program (WFP), which relies on financial support from donor countries. In the past, the WFP bought nearly half of its global wheat supplies from Ukraine[16]. Thus, the agency now must procure grain on the WM despite the currently high price levels, requiring major donors such as the EU and the US to quickly step up their financial support[17]. Indeed, financial need has increased dramatically not only due to the war but also in the wake of the COVID-19 pandemic. Between 2019 and 2020 the number of people experiencing severe hunger globally increased rapidly from 650 to 758 million and the current crises could add 8-13 million in 2022 according to recent FAO estimates, with the strongest relative increases in Sub-Saharan Africa and Asia Pacific[18]. These increases are qualitatively different from those of the 2007/08 and 2010/11 crises, which slowed the global decrease in the number of people experiencing severe hunger since 2004 but did not cause this trend to reverse globally.

International collaboration is key

Addressing the structural changes in the global food system is challenging. It is clear from our modeling that escalating export restrictions must be avoided. The key for avoiding such trade interventions is for countries to recognize that it is in their own self-interest[19] to maintain stable global food prices[19]. Enhanced capacity for in-situ systemic modeling of food security risks, building on ongoing efforts by the Agricultural Market Information System[20] and others, would increase transparency on different risk dimensions as well as the efficacy and cost of the different policy responses. Through this type of enhanced international food security surveillance, international collaboration can be promoted. For

example, collaborative efforts to reduce market uncertainties in the current crisis may include ensuring that trade of seeds, grains, and fertilizer is exempted from sanctions imposed on Russia. Further, direct support of farmers in Ukraine and other major breadbasket regions is needed to incentivize wheat cropping efforts and buffer the war-induced supply failures. Demand-side measures (such as the drastic reduction of food waste in developed and emerging economies[21]) and the reduction of land-competition for food and biofuel production[22] can take further pressure off the strained global food production system. Additionally, it is essential to facilitate shifts in grain procurement (e.g., away from blocked Ukrainian Black Sea ports to road and rail transport) through coordination with agribusinesses, commodity traders, and transport and logistics companies.

Scenario analyses of the global food system, as exemplified here, together with international cooperation can lead to transformational improvements in global food security. Leadership is absolutely essential to affect this change, whether it comes from individual countries, major grain associations, or intergovernmental forums like the G7. Costs of inaction could be especially high – both in the short term as hunger and social instability could rapidly spread – and in the long term as climate change[23], increases in demand due to population growth[24] and changing diets[25] induce additional pressures on global food systems.

Methods

We use a year-to-year, supply-demand model that includes consumer and producer stocks to estimate the global export price of grains[4]. At the equilibrium WM price P^e, the market clears and the supplied quantity

($Q_s \propto P^{e_s}$) equals the demanded quantity ($Q_d \propto P^{e_d}$), where e_s and e_d denote price elasticities of supply and demand, respectively. Global inventories I_p and I_c of producer p and consumer c, respectively, are updated according to

$$I_p(t) = I_p(t-1) + H(t) - Q_\chi(t-1), \quad (1)$$

$$I_c(t) = I_C(t-1) + Q_\chi(t) - Q_{out}(t), \quad (2)$$

where t, $H(t)$, $Q_\chi(t)$ and $Q_{out}(t)$ denotes the timestep, the harvest, the quantity traded between producer and consumer and the final consumption, respectively. Storage carryover from the previous time step is added to the subsequent stock. The model is driven exogenously by annual time series of global production and long-term trends in consumption and calculates annual changes in global storage level and annual WM prices for the international wheat TY. It is calibrated by using data from the United States Department of Agriculture (USDA) Production, Supply, and Distribution (PSD) database[26] for the period 1975–2021. The baseline demand and production projections for the TY ’22 are derived from the OECD-FAO Agricultural Outlook 2019–2028 report[27]. In the scenarios, we consider three different categories of impacts: i) national production anomalies by reducing the projected baseline world production for the TY

‘22 by the shares of the affected countries’ (derived from the period 2019-21) but keeping consumptions fixed to their projected baseline values, ii) export restrictions by assuming that when a country restricts exports by a certain share, this share of the national production is retained from the WM and available for domestic consumption, iii) fertilizer price increases above their long-term levels by assuming that with the fertilizer prices also the upper limit for the global producer selling price increase (cf. SI Secs. 1.1, 1.3, and 1.4 for details on the TWIST model, underlying data, and the derivation of the scenarios, respectively).

In addition to the price modeling, we study the supply balances at the country level. For that, we consider the annual food balance in kilocalories for each country

$$S = P + I - E + R, \qquad (3)$$

where S, P, I, E, and R, denote domestic supply, national production, imports, exports and ending stocks, respectively. We use country-to-country trade data from the Food and Agricultural Organization of the United Nations (FAOSTAT)[1] and country level production, consumption, and ending stocks (reserves) of USDA’s PSD database[26], averaged over the years 2019–2021. When a country reduces exports by a certain share, all bi-lateral exports are reduced by this share. To estimate the global repercussions of these export restrictions, we calculate i) the relative impaired supply $\chi = \frac{S - S_0}{S_0}$, where S_0 denotes the supply in the unperturbed baseline scenario and ii) the ratio of impaired supply to reserve $\chi_R = \frac{S - S_0}{R}$ for each country that imports from the country imposing export restrictions. In the case of production declines, we assume that the supply of the affected country will be directly impacted as described by the mass-balance equation (Eq. 3), while import and export remain constant.

Data availability

The data that support the findings of this study are publicly available from the USDA PSD database (https://apps.fas.usda.gov/psdonline), the FAO FAOSTAT database (http://www.fao.org/faostat), the World Bank commodity markets database (https://www.worldbank.org/en/research/commodity-markets) and the US Bureau of Labor Statistics (https://www.bls.gov). The data generated during the current study are included in this published article (and its SI).

Declarations

Acknowledgments

removed for double-blind review

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Figures

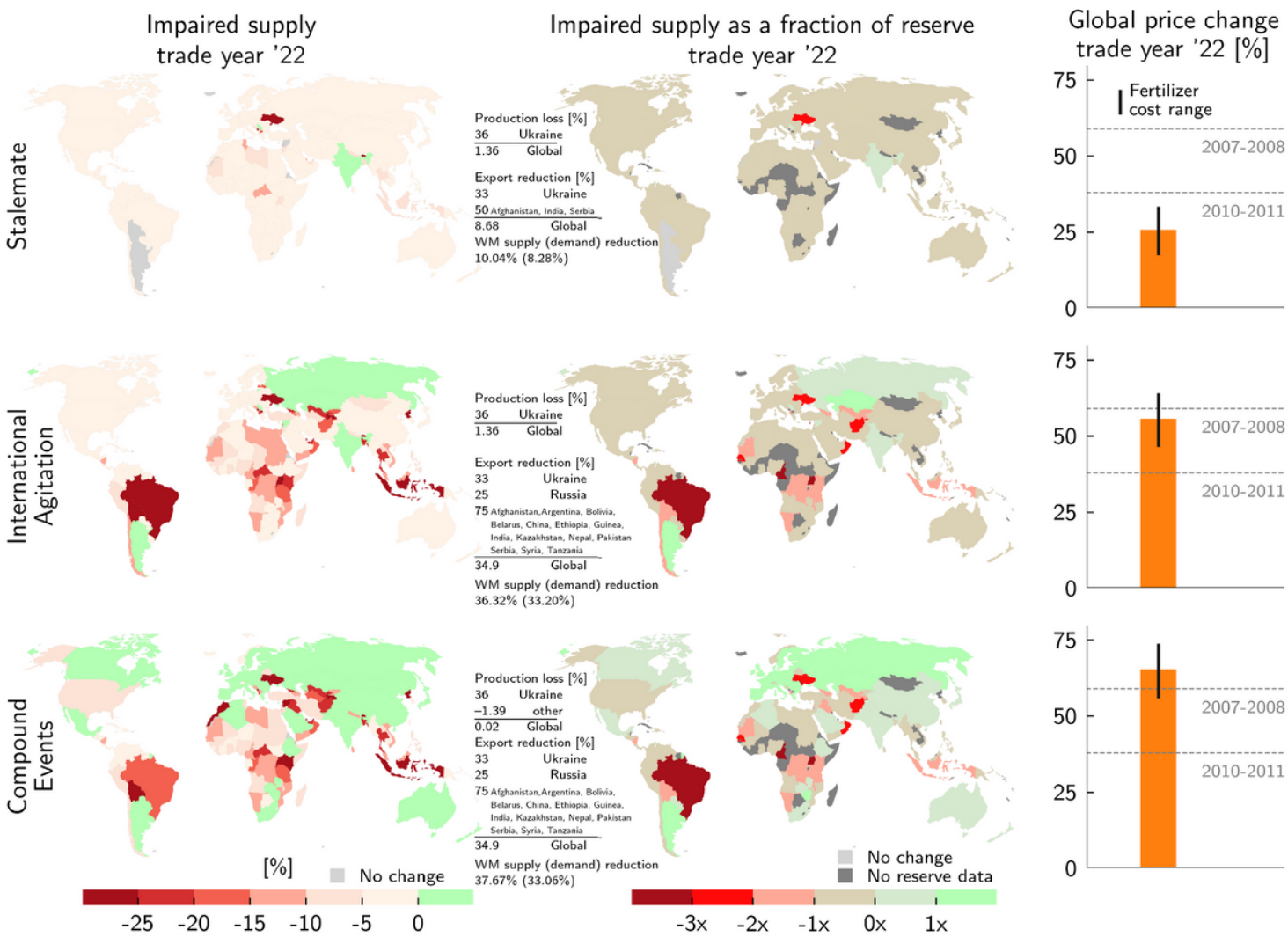

Figure 1

Food security impacts of the Russian Invasion of Ukraine. Three scenarios are considered: *Stalemate*, *International Agitation,* and *Compound Events* (rows). These describe supply failures and world market price hikes for the upcoming international trade year for wheat (July 2022 until June 2023) in response to war-and weather induced production declines, export restrictions as well as , world market (WM) demand and supply (see inserted Tables for details). Left: domestic impaired supply compared to baseline (left column) and to national reserves (right column). Right: estimated changes in the world market price for wheat. Black whiskers indicate price changes resulting from different fertilizer input prices (ranging between 1-3 times the current price levels). The dashed lines indicate price hikes during the 2007/08 and 2010/11 food price crises.

Supplementary Files

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