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Commentary

Extreme Events in a Globalized Food System

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Our food systems are complex and globally interdependent and are presently struggling to feed the world's population. As population grows and the world becomes increasingly unstable and subject to shocks, it is imperative that we acknowledge the systemic nature of our food system and enhance its resilience.

Introduction

After the prevalence of undernourishment had declined over the last decades, since 2015, the number of people who suffer from hunger is increasing again. Today, more than 820 million people in the world are hungry, and around 2 billion people do not have regular access to nutritious and sufficient food.[1] A growing and more affluent population will further increase the global demand for food and create stresses on land, for example, through deforestation. Additionally, food production and agricultural productivity are further affected by an increasingly changing and variable climate, including extreme events, which further undermine the resilience of our systems.

We are facing increased frequency, intensity, and duration of climate and extreme weather events, such as heat waves, droughts, and floods.[2] Increased temperatures have contributed to land degradation and desertification in many parts of the world. Erratic precipitation patterns and unpredictable rainy seasons increase uncertainty about planting times and can lead to crop failure. Changing land conditions through human actions on the regional scale, such as deforestation and urban development, can further accentuate these negative impacts at a local level. Given that extreme events are expected to further increase through the 21st century, we need to increase the stability of the global food system. Increases in global temperatures will affect processes involved in land degradation (such as vegetation loss or soil erosion) and food security (through crop losses and instabilities in the food supply). A 1.5°C global warming is projected to lead to high risks of food-supply instabilities, including periodic food shocks across regions and spikes in food pricing, and our current trajectory has us on course to significantly exceed this threshold.

Although climate and climate extremes affect our ability to produce food, food and nutrition security is more than just agricultural productivity. Today's food system is globalized and consists of highly interdependent social, technical, financial, economic, and environmental subsystems. It is characterized by increasingly complex trade networks, an increasingly efficient supply chain with market power located in fewer and fewer hands, and increased coordination across interdependent sectors via information technology. Between 1992 and 2009, trade connections for wheat and rice doubled and trade flows increased by 42% and 90% respectively. Furthermore, market power along the global food supply chains is consolidating. The three largest seed suppliers increased their combined market share from 10% in the 1990s to 55% in 2015. In the UK, the three largest supermarkets hold a market share of 60%.

Although these emergent network structures of commodity supply chains increase gains in economic efficiency, they lead to systemic instability susceptible to shocks. Trade networks are more interconnected and interdependent than ever, and research has shown that they can be intrinsically more fragile than if each network worked independently because they create pathways along which damaging events can spread globally and rapidly.[3] It is true that these trade networks could, for instance, help connect local producers to global markets and increase their incomes, but there is a risk that increasing network densities and complexities might lead to food insecurity in one part of the system as a result of the food system's inherent response to a shock rather than as a result of the initial shock itself. Furthermore, local events might trigger consequential failures in other parts of the system through path dependencies and strong correlations and thus lead to amplification of the initial shock through cascading effects. A shock in the integrated global food supply chains can lead to ripple effects in political and social systems. The 2010 droughts in wheat-producing countries such as China, Russia, and Ukraine, for instance, led to major crop failures, pushing up food prices in the global markets. This in turn contributed to deep civil unrest in Egypt, the world's largest wheat importer, as people were facing food shortages and helped the 2011 revolution to spread across the country. Although it has been shown that global economic integration continues to strengthen our resilience to smaller shocks through trade adjustments, the current network structure and functional relations create higher vulnerabilities to so-called systemic risks.

Failing Breadbaskets

Given how interconnected the food system is globally, taking a systems approach is vital to help us ensure food security. Doing so requires an understanding of the systemic characteristics and vulnerabilities of the global interconnected food system.

Although one extreme event and the consequent crop losses in a single production region can be buffered by high-yielding harvests in other places, grain storage, and trade, multiple-breadbasket failure is a growing reason for concern. Correlated or compound climate and weather events (a combination of correlated climate drivers that surpass the coping capacity of the underlying systems) on both local and global scales could trigger systemic risks in the global food system. Locally, non-linear dependencies between heat and drought conditions have been shown to have severe consequences for crop production in specific breadbasket regions, such as the Mediterranean. On a global scale, large-scale atmospheric circulation patterns, such as El Niño-Southern Oscillation or Rossby waves, can cause simultaneous extreme heat and rainfall events in different parts of the world. In summer 2018, simultaneous heat extremes in the Northern Hemisphere were associated with amplified Rossby waves, resulting in reduced crop production in central North America, eastern Europe, and eastern Asia.[4] Because those regions include important areas of crop production, such teleconnections have the potential to cause multiple, simultaneous breadbasket failures, posing a risk to global food security. If climate extremes are additionally co-occurring with other hazards, the systemic vulnerability of our global food system becomes apparent. This can currently be observed in East Africa and Yemen, where the population is fighting against a desert locust upsurge while experiencing conflicts, climate extremes, and coronavirus disease 2019 (COVID-19), all of which further constrain surveillance and control operations in the locust crisis. The combination of those multiple hazards has led to warnings that in the second half of 2020, 25 million people will experience acute food insecurity.[5]

The climate-agri-food system is characterized by dynamic interactions across spatial and temporal scales, ranging from global to local and from shocks such as heat waves to long-term stressors such as biodiversity loss. Non-linear dynamics in the climate system can lead to rapid and irreversible changes if the system surpasses a certain threshold. One of those so-called climate "tipping points" that might have major consequences for Europe's climate and lead to significant losses of crop yields is the weakening and potential collapse of the Atlantic meridional overturning circulation (AMOC).[6] Greenland melting and Arctic warming are driving an influx of fresh water with lower salinity and density into the North Atlantic, which is weakening the overturning circulation, an important part of global heat and salt transport by the ocean. If AMOC weakened and even collapsed in the coming decade as a consequence of further warming, Europe's seasonality would strongly increase and lead to harsher winters and hotter and drier summers. This is projected to reduce global agricultural productivity and to increase food prices.

Systemic Food-Systems Risks

Not all shocks to the globalized food system are directly linked to agricultural productivity or climate. The complexity and inter-connectedness and vulnerability of our globalized food system have become painfully evident in recent weeks after the emergence of a different type of shock to the system: a global pandemic. Having started as a health crisis, COVID-19 quickly trickled through the political, social, economic, technological, and financial systems. In the food system, lockdown measures and trade and business interruptions all over the world led to cascading effects that are projected to trigger food crises in many parts of the world. Although harvests have been successful and food reserves are available, interruptions to global food supply chains have led to food shortages in many places. Products cannot be moved from farms to markets, processing plants, or ports. Food is rotting in fields because transport disruptions have made it impossible to move food from the farm to the consumer. At the same time, many people have lost their income, and food has become unaffordable to them. The World Food Programme has warned that by the end of the year, 130 million additional people could face famine. In the fight against COVID-19, borders have been closed, and a lack of local production has led to price spikes in some places. In South Sudan, for example, wheat and cassava prices have increased by 62% and 41%, respectively, since February.[7] In the coming months, planting, harvesting, and transporting food are likely to further face logistical barriers, which will again exacerbate food shortages and drive up prices. A lack of food access and the related grievance could then lead to further cascading effects, such as food riots and collective violence.

Besides compound shocks, non-linear dynamics, and cascading events, the complexity of the global food system entails feedback loops that further amplify initial shocks. As a consequence of COVID-19, the fear of food shortages and price spikes due to global trade interruptions has led to export restrictions on food in several countries. At the time of writing, 11 countries have active, binding export restrictions on food, as shown by the International Food Policy Research Institute's Food Policy Tracker.[8] Russia, the world's biggest wheat exporter, announced in April that it will halt exports until July, when farmers will start to bring in grain from the new harvest. Other wheat suppliers, such as Kazakhstan and Ukraine, have also capped sales. Importers such as Egypt, on the other hand, are hoarding crops in fear of shortages, creating feedback loops that will further drive up prices. Especially in low-income countries, this might make food unaffordable for large parts of the population and increase the threats of food insecurity.

The visible and measurable systemic characteristics of the global food system are complemented by hidden links and consequences that become visible only after a shock has hit the system. The current pandemic has revealed structural weaknesses in our food system. Little storage and just-in-time supply chains have increased economic efficiency but led to systemic instability.[9] Just how vulnerable and easy to disrupt the supply chains in some parts of the world are has become evident in the last several weeks. Further food-system interdependences that were previously ignored but are becoming apparent now include the role of schools in providing nutritious food to children. The World Food Programme estimates that globally, 368 million school children miss out on meals that they would normally receive in schools because classes are shut down.[10] If we want to make the global food system resilient to future shocks, we need to pay attention to both quantifiable and uncertain systemic risks and food-system interdependencies.

Enhancing Resilience

To address the challenges of a globally interconnected, complex food system that is projected to be hit by more frequent and severe extreme events, we need to take a systems approach and

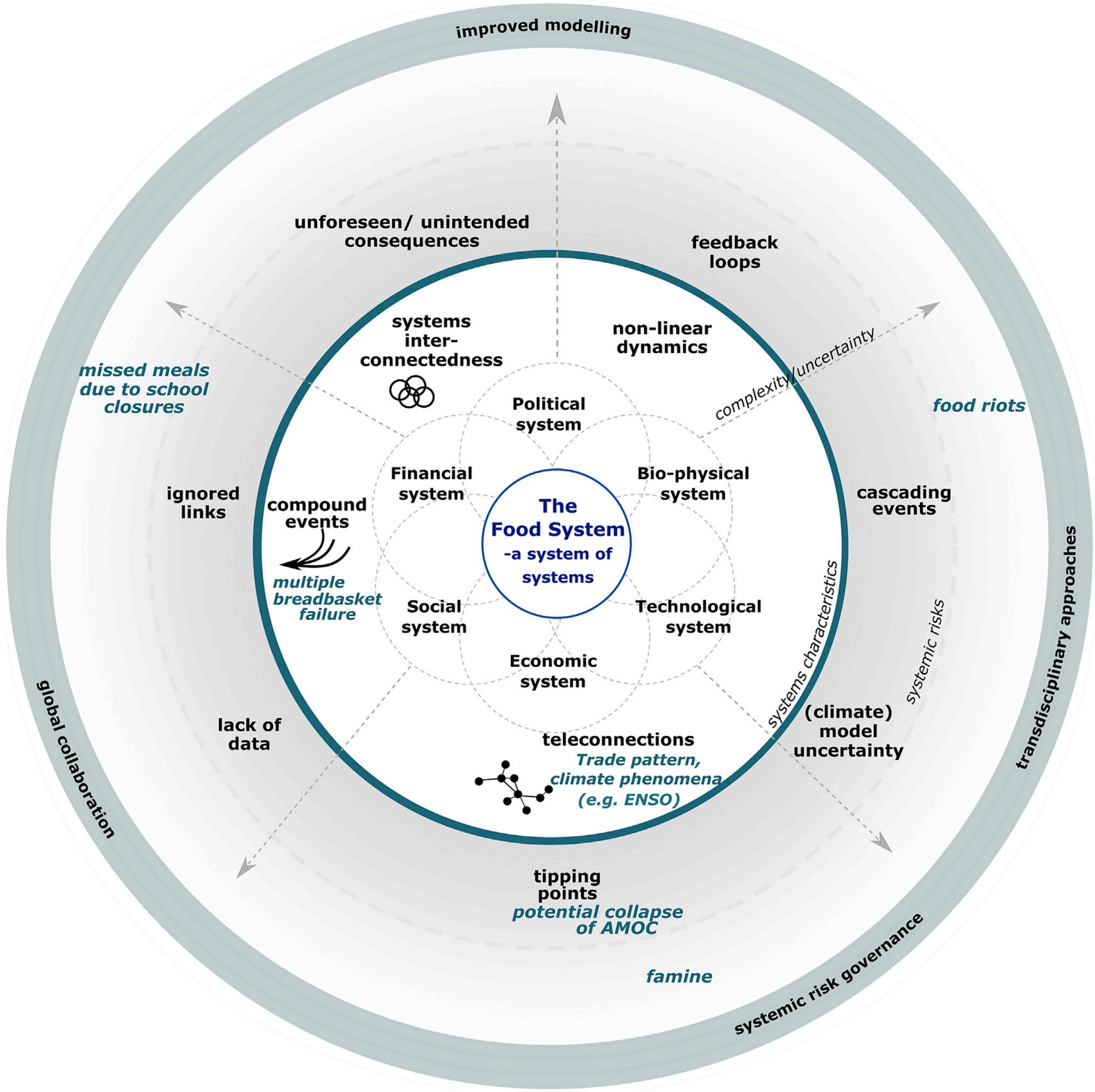

Figure 1. The Complexity of the Global Food System and Its Inherent Systemic Characteristics

acknowledge the systemic characteristics of the global food system (Figure 1).

We need better food-system models that can account for systemic risk characteristics and increase our understanding of non-linear dynamics, tipping points, feedbacks, dependence structures, and adaptive behaviors.[11] We need transdisciplinary approaches that bring together different disciplines as well as other forms of expertise, such as knowledge of local practitioners. Quantitative and qualitative methods need to be combined, and different model types need to be integrated to link climate hazards with technological and civilizational risks. Artificial intelligence and new machine-learning tools can improve our understanding of the food system's complexity but must be complemented by qualitative assessment, such as perceptions, social concerns, or socio-economic impacts. Robust data and statistics that are accurate, timely, disaggregated, and accessible are needed for monitoring and early warning systems.

Systemic risk and systemic opportunities need to be incorporated into the design of food-related policies.[12] Effective governance needs to consider the interconnectedness among different parts of the global food system. A network perspective that pays attention to the interdependent actors and nodes is required.[13] One solution could be a systemic-risk transaction tax as suggested for the financial markets.[14] Individual actors (such as large trading companies or retailers) that increase systemic risks in the network will be taxed proportionally to their marginal contribution to the overall systemic risks. The tax can be seen as insurance for the public against costs arising from cascading failure. Additionally, we need global collaboration to work toward better management of trade barriers to ensure that food value chains function even in moments of crises to prevent price spikes and provide "all people, at all times, [with] physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for a healthy and active life."[15]

More shocks are likely to hit our global food system in the future, unleashing the potential for systemic risks to cascade through the system and to lead to major impacts and system breakdowns. These include projected increases in simultaneous climate extremes in breadbasket regions, crop pests, and other, unexpected shocks. If we want to avoid major threats to food security, we need to take a systems perspective in analyzing, managing, and governing the global food system.

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