COLUMBIA CLIMATE SCHOOL
Climate, Earth and Society

Insights from COVID-19 impacts on food systems and supply chains

June 22, 2023
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Director & Senior* Research Scientist
Center for Climate Systems Research

Herrenhausen Conference 2023 Climate Related Systemic Risks: Lessons Learned from Covid-19

* As of 7/1/2023

State of the Global Food System

HUNGER AROUND THE WORLD

State of global hunger in 2023

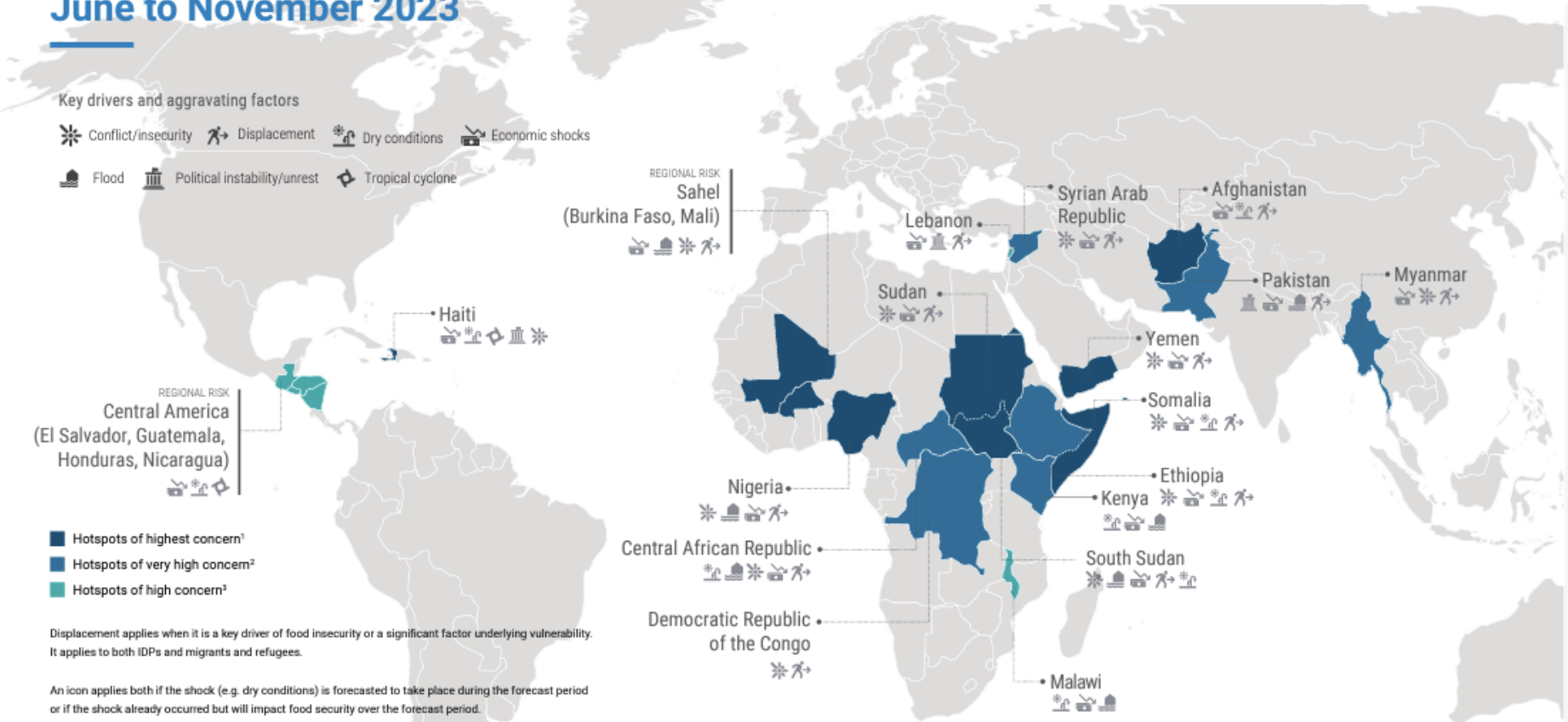
- Acute food insecurity: 345 million people; up about 200 million (!!) from early 2020
- “FAO and WFP warn that acute food insecurity is likely to deteriorate further in 18 hunger hotspots – comprising a total 22 countries – during from June to November 2023”

Sources: https://www.wfp.org/publications/wfp-global-operational-response-plan-update-7-february-2023, 04/18/2023. https://www.wfp.org/publications/hunger-hotspots-fao-wfp-early-warnings-acute-food-insecurity-june-november-2023 . 06/21/2023

Early warning hunger hotspots

June to November 2023

Source: https://www.wfp.org/publications/hunger-hotspots-fao-wfp-early-warnings-acute-food-insecurity-june-november-2023. 06/21/2023



Displacement applies when it is a key driver of food insecurity or a significant factor underlying vulnerability. It applies to both IDPs and migrants and refugees.

An icon applies both if the shock (e.g. dry conditions) is forecasted to take place during the forecast period or if the shock already occurred but will impact food security over the forecast period.

[1] This category includes hotspots already with populations in Catastrophe (Integrated Food Security Phase Classification [IPC]/Cadre Harmonisé [CH]), as well as hotspots at risk of deterioration towards catastrophic conditions. At risk are those hotspots where an extremely vulnerable population in Emergency (IPC/CH Phase 4) is facing severe aggravating factors – especially access constraints – that indicate a further deterioration and possible occurrence of catastrophic conditions in the outlook period. Per definition, this category also includes hotspots with Famine or Risk of Famine.

[2] These are hotspots with sizeable populations – over 500 000 people – estimated or projected to be in Emergency (IPC/CH Phase 4) levels of acute food insecurity or identified as severely acute food insecure as per WFP's Consolidated Approach for Reporting Indicators of Food Security (CARI) or remote CARI (rCARI) methodology, or hotspots with more than 10 percent of the analysed population in Emergency (IPC/CH Phase 4) or severely acute food insecure, and at least 50 percent of the population analysed. In the included countries, life-threatening conditions are expected to further intensify in the outlook period.

[3] Other countries, in which acute food insecurity is likely to deteriorate further during the outlook period, and which were identified as hunger hotspots.

Source of data: FAO and WFP. 2023. *Hunger Hotspots analysis (June to November 2023)*. Rome. **Source of map:** United Nations. 2020. *Map of the World*. Cited 20 September 2022. www.un.org/geospatial/content/map-world

State of the Global Food System

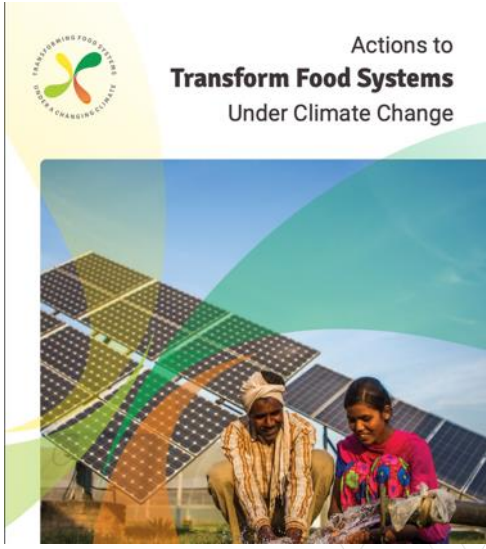
“BIG PICTURE” CONCEPTS

Overview of challenges

- Food security challenges are dynamic and interconnected
- Geopolitical, physical, social, and climate risks interact with each other (e.g., multiple bread basket failure, conflict, livelihoods, health).

“Our food systems are failing us"

- Inabilities of food systems
  - “to produce greater quantities of food to feed a growing world population”
  - “to meet nutritional needs”
  - “to benefit everyone equally and equitably, with both over- and underconsumption rife in current food systems”
- “Negative impacts of food systems on the environment and natural resources”
- Climate change
  - “increasingly having severe negative impacts on food systems”
  - “food systems themselves are part of the problem through direct and indirect emissions.”



Source: Steiner et al. 2020. Actions to transform food systems under climate change.

Rapid and radical transformation

The *dominant discourse* in academic circles

- Grandiose yet vague plans
- A tendency for one-size-fits-all solutions
- Very limited understanding of how interventions will impact complex system

> **"A radical transformation** of the global food system is urgently needed"
>
> — *EAT-Lancet report*


DISCUSSION STARTER

MARCH 2022

The price tag for transforming food systems under climate change

How transforming food systems under climate change will cost trillions, but inaction will cost more

PHILIP THORNTON, YULING CHANG, ANA MARIA LOBOGUERRERO, BRUCE CAMPBELL

Cost estimate: $1.3 trillion/year

Source: https://clim-eat.org/the-price-tag-for-transforming-food-systems-under-climate-change-2/, accessed 2/27/2023 .

Efficiency and resilience

Efficiency: Maximizing outputs (e.g., crop yields, economic value, nutritional value) relative to inputs (e.g., labor, land, water, or capital)

Resilience: Capacity of the system to absorb shocks and stresses and maintain function

Sometimes in tension… other times, reinforcing

The pursuit of efficiency

- Specialization: growing only one or a few crops (e.g., corn and soy monocultures)
- Consolidation: larger farms and businesses justified by "economies of scale"
- Intensification: high inputs to get high outputs

Important concepts for food systems

- Distributed Systems: Adaptability through geographic and production diversity
- Redundancy: Protection via duplicate system elements (e.g., multiple markets/sources)
- Diversity: Enhanced resilience through variety in crops or markets

We also need to be aware of…

- Unintended Consequences: Unforeseen side effects from system changes
- Naïve Interventionism*: Ill-informed interventions may cause more harm than good

Via negativa principle*

Eliminate harmful elements: Removing elements that cause harm or uncertainty instead of adding new elements or interventions.

Resilience through simplification: Reducing unnecessary complexity and avoiding potential hazards can enhance systemic resilience and stability

Transformation => more of a shift away from harmful practices *rather than an unchecked rush toward new ones*

*Taleb (2012) "Antifragile: Things That Gain from Disorder"

Via negativa for the food system

1. **Cut Synthetic Inputs:** Limit environmental harm and input dependencies.
2. **Minimize Waste:** Lower energy use and greenhouse gas emissions.
3. **Diversify Crops:** Boost resilience against pests, diseases, climate change, and economic risks.
4. **Decentralize Supply Chains:** Increase system robustness against disruptions.

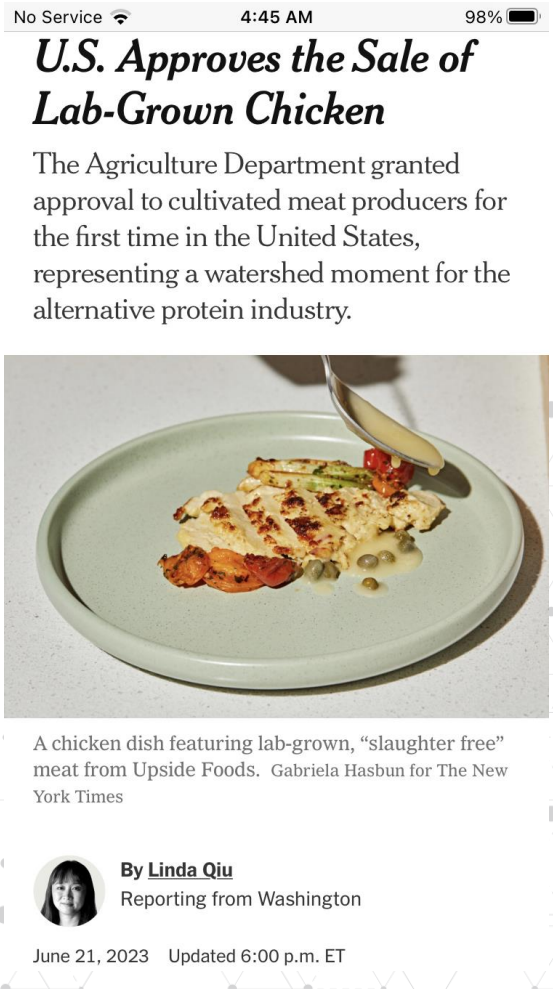
Improve our global food system by subtracting what harms it.

Via negativa for the food system

Transformation: avoid an unchecked rush toward new practices.

"We made too many wrong mistakes."

- Yogi Berra



No Service 4:45 AM 98%

U.S. Approves the Sale of Lab-Grown Chicken

The Agriculture Department granted approval to cultivated meat producers for the first time in the United States, representing a watershed moment for the alternative protein industry.

A chicken dish featuring lab-grown, "slaughter free" meat from Upside Foods. Gabriela Hasbun for The New York Times

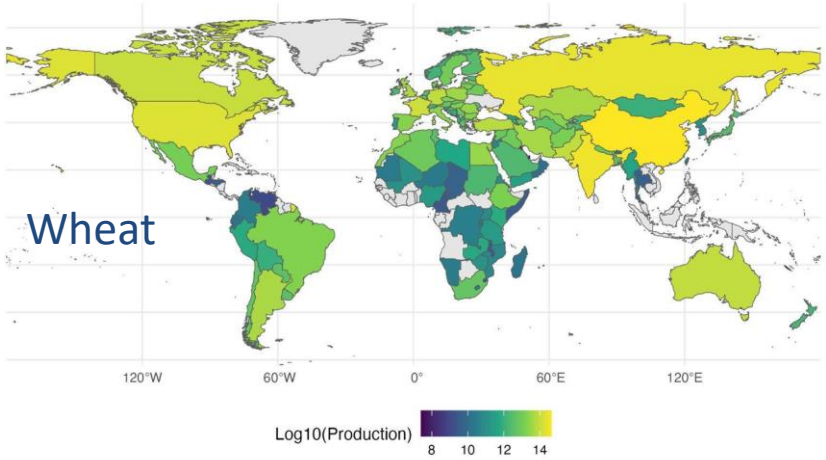
By Linda Qiu
Reporting from Washington

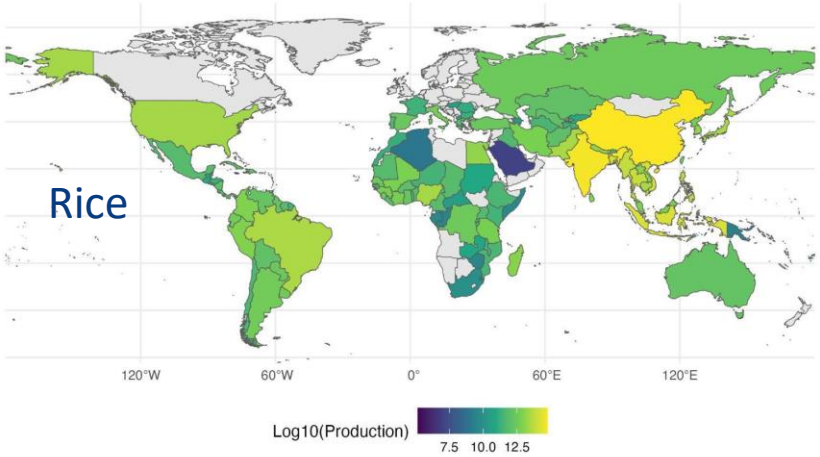
June 21, 2023 Updated 6:00 p.m. ET

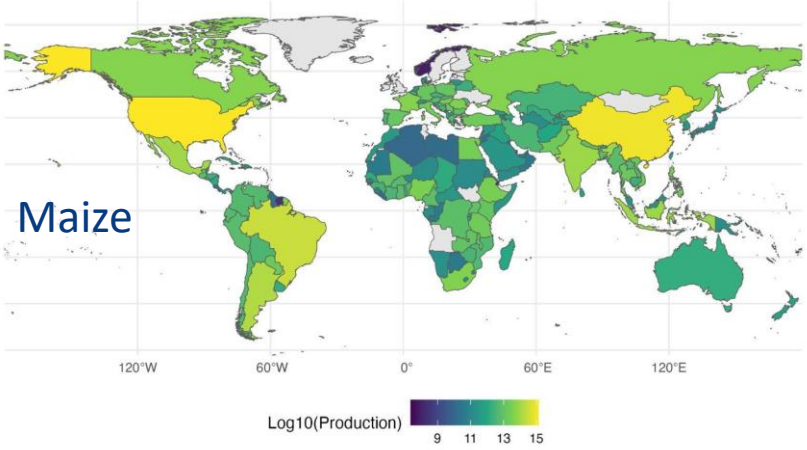
State of the Global Food System

INSIGHTS FROM NETWORK ANALYSES

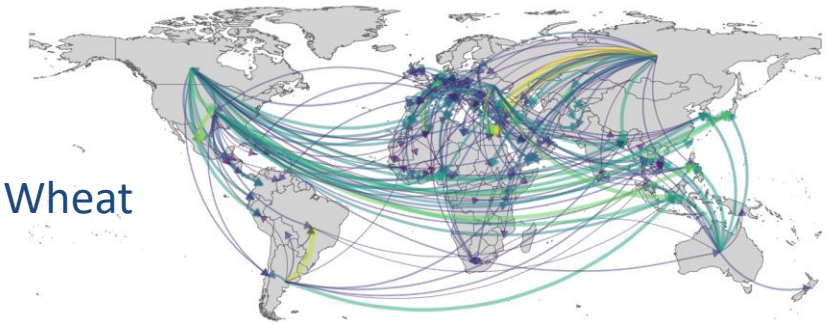
Food system structure – production

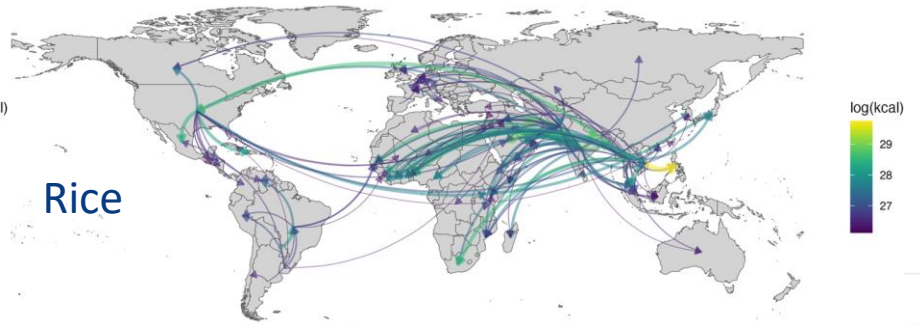


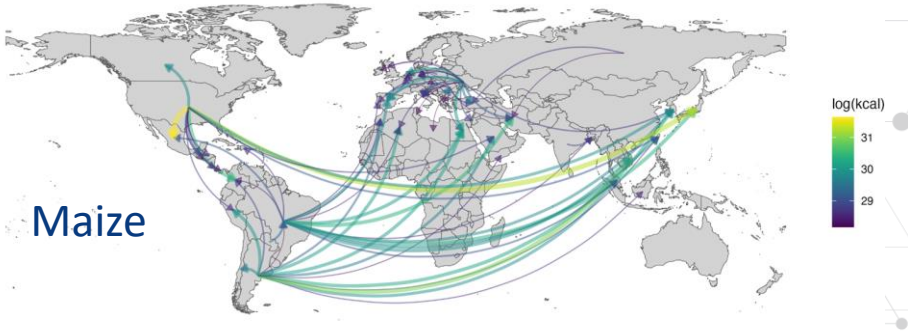




Food system structure – visualizing trade





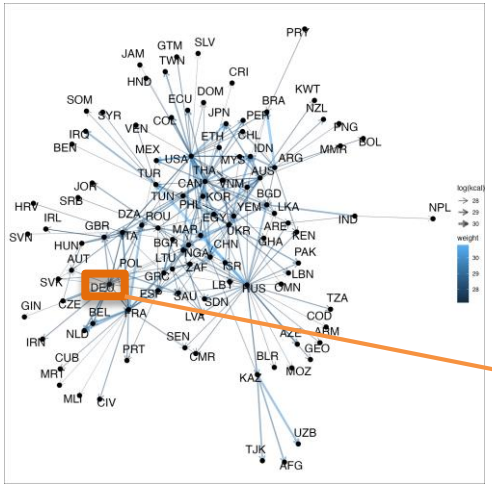


Flows account for 80% of the average total global trade from 2019 to 2021.

Wheat: largest 2.8% of flows
Rice: largest 3.5% of flows
Maize: largest 1.9% of flows

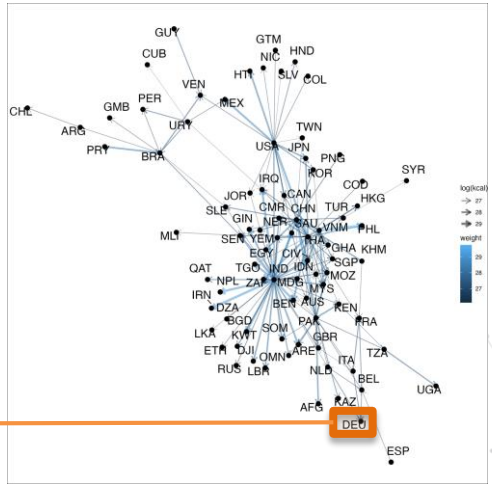
Food system structure – trade connectivity

Wheat

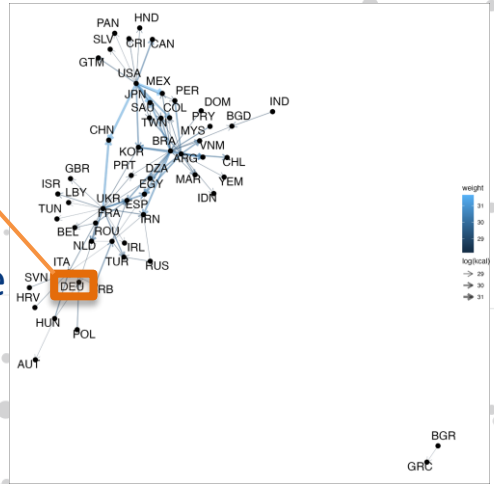


Germany

Rice



Maize



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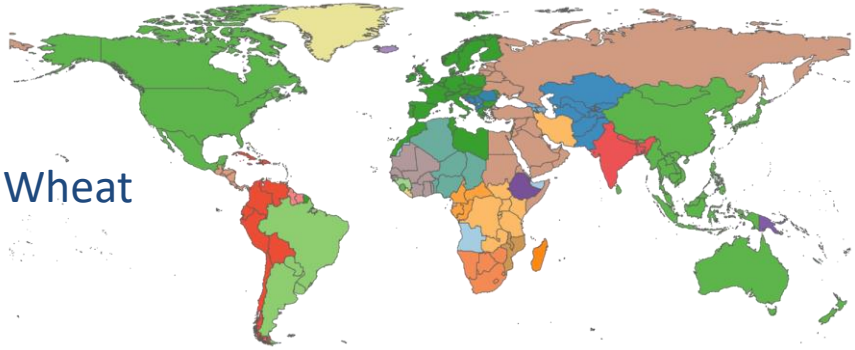
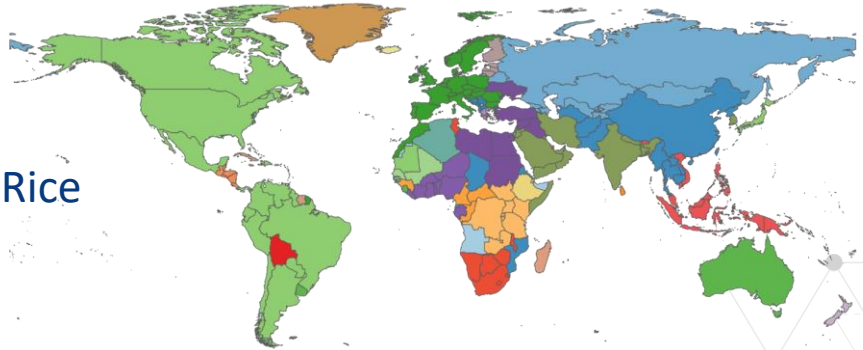
Food system structure – community structure

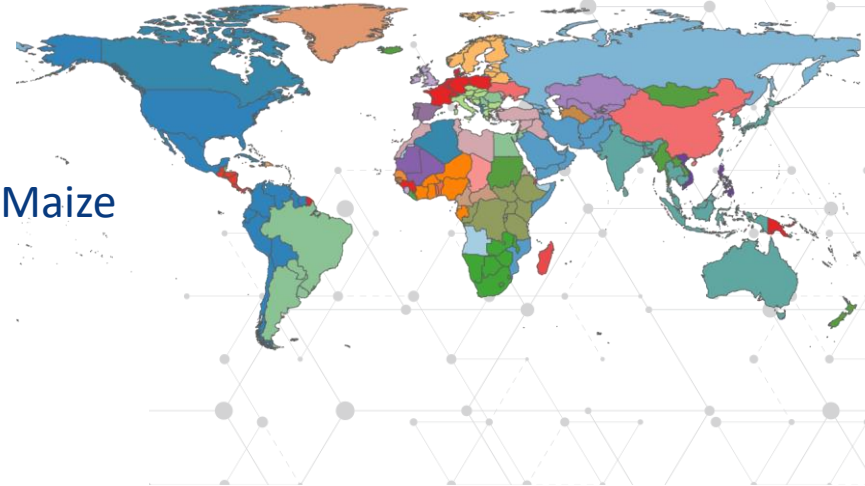




Same color => same trade community

Based on Infomap community detection

https://igraph.org/r/doc/cluster_infomap.html



Food system structure – efficiency/resilience metrics

Environ. Res. Lett. **16** (2021) 105003 https://doi.org/10.1088/1748-9326/ac1a9b

ENVIRONMENTAL RESEARCH
LETTERS

LETTER

A complex network framework for the efficiency and resilience trade-off in global food trade

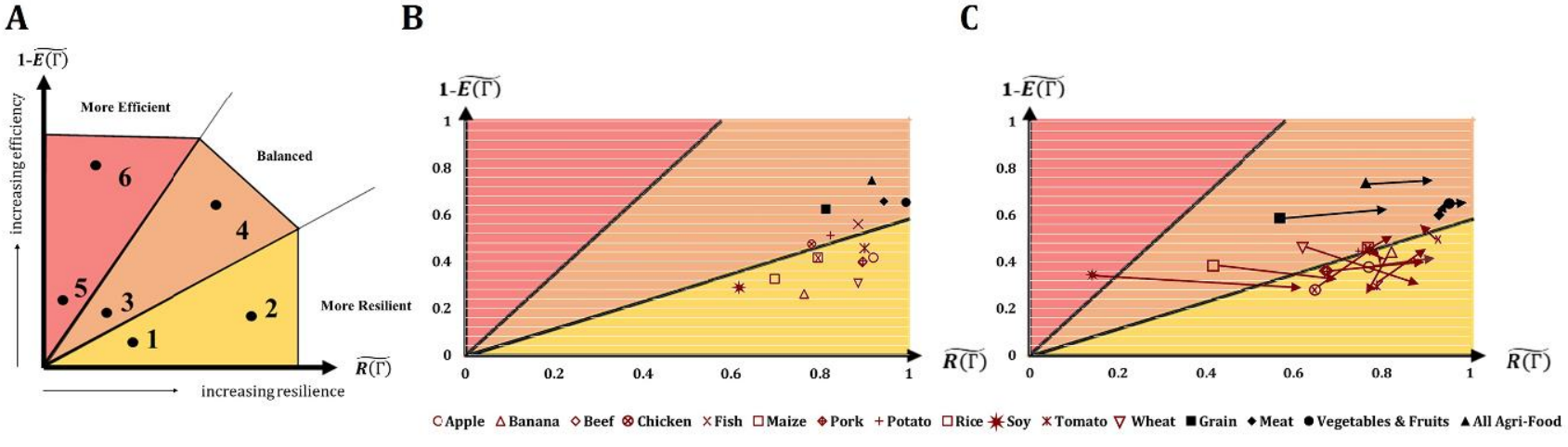
Deniz Berfin Karakoc and Megan Konar*

"**Figure 7**: Cooperation in efficiency and resilience for weighted food trade networks."

(A) Schematic of the cooperation scheme.

(B) Empirical values (2008–2018 avg)

(C) Change: Start: avg, 1965 – 1975; End: avg, 2008 – 2018



Food system structure – global network of ports

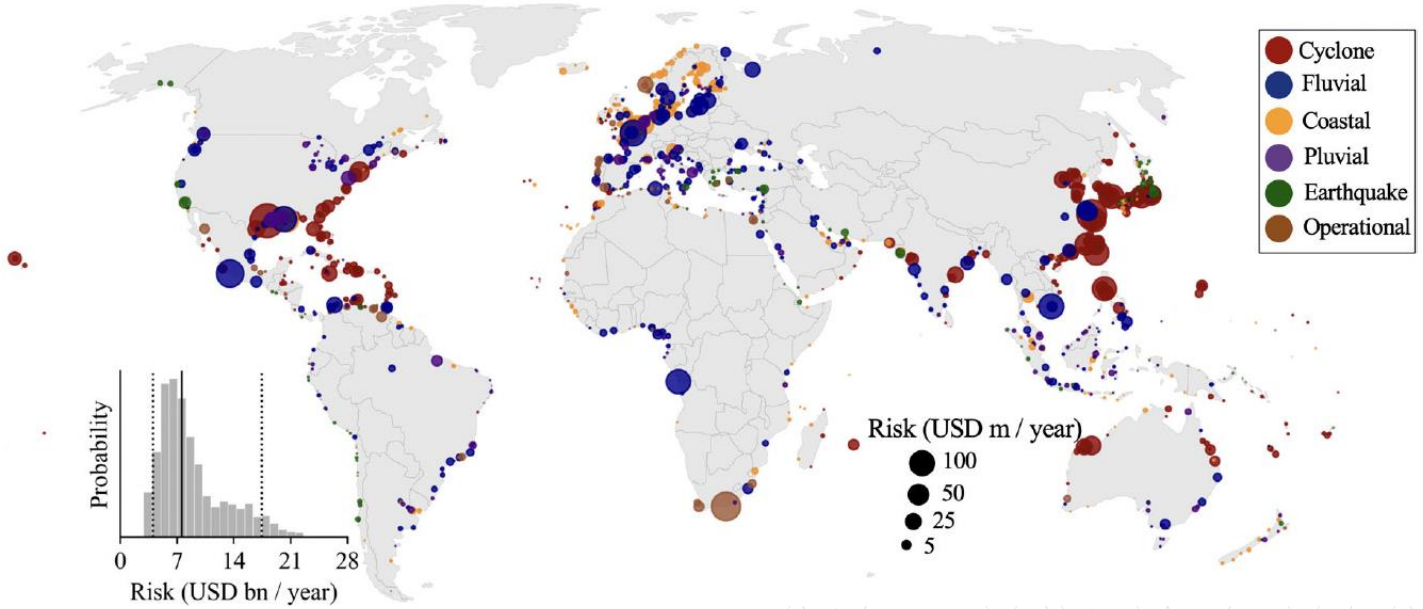
communications
earth & environment

ARTICLE

https://doi.org/10.1038/s43247-022-00656-7 OPEN

Multi-hazard risk to global port infrastructure and resulting trade and logistics losses

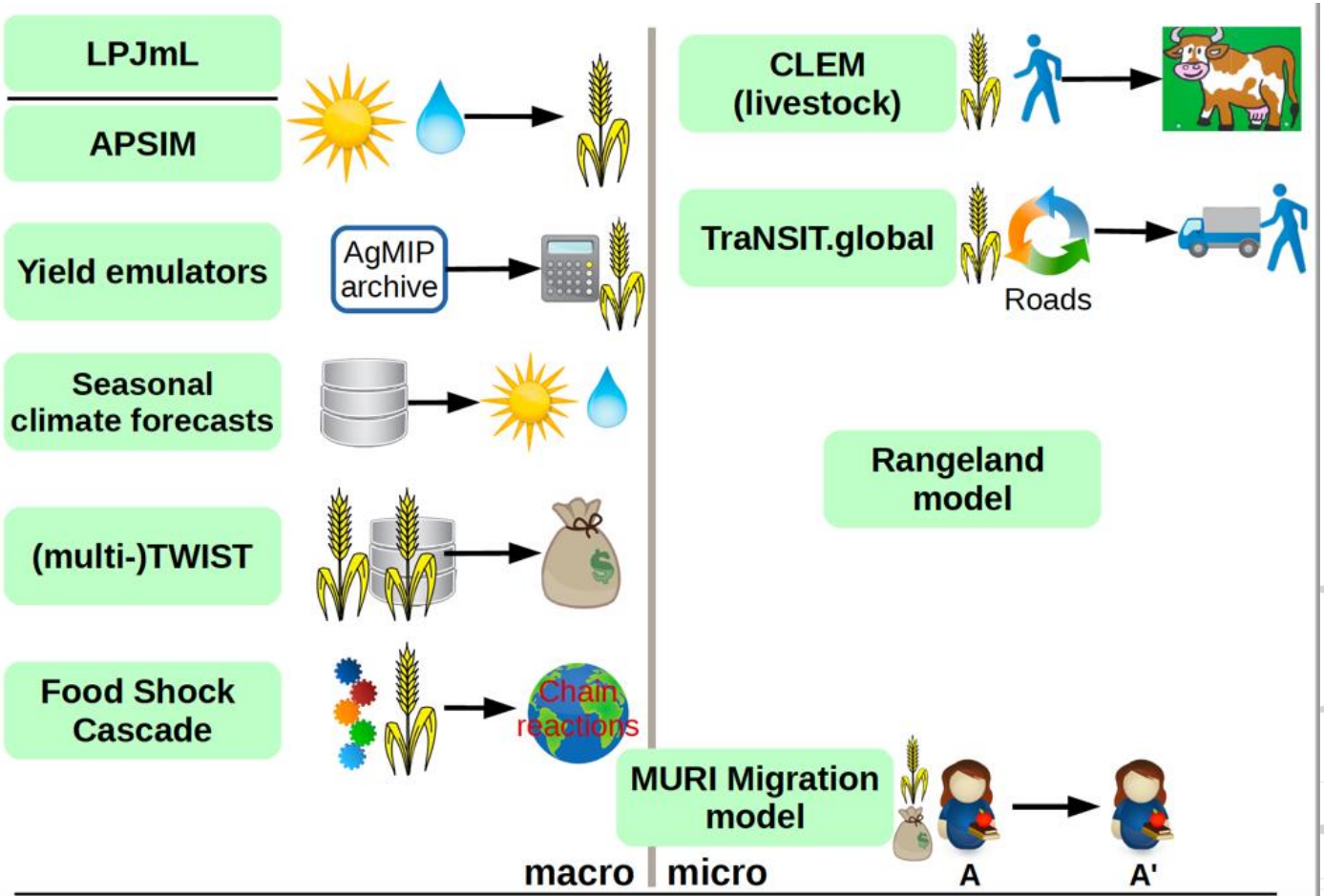
Jasper Verschuur[1✉], Elco E. Koks[1,2], Sihan Li[3] & Jim W. Hall[1]



State of the Global Food System

INSIGHTS FROM DYNAMIC MODELS

A cornucopia of models to examine system dynamics



From Schauberger, 2019

Scenarios for the COVID-19 pandemic

Several events are compounding the coronavirus disruptions to supply chains

- Locust infestation in the Horn of Africa and parts of the Middle East and South Asia
- Dry weather in Europe and South America
- A second wave of COVID-19 outbreaks
- Shortages of farm labor

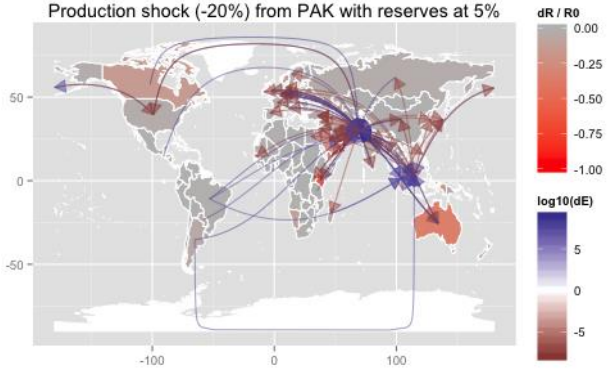
A *macro food systems* perspective

Wheat, maize, and rice: Form the backbone of global trade in staple crops, *with high importance for food security*

- 43% of the calories and
- 37% of the protein directly consumed by the human population

Food Shock Cascade (FSC) model

Source: Marchand et al. (2016); Heslin et al. (2020)



An inventory balance to compute impaired supply, i.e. supply that needs to be made up for through:

1) Inventory use,
2) New trade connections, and/or
3) Increased domestic production

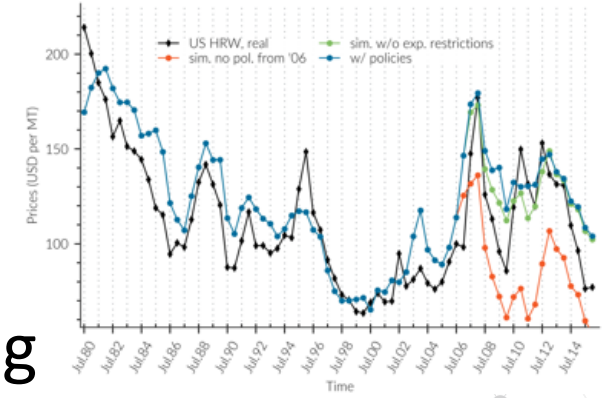
Domestic Supply =

Domestic Production + Imports – Exports + Reserve Use

Trade WIth Storage (TWIST) model

Source: Schewe et al. (2017)

- *Simulates* world market prices and storage movements
- *Accounts for* trade policies and commercial and public inventory holding



Three agents are represented

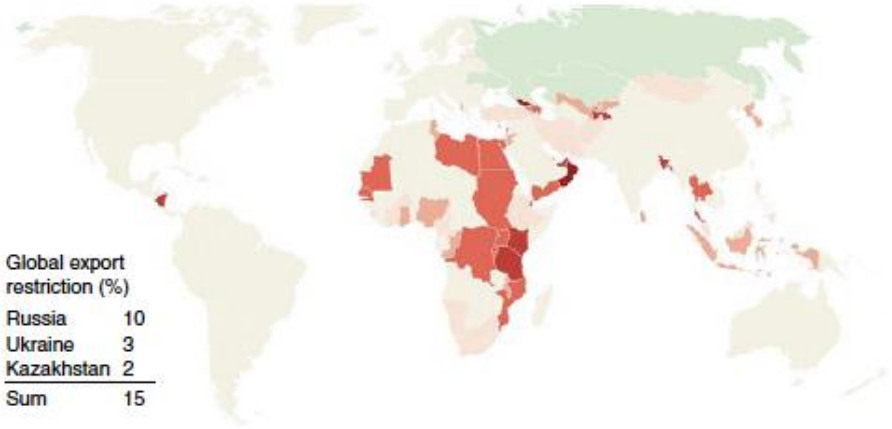
1) Commercial inventory holder: bounded rational profit optimizer with adaptive expectation and one-year forecast period
2) Strategic inventory holder: seeks optimal tradeoff btw cost and food security
3) Domestic consumer

Wheat scenarios

Production Effect

Production loss (%)	
Russia	8
Ukraine	21
Kazakhstan	18
Iran	10
Kenya	49
Saudi Arabia	45
Ethiopia	9
Yemen	23
Global	2.5

Production and Export Restriction Effect

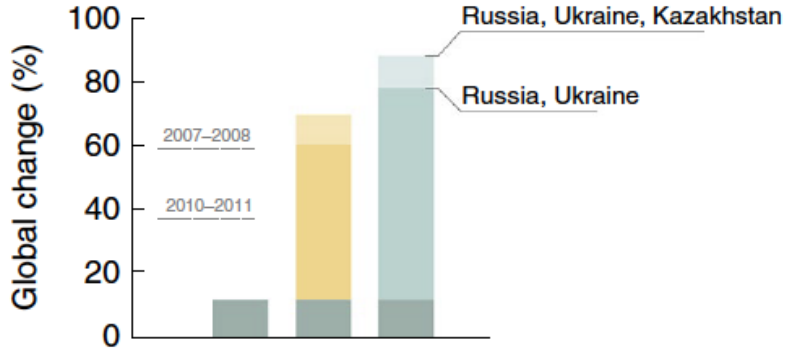


Global export restriction (%)	
Russia	10
Ukraine	3
Kazakhstan	2
Sum	15

Relative change (%)

–50 –40 –30 –20 –10 0

Production
Additional export restrictions
Additional stock-to-use change

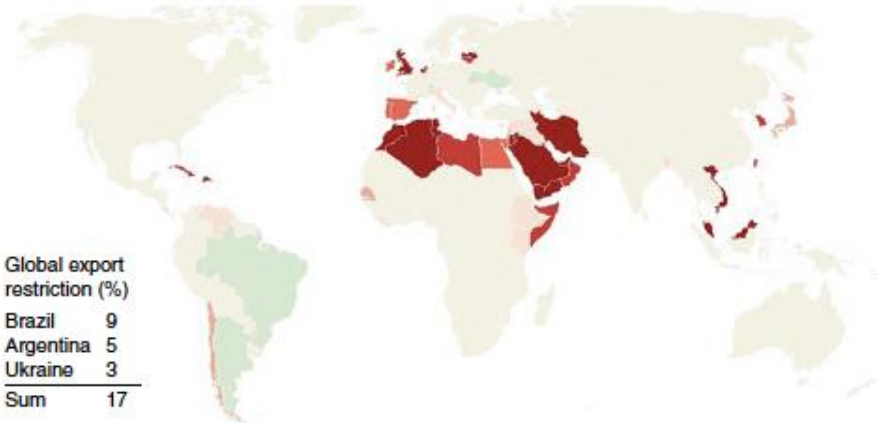


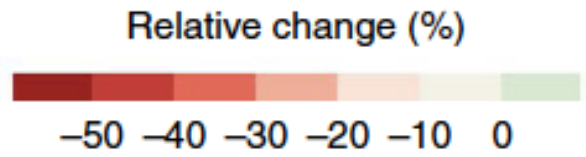
Source: Falkendal et al (2021), *Nature Food* | VOL 2 | January 2021 | 11–14

Maize scenarios

Production Effect

Production and Export Restriction Effect





Source: Falkendal et al (2021), *Nature Food* | VOL 2 | January 2021 | 11–14

Rice scenarios

Production Effect

Production loss (%)	
India	2
Thailand	2
Pakistan	20
Iran	18
Kenya	34
Global	0.9

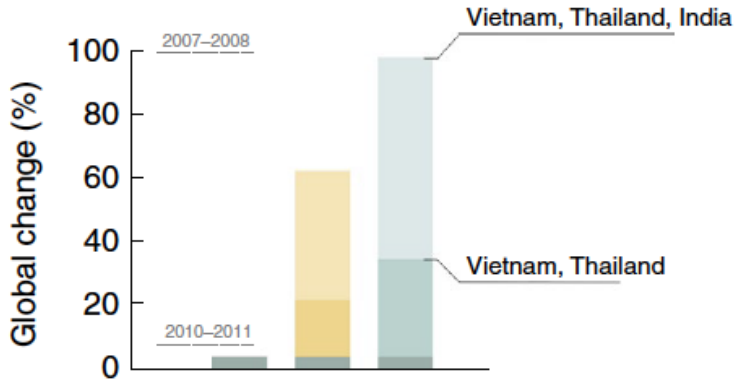
Production and Export Restriction Effect

Global export restriction (%)	
India	23
Vietnam	6
Thailand	4
Sum	33

Relative change (%)

–50 –40 –30 –20 –10 0

Production
Additional export restrictions
Additional stock-to-use change



Source: Falkendal et al (2021), *Nature Food* | VOL 2 | January 2021 | 11–14

Scenarios for the war in Ukraine

We have a collection of scenarios focused on wheat;

Looking at international cooperation scenarios with the Black Sea Grain Initiative and solidarity line.

Source: https://commons.wikimedia.org/wiki/File:Black_Sea_Initiative.svg#file, 11/17/2022

Source: https://commons.wikimedia.org/wiki/File:IMO_welcomes_maritime_humanitarian_corridor_in_Black_Sea_%2852233881214%29.jpg, 7/13/2022

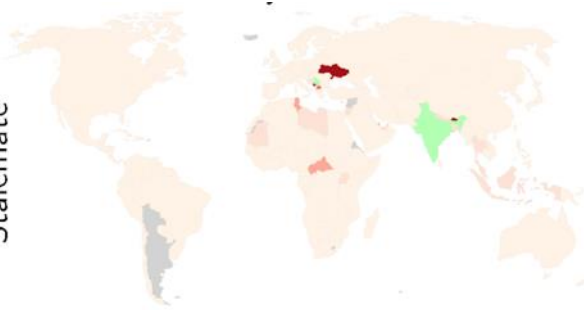
Baseline scenario: “stalemate”

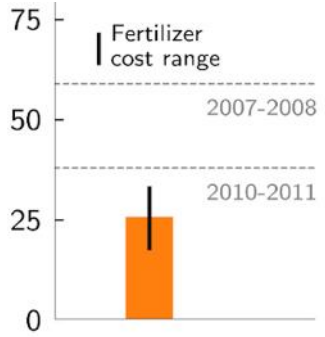
Impaired supply
trade year '22

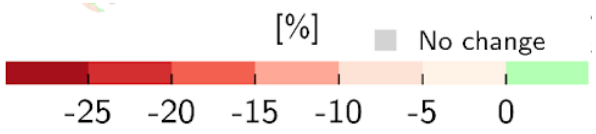
Impaired supply as a fraction of reserve
trade year '22

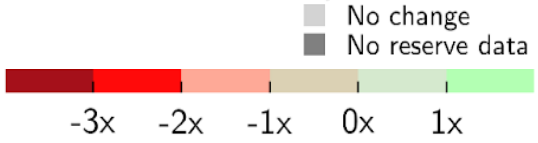
Global price change
trade year '22 [%]

Stalemate



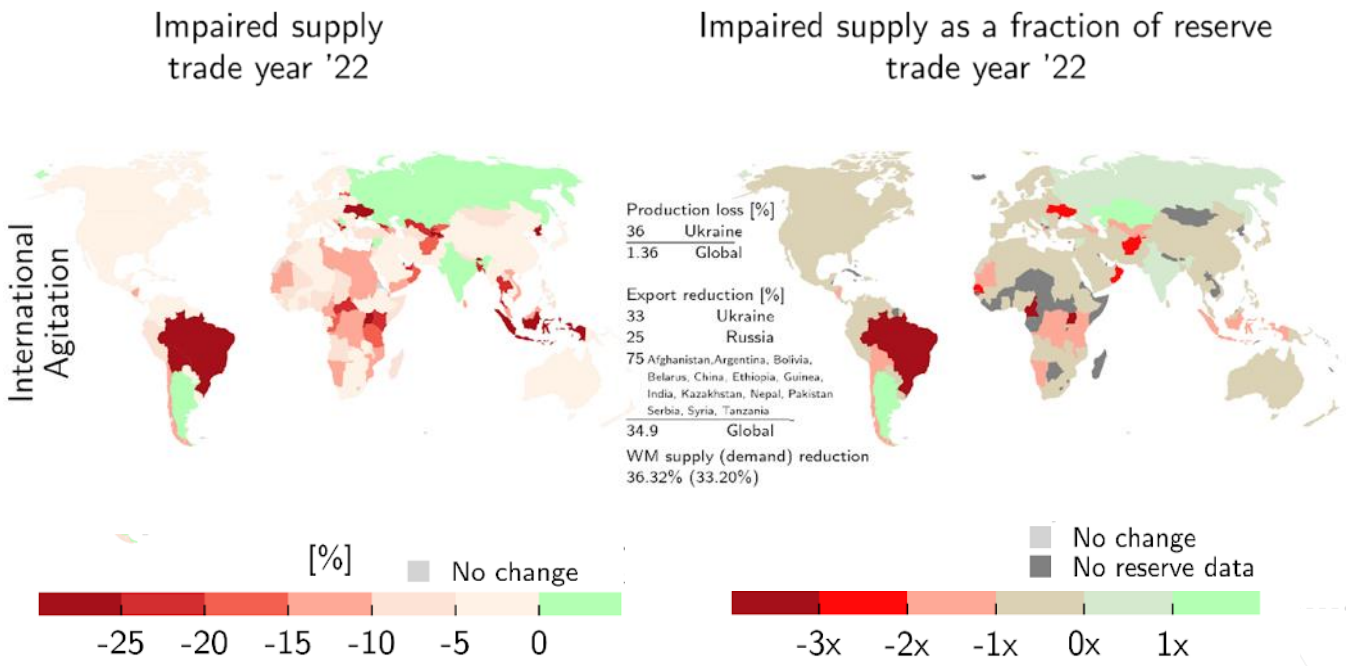






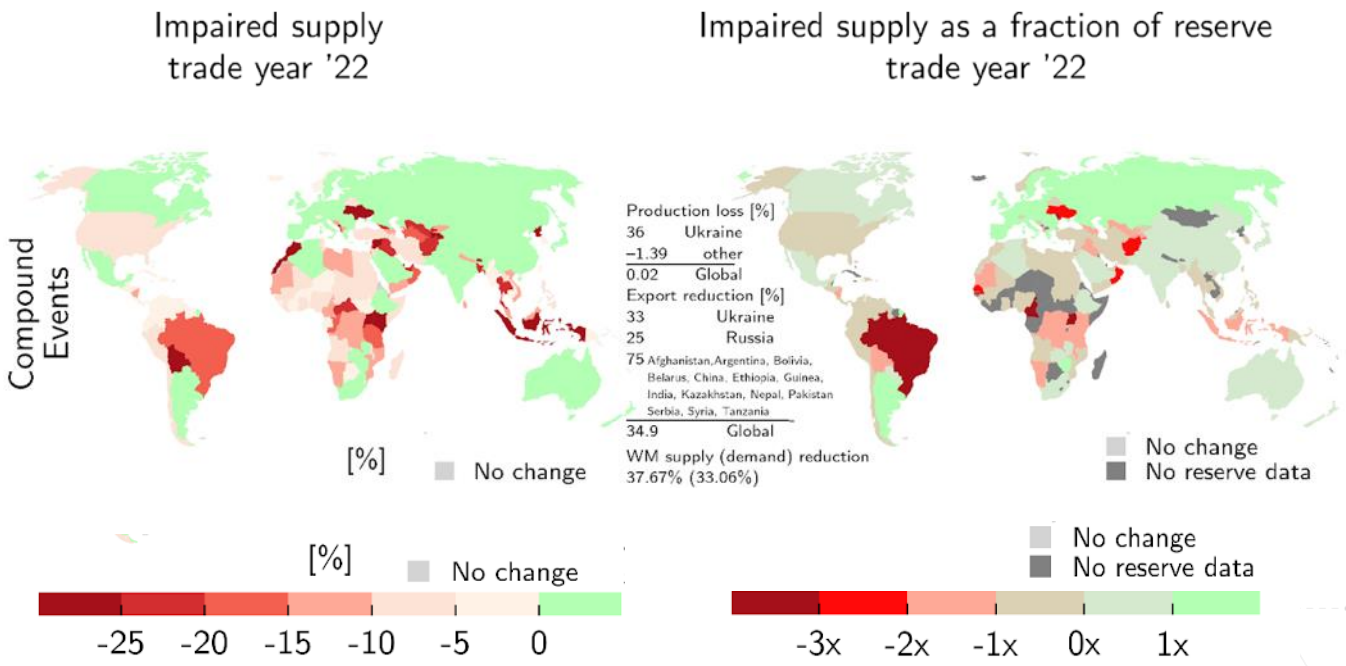
In revision

Trade disruptions: "international agitation"



In revision

Most severe scenario: “compound events”



In revision

Global supply networks

Agrimate: Dynamic model of agricultural trade flow and price dynamics

- Driven by production anomalies and export policies

Builds on experience with the **Acclimate** model

Contents lists available at ScienceDirect

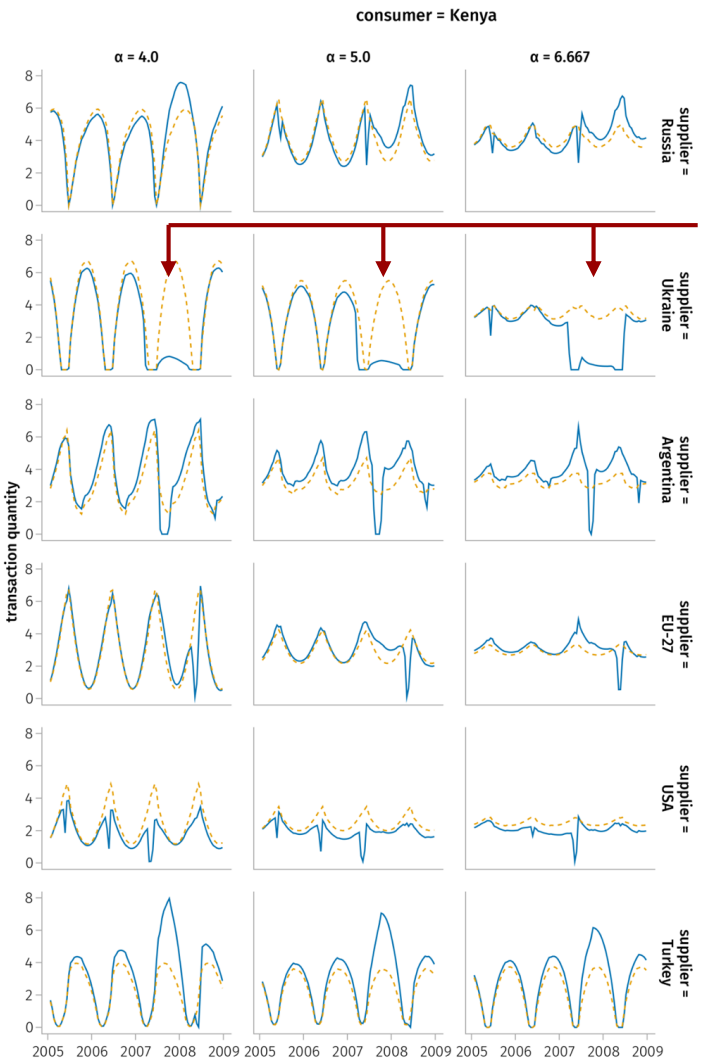
Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Modeling loss-propagation in the global supply network: The dynamic agent-based model acclimate

C. Otto[a,b,1,*], S.N. Willner[a,c,1], L. Wenz[a,d], K. Frieler[a], A. Levermann[a,b,c]

Wheat: trade flows 2005-2008



Ukraine: export restriction 2007/2008

State of the Global Food System

RECOMMENDATIONS

Pathways for the food system

1. **Via negativa**: Improve the food system by subtracting what harms it
   - Synthetic Inputs: Understand and reduce.
   - Waste: Minimize at all stages.
   - Crop Diversity: Increase for resilience.
   - Supply Chains: Decentralize for robustness.
2. **Systemic Risk Analyses**: Apply network science and dynamic systems models to anticipate, prepare for, and navigate potential disruptions and vulnerabilities in our food systems.
3. **Governance**: Build institutions that prioritize sustainability and resilience while upholding individual freedoms and liberties. Engage stakeholders at all levels, from local farmers to international bodies, to ensure the food system is fair and beneficial for all.

Embracing *via negativa*, rigorous analysis, and thoughtful governance will help us toward a more resilient, sustainable, and equitable global food system.

Danke!

mjp38@columbia.edu

Thanks to the Defense Advanced Research Project Agency (DARPA) for funding under the World Modelers program (Grant # W911NF1910013).