The Future of Food Security, Nutrition and Health for Agri-food Systems Transformation

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December 17, 2021

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December 17, 2021

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This document is one of a collection of three working papers and a synthesis brief edited by Steven Prager and Keith Wiebe, and prepared as part of foresight-related research supported by the CGIAR Research Program on Policy, Institutions, and Markets. These working papers are intended to provide a forward-looking perspective on key issues to support discussion on food, land, and water systems transformation. We are grateful to members of a steering committee (Stephan Weise, Frank Place, Marianne Bänziger, Vincent Gitz, Oscar Ortiz, Michael Phillips, Tom Randolph, May-Guri Saethre, and Mark Smith) for their guidance, as well as to several anonymous reviewers for their comments on an earlier draft.

These working papers and the synthesis brief will be made available at http://foresight.cgiar.org.

Abstract

Global progress towards food security and nutrition has been slow in many places and even reversing in others. Against the background of changes in population, income, technology, climate, and other drivers, the pressures on food systems are daunting. When designing and rolling out future interventions towards these goals it is of vital importance to utilize foresight knowledge to anticipate, shape, and prepare for alternative possible futures. Overcoming current and emerging challenges but also seizing opportunities as they present themselves requires continued efforts to provide robust analysis to inform decision making. Here we collated the latest insights from foresight studies around three central aspects within the food system. First, consumer demand and the changes this is undergoing is a key aspect shaping the food system itself as well as nutritional and environmental outcomes. Second, distributional inequalities and trade-offs within the food system have further been identified as key challenges to tackling adverse health outcomes of the current food system. And third, amplified by the COVID crisis, enhancing the resilience of the food system that is increasingly under threat from multiple risks has risen to the top of the agenda.

Contents

Acknowledgements

This paper was prepared with support from the CGIAR Research Program on Policy, Institutions, and Markets (PIM); CGIAR Research Program on Fish Agri-food Systems (FISH); CGIAR Research Program on Roots, Tubers and Bananas (RTB).

Introduction

Food, land, and water systems are facing unprecedented change. The world's population is projected to grow to approximately 10 billion people by 2050, while aging and declining in some regions. Global average incomes are expected to keep increasing at a slow but steady pace. With increasing incomes and the ability of consumers to purchase more and better food in combination with population growth, food demand is projected to grow substantially over the next three decades. Meanwhile, demographic changes and economic development also drive urbanization, migration, and structural transformation of rural communities. Currently, humanity is approaching or exceeding planetary boundaries in some areas, with over-use of limited productive natural resources such as water and phosphate, net emissions of greenhouse gases, and decreases in biodiversity. This all is aggravated by continuous climate change.

Much is published about food and agriculture, but no single source focuses regularly and systematically on the future of agriculture and food systems, particularly on the challenges and opportunities faced by developing countries. This working paper is part of an effort by the CGIAR foresight team to help fill that gap. The effort recognizes that there is much to learn from past experience, and there are clearly many urgent and immediate challenges, but given the pace and complexity of change we are currently experiencing, there is also an increasing need to look carefully into the future of food, land, and water systems to inform decision making today.

Food Security, Nutrition and Health for Development Outcomes

Improving food security and nutrition to achieve the Sustainable Development Goal (SDG) 2 on Zero Hunger is critical to ensure the wellbeing of future generations. Placing this alongside improved health and other development outcomes makes the level of ambition and complexity readily apparent. Global and regional food systems are highly heterogeneous and are differently affected by powerful drivers; while this heterogeneity compounds the challenge it also opens the door to a broad set of potential solutions. As they are commonly defined (Figure 1), food systems include the relationships between food supply chains, food environments, consumer behavior, diets, nutrition and health outcomes and impacts, while also encompassing macro-level drivers such as policy and institutions, climate change and socioeconomic interactions (HLPE, 2017). Understanding the future of food systems thus requires a simultaneous look at food system(s) complexity, including major drivers, interactions, interventions, and expected development outcomes. A fundamental cultural shift on the part of researchers, funders and business, policy decision-makers, as well as shifts in incentives (Karp et al., 2015) are also imperative for a more inclusive perspective on solutions to the food systems challenges (Fanzo et al., 2020). Substantial agriculture development-related research is currently focusing on increasing the knowledge of the structure and functions of food systems (Béné et al., 2019). From the recent EAT-*Lancet* report that evaluates diets in relation to planetary boundaries (EAT, 2019), to more focused studies on specific commodities (Béné et al., 2015) and cross-cutting issues (Rosegrant et al., 2017), understanding the multiple facets and dimensions of food demand is widely recognized as one of the key areas for research. This brings us to our first insight:

> **Insight 1:** Consumer behavior, corresponding preferences, and resulting **demand** will become increasingly important factors driving the structure and function of food systems globally and in all regions. This will have ramifications both throughout food systems and development outcomes, including food production level and quality, value chains, diets, health, and the environment.

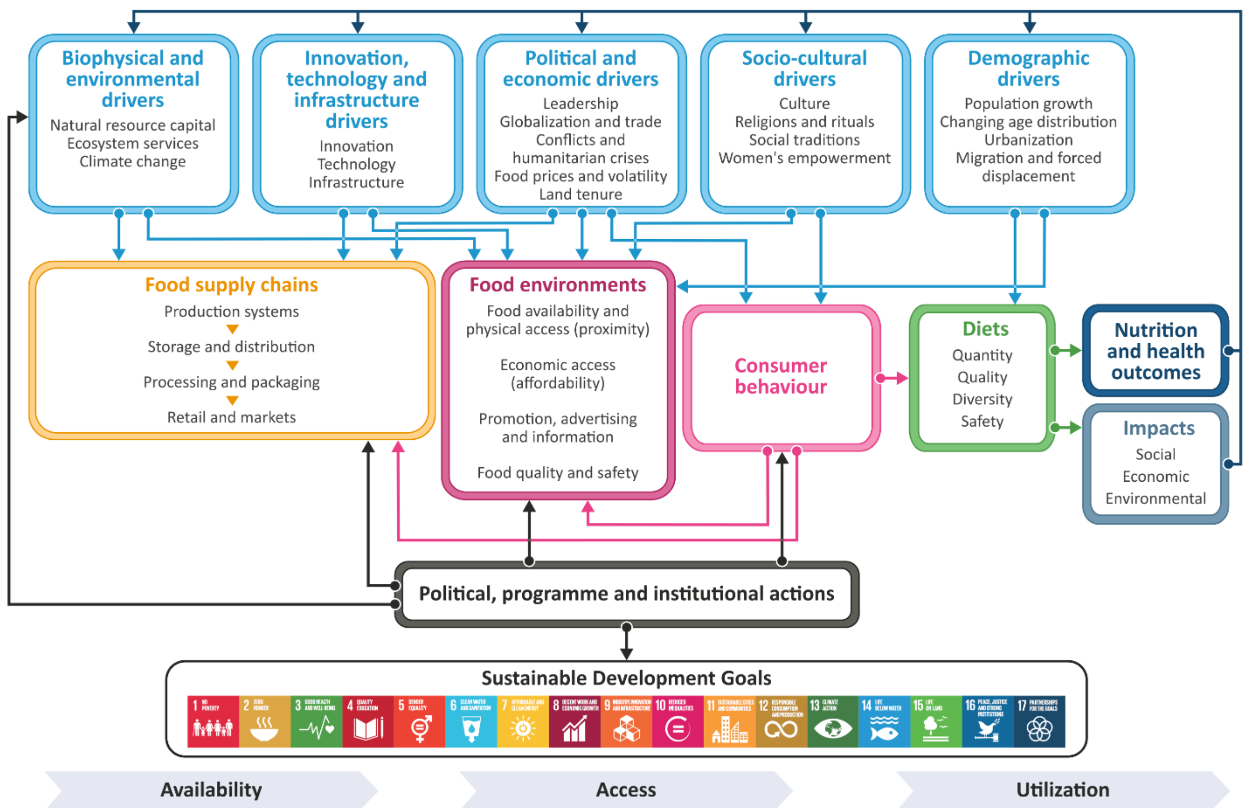

Figure 1. The food systems framework.

Source (HLPE, 2017). Reproduced with permission (Simmance et al., 2021)

Though demand is generally recognized as changing in response to a variety of influences such as increased incomes and increased recognitions of nutrient and health benefits of animal-sourced foods driving a shift away from starchy staples (Mayén, Marques-Vidal, Paccaud, Bovet, & Stringhini, 2014; Wang et al., 2021) , investments in improving food systems must also better target the linkages between demand, drivers, and corresponding outcomes. While investment in agricultural development has historically focused on supply-side and production-related advances (Rosegrant et al., 2014), we must complement this perspective to address cross-sectional and temporal dimensions of demand-related issues from food preference to consumer behavior. Furthermore, responding successfully in one area (e.g., demand) may, however, neglect or even contradict another. This is our second insight:

> **Insight 2:** Responding to changing demand will not guarantee that we also meet food security, nutrition and sustainability goals; those will require the implementation of additional, deliberate measures along with clear articulation of possible trade-offs.

Strategic foresight approaches offer the opportunity to explore plausible alternative futures as they relate to key global and regional agri-food systems, especially in the developing world, which has received insufficient attention in recent studies. For the foreseeable future, we anticipate that, in most developing countries, food security and nutrition, livelihoods, and environmental outcomes will continue to be primarily determined by production-dominated food systems for the foreseeable future. At the same time, agri-food systems, value chains, and the resultant outcomes are also facing an increasingly complex set of globally connected challenges ranging from price volatility to biophysical shocks. With this in mind, we present our final insight:

> **Insight 3:** More generally, food production and food systems will face increased frequency and intensity of both man-made shocks and natural hazards affecting all dimensions of food security and nutrition. Making food systems more resilient to these acute and chronic shocks will require a new approach to deliberate food system policy.

While seemingly intuitive, the three insights above systematize a series of complex issues we must consider if we wish to invest in agricultural research for development (AR4D) that is anticipatory rather than reactive. In the following sections, existing foresight analyses and supporting context illustrate the necessary, albeit not necessarily sufficient, conditions for integrating across food security, nutrition and health outcomes while working towards long-term sustainable food systems.

Reconciling Food Demand Issues

A food system perspective gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socioeconomic and environmental outcomes (Figure 1) (HLPE, 2017). Though food systems are highly complex, targeted research enables the exploration thereof to improve understanding of how they function and their influence on human and environmental well-being. Increased knowledge of food system structure and function improves our capacity to support evidence-based policymaking aimed at balancing and mitigating the trade-offs associated with pertinent development strategies (EAT, 2019). Understanding the various dimensions of food demand is increasingly recognized as a critical pillar of food systems research (Depenbusch & Klasen, 2019; Henchion, Hayes, Mullen, Fenelon, & Tiwari, 2017; Mottaleb, Rahut, Kruseman, & Erenstein, 2018). For example, the recent EAT-*Lancet* report (EAT, 2019) reviewed the relationship between healthy diets and a sustainable food system, and actions to support food system transformation.

Nourishing 9.8 billion people with a healthy and sustainable diet by 2050 and within planetary boundaries is recognized as one of the biggest challenges for now and in the future (McDermott & Wyatt, 2017; Springmann et al., 2018). Global commitments to achieve SDGs by 2030 recognized that food system transformations would be imperative to eradicate all forms of malnutrition while simultaneously sustaining natural resources and the environment (HLPE, 2017). Malnutrition that affects vulnerable and marginalized populations in developing countries is one of the major challenges in achieving these development goals. The minimum dietary diversity standards needed for growth are met by fewer than one-third of all young infants across sixty low- and middle-income countries (Global Panel, 2016), and recent research shows that healthy diets are not affordable for many of the world's poor (Hirvonen, Bai, Headey, & Masters, 2019). Each year, more than 3.1 million child deaths are attributed to poor nutrition (Abraham & Pingali, 2020). At this rate, the global nutrition targets, including SDG target 2.2 to end all forms of malnutrition by 2030, will not be met (Serraj, Krishnan, & Pingali, 2018).

At the same time, increased investment in productivity growth across a wide range of crops has the potential to reduce hunger by nearly 30 million people by 2030 (Wiebe et al., 2021). Also, sustained investments are critical to sustain capture fisheries and support aquaculture growth for food system transformation towards healthier diets (Chan et al., 2021).

Such productivity increases will not happen in isolation, and these changes will likely occur amidst sharper differentiation and widening income disparities among small farmers' livelihood strategies (Hazell & Varangis, 2020). Most of the world's poor and hungry are rural people who rely on agriculture, fisheries, aquaculture and forestry for large shares of their incomes; in some regions, income from agriculture often represents the largest share of household earnings. This differentiation increases when combined with increased incomes, population growth, and urbanization (Thurstan & Roberts, 2014). These drivers are likely to induce dietary shifts away from traditional staples and, depending on income, towards highly processed food or food with high nutrition value, particularly fruits, vegetable, and nuts (EAT, 2019), as well as animal-sourced food (Liverpool-Tasie, Sanou, Reardon, & Belton, 2021; Thurstan & Roberts, 2014; Wang et al., 2021; Wang, Tran, Wilson, Chan, & Dao, 2019). These dietary shifts will have an essential bearing on the evolution and capacities of environmental systems to support food demand in the future (Springmann et al., 2018).

Meat and fish consumption, in particular, illustrates fundamentally changing patterns in demand. Foresight analyses repeatedly show that per capita meat and fish consumption in developing countries is projected to increase (Chan et al., 2017; Komarek et al., 2021), with one study suggesting an increase of 50% when comparing 2050 to consumption rates in 2005–07 (Alexandratos & Bruinsma, 2012). Herrero et al. (2018) found that increases in consumption of animal-sourced foods in recent years have varied significantly, with demand for beef growing slower than projected two decades ago, while demand for poultry has grown much faster than projected. Similarly, demand for fish and aquatic foods has been increasing rapidly. These changes derive not only from population and income growth but also from an increasing appreciation for the health benefits of fish consumption (Chan et al., 2017; Chan et al., 2019; Tran et al., 2019; Wang et al., 2021; Wang et al., 2019) as well as changes in lifestyles and preferences associated with rapid urbanization and globalization. These new analyses illustrate the importance of iterative foresight, incorporating new knowledge regarding both drivers and corresponding demand.

Optimizing Outcomes

Responding to meet changing demand in increasingly complex and interconnected food systems is challenging; this is partially because, although we produce enough food in terms of available calories (Willett et al., 2019), the quality of the food produced is insufficient to *nourish* the world. Moreover, significant inequalities hinder distribution and access to food, both in terms of quantity and quality (Béné et al., 2019; Hirvonen, 2020). In some regions and in some parts of society, food and nutrition insecurity remain unacceptably high. For example, across Sub-Saharan Africa, undernourishment still affects one in four people (FAO, IFAD, UNICEF, WFP, & WHO, 2018), whereas in the Pacific, the transition of diets towards imported and low nutritional quality foods is leading to malnutrition in the form of overweight and obesity. Micronutrient deficiencies, overweight, and obesity are expected to remain the leading drivers of the global burden of diseases caused by inadequate food consumption (Development Initiatives, 2018; FAO, 2018).

While poverty is persistently one of the root causes of hunger (von Grebmer et al., 2019), the relationship between income, nutrition, and healthy diets is much more complex. On the one hand, economic growth only moderately reduces undernutrition (Alderman, Haddad, Headey, & Smith, 2014; Tran et al., 2021; Vollmer et al., 2014), and on the other hand, it often leads, especially in urban settings, to a higher prevalence of overweight (Headey & Alderman, 2019). Multiple factors such as education and income distribution, both inter- and intra-household, play a critical role in this relationship. Even where poverty has been reduced, pervasive inequalities remain, hindering the eradication of hunger (FAO, 2017). In this regard, the explicit incorporation of gender, poverty and nutrition outcomes into foresight work has been proposed in an effort to better address inequalities and nutritional and gender disparities (Lentz, 2021). Food safety is another vital factor related to income and nutritional outcomes, and this has been highlighted as a necessary component of future studies associated with understanding food systems (de Haen & Réquillart, 2014). Even though consumers in developing countries are increasingly willing to pay a premium for safer foods as incomes rise (Birol, Karandikar, Roy, & Torero, 2015; Tran et al., 2022), pathogens continue to account for the vast majority of the health burden due to food-borne illness in those countries (Kher et al., 2013; WHO, 2015). Growing evidence is suggesting that food-borne or food-system-related diseases, especially zoonoses, potentially leading to extremely disruptive epidemics or pandemics for the food chains will increase in the future unless profound adjustments are made to current food systems (Nicoll, Huang, Xie, & the Foresight China Project Group Collective, 2009). The Covid-19 pandemic provides a devastating example of the degree of interconnection and interdependence between global health systems and global food systems. There is a scope for global research in this area, looking at a wide range impact of natural disasters and pandemic on food systems disruptions in the short, medium and long run, and its implications on income growth, poverty, food security and nutrition. It also highlighted the need to revisit the spatial dimension of food production and consumption in relation to wild animal life. It is expected that more system thinking and analysis will take place in the near future, leading to a redefinition of the safe operating space for food systems vis-a-vis health systems and probably others.

As with demand, decisions regarding development strategies and optimality of trade-offs will be unequally distributed globally, with nearly 90% of the population increases anticipated by 2050 occurring in Asia and Africa (United Nations, 2019). However, by mid-century, the total population will begin to decline in Asia, while projected to continue growing in sub-Saharan Africa through the end of the century (United Nations, 2019). Societies with declining populations will face different challenges in supporting the elderly and dietary change, while those with growing populations will face challenges in meeting rising and changing demand for food. Barring major catastrophes, profoundly disrupting civil unrest, widespread warfare, and acute pandemics, this growing population is projected to be more affluent than the current one, requiring between 50% and 70% more food than current levels by 2050 (FAO, IFAD, UNICEF, WFP, & WHO, 2021; Godfray et al., 2010; Nelson et al., 2018; Pretty et al., 2010; Keith Wiebe et al., 2015). While the world is already predominantly urban, the share of the population living in cities continues to rise, and 82% of the world's urban population will be based in today's less-developed regions by 2050 (Hazell, 2018).

One major set of trade-offs that will be of increasing concern is between meeting food demand and maintaining ecosystem services provision (Enahoro et al., 2019; Rosegrant et al., 2017; Wang et al., 2021). A recent study (Enahoro et al., 2019), projected that improved global economic conditions would lead to increased food supplies and reduced prevalence of hunger and undernutrition in Tanzania in 2030, but with trade-offs emerging between meeting the demand for nutrient-rich animal-sourced foods and maintaining ecosystem services. More recent research highlights important regional differences in what individuals, households or communities will be able to access in terms of food diversity according to their dietary and cultural preferences and what they will be able to afford (Hirvonen, 2020). As the economic transition occurs in a growing number of developing countries, identifying and articulating the specific trade-offs linked to dietary changes and increased pressure from climate change will become one priority for research and the design of policy interventions.

Suppose the current trend in income distribution continues into the future without adequate policy response. In that case, the gaps between the wealthiest and poorest segments of the population are likely to increase (Alvaredo, Chancel, Piketty, Saez, & Zucman, 2018), creating a dichotomy in food systems' developments. Population with higher income levels and easier access to food markets will fulfill demand through markets similar to those in developed countries. For example, supply chains will further develop, driven by a growing role of supermarkets in major urban centers with associated developments in services (Reardon, Timmer, & Berdegué, 2008). This trend, along with demand shifts resulting in higher consumption of nutritious foods, such as fruits, vegetables, and animal-sourced foods, will likely improve nutritional outcomes due to improved consumer access to diversified foods (Debela, Demmler, Klasen, & Qaim, 2020). However, population groups with lower income levels in both urban and rural areas will continue to access food through local markets and own production, and will continue to face limitations on the quantity, quality and diversity of food they can access (FAO, 2017; Proctor & Berdegué, 2016). In many cases, the poorest consumers will turn to heavily-marketed convenience fast food, particularly unhealthy, highly processed items (Lara Cockx, Colen, & De Weerdt, 2019; L. Cockx, Colen, De Weerdt, & Gomez Y Paloma, 2019) or will continue to rely on public distribution programs heavily focused on delivering calories instead of nutrition. This is already a visible trend for a significant fraction of the Indian population (Kozicka, Weber, & Kalkuhl, 2019; Pingali, Mittra, & Rahman, 2017).

Enhancing Resilience via Food System Policy

The need to address emerging demand alongside a variety of context- and geographically specific trade-offs can potentially shift how we look at food security in the near future. In examining the future of EU policies relating to global food security, Maggio, Van Criekinge, and Malingreau (2015) illustrate a shift from consideration of policies related to food *insecurity* to policies that treat food security as “securing food supply in response to a new and emerging demand.” They emphasize the need for food systems to become increasingly demand-driven, and balance between local and global scales with nested governance and high levels of transparency.

A focus on “securing food supply” at global, regional, and local scales opens the door to policy and approaches that recognize food system complexity and the need for systems-level strategies to enhance resilience. The widely accepted constructs of food security, including access, availability, stability and utilization still offer an important foundation from which to understand the overall functioning and resilience of food systems. Climate change, for example, will continue to be a major driver of food insecurity with its corresponding impacts particularly affecting the poorest that are already vulnerable and disproportionately exposed to other risks related to natural resource use, market, or political stability as compounding factors (FAO, 2017). Building resilience of our food systems to future acute shocks and chronic stresses will be critical in the years to come.

Biophysical factors are just one element of risk management and resilience in the food system. In the long-run it is likely that the decline in real food prices observed through most of the past century, and as predicted by Baldos and Hertel (2014), will eventually slow and reverse. OECD/FAO (2019) projections show more or less stable prices over the next decade, but the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) and many other global economic models show food prices rising over the longer term (Delincé, Ciaian, & Witzke, 2015; Wiebe et al., 2015). Along with rising demand for food, large-scale land-based climate mitigation strategies, policies, trade barriers, and regulations forcing the reintegration of negative health and environmental externalities in the cost of production of agricultural commodities (European Commission, 2020) might lead to higher food prices and lower food availability (Doelman, Stehfest, Tabeau, & Van Meijl, 2019; IPCC, 2019; van Meijl et al., 2017). Many researchers call for reintegrating the externalities in the cost structure of food and prompt decision makers to revisit the support to agriculture to create a level-playing field for alternative production models and ultimately healthier and more sustainable diets. Further challenges will come from growing competition for land to the detriment of agriculture in an increasing number of countries, especially those with high levels of productivity. Rising prices will create pressure on food access that is compounded by proportionally slower growth in income. While price increases can be reversed by sufficient increases in productivity, which are strongly dependent on climate impacts and investment in R&D (Baldos & Hertel, 2016; Doelman et al., 2019), these are set against the composite backdrop of resource conflicts, social unrest and other stress multipliers that may undermine otherwise well-intentioned investments (Bleischwitz, Johnson, & Dozler, 2014).

While the absolute and relative food prices are shaping food and nutrition of the poor mainly through the accessibility pillar of food security, food price volatility plays an important role in affecting the stability of the conditions that enable individuals to meet their food demand. Even though high food prices are bad for net consumers, they can have positive impact on net food producers. By contrast, increased food price volatility negatively affects both consumers and producers (Kalkuhl, von Braun, & Torero, 2016). Future climate extremes are expected to further amplify food price volatility given that persistent large-scale harvest failures may deplete grain stocks that together with trade have been smoothing the damage from extreme events in the last years (Briones, Durand-Morat, Wailes, & Chavez, 2012; Chen & Villoria, 2019; Hertel, 2018).

In many ways, some of the vulnerabilities in the food system are self-made, both environmental and nutritional. Without adequate policy intervention, staples and highly processed foods with high sugar content will continue to outcompete many healthy foods due to the comparatively higher prices for nutrient-dense foods such as vitamin A-rich fruit and vegetables, green leafy vegetables or eggs (Headey & Alderman, 2019). This will add further pressure on food and nutrition security of lower income population (also in high income countries) and exacerbate consequences of income inequalities (J. Fanzo, Davis, McLaren, & Choufani, 2018). A potential shift in the nearly $650 billion worth of agricultural subsidies (OECD/FAO, 2019) away from cereals and dairy to rebalance policy support toward healthier and more sustainable food systems might tip the balance in support of healthier diets. In spite of a growing debate on the need to repurpose the public support to agriculture in the wake of COP26 in Glasgow or the COP15 in Kunming, it is projected that agricultural subsidies given to producers globally could increase further by 2030 (FAO, UNDP, & UNEP, 2021).

While investment (much of it private) in food value chains will offer improvements in food quality, safety, and utilization, food utilization will at the same time be challenged because of increased occurrence of bacteria, viruses, parasites, fungi and their corresponding foodborne diseases and risk of toxic contaminations resulting from climate-change-related erratic rainfall patterns and increases in extreme weather events and average temperatures (WHO, 2015). This will increase the global burden of food-related disease and mortality, including under-nutrition, communicable, non-communicable, and diarrheal- and vector borne diseases (WHO, 2015).

While food access, stability, and even utilization are certainly at increased risk due to climate change, concerns about food availability cannot be ruled out in the next decades either. This is due to: 1) yield reductions for some crops and regions due to climate change (Deutsch et al., 2018; Liu et al., 2013; Rosenzweig et al., 2014) and more frequent episodes of drought or flooding (Seneviratne et al., 2012). Moreover, land use will also be affected in some areas, reducing the amount of land available for food production as a result of deforestation, urbanization, sea level rise, land degradation as well as land reclamation (Olsson et al., 2019); 2) increased climate variability and more extreme weather events will also affect food availability through lower and greater uncertainty over yields (crop and animal). Several studies have shown the long-term malnutrition effects of short-term shocks in food availability (Alderman, Hoddinott, & Kinsey, 2006; Hirvonen, 2020; Majid, Behrman, & Mani, 2019); 3) biodiversity loss will increase vulnerability of production systems and as a result lead to higher frequency and severity of food supply shocks (FAO, 2019; Roe, 2019; Roe, Seddon, & Elliott, 2019); and 4) increased vulnerability of food systems to the disruption of food supply chains as a result of pandemics and other major health crises could cause labor shortage, restrictions on transport, trade, and retail, as evident currently in the case of Covid-19. As a result, food may not be supplied when and where it is needed.

Future perspectives on food security and nutrition depend not only on the income growth and distribution, but also program interventions that focus on food safety and nutrition (Alderman et al., 2006; Headey, 2013). As future trends are likely to further increase the gaps between the wealthiest and poorest segments of the population within countries, there is a need to address income disparities; gender inequalities; poor access to education, healthcare, and technology; and the compounded effects of these issues (de Haen & Réquillart, 2014). Policy measures such as food price stabilization policies, trade regimes and the formalization of grain reserve arrangements (Headey & Fan, 2010; von Braun & Torero, 2009) need to be considered to protect both consumers and producers against consequences of price shocks and price volatility resulting from increasing likelihood of extreme events.

We need to redefine our approach to food systems resilience to include consideration of 1) the robustness of the food system, 2) redundancy within the food system, 3) agility and rapidity of response to perturbation, and 4) resourcefulness and adaptability of food system actors (Tendall et al., 2015). More resilient food systems will have the potential to support increased incomes for farmers through increasing participation in markets. Conversely, improved access to markets for farmers will have the potential to have positive feedback elsewhere in the food system. A complex series of feedbacks emerge in the food system such that if the food system is more resilient to climate and environmental shocks, the translation of those shocks to impact on the population and income may be largely mitigated.

To build a more resilient food system in the future, there is a clear need to improve our understanding of the attributes of concurrent and recurrent shocks across the globe in order to enable specification of optimal food stock quantities (Chatzopoulos, Domínguez, Zampieri, & Toreti, 2020) as well as market information, trade policies, and financial risk-management measures. Overall, it is necessary to focus renewed attention on policy research (Fanzo et al., 2020) and risk analysis with a focus on a deeper understanding of what risks exist within a framework of interconnected and interdependent systems, and on how these risks can be mitigated through better preparedness to achieve greater food system resilience.

Synthesis, Outlook, and Opportunities

Though food systems dynamics are in many ways infinitely complex, in exploring the three insights, we focus on themes that have the potential to influence food system outcomes in a favorable direction. Based on our understanding of both food system structure and function and the future potential states as evidenced by various foresight analyses, we explore how emphasizing a demand-led perspective, an intentional approach to considering trade-offs, and a deliberate resilience policy approach are required to achieve long-term food security, nutrition, and health outcomes.

In each of the three themes, we used futures-oriented studies to show how a number of critical drivers could be viewed as priorities for thinking about policy interventions or as the focal points for further investment in agricultural research. Three key drivers that emerged in the analysis include the changes in income, changes in population and demographic characteristics, and changes in environmental and climate conditions. Each one of these drivers forms the basis of numerous shifts in the structure and function of food systems and sets the stage for the solution space in which we might operate to assure long-term food and nutrition security as well as healthy, sustainable diets for the global population.

Changes in food system structure and function, either deliberate or passive, are the sources of food system (un)sustainability. The manner in which the three drivers mentioned above are inducing a positive or negative transformation in the food system is largely determined by three enabling "levers." These levers are a set of entry points to influence the direction of a change in food systems. Three potential levers that emerged from the above analysis include improved markets and trade regimes, enhanced policy (e.g., tailored and geographically specific), and context-appropriate innovation and technology (Table 1). This is reinforced in early views on this matter from Ruttan (2002) who noted that, "If the world fails to meet its food demands in the next half-century, the failure will be at least as much in the area of institutional innovation as in the area of technical change" (p. 180).

Table 1. Understanding how different intervention spaces are formed relative to levers of change and major global drivers.

	Income	Population & Demographic	Climate & Environment
Markets & Trade	• Upgrade value chains • Segmentation • Capital flow • Diversify food intake to tackle malnutrition • Reduce food loss & waste	• Food import in mega cities • Self-sufficiency vs. self-reliance • Food loss & waste • Urbanization and food habits (street food) • Nutrition and gender equity	• Greenhouse gas emission • Carbon markets linked to food systems • Relocation of production
Policy & governance	• Inclusive growth • Diversification (biodiversity, agroforestry) • Value chain development • Competition • Tax on sugar, processed food	• Rural transformation • Food procurement • Gender and youth • Food safety standards • Awareness raising /education on nutrition	• Buffer stock • Insurance • Safety nets • Financial instruments (loans, insurance) • Land use
Innovation & Technology	• Information system • Integrated pest management • Fortification, supplementation and bio-fortification • Novel dietary diversity	• Vertical agriculture • Alternative meat/seafood production • Mechanization/ motorisation	• Climate-smart agriculture/fisheries/ aquaculture • Stress resilience • Water management • Precision agriculture

Given the highly complex and heterogeneous nature of food systems, high levels of future uncertainty, and the wide range of possible interventions, there are no "one size fits all" solutions. The various foresight scenarios offer a series of plausible futures, which then provide insight for synthesizing across the analyses in each of the previous sections and the drivers, and levers that emerged. From this, we see a series of intervention spaces. These intersections between drivers and levers, aligned with the three "insights," offer ideas as to the nature and dimensionality of the programs and policies that will be required to assure a sustainable food future. Table 1 shows a matrix laying out the intervention spaces and offers examples of policy elements that could be woven together as the basis for a future systems-level investment.

The elements represented in Table 1 are neither exhaustive nor universal. Rather, they are illustrative and suggest how policy and, by extension, investment in agriculture development, must be holistic in nature in order to serve the food system. Just as evidence has shown that there are no single solutions to guarantee increases in agricultural productivity, there are no single solutions to improve food system outcomes. The future demands integrated solutions that are tailored to specific contexts and geographies, nested with solutions and complimentary scales, and that empower actors, from the poorest farmer to the policy makers in the developed world.

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