UNITED NATIONS FOOD SYSTEMS SUMMIT 2021

The Scientific Group for the
UN Food Systems Summit
https://sc-fss2021.org/

A paper from the Scientific Group of the UN Food Systems Summit
March 8, 2021

BUILDING RESILIENCE TO VULNERABILITIES, SHOCKS AND STRESSES

A PAPER ON ACTION TRACK 5

by
Thomas W. Hertel, Ismahane Elouafi, Frank Ewert and Morakot Tanticharoen

The Scientific Group for the UN Food Systems Summit is an independent group of leading researchers and scientists from around the world. Its members are responsible for ensuring the robustness, breadth and independence of the science that underpins the Summit and its outcomes.

ABSTRACT

Transforming food systems involves five action tracks: i) access to safe and nutritious food, ii) sustainable consumption, iii) nature-positive production, iv) equitable livelihood, and v) resilience to shocks and stress.

Action Track 5 of the Food Systems Summit aims to ensure food system resilience in the face of increasing stresses from climate change, population growth and conflict over limited natural resources. We identify five distinct capacities that are key to a resilient food system in the face of these shocks: (i) to anticipate, (ii) to prevent, (iii) to absorb, (iv) to adapt to an evolving risk and (v) to transform in cases where the current food system is no longer sustainable. Resilience at the individual, community, government and global food system level must be built in such a way that the economic, social and environmental bases to generate food security and nutrition for current and future generations are not compromised anywhere in the world. This means that it is equitable in a financial sense (economic resilience), it is supportive of the entire community (social resilience), and it minimizes harmful impacts on the natural environment (ecological resilience).

There are a number of key trade-offs which must be navigated as we strive to achieve greater food system resilience. These include the need to deliver short term humanitarian aid without jeopardizing long run development, mitigation of rising global temperatures even as the food system adapts to the inevitable changes in the earth's climate, taking advantage of the benefits of globalization while avoiding the downsides, and encouraging agricultural production and boosting rural incomes while also protecting the environment. All of these trade-offs become more pronounced in the context of small farms operating in marginal environments. In order to address these trade-offs, cooperation and coordination across policy makers, local communities and public and private institutions and investors will be required.

A range of local, regional, national and global solutions covering different parts and contexts of the food system have been reviewed to understand progress and challenges in building resilience to improve food security. The resilience framework is helpful to conceptualise complex problems related to food security and allows us to point to important challenges that need to be overcome. From this analysis we conclude that developing an operational resilience approach is always context-specific and requires the involvement of relevant local, national and international actors, organisations and agencies. Hence, there is no single game changing solution that will ensure resilience across multiple food security challenges. Instead, adopting resilience as a systems approach to support the conceptualisation and operationalization considering the respective actors will contribute to the development of context-specific solutions. Beyond that, much will be gained by highlighting successful solutions and facilitating exchange of tools, data, information and knowledge and capacity. This will also contribute to the further develop of the resilience approach as a key concept to achieve food security.

INTRODUCTION

Action Track 5 seeks to provide an integrative perspective across all other action tracks encompassing the entire food system but with the specific focus on building resilience (Fig. 1). This review of the state of scientific understanding of resilience is broken into four parts: (Fig. 1), (i) the challenges faced by the food system and our ambition to meet these challenges, (ii) the identification of key trade-offs and synergies, (iii) operational aspects towards practical solutions and, as part of this, (iv) the contextualization of specific food system related problems.

Following the (OECD 2020) and the FAO (UN FAO 2020), we distinguish five capacities of resilient food systems to deal with changes or shocks (Fig. 2), i.e. (i) to anticipate, (ii) to prevent, (iii) to absorb, (iv) to adapt to an evolving risk and (v) to transform in cases where the current food system no longer sustainable. Our definition also includes two more aspects to achieve targeted solutions. On the one hand, building resilience requires clear understanding and consideration of the specific food system context (region, time-period, system complexity, involved actors, institutional structures, etc.). On the other hand, conceptual ideas need to be operationalized, developing concrete measures and processes for the five capacities of resilient food systems.

CHALLENGES AND AMBITIONS

As highlighted in the Global Assessment Report on Disaster Risk Reduction (UN Office for Disaster Risk Reduction 2019), global change and the increasingly interconnected nature of society are inducing unprecedented hazards that are likely to prove disastrous for many of the world's most vulnerable populations. This has led the United Nations to issue a report focusing specifically on resilience guidance (United Nations 2020). Action Track 5 of the Food Systems Summit aims to ensure such resilience in the regional to national and global food system(s), such that people are empowered to prepare for, withstand, and recover from instability. They must be able to participate in a food system that, despite shocks and stressors, delivers food security, nutrition and equitable livelihoods for all. Resilience at the individual, community, government and global food system level must be built in such a way that the economic, social and environmental bases to generate food security and nutrition for current and future generations are not compromised anywhere in the world. This means that it is equitable in a financial sense (economic resilience), it is supportive of the entire community (social resilience), and it minimizes harmful impacts on the natural environment (ecological resilience).

The concept of resilience first emerged in the context of ecological stability theory (Holling 1973). It was directed at understanding the capacity of ecosystems to sustain perturbations

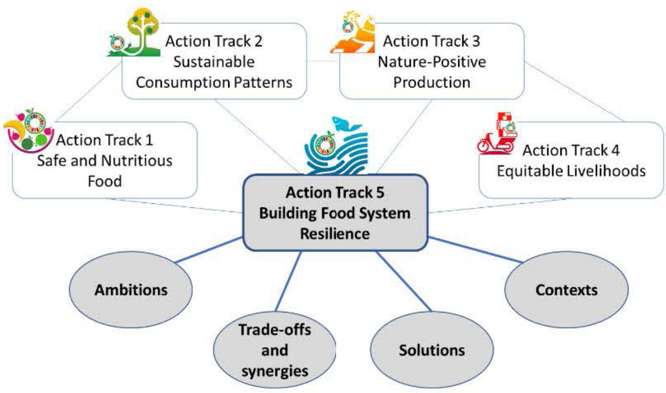

Figure 1. *Representation of the integrative perspective of Action Track 5 across other action tracks and key elements addressed by Action Track 5 to build food system resilience.*

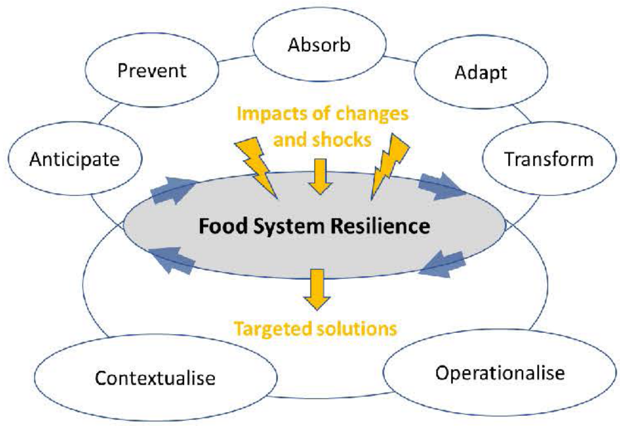

Figure 2. *Schematic representation of the scope of food system resilience as proposed by Action Track 5 considering five capacities of food systems to anticipate, to prevent impacts of changes and shocks, to absorb, to adapt and to transform, and activities to develop concrete targeted solutions considering the respective food system context and to develop required operational measures and tools.*

persisting in the original state. The resilience concept has evolved to address complex socio-ecological systems and their capacity to adapt while remaining within critical thresholds (Folke 2016). In the context of food systems, resilience has contributed to the foundation of adaptive resource management (Walters 1986) with widespread use in cropping and farming systems (Webber et al. 2014). This concept has also surfaced in the field of economics where it has been linked to 'development resilience' which focuses on the capacity to avoid and escape from poverty in the face of unforeseen external shocks and stressors (Barrett and Constas 2014). This literature explicitly considers issues of risk, dynamics, and ecological feedback. The recent OECD report (2020) on agricultural resilience usefully distinguishes between: (a) risks that are best managed at the farm level, i.e., normal business risks, (b) larger, less frequent risks requiring market interventions such as insurance and futures markets, and (c) infrequent, catastrophic risks requiring emergency assistance.

Box 1: *Food System Resilience during the COVID-19 Pandemic*

Evidence about the impact of COVID-19 on food system resilience is just beginning to emerge in the peer-reviewed literature (High Level Panel of Experts 2020), but it is evident that the pandemic is affecting all four pillars of food security (Laborde et al. 2020). Estimates of the increase in food insecurity range from 83-132 million, reflecting and exacerbating many of the existing inequities in the food system (Klassen and Murphy 2020; FAO 2020b). These impacts are not just being felt in the developing world. In the United States, food insufficiency increased three-fold compared to 2019. Food insufficiency among black adults is estimated to be two to three times higher than for whites and reached one in five individuals in July of 2020 (Ziliak (2020)).

Food insufficiency captures lack of access to food due to limited resources. This can arise in a pandemic due to limited availability, high prices or loss of income. Evidence to date shows that the impact of the pandemic on prices and food availability varies widely across commodities and countries. In India, where there was a sudden, unanticipated lockdown put in place for three weeks in late March/early April, the evidence on price impacts is mixed. In a detailed study based on data from just one of the largest online retailers in India, Mahajan and Tomar (2020) find that online prices during the lockdown were largely unaffected. Instead, availability of food was reduced – by 8% in the case of fruits and vegetables and 14% for edible oils. In contrast to these findings, Narayanan and Saha (2020) use publicly available data from the Government of India to analyze urban food prices across a range of markets and suppliers and find evidence of marked price increases during the lockdown – particularly for pulses, oils and vegetables -- ranging from 3.5% to 28%, depending on the commodity in question. Nonetheless, a recent household survey in Ethiopia suggests that the food system has proven relatively robust in that country, with dietary intake being largely unaffected by the pandemic (Hirvonen, Brauw, and Abate 2021).

The consequences of the COVID-19 pandemic for labor markets, and hence crop cultivation activities (Ayanlade and Radeny 2020) as well as household incomes, appears to a key channel for increasing food insecurity (Béné 2020). In West Africa, the agricultural workforce already has a poor nutritional and health profile and are especially vulnerable to pandemic illness during critical planting and harvesting periods (Ali et al. 2020). In a forthcoming model-based study of the impacts of COVID-19, Laborde, Martin and Vos (2020) predict that the global recession caused by this pandemic will be much deeper than that of the 2008-2009 financial crisis. The predicted increases in poverty are concentrated in South Asia and Sub-Saharan Africa with more severe impacts in urban areas than in rural communities. They project that almost 150 million people will fall into extreme poverty and food insecurity as a result of this pandemic. When combined with limited health care resources, large households and high incidence of co-morbidities the human toll is expected to be extreme in Sub Saharan Africa (Walker et al. 2020).

Food systems are becoming increasingly global, dynamic, and complex. Today, food goes through agri-food supply chains involving networks of farms, production or processing facilities, and storage and distribution channels. With this growing complexity, new and challenging risks are emerging as evidenced by the ongoing COVID-19 pandemic the impacts of which are skewed towards the world's most vulnerable populations (Box 1). In addition, there are many other, ongoing challenges, including technological accidents, infectious diseases, transportation hazards, cyber-attacks, product contamination, theft, and unexpected shutdowns of key supply chain nodes (Leat and Revoredo-Giha 2013; Manning and Soon 2016). Such disruptions could lead to significant public health and economic consequences. A study by the World Bank finds that the impact of unsafe food costs low- and middle-income economies about US$ 110 billion in lost productivity and medical expenses each year (Jaffee et al. 2019). Yet a large proportion of these costs could be avoided by adopting preventative measures that improve how food is handled along the global supply chains pointing to the great scope for collaboration and learning using South-South and Triangular cooperation adopted by several UN Organizations, namely FAO, IFAD, and WHO.

Successful management of socio-ecological systems necessitates understanding the contextual factors that drive changes in resource-use patterns and influence societal capacity to adapt in the face of stresses. Schwarz et al., (2011) find that perceptions of risk, preference, belief, knowledge, and experience are key factors determining whether and how adaptation takes place – both at the individual and societal levels. They suggest that elements of good community-level governance such as social cohesion, leadership, or individual support for collective action improve the perception that people have of the resilience of their community. Creation of a food system that delivers broad-based benefits for all people, requires covering all the societal bases of equity and inclusiveness. Developing capacity to improve resilience requires actions at both the individual and societal levels. Capacity building for resilient food systems is a non-static process to develop stronger capacity that enables food systems to be more resilient to future shocks (Babu and Blom 2014).

WHAT ARE THE KEY TRADE-OFFS AND SYNERGIES?

Over the next decade, food systems will face a complex challenge to deliver sufficient safe and nutritious food for all in a sustainable manner in the face of a changing climate, while reducing greenhouse gas emissions and preserving ecosystems and biodiversity, and also providing equitable livelihoods to all the actors in the food chain and promoting sustainable development. Attainment of these diverse goals while ensuring food system resilience gives rise to complex synergies and trade-offs across economic, political, social and environmental dimensions that need to be considered in setting priorities across productivity growth, environmental sustainability and hunger reduction (Béné et al., (2019). In this section of the paper, we review some of the most salient trade-offs and synergies that arise in the context of food system resilience.

Short term humanitarian aid vs. Long term development assistance

Based on our definition of resilience (Fig. 2), an important component involves anticipating and preventing adverse impacts of external shocks to the food system. However, less than one percent of emergency assistance goes to disaster prevention and preparedness (Kellet and Sparks 2012). The UN Secretary General convened a World Humanitarian Summit in 2016 to deal with these issues. The summary report calls for a long-sought commitment to change the way humanitarian and development actors work together (UN Secretary General 2016). Particular emphasis is placed on health and education of children and young people in crisis. In some cases such joined-up activities are complementary. However, linking actions and interventions that involve inherent tradeoffs such as disaster risk reduction and conflict prevention remains a significant challenge (Peters, Keen, and Mitchell 2013).

Rural and Urban communities

To identify potential trade-offs and synergies between rural and urban communities, Blay-Palmer et al., (2018) assess the value and utility of the evolving City Region Food Systems approach to improve our insights into flows of resources from rural to peri-urban to urban areas. Resolution of conflicts at the boundaries of agricultural and other land uses and communities, e.g. forest, urban, diversification and specialization, as well as the need to combine the benefits of diversification with scale economies. Conflict frequently arises at the boundary of agriculture and forests where encroachment on natural habitat can lead to conflict, for example between wildlife and rural populations (Shaffer et al. 2019). Rural and urban communities also face competition for resources, including land and water. Agriculture accounts for nearly three-quarters of water consumption globally. As urban and suburban water scarcity emerges, we expect some reallocation of this resource to occur (Molden et al. 2007). In contrast, rural-urban labor movement can offer an important source of resilience. Migration is perhaps the most important resource flow. This is generally motivated by a desire to diversity and raise household income. A survey of 1,874 rice-farming households in Northeast Thailand found that income from migration represented 38% of their incomes (Paris et al. 2009). In addition, better knowledge and skills through migration and education at their destination have contributed to improvements in agriculture, e.g. improvement of land-use techniques taken place in the Northeast region (Huguet and Aphichat Chamratrithirong 2011). Migration can also provide an important adaptation strategy to climate related risks (Sterly 2020).

Climate change adaptation and mitigation

Much progress has been achieved in identifying possible trade-offs between measures to support climate adaptation and mitigation in agriculture. Most prominent is the climate-smart agriculture approach (CSA), defined by the FAO as “agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals” (Reiche et al. 2012; Lipper et al. 2014). However, recent analyses suggest that knowledge about the exploitation of interrelationships between adaptation and mitigation measures in agriculture is still limited and greatly depend on their context, design and implementation, so that actions have to be tailored to the specific conditions (Kongsager 2018). Even less is known for the larger food system but the importance to identify tailored, resilient solutions considering the context of specific conditions will also apply.

Globalization vs. self-sufficiency

There are important trade-offs between integration into global supply chains and world markets, on the one hand, and the desire for locally sourced products, with shortened supply chains and greater food self-sufficiency, on the other. Better integration into world markets can ensure food security in the face of local drought, flooding and other natural disasters. In pre-colonial India, weather-induced famines were common, resulting in tens of millions of deaths when flooding or drought destroyed local crops. However, with the introduction of railroads in colonial India, Burgess and Donaldson (2010) find a dramatic reduction in the number of deaths associated with comparable extreme weather events, suggesting that improved market integration greatly enhanced food security by allowing for timely food imports. Recent studies of the role of international trade in mitigating adverse impacts of climate change reinforce the benefits of globalization for resilience to adverse climate impacts (Baldos and Hertel 2015; Gouel and Laborde 2018). However, when the source of adverse shocks is the global market, countries may have an incentive to insulate themselves from these developments. The problem with this strategy is that, the more countries insulate themselves from world markets, the more volatile those markets will become, as was found in the context of the food price crises of 2006-2008 and 2010-2011 (Martin and Anderson 2012). This harms those countries – often the poorest – who rely on these markets for critical food imports.

Livestock production as a source of income and nutrition vs. environmental sustainability

The role of livestock in a resilient food system has been recently challenged on the argument that reduced consumption of livestock products will enhance health outcomes while reducing environmental stress (Willett et al. 2019). Beef production, in particular, has been shown to be extremely resource intensive, resulting in significant environmental stress (Eshel et al. 2014). However, in many developing countries, livestock products are a critical source of dietary diversity – particularly in the critical first 1,000 days of life (Alonso, Dominguez-Salas, and Grace 2019). Livestock production is also crucial for resilience as this contributes in several ways to daily subsistence of rural poor in developing countries through food production, income generation, labour and transportation, as mobile assets and wealth storage, integration with agricultural systems, diversification of activities, utilization of marginal lands and women's empowerment (FAO 2016).

All of these trade-offs are made more challenging in the context of small farms, operating in marginal environments

Small farmers play a crucial role in fostering rural growth by playing multifunctional roles in development. A large body of empirical research argues that smallholders are still key to global food security and nutrition. Although these farms account for only 12% of the world's farmland, they provide livelihoods for more than 2 billion people and produce about 80% of the food in Sub-Saharan Africa and Asia (Paloma, Riesgo, and Louhichi 2020). Empirical evidence suggests that populations living on less favored agricultural lands in developing countries cope with major poverty-environment traps (Barbier 2010; Barbier and Hochard 2019). The poor are often trapped in a vicious downward spiral as they overuse environmental resources to survive from day to day, and the impoverishment of their environmental resources further deprives them, making their survival ever more uncertain and difficult (Gray and Moseley 2005). Since marginality is not a permanent state (Gurung and Kollmair 2005) and those affected by it can be helped with targeted support and appropriate policies in place, there is an opportunity to target the oft-overlooked rural poor under marginal conditions. These marginalized communities will benefit from risk informed and safety net social protection schemes as well as remuneration for ecosystem services they can provide through wise management and custodianship of renewable natural resources

In order to address trade-offs properly, attention is required by:

- *Policy makers*, to strengthen coordination among international actors and across scales, allowing for positive synergies in which governments and NGOs can learn from the successes and failures of other nations and institutions (Wiener and Alemanno 2015).
- *Institutions*, to combine activities at "multilateral", "bilateral" institutions, NGOs and foundations, as well as creating suitable consultative and participatory platforms so the voices of smallholders and food workers can be heard by policy makers.
- *Coordinated public and private investments* in the food sector focusing on the co-creation of solutions that meet individual and collective ambitions for tackling human and planetary crisis. (Mushtaq et al., (2020)with increased frequency and intensity of droughts, floods, storms and other extreme climatic events predicted in many regions. In order for food production systems to remain viable and resilient under a changing climate, novel approaches, which integrate risk management (i.e. adaptation).
- *Local communities* to mobilize for collective action in the face of increasing hazards (UN Office for Disaster Risk Reduction 2019).

Table 1. *Application of the resilience approach to develop solutions for food security considering contributions (capacities) for building resilience, the organisations and agencies involved and the trade-offs and synergies addressed and achieved, respectively.*

Solution	Contribution to resilience	Institutional Engagement (examples)	Trade-offs and Synergies
Early Warning Systems	Anticipate, Prevent, Adapt	FAO, WFP, FEWS-NET, Cadre Harmonise du Sahel	Humanitarian relief vs. development assistance; regional coordination and collective actions (adaptation)
Weather index insurance	Absorb, Adapt	R4, WBCIS, WFP, IFAD	Enhanced through improved data and monitoring; Lowers credit risk
Enhanced market information	Anticipate, Prevent, Absorb, Adapt	Agricultural Market Information System	Prevents overreaction to shocks; Allows for informed decision making
Food insecurity in conflict zones	Anticipate, Prevent, Absorb, Adapt	FAO, WFP, national agencies	Joining resources, implementing complementary activities for effective resource utilization and supporting communities
Enhanced rural-urban labor mobility	Absorb, Adapt, Transform		Facilitates climate resilience; Enhanced through education
Transport infrastructure	Absorb, Transform	Railroads in colonial India	Improved market access benefits rural communities
Irrigation systems	Prevent, Absorb, Adapt	IWMI, FAO	Enhanced climate resilience; increase farmers income; Potential for groundwater depletion
Social protection	Anticipate, Absorb, Transform	Ethiopia: Productivity Safety Net; FAO: Cash+ program	Avoid poverty traps; improved health and nutrition; asset and skill enhancement
Aquaculture diversification	Absorb, Adapt, Transform	Integrated Agriculture-Aquaculture Program	Income gains; Enhanced dietary outcomes; lose gains from specialization; improved nutrition, water reuse/circulation
Crop diversification	Absorb, Adapt, Transform	ICBA, CFF, CGIAR,	UImproved food security
Postharvest Loss Reduction	Anticipate, Absorb, Transform	Gates Foundation: PIC	Improve food security; Encourage adoption of new seed varieties
Development, dissemination and utilization of agricultural big data	Anticipate, Adapt, Transform	WASCAL; CGIAR: INSPIRE; AgMIP	Enhances weather insurance, market, information and research impacts
Enhanced equity in food systems	Absorb, Adapt, Transform	FAO, IFAD	Improved development outcomes; Enhanced indigenous capacity
Agro-ecology	Anticipate, Prevent, Absorb	ICBA	Improved ecosystems vs. reduced farmer incomes
Transnational policy coordination	Anticipate, Prevent, Adapt	Sahel-CILSS; EU-JPI; PPPs	Improve human health
Food safety policies	Ancitipate, Prevent, Adapt	FDA: PCHF in Thailand; Bangladesh Food Safety Network	Improved health outcomes
Community organization	Anticipate, Adapt, Transform	Bann Samkha community action	Circular economy; enhanced incomes

WHAT NEEDS TO BE DONE?

To address these resilience challenges, solutions need to be defined around cross cutting levers of joined-up policy reform, coordinated investment, accessible financing, innovation, traditional knowledge, governance, data and evidence, and empowerment. Much can be learned from successful ongoing initiatives and programs. Hence, a range of concrete solutions are reviewed in this section to highlight how food security challenges have been addressed successfully but also to identify limitations of present approaches. The examples are summarised in table 1 describing the main contributions for building resilience, the organisations and agencies involved, and the challenges and synergies addressed.

Early warning system

An important step to improve resilience is strengthening the capacity to monitor and analyse vulnerability, capacities and risks (World Food Programme 2020). There are now nearly two dozen organizations involved in food security and drought early warning systems, a number that has been growing since the inception of FEWS NET in the mid-1980s (Funk et al. 2019). The joint FAO-World Food Program Early Warning System now provides up to date analysis of acute food security hotspots and plays a key role at the global level (FAO and WFP 2020). Strengthening resilience has emerged as an important means to prevent, mitigate and prepare for risks associated with a range of threats to development. Resilience is also a key element of the UN pillars of development – human rights, peace and security – and resilience is a key to achieving sustainable development (UNISDR 2015). At the regional level, a promising example of actions to promote resilience is offered by the “Cadre Harmonise du Sahel” which provides a set of functions and protocols for the identification and analysis of populations in the Sahel region at risk of food and nutrition insecurity. It seeks to answer questions related to the severity of a given crisis, how many people are affected, when and where intervention should be undertaken, and what are the limiting factors? Stakeholders include national, regional (West Africa-wide) and international entities.

Weather index insurance

As climate extremes become more frequent and more pronounced in the future, producers will face increasing risks. Weather variability will affect agricultural seasons through changes in rainfall and temperature patterns that affect both production quantity and quality. Effective drought risk management requires an early warning system (e.g., FEWS NET), risk assessment, drought preparedness, mitigation and response (Funk and Shukla, 2020). Traditional risk sharing mechanisms within a community have been a key vehicle for protecting against idiosyncratic shocks to income. But these do not perform well when adverse events such as drought affect an entire community (covariate risks). Weather index insurance has been developed specifically for such circumstances (Gine, Townsend, and Vickery 2008). Here, households enroll at the beginning of the season and payouts are made based on (e.g.) rainfall in the region (not the outcome on their specific farm) dropping below a trigger level. It is typically provided initially by the public sector, and can entail relatively low overhead if the triggers are transparent and not subject to manipulation.

Since its inception, weather index insurance has faced challenges in reaching the poorest households tend who typically face they face severe credit constraints (Binswanger-Mkhize 2012). However, recent innovations are permitting index insurance to thrive in a number of key locations (Hazell et al. 2010). In India, participation in the Weather Based Crop Insurance System (WBCIS) expanded from 300,000 in 2009 to more than 13 million in 2013. Case studies of these successes suggest that participation in index insurance enhances farmers’ access to credit, allowing smallholders to participate in more risky, higher return farming activities (CCAFS 2015). The R4 initiative in Ethiopia and Senegal has a clear plan for introducing weather index insurance in new locales, operating in partnership with private financial institutions and insurers. They begin with a dry run in which local farmers and experts are consulted and the plan is modified to fit the local conditions. It is subsequently rolled out to several thousand farmers and further refined prior to being scaled up. Insured farmers have boosted savings, increased the number of oxen and increased access to loans. The R4 initiative has been particularly successful at reaching low income farmers. However, this program continues to face data challenges in due to relatively sparse ground-based weather monitoring stations in many parts of Sub Saharan Africa (CCAFS 2015).

Enhanced market information

The recent pandemic has heighted some important global food system resilience successes. OECD trade ministers held a record number of meetings during 2020 (all virtual), and these meetings were substantive, focusing on specific measures to facilitate the movement of critical goods and services during the pandemic. This was reflected in the fact that, by OECD measures, growth in trade facilitation activities outweighed trade restrictions during the COVID-19 pandemic (Jansen 2020). Increased digitalization of trade regulations and monitoring has facilitated more rapid movement of critical goods. Meanwhile, where export restrictions have been put in place, they have been targeted, transparent and temporary. This has been reflected in the fact that, unlike the commodity crisis period: 2006-2011, when agricultural prices became extremely volatile in the wake of widespread cascading export restrictions, commodity prices were relatively flat throughout 2020 (Jansen 2020). The OECD attributes much of this stability to the implementation of the Agricultural Market Information System (AMIS). AMIS provides up to date information on agricultural commodity prices and availability, thereby preventing over-reactions on the part of governments and markets (Jansen 2020). This has resulted in far more resilient global markets for agricultural products.

Addressing food insecurity in conflict zones

Over the past two decades, conflict-plagued countries' share of stunted children grew from 46% to 75% (FAO 2017). There is mounting evidence that climate change is a key driver of conflict (Hsiang, Burke, and Miguel 2013; Maystadt, Calderone, and You 2015), suggesting that this trend will only increase, absent significant interventions. Strengthening dispute resolution mechanisms and sound natural resource management might significantly help to reduce conflict in fragile states (Calderone, Headey, and Maystadt 2014). The World Food Program has introduced several programs to address food insecurity in conflict zones, such as the Food Assistance for Assets program, which aims at addressing the most food-insecure people's immediate food needs with cash, voucher, or food transfers while helping improve their long-term food security and resilience. Within this program, people receive cash or food-based transfers while they boost assets, such as constructing a road or rehabilitating degraded land to improve their livelihoods. The combination of conditional food assistance and asset creation work helps food-insecure communities to shift away from reliance on humanitarian aid to achieve more sustainable food security.

The crisis in Somalia offers an example of the compound risks from severe weather events coinciding with conflict. Rapid shifts from drought to flooding in the context of ongoing violence and conflict have led to a series of food security crises in that country. The World Food Program (WFP) and the Food and Agriculture Organization (FAO), in conjunction with international/local NGOs have joined forces to implement a multi-year, joint resilience program in Burao and Odweine districts of Somaliland. The program allows agencies to pull resources together and implement complementary activities, contributing to effective resource utilization and supporting communities over long periods. Through this partnership, water catchments, vegetable gardens, and nutrition-awareness programs were implemented.

Social protection

In Ethiopia, an effort is underway aimed at breaking the cycle of dependence on food aid. The Productivity Safety Net Program (PSNP) focuses on the chronically food insecure households, providing cash or food transfers on a predictable basis for five years, along with financial and technical support. Where there are able-bodied beneficiaries, they are required to provide labor in exchange for these transfer payments. The goal is to help these households build assets which can sustain them through future crises, along with contributing to the construction of rural infrastructure.

Integrating smallholders more fully into regional markets can also enhance resilience. In Ethiopia, a pilot effort dubbed P4P: Purchase for Progress, run by the World Food Program, works through farmer organizations in order to better integrate farmers into these markets. This involves improving the efficiency of these organizations, reducing transactions costs and improving information flows and as well as encouraging additional value-added for smallholder-grown products. In some cases, P4P also involves the purchase of commodities for use in the WFP's food aid activities. A recent study (Gelo et al. 2020) of the P4P pilot project in Ethiopia finds that these interventions have resulted in significant increases in household welfare – as measured by a roughly 25% increase in spending – as well as sharply increased investment in children's education. This suggests that such programs can address both short term resilience as well as longer term development objectives.

Aquaculture diversification

Aquaculture can also provide an important vehicle for improving the resilience and well-being of smallholder farm households, particularly in Asia and Sub Saharan Africa. In Malawi, Integrated Agriculture-Aquaculture (IAA) farming practices have been introduced to help farmers boost earnings and increase food security. Integrated farming enables farmers to boost total farm productivity by 10% while increasing farm income by 61% more income (Dey et al. 2007)providing essen-tial protein and micronutrients. However, due to declining catches from the lakes and a doubling of the population since the 1970s, per capita annual fish consumption decreased from 14 kg in the 1970s to 4.2 kg in 2005, with a corresponding increase in fish prices. This has further wors-ened food insecurity, especially of the rural population in a country (Fig. 7.1, as well as boosting household resilience during times of drought, leading one farmer to note: "Fish in the pond is like money in the bank." (https://www.worldfishcenter.org/content/combining-aquaculture-and-agriculture-promote-food-security-malawi). This has also resulted in a tripling of fresh fish consumption, thereby enhancing the protein content of diets. The techniques used by the IAA program are simple and low-cost. Fish are fed maize bran and household leftover while manure from goats; chickens and rabbits help fertilize the ponds (Dey et al. 2007).

Postharvest loss reduction

Programs aimed at reducing post-harvest storage losses can also enhance resilience, in addition to promoting food availability. By encouraging more successful storage of commodities over the course of the year, they can improve intra-annual food security, making more food available during the 'lean season' (Aggarwal, Francis, and Robinson 2018; Kumar and Kalita 2017). Often new seeds are more vulnerable to pests and are therefore viewed as undesirable in the context of traditional grain storage. By overcoming these losses, improved storage technologies can enhance incentives for adoption of new seed technologies which, in turn can boost productivity (Omotilewa et al. 2018).

Development, dissemination and utilization of agricultural big data

Development of resilient and sustainable agriculture is also being facilitated by the Big Data initiative of the Consultative Group for International Agricultural Research (CGIAR), dubbed INSPIRE, https://bigdata.cgiar.org/inspire, which seeks to harness recent advances in remote sensing, machine learning and robotics to support agricultural research and innovation in support of sustainable development and food security. These and other new scientific tools including precision biology (cell factories), combined with artificial intelligence. offer the prospect of making every element of the food system more efficient https://www.weforum.org/reports/innovation-with-a-purpose-the-role-of-technology-innovation-in-accelerating-food-systems-transformation. There is also an increasing emphasis on integrated systems approaches in which farming practices seek to imitate nature's ecological principles, whereby not only crops but also varied types of plants, animals, birds, fish, and other aquatic flora and fauna, are utilized for production.

Initiatives targeted at policy makers, researchers, agribusinesses need to be aligned with capacity development actions. This should seek to integrate knowledge generation with knowledge sharing in a manner that can effectively inform, and be informed by, action (Virji, (2012). Farm households' decision-making in the context of risk and resilience challenges is often constrained by a lack of information on weather and market conditions. Many farmers in low income countries rely on informal knowledge of local climates and weather patterns that has been acquired over decades or even centuries. The challenge posed for these households by climate change is that much of this knowledge base is effectively destroyed as it is rendered irrelevant under the new climatology (Quiggin and Horowitz 2003). In this context accurate weather forecasting is of critical importance to the farming community. Indeed, Gine, Townsend and Vickery (Gine, Townsend, and Vickery 2007) found that farmers in India with less access to risk-coping mechanisms invested more in acquiring accurate weather forecasts.

The usefulness of modern climate forecasts will depend on "developing focused knowledge about which forecast information is potentially useful for which recipients, about how these recipients process the information, and about the characteristics of effective information delivery systems and messages for meeting the needs of particular types of recipients" (Stern and Easterling 1999). An example where a close link between research and capacity building has been planned from the beginning is the West African Science Service Centre on Climate Change and Adaptive Land Use (WASCAL, https://wascal.org) with human capital programs comprising 10 graduate schools closely linked to the respective research activities and research institutions. Close links between research activities and capacity building are also considered in other larger research programs such as N2Africa which emphasizes putting nitrogen fixation to work for smallholder farmers in Africa, https://www.n2africa.org, as well as through the AgMIP (https://agmip.org) regional studies in Africa, Asia and other parts of the world. While all these programs have achieved good progress, links among these programs are under-developed and they would generate greater impact through coordinated research and funding activities at the national and international scales.

Enhanced equity in food systems

The socio-economic and institutional context in which innovations are introduced is key for advancing equity in farming communities (Bayard, Jolly, and Shannon 2007). However, solutions aiming to enhance agricultural productivity often focus on technological innovations but do not necessarily consider social, economic, and gender disparities. Growing evidence suggests that agriculture innovations can affect women and men differently within households and communities due to differences in power, roles, and access to rights (Doss 2001; Beuchelt 2016). Equity in agri-food systems, including being inclusive and sensitive to gender and social inequalities, can contribute to improving productivity (Beuchelt 2016). Development policies must address challenges and knowledge gaps related to social justice issues, environmental equity, and economic equity for smallholder farmers. Such achievements are possible only in a policy environment that promotes context-specific pro-smallholder value chains with equal access to innovations, capacity building opportunities, and smallholder-friendly financing and investment, as well as policies that support productive social safety nets. The FAO and IFAD are collaborating to strengthen the capacity of the indigenous groups, women and rural youth. Five percent of the world population belongs to indigenous people (FAO 2018) and they are culturally unique and have unique resilience strategies and challenges. IFAD is also working on 4Ps (public-private-producers-partnership) in agricultural sector to provide enabling environment as strategic goal. Some examples for advancing equity in the context of smallholder agriculture including strengthening social protection systems (e.g., food banks, emergency food pantries, nutrition-sensitive cash-transfer programs, etc.), as well as supporting grassroots activities dedicated to providing vulnerable populations with access to healthy and sustainable food.

Agro-ecology

Other measures include direct use of saline waters for agriculture and food, feed, fiber production, along with efforts to increase productivity for marginal and or subsistence farms (International Center for Biosaline Agriculture). This has the potential to improve the food security of poor households in rural areas by increasing food supply, and by reducing dependence on purchasing food in a context of high food price inflation. The UN Special Rapporteur on the Right to Food, Oliver De Schutter (2011), highlights in his report that marginal and or small-scale ecological farming is already very productive and can do even better. He calls for the use of agro-ecological methods to increase food production where the hungry live. Leveraging agriculture-ecosystem mutualism can improve productivity and may be more accessible and viable for marginalized or smallholder livelihoods than methods reliant on high agrochemical inputs (Seppelt et al. 2020). Eco-farming for food security can be expanded to include the matrix of adjacent wild land, given the importance of landscape complexity for agro-ecological functions such as pest management, pollination, soil and water quality (Tscharntke et al. 2005; Ricketts et al. 2008).

Trans-national policy coordination

In addition to providing sustainable incomes, the food system must ensure food safety along the entire food chain. For many low- and middle-income countries, rapid demographic and dietary changes, among others, are contributing to broader exposure of populations to foodborne hazards, stretching limited capacity to manage food safety risks. However, food safety receives relatively little policy attention and is under-resourced. Building resilience in such complex agri-food value chains calls for more significant and smarter investments in food safety management capacity, particularly in low- and middle-income countries. Comprehensive national food safety policies require cross-ministerial collaborations, spanning agriculture, industry, public health, domestic and international trade, science, technology and education, in the setting food quality and safety strategies and ensuring their governance. Policy implementation of the food quality and food safety system must include elements of quality control and quality assurance systems, food safety standards, risk analysis, diagnostic technology, and traceability systems. Proactive and effective surveillance and rapid response are also critical aspects of food safety systems' performance to tackle risks (Jaffee et al. 2019). Further, food safety systems are a critical ingredient of successful food export performance. Recognizing this potential barrier, Thailand's food sector has worked closely with the U.S. Food and Drug Administration (FDA) to meet the Preventive Controls for Human Food (PCHF) regulation, thereby avoiding burdensome export restrictions.

The Permanent Interstates Committee for Drought Control in the Sahel, known as "CILSS," is an international organization established in 1973, consisting of 13 countries in the Sahel of West Africa. The mandate of CILSS is to address desertification and to improve food security in the Sahel. Over the years, CILSS has established itself as its member states' technical arms in the area of Food Security. Subsequently, the Economic Community of West African States (ECOEarWAS) entrusted CILSS to support member states in developing their National Agriculture Investment Plans. In addition, CILSS created the Sahelian Pesticide Committee, known as the "CSP," a common regulation for the registration of pesticides in CILSS member states to combine the expertise in pesticide evaluation and management to improve pesticide registration. In line with the Rotterdam Convention framework for the regulation of hazardous chemicals and pesticides in international trade. The CSP has the authority to issue full or provisional registrations as well as refusing registration of a specific pesticide product. Besides facilitating the Rotterdam Convention's agenda, this approach has entirely replaced national pesticide registration in individual CILSS member states.

Food safety policies

Consumers also directly affect the safety of foods through their food handling and preparation practices. Poor hygienic practices in the home are responsible for between 30-40% of food-borne illness. Many countries invest in educating and informing the public about food safety as an important means of reducing food-borne illness. For example, the Bangladesh Food Safety Network developed a range of initiative and Information, Education and Communications (IEC) materials to enhance awareness of food hygiene and safety among targeted groups, household food preparers, school children, and street food vendors. Recently, the FAO has worked with public health and food safety authorities and with consumer bodies to assist in the design of public information/education programs/campaigns, including the monitoring of their effectiveness. In addition, FAO assists in the development of appropriate messages for use in such programs to facilitate behavior, as well as to improve food hygiene practices in food service sector (FAO 2020a).

Policy coordination will be key in enhancing future food system resilience. Schipanski et al., (2016) proposed integrated strategies for fostering food system resilience across scales, including (a) integrating gender equity and social justice into food security research and initiatives, (b) increasing the use of ecological processes rather than external inputs for crop production, (c) fostering regionalized food distribution networks and waste reduction, and (d) linking human nutrition and agricultural production policies. Enhancing social–ecological links and fostering adaptive capacity are essential to cope with short-term volatility and longer-term global change pressures. Pingali et al., (2005) explores the linkages between food security and crisis in different contexts, outlining the policy and institutional conditions needed to manage food security during a crisis and to rebuild the resilience of food systems. In the Sahel, CILSS has emerged as an important vehicle for regional policy coordination on matters of food security. In the context of wealthy nations, the Joint Programming Initiative (JPI) in the EU (https://ec.europa.eu/programmes/horizon2020/en/h2020-section/joint-programming-initiatives) has improved the harmonization of research activities across countries of the EU. A prominent example in the domain of the Summit21 is the JPI FACCE (Food Security, Agriculture and Climate Change, https://www.faccejpi.net/en/FACCEJPI.htm) which is presently further developed to also link research to national and EU stakeholders including policy makers to better coordinate research and policies.

Increasing risk-informed investments at all levels (local, regional, national and international) are needed to improve food security and resilience of food systems to ensure food security and adequate nutrition. Public Private Partnerships (PPP) offer an important opportunity to leverage resources from the private sector. PPPs also bring in new technologies and innovation and they can facilitate risk-sharing. The Committee on World Food Security (CFS) established criteria for responsible agricultural investments in 2015. A recent review (Mangeni 2019) on the role played by PPPs in disseminating acceptable technology to farmers, explores the current state of the field, and details approaches and methods for the establishment and promotion of PPPs in sub-Saharan Africa.

Community organization and local innovation

Bann Samkha, a small community in northern Thailand, has faced severe drought, leading to food insecurity. They solved this problem through community water resource management, allowing them to attain self-sufficiency in rice production. However, the long distance between rice farms and the commercial rice mill led to high transport costs. To cope with this problem, a compact and highly efficient small-scale rice mill machine has been developed. This user-friendly machine proven highly suitable for rice milling in rural areas, allowing farmers to sell high-value milled rice instead of paddy rice. Furthermore, the community uses the rice straw to produce rice straw paper through an organic process. With local wisdom, the community has now created an 'eatable calendar' wherein each page of the calendar is embedded with seeds of the month that grow into plantlets after being watered. The rice straw paper and the eatable calendar production have brought more income and a sustainable economy to the community. This illustrates the potential for communities to create high-value, circular and sustainable bio-economies (Thangphisityothin 2020).

THE IMPORTANCE OF CONTEXT SPECIFICITY

Resilience interventions will have differential impacts depending on their agroecological context, cultural aspects, policies and institutional capacities. The determinants of access to safe and nutritious food vary widely, reinforcing the fact that solutions cannot be "one size fits all". An estimated 1.4 billion people live and work in marginal environments (Chen and Ravallion 2004). Vulnerability for safe and nutritious food looms over all agro-ecologies in the face of climate change and biodiversity loss; but the fragile agroecologies are the most vulnerable. These regions are highly populated and stricken by poverty, food, nutritional and social insecurity. Site specific agroecological solutions, along with access and tenure to land and other renewable natural resources, could contribute to economic viability, provide appropriate solutions to many of the environmental challenges and be socially inclusive, addressing rural employment and livelihoods. This is particularly relevant in parts of Africa, South and South East Asia and Latin America countries agriculture still accounts for as much as three-quarters of employment (Roser 2013). The adoption of promising agricultural technologies has been far from universal, and has remained particularly low among the poor (Freebairn 1995). As a result, the Green Revolution may actually have created new sources of food insecurity in marginal areas by targeting high potential areas and a handful of high value crops grown there (wheat, rice, maize) (Pearse 1990; Shiva 1991; P. L. Pingali, Hossain, and Gerpacio 1997). However, enhancing agricultural development for marginal farmers and smallholders can create strong links to the rest of the rural sector (Koonin 2006), both through hiring of extra local labor at peak farming times and through more-favorable expenditure patterns for promoting growth of the local non-farm economy, including rural towns (IFAD, 2013).

Many coastal communities and small island states also face difficult economic conditions. However, in many cases the development of tourism can make a valuable contribution. Indeed, coral reef tourism is a critical, undervalued ecosystem service generating $36 billion in global revenue (Spalding et al. 2017). In many cases, local fisherman can convert their boats to tourism and boost their incomes. While coral reefs face an immediate threat from climate change, there is potential to make them more resilient by managing fishing effort (Hughes et al. 2007). More generally, the impacts of climate change and extreme events differ considerably across the planet (IPCC 2014). Resilience and vulnerability strongly depends on the ability to adapt to climate change which again depends of economic conditions (Wheeler and Braun 2013) with poorer, less diversified regions being more vulnerable (Reidsma and Ewert 2008).

CONCLUDING REMARKS

Several reports have addressed resilience of food systems from different perspectives considering different parts of the food system and contexts of food security challenges (Fan, Pandya-Lorch, and Yosef 2014). As evident from these reports and other studies, including the present review, resilience has successfully been used as a conceptual framework to improve food security as well as vehicle for organizing links among respective actors, agencies and institutions. In the present study we have particularly addressed the contributions of the resilience approach as outlined in Figure 2, with respect to addressing important trade-offs and synergies. From the range of reviewed studies several conclusions can be drawn:

- The resilience approach has been helpful in developing solutions for food security, considering at least two but often more capacities. However, primary emphasis in the reviewed programs and initiatives is focused on the absorption, adaptation and anticipation capacities and less on prevention and transformation. These important aspects need to be more considered in future studies. None of the studies integrates all capacities.
- The resilience approach is helpful in addressing trade-offs and synergies. However, key trade-offs identified here demand more attention. Furthermore, systematic approaches for analysis of these trade-offs are often missing.
- The reviewed initiatives and programs have been successful in developing solutions for food security for the specific challenges and contexts. However, links among these programs are often not well developed and additional benefits can be obtained by greater investment in institutions to facilitate the exchange of tools, data, information and knowledge. Such links would generate greater impact through coordinated research and funding activities at national and international levels and also support the further development of the resilience approach.
- Most importantly, these examples clearly reveal that there is no single game-changing solution that solves the range of different food security challenges. Instead, operationalization of the resilience concept to build food security will depend on the specific context of the food security challenge and the respective actors involved. Hence, using resilience as a systems approach to support the conceptualization of the food security challenge and the integration of actors, organizations and agencies to develop context-specific solutions offers a promising way forward.

REFERENCES

Aggarwal, S., E. Francis, and J. Robinson. 2018. "Grain Today, Gain Tomorrow: Evidence from a Storage Experiment with Savings Clubs in Kenya." *Journal of Development Economics* 134 (September): 1–15. https://doi.org/10.1016/j.jdeveco.2018.04.001.

Ali, Zakari, Rosemary Green, Robert B. Zougmoré, Siyabusa Mkuhlani, Amanda Palazzo, Andrew M. Prentice, Andy Haines, Alan D. Dangour, and Pauline F. D. Scheelbeek. 2020. "Long-Term Impact of West African Food System Responses to COVID-19." *Nature Food* 1 (12): 768–70. https://doi.org/10.1038/s43016-020-00191-8.

Alonso, Silvia, Paula Dominguez-Salas, and Delia Grace. 2019. "The Role of Livestock Products for Nutrition in the First 1,000 Days of Life." *Animal Frontiers* 9 (4): 24–31. https://doi.org/10.1093/af/vfz033.

Ayanlade, Ayansina, and Maren Radeny. 2020. "COVID-19 and Food Security in Sub-Saharan Africa: Implications of Lockdown during Agricultural Planting Seasons." *Npj Science of Food* 4 (1): 13. https://doi.org/10.1038/s41538-020-00073-0.

Babu, Suresh Chandra, and Sylvia Blom. 2014. "Capacity Development for Resilient Food Systems: Issues, Approaches, and Knowledge Gaps:" 6. *2020 Conference Papers*. 2020 Conference Papers. International Food Policy Research Institute (IFPRI). https://ideas.repec.org/p/fpr/2020cp/6.html.

Baldos, U.L.C., and T.W. Hertel. 2015. "The Role of International Trade in Managing Food Security Risks from Climate Change." *Food Security* 7 (2): 275–90. https://doi.org/10.1007/s12571-015-0435-z.

Barbier, Edward B. 2010. "Poverty, Development, and Environment." *Environment and Development Economics* 15 (6): 635–60. https://doi.org/10.1017/S1355770X1000032X.

Barbier, Edward B., and Jacob P. Hochard. 2019. "Poverty-Environment Traps." *Environmental and Resource Economics*, August. https://doi.org/10.1007/s10640-019-00366-3.

Barrett, Christopher B., and Mark A. Constas. 2014. "Toward a Theory of Resilience for International Development Applications." *Proceedings of the National Academy of Sciences of the United States of America* 111 (40): 14625–30. https://doi.org/10.1073/pnas.1320880111.

Bayard, Burdy, Curtis M. Jolly, and Dennis A. Shannon. 2007. "The Economics of Adoption and Management of Alley Cropping in Haiti." *Journal of Environmental Management* 84 (1): 62–70. https://doi.org/doi.org/10.1016/j.jenvman.2006.05.001.

Béné, Christophe. 2020. "Resilience of Local Food Systems and Links to Food Security – A Review of Some Important Concepts in the Context of COVID-19 and Other Shocks." *Food Security* 12 (4): 805–22. https://doi.org/10.1007/s12571-020-01076-1.

Béné, Christophe, Peter Oosterveer, Lea Lamotte, Inge D Brouwer, Stef de Haan, Steve D Prager, Elise F Talsma, and Colin K Khoury. 2019. "When Food Systems Meet Sustainability – Current Narratives and Implications for Actions." *World Development*, 15.

Beuchelt, Tina D. 2016. "Gender, Social Equity and Innovations in Smallholder Farming Systems: Pitfalls and Pathways." In *Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development*, 181–98. SpringerOpen.

Binswanger-Mkhize, Hans P. 2012. "Is There Too Much Hype about Index-Based Agricultural Insurance?" *Journal of Development Studies* 48 (2): 187–200. https://doi.org/10.1080/00220388.2011.625411.

Blay-Palmer, Alison, Guido Santini, Marielle Dubbeling, Henk Renting, Makiko Taguchi, and Thierry Giordano. 2018. "Validating the City Region Food System Approach: Enacting Inclusive, Transformational City Region Food Systems," 23.

Burgess, Robin, and Dave Donaldson. 2010. "Can Openness Mitigate the Effects of Weather Shocks? Evidence from India's Famine Era." *American Economic Review* 100 (2): 449–53. https://doi.org/10.1257/aer.100.2.449.

Calderone, Margherita, Derek Headey, and Jean-Francois Maystadt. 2014. "Resilience to Climate-Induced Conflict in the Horn of Africa." In *Resilience for Food and Nutrition Security*. Washington D.C.: IFPRI. https://ebrary.ifpri.org/digital/collection/p15738coll2/id/128445/.

CCAFS. 2015. "Scaling up Index Insurance for Smallholder Farmers: Recent Evidence and Insights." CGIAR. https://ccafs.cgiar.org/resources/publications/scaling-index-insurance-smallholder-farmers-recent-evidence-and.

Chen, S., and M. Ravallion. 2004. "How Have the World's Poorest Fared since the Early 1980s?" *The World Bank Research Observer* 19 (2): 141–69.

Dey, Madan, Patrick Kambewa, Mark Prein, Daniel Jamu, F Paraguas, Diemuth Pemsl, and Roehlano Briones. 2007. "Fish WorldFish Centre. Impact of the Development and Dissemination of Integrated Aquaculture–Agriculture Technologies in Malawi." In , 118–46.

Doss, Cheyrl R. 2001. "Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience." *World Development* 29 (12): 2075–92. https://doi.org/doi.org/10.1016/S0305-750X(01)00088-2.

Dror, Shany, Franziska Harich, Orawan Duangphakdee, Tommaso Savini, Ákos Pogány, John Roberts, Jessica Geheran, and Anna C. Treydte. 2020. "Are Asian Elephants Afraid of Honeybees? Experimental Studies in Northern Thailand." *Mammalian Biology* 100 (4): 355–63. https://doi.org/10.1007/s42991-020-00042-w.

Eshel, G., A. Shepon, T. Makov, and R. Milo. 2014. "Land, Irrigation Water, Greenhouse Gas, and Reactive Nitrogen Burdens of Meat, Eggs, and Dairy Production in the United States." *Proceedings of the National Academy of Sciences* 111 (33): 11996–1. https://doi.org/10.1073/pnas.1402183111.

Fan, Shenggen, Rajul Pandya-Lorch, and Sivan Yosef. 2014. "Resilience for Food and Nutrition Security." 0 ed. Washington, DC: International Food Policy Research Institute. https://doi.org/10.2499/9780896296787.

FAO. 2016. "Livestock in Protracted Crises : FAO in Emergencies." Guidance Note. Rome: FAO. http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/461428/.

———, ed. 2017. *Building Resilience for Food and Food Security*. The State of Food Security and Nutrition in the World 2017. Rome: FAO.

———. 2018. "Report on the Work of the FAO Indigenous Peoples Team." http://www.fao.org/fileadmin/user_upload/faoweb/2018-New/Our_Pillars/2018_Annual_Report_FAO_Indigenous_Peoples_Team.pdf.

———. 2020a. "Consumer Awareness: Improving Food Safety in Bangladesh." 2020. http://www.fao.org/in-action/food-safety-bangladesh/activities/consumer-awareness/en/.

———. 2020b. "The State of Food Security and Nutrition in the World 2020 | FAO | Food and Agriculture Organization of the United Nations." FAO. https://doi.org/10.4060/CA9692EN.

FAO and WFP. 2020. *FAO-WFP Early Warning Analysis of Acute Food Insecurity Hotspots: July 2020*. Rome, Italy: FAO and WFP. https://doi.org/10.4060/cb0258en.

Folke, Carl. 2016. "Resilience (Republished)." *Ecology and Society* 21 (4). https://doi.org/10.5751/ES-09088-210444.

Freebairn, Donald K. 1995. "Did the Green Revolution Concentrate Incomes? A Quantitative Study of Research Reports." *World Development* 23 (2): 265–79. https://doi.org/10.1016/0305-750X(94)00116-G.

Funk, Chris, Shraddhanand Shukla, Wassila Mamadou Thiaw, James Rowland, Andrew Hoell, Amy McNally, Gregory Husak, et al. 2019. "Recognizing the Famine Early Warning Systems Network: Over 30 Years of Drought Early Warning Science Advances and Partnerships Promoting Global Food Security." *Bulletin of the American Meteorological Society* 100 (6): 1011–27. https://doi.org/10.1175/BAMS-D-17-0233.1.

Gelo, Dambala, Edwin Muchapondwa, Abebe Shimeles, and Johane Dikgang. 2020. "Aid, Collective Action and Benefits to Smallholders: Evaluating the World Food Program's Purchase for Progress Pilot." *Food Policy* 97 (December): 101911. https://doi.org/10.1016/j.foodpol.2020.101911.

Gine, X., R. M Townsend, and J. Vickery. 2007. "Rational Expectations? Evidence from Planting Decisions in Semi-Arid India." Working Paper, The World Bank (DECRG), University of Chicago and Federal Reserve Bank of New York FED. Google Scholar.

Gine, X., R. Townsend, and J. Vickery. 2008. "Patterns of Rainfall Insurance Participation in Rural India." *The World Bank Economic Review* 22 (3): 539.

Gouel, Christophe, and David Laborde. 2018. "The Crucial Role of International Trade in Adaptation to Climate Change." Working Paper 25221. National Bureau of Economic Research. https://doi.org/10.3386/w25221.

Gray, Leslie C, and William G Moseley. 2005. "A Geographical Perspective on Poverty-Environment Interactions." *The Geographical Journal* 171 (1): 9–23. https://doi.org/10.1111/j.1475-4959.2005.00146.x.

Gurung, Ghana S, and Michael Kollmair. 2005. "Marginality: Concepts and Their Limitations, IP6 Working Paper No. 4." *University of Zurich, Winterthurerstr*.

Hazell, Peter B. R., J. Anderson, N. Balzer, A. H. Clemmensen, U. Hess, and F. Rispoli. 2010. *The Potential for Scale and Sustainability in Weather Index Insurance for Agriculture and Rural Livelihoods*. Rome, Italy: IFAD-WFP. /paper/The-Potential-for-Scale-and-Sustainability-in-Index-Hazell-Anderson/f4edc50de49fb13bee-390a01a326e72f07b8a6b8.

High Level Panel of Experts. 2020. "Impacts of COVID-19 on Food Security and Nutrition: Developing Effective Policy Responses to Address the Hunger and Malnutrition Pandemic." Issue Paper. Rome: Committe on World Food Security: High Level Panel of Experts.

Hirvonen, Kalle, Alan de Brauw, and Gashaw T. Abate. 2021. "Food Consumption and Food Security during the COVID-19 Pandemic in Addis Ababa." *American Journal of Agricultural Economics*, no. February. https://doi.org/10.1111/ajae.12206.

Holling, C S. 1973. "Resilience and Stability of Ecological Systems." *Annual Review of Ecology and Systematics* 4 (1): 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245.

Hsiang, Solomon M., Marshall Burke, and Edward Miguel. 2013. "Quantifying the Influence of Climate on Human Conflict." *Science* 341 (6151). https://doi.org/10.1126/science.1235367.

Hughes, Terence P., Maria J. Rodrigues, David R. Bellwood, Daniela Ceccarelli, Ove Hoegh-Guldberg, Laurence McCook, Natalie Moltschaniwskyj, Morgan S. Pratchett, Robert S. Steneck, and Bette Willis. 2007. "Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change." *Current Biology* 17 (4): 360–65. https://doi.org/10.1016/j.cub.2006.12.049.

Huguet, Jerrold W and Aphichat Chamratrithirong. 2011. *Thailand Migration Report: Migration for Development in Thailand : Overview and Tools for Policymakers*. Bangkok, Thailand: International Organization for Migration, Thailand Office.

IFAD. 2013. "Smallholders, Food Security, and the Environment." International Fund for Agricultural Development: Rome.

IPCC. 2014. “Climate Change 2014: Impacts, Adaptation, and Vulnerability.” In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Jaffee, Steven, Spencer Henson, Laurian Unnivehr, Delia Grace, and Emilie Cassou. 2019. “The Safe Food Imperative: Accelerating Progress in Low- and Middle-Income Countries. Agriculture and Food Series. Washington, DC: World Bank. Doi:10.1596/978-1-4648-1345-0. License: Creative Commons Attribution CC BY 3.0 IGO.”

Jansen, Marion. 2020. “COVID-19 and the Global Economy.” In *COVID-19 and the Global Economy*. Virtual.

Kellet, Jan, and Dan Sparks. 2012. “Disaster Risk Reduction: Spending Where It Should Count.” Briefing Paper. https://devinit.org/resources/disaster-risk-reduction-spending-where-it-should-count/.

Klassen, Susanna, and Sophia Murphy. 2020. “Equity as Both a Means and an End: Lessons for Resilient Food Systems from COVID-19.” *World Development* 136 (December): 105104. https://doi.org/10.1016/j.worlddev.2020.105104.

Kongsager, Rico. 2018. “Linking Climate Change Adaptation and Mitigation: A Review with Evidence from the Land-Use Sectors.” *Land* 7 (4): 158. https://doi.org/10.3390/land7040158.

Koonin, S. E. 2006. “Getting Serious about Biofuels.” *Science* 311: 435–36.

Kumar, Deepak, and Prasanta Kalita. 2017. “Reducing Postharvest Losses during Storage of Grain Crops to Strengthen Food Security in Developing Countries.” *Foods* 6 (1). https://doi.org/10.3390/foods6010008.

Laborde, David, Will Martin, Johan Swinnen, and Rob Vos. 2020. “COVID-19 Risks to Global Food Security.” *Science* 369 (6503): 500–502. https://doi.org/10.1126/science.abc4765.

Laborde, David, Will Martin, and Rob Vos. 2020. “Impacts of COVID-19 on Global Poverty, Food Security and Diets.” *Agricultural Economics* Forthcoming.

Leat, Philip, and Cesar Revoredo-Giha. 2013. “Risk and Resilience in Agri-Food Supply Chains: The 404 Case of the ASDA PorkLink Supply Chain in Scotland.” *Supply Chain Management: An International Journal* 18 (2): 219–213.

Lipper, Leslie, Philip Thornton, Bruce M. Campbell, Tobias Baedeker, Ademola Braimoh, Martin Bwalya, Patrick Caron, et al. 2014. “Climate-Smart Agriculture for Food Security.” *Nature Climate Change* 4 (12): 1068–72. https://doi.org/10.1038/nclimate2437.

Mahajan, Kanika, and Shekhar Tomar. 2020. “COVID-19 and Supply Chain Disruption: Evidence from Food Markets in India.” *American Journal of Agricultural Economics* n/a (n/a). https://doi.org/10.1111/ajae.12158.

Mangeni, Bonphace. 2019. “The Role of Public-Private Partnerships (PPP) in Ensuring Technology Access for Farmers in Sub-Saharan Africa.” *African Journal of Food, Agriculture, Nutrition and Development* 19 (February): 14137–55. https://doi.org/10.18697/ajfand.84.BLFB1018.

Manning, Louise, and Jan Mei Soon. 2016. “Building Strategic Resilience in Food Supply Chain.” *Brithish Food Journal* 118 (6): 1477 – 1493. https://doi.org/doi.org/10.1108/BFJ-10-2015-0350.

Martin, Will, and Kym Anderson. 2012. “Export Restrictions and Price Insulation During Commodity Price Booms.” *American Journal of Agricultural Economics* 94 (2): 422–27. https://doi.org/10.1093/ajae/aar105.

Maystadt, Jean-François, Margherita Calderone, and Liangzhi You. 2015. “Local Warming and Violent Conflict in North and South Sudan.” *Journal of Economic Geography* 15 (3): 649–71.

Molden, David, Karen Frenken, Randolph Barker, Charlotte de Fraiture, Bancy Mati, Mark Svendsen, Claudia Sadoff, and C. Max Finlayson. 2007. "Trends in Water and Agricultural Development." In *Water for Food, Water for Life*, edited by David Molden, 57–89. Colombo, Sri Lanka: EarthScan London and International Water Management Institute.

Mushtaq, Shahbaz, Jarrod Kath, Roger Stone, Ross Henry, Peter Läderach, Kathryn Reardon-Smith, David Cobon, et al. 2020. "Creating Positive Synergies between Risk Management and Transfer to Accelerate Food System Climate Resilience." *Climatic Change* 161 (3): 465–78. https://doi.org/10.1007/s10584-020-02679-5.

Narayanan, Sudha, and Shree Saha. 2020. "Urban Food Markets and the Lockdown in India." SSRN Scholarly Paper ID 3599102. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3599102.

OECD. 2020. *Strengthening Agricultural Resilience in the Face of Multiple Risks*. Paris: OECD Publishing. https://doi.org/10.1787/2250453e-en.

Oliver De Schutter. 2011. "Report on the Right to Food. UN Human Rights Council." *Online at <http://Rs.Resalliance.Org/?P=4612*. http://rs.resalliance.org/?p=4612.

Omotilewa, Oluwatoba J., Jacob Ricker-Gilbert, John Herbert Ainembabazi, and Gerald E. Shively. 2018. "Does Improved Storage Technology Promote Modern Input Use and Food Security? Evidence from a Randomized Trial in Uganda." *Journal of Development Economics* 135 (November): 176–98. https://doi.org/10.1016/j.jdeveco.2018.07.006.

Paloma, Sergio Gomez y, Laura Riesgo, and Kamel Louhichi. 2020. *The Role of Smallholder Farms in Food and Nutrition Security*. https://doi.org/10.1007/978-3-030-42148-9.

Pearse, A. 1990. *Seeds of Plenty Seeds of Want: Social and Economic Implications of the Green Revolution.* Oxford University Press: New York.

Peters, Katie, David Keen, and Tom Mitchell. 2013. "When Disasters and Conflicts Collide: Improving Links between Disaster Resilience and Conflict Prevention." Overseas Development Institute: London. https://www.odi.org/publications/7257-disasters-conflicts-collide-improving-links-between-disaster-resilience-conflict-prevention.

Pingali, P.L., M. Hossain, and R.V. Gerpacio. 1997. "Asian Rice Bowls: The Returning Crisis." *CAB International: Wallinford.*

Pingali, Prabhu, Luca Alinovi, and Jacky Sutton. 2005. "Food Security in Complex Emergencies: Enhancing Food System Resilience: Food Security in Complex Emergencies: Enhancing Food System Resilience." *Disasters* 29 (June): S5–24. https://doi.org/10.1111/j.0361-3666.2005.00282.x.

Quiggin, J., and J. Horowitz. 2003. "Costs of Adjustment to Climate Change." *The Australian Journal of Agricultural and Resource Economics* 47 (4): 429–46.

Reiche, M., N. Azzu, A. Bogdanski, S. Braatz, S. Bunning, V. Evtimov, Michelle Gauthier, et al. 2012. "Mainstreaming Climate Smart Agriculture into a Broader Landscape Approach." Rome, Italy: FAO. /paper/MAINSTREAMING-CLIMATE-SMART-AGRICULTURE-INTO-A-Reiche-Azzu/ee0a42a4feca1698a933b50c4eb6492a35fede01.

Reidsma, P., and F. Ewert. 2008. "Regional Farm Diversity Can Reduce Vulnerability of Food Production to Climate Change." *Ecology and Society* 13 (1). https://doi.org/10.5751/es-02476-130138.

Ricketts, Taylor H., James Regetz, Ingolf Steffan-Dewenter, Saul A. Cunningham, Claire Kremen, Anne Bogdanski, Barbara Gemmill-Herren, et al. 2008. "Landscape Effects on Crop Pollination Services: Are There General Patterns?" *Ecology Letters* 11 (5): 499–515. https://doi.org/10.1111/j.1461-0248.2008.01157.x.

Roser, Max. 2013. "Employment in Agriculture." *Our World in Data*, April. https://ourworldindata.org/employment-in-agriculture.

Schipanski, Meagan, Graham Macdonold, Steven Roseenzweig, and Chappel. 2016. "Realizing Resilient Food Systems" 67: 11.

Schwarz, Anne-Maree, Christophe Béné, Gregory Bennett, Delvene Boso, Zelda Hilly, Chris Paul, Ronnie Posala, Stephen Sibiti, and Neil Andrew. 2011. "Vulnerability and Resilience of Remote Rural Communities to Shocks and Global Changes: Empirical Analysis from Solomon Islands." *Global Environmental Change* 21 (3): 1128–40. https://doi.org/10.1016/j.gloenvcha.2011.04.011.

Seppelt, Ralf, Channing Arndt, Michael Beckmann, Emily A. Martin, and Thomas W. Hertel. 2020. "Deciphering the Biodiversity–Production Mutualism in the Global Food Security Debate." *Trends in Ecology & Evolution* 0 (0). https://doi.org/10.1016/j.tree.2020.06.012.

Shaffer, L. Jen, Kapil K. Khadka, Jamon Van Den Hoek, and Kusum J. Naithani. 2019. "Human-Elephant Conflict: A Review of Current Management Strategies and Future Directions." *Frontiers in Ecology and Evolution* 6. https://doi.org/10.3389/fevo.2018.00235.

Shiva, V. 1991. "The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics. T." *Third World Network: Malaysia.*

Spalding, Mark, Lauretta Burke, Spencer A. Wood, Joscelyne Ashpole, James Hutchison, and Philine zu Ermgassen. 2017. "Mapping the Global Value and Distribution of Coral Reef Tourism." *Marine Policy* 82 (August): 104–13. https://doi.org/10.1016/j.marpol.2017.05.014.

Sterly, Patrick Sakdapolrak and Harald. 2020. "Building Climate Resilience through Migration in Thailand." Migrationpolicy.Org. December 2, 2020. https://www.migrationpolicy.org/article/building-climate-resilience-through-migration-thailand.

Stern, P. C, and W. E Easterling. 1999. *Making Climate Forecasts Matter*. National Academies Press.

Tscharntke, Teja, Alexandra M. Klein, Andreas Kruess, Ingolf Steffan-Dewenter, and Carsten Thies. 2005. "Landscape Perspectives on Agricultural Intensification and Biodiversity – Ecosystem Service Management." *Ecology Letters* 8 (8): 857–74. https://doi.org/10.1111/j.1461-0248.2005.00782.x.

UN FAO. 2020. "Resilience : FAO in Emergencies." 2020. http://www.fao.org/emergencies/how-we-work/resilience/en/.

UN Office for Disaster Risk Reduction. 2019. *Global Assessment Report on Disaster Risk Reduction :* UN Office for Disaster Risk Reduction. http://digitallibrary.un.org/record/3825375.

UN Secretary General. 2016. "Outcome of the World Humanitarian Summit." New York: UN.

UNISDR. 2015. "Disaster Risk Reduction and Resilience in the 2030 Agenda for Sustainable Development." New York: United Nations. https://www.undrr.org/publication/disaster-risk-reduction-and-resilience-2030-agenda-sustainable-development.

United Nations. 2020. "The UN Common Guidance on Helping Build Resilient Societies." New York. https://www.sparkblue.org/basic-page/un-common-guidance-helping-build-resilient-societies.

Virji, Hassan. 2012. "Capacity Building to Support Knowledge Systems for Resilient Development—Approaches, Actions, and Needs." *Current Opinion in Environmental Sustainability*, 7.

Walker, Patrick G. T., Charles Whittaker, Oliver J. Watson, Marc Baguelin, Peter Winskill, Arran Hamlet, Bimandra A. Djafaara, et al. 2020. “The Impact of COVID-19 and Strategies for Mitigation and Suppression in Low- and Middle-Income Countries.” *Science* 369 (6502): 413–22. https://doi.org/10.1126/science.abc0035.

Walters, C. 1986. *Adaptive Management of Renewable Resource*. New York: Macmillan Publishing.

Webber, H., H. Kahiluoto, R. Rötter, and F. Ewert. 2014. “Enhancing Climate Resilience of Cropping Systems.” In *Climate Change Impact and Adaptation in Agricultural Systems*, 167–85.

Wheeler, Tim, and Joachim von Braun. 2013. “Climate Change Impacts on Global Food Security.” *Science* 341 (6145): 508–13. https://doi.org/10.1126/science.1239402.

Wiener, Jonathan B., and Alberto Alemanno. 2015. “The Future of International Regulatory Cooperation: TTIP as a Learning Process toward a Global Policy Laboratory.” *Law and Contemporary Problems* 78 (4): 103.

Willett, Walter, Johan Rockström, Brent Loken, Marco Springmann, Tim Lang, Sonja Vermeulen, Tara Garnett, et al. 2019. “Food in the Anthropocene: The EAT–Lancet Commission on Healthy Diets from Sustainable Food Systems.” *The Lancet* 393 (10170): 447–92. https://doi.org/10.1016/S0140-6736(18)31788-4.

World Food Programme. 2020. “Global Report on Food Crises.” https://www.wfp.org/publications/2020-global-report-food-crises.

Ziliak, James P. 2020. “Food Hardship during the Covid-19 Pandemic and Great Recession.” *Applied Economic Perspectives and Policy* n/a (n/a). https://doi.org/10.1002/aepp.13099.

Papers like this one from the Scientific Group for the UN Food Systems Summit are shared with the aim of providing information and facilitating discussion for transparent and evidence-based Summit preparations. This paper was revised by the authors after intensive external peer review. It remains under the responsibility of the authors. The views presented may not be attributed to the organisations with which the authors are affiliated.

Helpful comments on an earlier draft by five external peer reviewers, by colleagues in the Scientific Group are gratefully acknowledged.

For further information about the Scientific Group,
visit **https://sc-fss2021.org**
or contact **info@sc-fss2021.org**
or follow **@sc_fss2021** on twitter