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EDITORIAL

Food, trade, and the environment

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Introduction

Changes in human population density relative to the distribution of agricultural production and natural resources have increased international trade in the global food system (D’Odorico et al 2018). A fundamental benefit of trade is that it can increase carrying capacities relative to local environmental limits (Porkka et al 2017). At the same time, dependence on international trade has many potential costs for the food system. For example, trade may decrease resilience of food supplies to crop failures and sudden economic or political changes taking place in key ‘breadbaskets’ that produce food for the export market (Bren d’Amour et al 2016, Marchand et al 2016, Tighelaar et al 2018). Trade also distances consumers from the locations of agricultural production, displacing pollution to producing countries, and changing patterns of resource use (O’Bannon et al 2014, Dalin and Conway 2016, Nesme et al 2016).

Understanding the complex interdependencies among national food supplies, international trade, and the environment is a key aspect of global sustainability. This Focus Issue contains 29 articles that collectively describe, evaluate, and synthesize diverse aspects of the relationships between trade, food and water security, and the environment at local to global scales (figure 1). The current trend to protectionist policies in many countries, including in important food producing countries like the United States, makes this collection especially timely. The papers in this Focus Issue present actionable results that provide insights which can help guide further research and inform decision-making around trade. Below we highlight two of the areas that studies in this Focus Issue contribute to understanding: resilience in the global food system and cross-scale connections.

Resilience and the global food system

The proportion of global food production that is traded internationally has dramatically increased during the past two decades (D’Odorico et al 2018). Expansion and intensification of trade networks has created a new potential for local production failures or export disruptions to propagate into global food crises (Gephart et al 2016, Marchand et al 2016). Such shocks may be caused by environmental factors, such as extreme weather, or due to geopolitical factors such as trade restrictions (Bren d’Amour et al 2016, Gephart et al 2017). With the growing dependence on trade for food supplies of many countries, national food security therefore increasingly rests on the ability of food production and distribution systems to cope with disruptions (Seekell et al 2017). Understanding the food system’s ability to respond and adapt to such disruptions (i.e. its resilience to sudden environmental or socioeconomic change) requires first characterizing the key structures involved. The Focus Issue makes important contributions in this area, including by highlighting the complexity and uncertainty that can make these properties difficult to predict.

Several articles in this Focus Issue present core findings relevant to food system resilience—with particular emphasis on different elements of food supplies and food stocks (n = 7). First, changing patterns of resource availability in trade networks have already felt around the globe. For example, environmental conditions and government-imposed export restrictions to key producing countries drove up staple food prices in some countries in 2007 and 2011, contributing to food insecurity and social unrest in distant countries, including violence in some particularly vulnerable regions (Buhaug et al 2015, Seekell et al 2017). Secondly, countries with the most exposure often have the least capacity to deal with food crises. For example, with respect to global cereal trade, shocks disproportionately impact consumption in central and western Africa (Bren d’Amour et al 2016, Marchand et al 2016). Other lower income economies are also particularly vulnerable to shocks in cereal trade as well.
as fisheries trade (Bren d’Amour et al 2016, Gephart et al 2016).

Only a handful of countries export the majority of the world’s staple cereals and export disruptions from these countries could put up to 200 million people at risk for food insecurity, 90% of whom live in sub-Saharan Africa (Bren d’Amour et al 2016). Contributing to this vulnerability are the region’s relatively small and highly volatile food stocks (Laio et al 2016). Indeed, food reserves and other country-level redundancies can be important contributors to the general resilience of the food system (e.g., Fader et al 2016). However, predictions of the impacts of future shocks to these countries are highly variable among climate and trade scenarios. Konar et al (2016) applied shocks to coupled global hydrology-trade models under a variety of scenarios and found that a number countries are often predicted to have either increased or decreased crop yield in response to shocks, depending on the crop and specific context of the scenario. Building from this research, more integrated understanding of potential social, economic, and political responses to enhance food system resilience across scales is needed.

Importantly, the Focus Issue offers evaluations of both agricultural and marine fisheries trade. For example, as with cereals trade, Gephart et al (2016) found that many Central and West African countries are most vulnerable to shocks in international fish trade because of strong import dependence. Collectively, these studies show that increased trade alters patterns of exposure to shocks, and that trade dependency and food reserves are important factors to manage when constraining potential changes in national food supplies. Most evaluations of global agricultural production and trade are based on the same FAO datasets and consequently inherit the same potential errors and limitations. Data on marine capture fisheries are generated and curated independently of the agricultural databases (e.g., Gephart and Pace 2015), and consistent results across these studies indicate robustness to the overall conclusions.

**Connections across scales**

With an increasingly globalized food system, there is an urgent need to understand interdependencies across countries as well as the drivers that influence social and ecological outcomes at actionable scales (e.g., communities and households). Global scale studies provide important context on potential interactions across countries that help to ‘benchmark’ different scenarios (e.g., Fader et al 2016, Jägermeyr et al 2016, Konar et al 2016). Recent research comparing food flow networks at the local, national, and global scales shows that structural network properties are surprisingly similar across scales (Konar et al 2018). Hence, global scale studies can raise important questions about potential tradeoffs and consequences for different actors at the local scale (MacDonald et al 2016). Studies in this Focus Issue lay the groundwork for these connections, with at least 14 at the global scale and 12 dealing with national, regional, or multi-country case studies. Additionally, one study presents a ‘middle-ground’ approach that combines sub-national data on commodity production with customs data to uniquely summarize international trade flows by corporation and production regions within a country (Godar et al 2016). This is an
important methodological innovation for the cross-scale analysis of trade.

Many of the studies in the Focus Issue center on water resources and trade \((n = 7)\). Water scarcity is a limiting factor to food production in regions that are home to up to 2.2 billion people (Porkka et al 2016). Global hydrological model analyses by Jägermeyr et al (2016) show that global application of four different integrated crop water management interventions could theoretically increase food production on current agricultural lands by 18%–60%. However, more focused model analyses and surveys of smallholder farmers in the Mount Kenya region of Kenya revealed that levels of risk aversion for individual farmers are an important determining factor for whether or not these interventions are adopted (Gower et al 2016). Smallholder farms make up the majority of the agricultural land area in countries where integrated crop water stands to make the biggest production gains; so reconciling the biophysical potential of specific interventions with the cultural and economic diversity of smallholder farmers is a key research priority (MacDonald et al 2016).

Studies in the Focus Issue also consider land-use change \((n = 4)\) and livestock systems \((n = 3)\) in global agricultural trade and food systems. Livestock production and consumption is increasing globally due to the growing global population and widespread dietary shifts to higher meat and dairy consumption (Davis et al 2015, Lassaletta et al 2016). The feed-to-food conversion efficiency for livestock is relatively low, with vast amounts of land now directed to producing crops for livestock feed compared to the land area embodied in plant- or fish-based diets (Gephart et al 2014, Davis et al 2015, Shepon et al 2016). Production efficiency has grown substantially for many countries in recent decades, but examining national level statistics in isolation hides considerable sub-national heterogeneity and displacement of environmental impacts among countries (Godar et al 2016). For example, beef and soy supply chains have been key contributors to deforestation in Latin America (Henders et al 2015). Jadin et al (2016) offer an insightful case study of agricultural intensification in Costa Rica: while there has been a reduction of land dedicated to livestock production and subsequent afforestation, this forest is primarily returning to lands seen as having low ecological value, but plantations of export-oriented cash-crops have increasingly converted forests, pastures, and farmland used for traditional crops in high ecological value regions. Moreover, much of the reduction in land use for livestock production was also achieved by shifting production to other countries, like the United States. Hence, improvements at the national scale can mask unintended consequences at local scales relevant to ecosystem management and human wellbeing—with implications for how the net benefits for global sustainability are understood. Making the connection between studies that set global goals and benchmarks, and those that evaluate specific mechanisms for reaching these goals at policy-relevant scales, can be achieved by synthesizing across multiple studies and creating this potential is an important contribution of this Focus Issue.

Measurable and immediate impact

To date, the papers in this Focus Issue have been downloaded more than 207 000 times and cited in 524 scholarly articles. These citations come from diverse fields including Fisheries Science, Environmental Science and Management, Human Geography, Applied Economics, Public Health, Political Science, and Plant Biology. The papers have reached as many as 1.3 million Twitter users and are described in at least 40 posts on social media including blogs, Facebook, and Reddit. There have been at least 69 reports in the news media. These statistics are testament to the widespread and growing interest in the nexus of food, trade and environment among both researchers and the public.

The vulnerability of food production systems to climate change has been recognized by the Paris Agreement, and ending hunger and safeguarding food security are priorities for international response (Elbehri et al 2017). Understanding connections among environment, food production, and trade is central to developing viable policy for achieving these goals. Policy documents already rely on articles from this Focus Issue to unravel some of the complexity inherent in these connections (e.g., Bailey and Wellesley 2017, Elbehri et al 2017), including in the areas of:

* Human impacts on water resources and links to climate change (Porkka et al 2016),
* Cause and effects of forest transitions (Jadin et al 2016),
* Relationships between trade and water scarcity (Dalin and Conway 2016), and
* The role of trade in climate mitigation and adaptation (Dalin and Rodriguez-Iturbe 2016).

In this era of global change, the type of actionable research contained within this Focus Issue will be critical to informing policy that is effective among the complex connections between food, trade, and the environment.

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