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COMMENTARY ON COVID-19 AND THE FOOD SYSTEM

Ecological resilience of food systems in response to the COVID-19 crisis

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Abstract
Resilience of food systems is being tested by the COVID-19 disruption. As with any severe disruption, collapse of some systems, innovation in others, and total reorganization of some will occur. Direct delivery of food, online farmers markets, community supported agriculture operations (CSAs), backyard food production, expansion of seed producers and plant nurseries, and decrease in restaurant share of the food dollar with increased home cooking are some trends that may be lasting. These trends can be seen as complex adaptive systems following the adaptive cycles of all open systems. The crisis provides an opportunity to examine a model of food system resilience (CLIMATED) and apply it more broadly.

Introduction
The food choice that precipitated the COVID-19 crisis was predicted more than a decade ago,[1] and the disruption induced by the virus fits a model of adaptive cycle dynamics developed nearly 50 years ago (Holling, 1973). Adaptive cycles of rapid

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[1] After a previous coronavirus epidemic (SARS), researchers at Hong Kong University predicted that a pandemic from novel coronavirus would be likely to occur in the future due to the "presence of a large reservoir of SARS-CoV-like viruses in horseshoe bats, together with the culture of eating exotic mammals in southern China" (Cheng, Lau, Woo, & Yuen, 2007, p. 683). The Rockefeller Foundation contends that meat from a bat or pangolin sold in late 2019 in a wet market in Wuhan enabled the novel virus to infect humans (Steiner, Ehsani, Milani, & Ruben, 2020).

growth, maturity, release, and reorganization are ubiquitous in social-ecological systems. Ecological resilience refers to the degree of disturbance a system can buffer before entering the collapse/release and reorganization phases. Systems can induce collapse and reorganization that affects the resilience of their subsystems as well as other systems (Sundstrom & Allen, 2019).

In recent years the concept of ecological resilience has been applied most vigorously to food systems and climate change. Agriculture is affected by climate change perhaps more than any other sector of our society (National Sustainable Agriculture Coalition [NSAC], 2019). One recent policy response is the Agriculture Resilience Act (2020), which seeks to mitigate climate change by sequestering carbon and reducing other greenhouse gases through processes that enable food systems to cope with climate change by increasing soil health and, thereby, yields and profits.

Until recently, many were losing hope that anything could be done to counter the existential threat of climate change (Lenton et al., 2019). In a few short weeks, however, the response to the COVID-19 virus has reduced greenhouse gas (GHG) emissions in China by an estimated 25% (Wright, 2020), caused a 50% reduction in nitrogen oxides in California (Gohd, 2020), and visibly reduced NO_2 levels over Italy and China (Ghosh, 2020). Worldwide, the largest reduction in CO_2 release in the last 50 years is predicted for 2020 by the Global Carbon Project (Nasralla, Volcovici, & Green, 2020), since millions of people around the world have virtually stopped traveling by car or airplane—or even leaving their homes and factories are shut down. The reduction in GHGs by 2020 urged by many (United Nations, 2018) has occurred. Whether the GHG reduction can continue is just as unpredictable as the COVID-19 disturbance itself.

The unexpected impact of the disturbance induced by COVID-19 on GHGs fits a basic realization of Holling and ecologists who followed him: the nature of Nature is change. Ecologists have now well established that natural systems do not move toward a sustainable equilibrium; instead, disruptions of existing systems of species and communities are a regular and often necessary feature for systems to be resilient (Kricher, 2009). Suppression of disruption (e.g., classic forest fire management) can prolong an untenable mature phase that makes a system less likely to survive and thrive in the future. Holling made a crucial distinction between "engineering resilience" and ecological resilience. Engineering resilience seeks stability. Stability is often the antithesis of resilience in ecological systems (Holling, 1996).

Resilient systems can fluctuate wildly and change abruptly, to reshape, reform, and adapt themselves. Many resilience researchers recognize the value of viewing biological systems as complex adaptive systems as defined in chaos theory: hierarchically nested systems that interact with each other and show adaptive and emergent qualities (Sundstrom & Allen, 2019).

Resilience researchers have also pointed out the difference between general and specific resilience. Specific resilience to a virus is a vaccine. General resilience is establishing a robust immune system that withstands a variety of viruses as they mutate and evolve.

Grocery stores appear to have a general resilience to the COVID-19 disruption. Groceries are some of the few businesses adding employees during the crisis. Surveys of consumers, grocers, and restaurateurs indicate that restaurants are unlikely to regain the 60 cents of every food dollar they received before the crisis (Redman, 2020). The owner of the largest grocery chain in New York City contends that preparing food at home was a lost art that is being rediscovered by New Yorkers. They will not go back to restaurant food, he predicts (Varadarajan, 2020).

Many researchers have attempted to define the qualities of food systems that make them generally resilient to disruptions. One summary of those frameworks (Worstell & Green, 2017) posits eight necessary qualities of resilient local food systems that are summarized by the acronym CLIMATED (Worstell, 2017), where resilience is postulated to be a function of eight qualities:

Resilience=f(Connectivity, Local self-organization, Innovation, Maintenance/redundancy, Accumulation of value-added infrastructure, Transformation, Ecological integration, Diversity)

The remainder of this essay will explore how these qualities are exemplified in the current COVID-19 crisis.

The T and I of CLIMATED refer to Transformation and Innovation.

Innovation is transformation at a smaller scale. No-till agriculture is a transformation at the level of the soil, but an innovation at the level of the farm. A system can maintain itself in the growth phase by stimulating the release and reorganization of subsystems. New complex adaptive systems compete with old, mature, calcified systems (often controlled by government or monopolistic gatekeepers), which stay alive through subsidies and bailouts and the hesitancy of past investors to embrace oncoming collapse and release. A mature system may require transformation to cope with novel disruptions.

Gatekeepers stifle innovation. After Chinese scientists released the genetic code of COVID-19, adroit researchers in Berlin created an easily replicable test for COVID-19 infection in late January (Becker, 2020; Schmitz, 2020). The World Health Organization (WHO) rapidly shipped hundreds of thousands of those test kits to 57 countries and posted the protocol online so other labs could create their own tests. The Centers for Disease Control and Prevention (CDC) initially did not permit use of the German test in the U.S. Testing in the U.S. was delayed until the CDC developed its own test, which was then recalled because it included a bad reagent and did not work (Cohen, 2020). Centralization and gatekeeping by national bureaucracies undermines the innovation needed for resilience.

The COVID-19 disruption has induced widespread innovation in food system marketing. Fear of infection at farmers markets led to closure of all markets in some cities (e.g., Los Angeles, Washington, D.C., and Seattle) and the implementation of new procedures at farmers markets to meet social distancing standards and eliminate transmission of COVID-19 (Appalachian Sustainable Agriculture Program [ASAP], 2020). These procedures were propagated nationwide by the Farmers Market Coalition (2020) to inspire consumer confidence in traditional farmers markets.

With these new procedures being adopted and at the urging of state and local nonprofits, many states and cities declared that farmers markets were "essential services" and must remain open (Greenaway, 2020). Among the nonprofits who convinced governors to let social distancing farmers markets stay open were Ohio Ecological Food and Farm Association (A. Lipstreu, policy director of OEFFA, personal communication, April 5, 2020) and the Groundworks Center for Resilient Communities in Michigan (J. Schaap, local food policy specialist, GCRC, personal communication, April 5, 2020).

More transformative systems have also been strengthened by the COVID-19 crisis. As Torry (2020) notes, "The new coronavirus pandemic is deepening a national digital divide, amplifying gains for businesses that cater to customers online, while business reliant on more traditional models fight for survival" (para. 1). The complex adaptive systems of CSAs and online farmers markets are newly flourishing as the COVID-19–induced disruption provides a new environment. A movement already underway has been invigorated by the desire for direct delivery of food and more direct value chains to minimize COVID-19 contamination (Ricker & Kardas-Nelson, 2020). The resurgence of CSAs benefits farmers in several ways: it provides funds ahead of planting and reduces the marketing and distribution costs associated with traditional farmers markets (including time of farmer and employees at market and the cost of hauling to market more produce than is needed, rather than just the ordered amount).

Reduction in GHGs due to the COVID-19 disruption has stimulated the California Air Resources Board to explore incentives to encourage more workers to work from home after the crisis ends (Gohd, 2020) with the hope of continued reduction in GHG emissions.

The COVID-19 disruption, as with all disruptions, provides an opportunity for the creative destruction of mature systems and opportunities for transformation. Resilient societies, communities, farms, and other food businesses will take advantage of the opportunities awakened by the disturbance. New jobs in home delivery, already underway with companies like Amazon and local food delivery businesses such as Instacart, Grubhub, and DoorDash, are one such opportunity in the food system. Whether working conditions at these emerging firms will undermine resilience is unknown, however.

The C, L, E and D of CLIMATED refer to modular Connectivity, Local self-organization, Ecological integration and complementary Diversity.
Communities have become dependent on outside sources of food. Even in many highly agricultural U.S. counties, nearly all food is imported (Fink, 2019). Just as the COVID-19 crisis has made the U.S. aware that 90% of many basic pharmaceuticals are imported (Palmer & Bermingham (2019), the long, rigid, and easily disrupted U.S. food supply chains have also been laid bare. One striking instance is farmers having to dump eggs and milk when both are scarce in grocery stores (National Farmers Union, 2020). A self-organized local supply of food is seen by many (e.g., Schuman, n.d.) as a positive outcome of the COVID-19 crisis. Resilience requires creating a network of relatively independent, self-reliant nodes, so that the failure of one node does not imperil the entire system. In ecological circles, such systems are known as "modular." To be resilient, farms must be highly networked, but independent.

The more self-reliant a community is the less global disruptions will matter. Local self-organization begets more local self-organization. Not only does this boost local economic multipliers (which increases income, wealth, and jobs), but self-organization in areas such as health clinics and senior assistance results in a healthier population. An index of food system resilience, based on CLIMATED, has shown high correlations with both lower poverty and positive health outcomes (Green, Worstell, & Canarios, in press; Green et al., 2018). As yet unexamined is any quantitative correlation of food system resilience to responses to the COVID-19 crisis.

Redundancy, the ability of a system to replace its components as needed, is dependent on a diverse array of complementary individual components. When people rely on one source of food, they are likely to hoard as much as possible in times of scarcity. When they have multiple sources, hoarding is unnecessary.

Diverse systems are critical because they are less likely to fail all at once or in the same way. When the only source for COVID-19 tests is the CDC, and the CDC test fails, the entire country suffers. Consumers who previously bought all their groceries at a grocery store have become aware, due to the COVID-19 disruption of grocery supplies, that farmers can deliver direct. This will be an opportunity for producers who can master distribution systems. Where logistic and distribution challenges can be met, consumers will not be dependent on grocery stores, but can buy from multiple farmers.

Gatekeepers, whether elected on unelected, can decrease the diversity and resilience of food systems by closing all farmers markets regardless of their social distancing and hygiene standards, as many U.S. mayors have done in the COVID-19 crisis.

Bringing food production to its local apex—planting of "victory gardens"—is an activity being adopted by many families forced to stay home by the COVID-19 crisis (Rao, 2020). Producing food locally requires integration into the local ecosystem to produce the food products best fitted to one's local ecological conditions. This trend induced by the pandemic has also led to reported increases in sales and jobs at plant nurseries and seed providers (Marantos, 2020).

Although social distancing is a major output of the crisis, social bridging has also been a result of the COVID-19 crisis (Webb, 2020). Hundreds of voluntary, nonprofit initiatives are sourcing food from farmers and delivering to the elderly or others staying at home (Grillo, 2020). In one example, 35 Facebook groups have been set up with 30,000 members in three counties in Nova Scotia to connect those who need assistance with those who would like to provide it. These groups say they are countering fearmongering with "caremongering" (Gerken, 2020).

The M of CLIMATED refers to Maintenance (or redundancy, in ecological terms).
Just-in-time supply chains can be efficient, but efficiency can be the enemy of resilience. Times of disruption reveal whether systems have enough redundancy to maintain their crucial functions. The current crisis has revealed the lack of crucial hospital equipment and of local and even national capacity for the production of simple items such as masks and reliance on a single, often distant, source for crucial drugs and equipment.

The lack of grocery stores in urban areas has resulted in pressure to keep open local convenience stores, which sell mostly tobacco, liquor, and lottery tickets, but are the only source of food for those without personal transportation. With high levels of COVID-19 contraction occurring in urban areas, the resilience of both urban food production and alternative, more direct sourcing of food to urban areas is underscored (Sowerwine, 2020).

The A of CLIMATED refers to Accumulation of value-adding infrastructure.
Self-organizing, modular connectivity and complementary diversity only produce lasting results when local food system agents acquire and maintain value-adding infrastructure. For climate change, the most basic infrastructure is the soil. If soil health (chiefly dependent on sequestered carbon) is not increasing, resilience is decreasing. In the current pandemic, the most publicized lack of crucial infrastructure are manufacturing capacity for ventilators and PPEs and sufficient hospital beds in some areas. Response to the pandemic shows some sign of reversing the trend toward underfunding and closing local hospitals, especially in rural areas (Bolin, Watzak, & Dickey, 2019; Holt, 2020).

To increase the resilience of the food system, many advocates are pushing for investment in on-farm storage, processing, and local distribution capacity to transform value chains to enable a more robust response to similar disruptions in the future—and to capture more of the added value for the farm. For example, as we shift from market-style set-ups at CSAs and farmers markets to pre-ordered, prepacked, and prepaid models, farm businesses must purchase packaging equipment to meet current safety protocols (ASAP, n.d.). Distribution is an often overlooked aspect of resilience-supporting infrastructure. Those with storage, on farm processing, and transportation infrastructure will rule the post–COVID-19 environment.

Consistent with the proposed federal stimulus packages focused on infrastructure, NSAC, the Farmers Market Coalition, and state policy groups are working to ensure that the infrastructure needs of farmers and the food system are not forgotten (W. King, National Sustainable Agriculture Coalition, personal communication, April 5, 2020).

Concluding Summary

The COVID-19 disruption provides an opportunity to test the validity of food system resilience models and their broader applicability. Although the outcome of the crisis is unknown at this point, many predict a wide-ranging transformation of U.S. food systems. A global public health experiment is in progress of which the food system is an integral part. The governments of other countries, such as Sweden, Germany, Brazil, and Mexico, have imposed less severe disruptions than the U.S. This essay is an initial attempt to examine the eight qualities proposed as necessary for ecologically resilient systems in the CLIMATED model and examine how broadly these qualities may apply in this particular disruption.

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