Transforming Food Systems

"One cannot think well, love well, sleep well, if one has not dined well."
Virginia Woolf, a room of one's own

MARCH 2021

Positions such as the Prime Minister of Portugal, the President of the European Council, the UN high Commissioner for Refugees, and now the Secretary-General of the United Nations have made António Guterres accustomed to leading change. In just over half a year, the UN Food System Summit will commence congregating UN institutions and officers, member states, various interest organizations and the public.[1] An increase of 50% in food production by 2050 will be needed to feed the expected population growth amounting to 2.5 billion people.[2] With 50% of Earth's ice-free land surface already used for agriculture and 70% of available freshwater consumed for this purpose, the agriculture's toll on Earth and the ocean will continue to increase.[3] The Secretary-General will need to gather all forces to lead this tremendous change. The pressure is on.

We are at a crossroad. Contemporary expectations of food availability, equality, quality, and sustainability never stop mounting. Those expectations do not go hand in hand with an archaic system designed in the post WW2 era for a very different purpose. When designed, the aim was to "provide ample, cheap, shelf-stable, starchy calories for a growing world population, fortified with key micronutrients when feasible to prevent clinical nitrite deficiencies [5]. Human and planetary concerns of the 21st century – the intersections of chronic diseases, improved but continuing food insecurity, undernutrition, and sustainability – require a fundamental transformation of food systems to meet evolving and future needs of consumers, produces, and the resource base in which all life depends."[4]

To complicate the issue, various reports establish that the "transformed, sustainable food systems are also one of the most effective levers to achieve the Sustainable Development Goals by 2030."[5] The achievement of SDG 1, no poverty and SDG 2 zero hunger clearly requires a disruption of the current food system. Furthermore, SDG, 3 good health and well-being; SDG 10, reduced inequalities; SDG 11, sustainable cities and communities; SDG 12, responsible

[1] The case is for illustration and educational purposes only. It does not convey the opinions of any institution or person.
[2] FAO. 2017a. The future of food and agriculture: Trends and challenges. Rome: FAO.
[3] Hooke, R., Martin-Dunque, J., & Pedraza, J. 2012. Land transformation by humans: A review. ***GSA Today***, 22(2): 4-10. FAO. 2017c. Water for sustainable food and agriculture. Rome: FAO.
[4] Kennedy, E., Webb, P., Block, S., Griffin, T., Mozaffarian, D., & Kyte, R. 2020. Transforming Food Systems: The Missing Pieces Needed to Make Them Work. ***Current Developments in Nutrition***, 5(1). p.1.
[5] Shaping Solutions: Way forward for preparation of the UN Food System Summit, version 07.02.2021. See also: Global Nutrition Report 2020 at file:///C:/Users/fgl99066/Downloads/Executive_Summary_2020_Global_Nutrition_Report.pdf.

consumption and production; SDG 13, climate action; SDG 14, life below water; and SDG 15, life on land, can only be met by redesigning the food systems.[6]

Hence, there is much at stake. If the summit does not generate creative ideas that can motivate and energize member states and more importantly the public to take meaningful and immediate action to disrupt and transform our food systems, the achievement of the Agenda 2030, namely the achievement of a better and more sustainable future for all by 2030, will be in even greater jeopardy. With mounting challenges, such as the sustainability crisis, slower-than expected change in food-related human behavior and production processes, economic downturn, and human COVID-related suffering, the task at hand quickly becomes unruly.

Mounting challenges

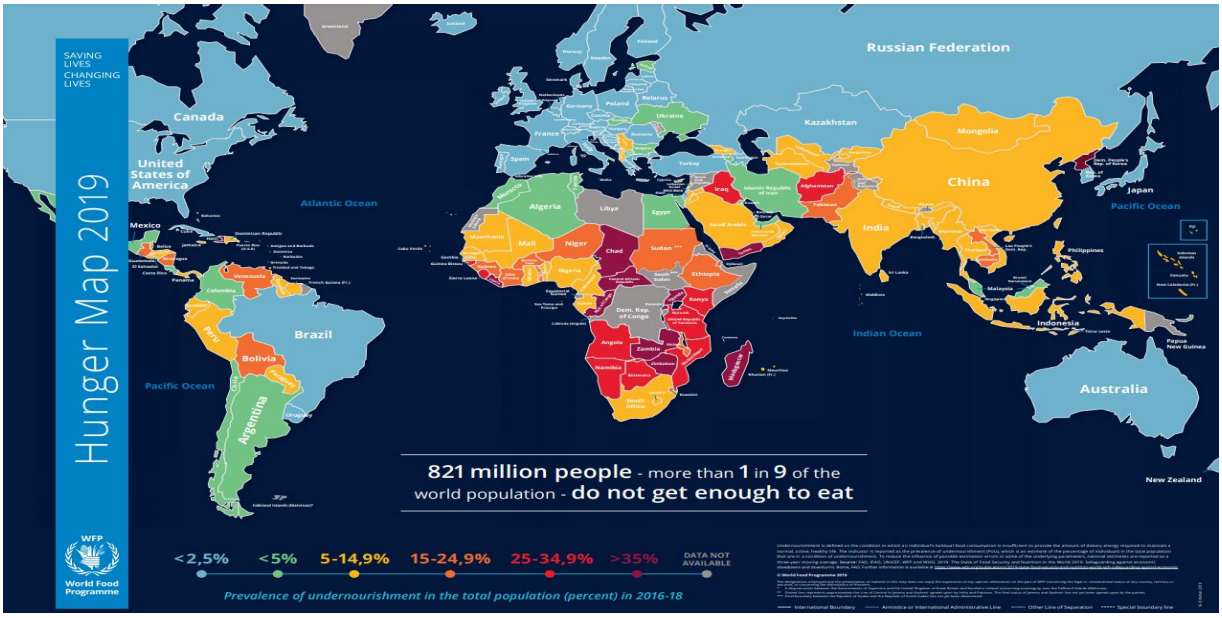
Various high-level reports and commissions have repeatedly mentioned a number of challenges: Hunger (SDG2, zero hunger), food loss and waste (SDG 12.3), obesity, relative cost of food and healthy diets, incentives and disincentives for farmers, producers, and consumers, and health and environmental consequences. Furthermore, those challenges are unequally distributed by age, gender, and region.

While estimates of the prevalence of hunger vary widely due to both lack of accurate data and the utilization of differing definitions, a consensus is that the achievement of SDG2, zero hunger, is miles away. A joint work of FAO, IFAD, UNICEF, WFP and WHO estimates that "nearly 690 million people are hungry, or 8.9 percent of the world population – up by 10 million people in one year and by nearly 60 million in five years. The number of people affected by severe food insecurity, which is another measure that approximates hunger, shows a similar upward trend. In 2019, close to 750 million – or nearly one in ten people in the world – were exposed to severe levels of food insecurity. Considering the total affected by moderate or severe food insecurity, an estimated 2 billion people in the world did not have regular access to safe, nutritious, and sufficient food in 2019."[7] The UN World Food Program's Hunger Map is worth a thousand words. It communicates both the prevalence of lack of food and the inherent inequality in its distribution between the northern and southern hemispheres.

[6] Kennedy, E., Webb, P., Block, S., Griffin, T., Mozaffarian, D., & Kyte, R. 2020. Transforming Food Systems: The Missing Pieces Needed to Make Them Work. ***Current Developments in Nutrition***, 5(1). p.2.

[7] FAO, IFAD, UNICEF, WFP and WHO 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en, p. xvi.

Figure 1: World Hunger Map[8]



FAO, IFAD, UNICEF, WFP and WHO raise the red flag concerning the work to reduce the number of undernourished people in the world. With tremendous effort, the number of undernourished people was reduced from 825m in 2005 to 678 in 2018. Projections to 2030, however, estimate that the down-slopping trend will be overturned, nullifying the achievements.[9] COVID-19 will exacerbate the situation potentially increasing the number of undernourished by 132 million people.[10] The global hunger index, which combines undernourishment, child wasting, child stunting[11] and child mortality establishes that, in addition to political and social challenges, the hunger problem is also economical. As GDP increases, the hunger index falls.[12]

While undernutrition is prevalent, so is food wastefulness. Intentional or unintentional wastefulness lead to a reality in which "around 14 percent of food produced is lost from the post-harvest stage up to, but excluding, the retail stage."[13] The only comprehensive study, notwithstanding its limitations, which examined both food loss and waste, estimated that about 1.3 billion tons, or about one-third of edible parts of food produced per year, were either lost or wasted.[14] In a meta-analysis of reported food waste percentages at the consumption stage in North America and Europe 2012-2017, FAO provides evidence that the

[8] World Food Program 2019. Hunger Map 2019. URL: https://docs.wfp.org/api/documents/52c3c66390dc436da192ea782a2bdb3d/download

[9] FAO, IFAD, UNICEF, WFP and WHO (2020). The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en, p. 4.

[10] FAO, IFAD, UNICEF, WFP and WHO (2020). The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en, p. xvi.

[11] Acute, short duration malnutrition and chronic malnutrition.

[12] Roser, M. and Ritchie H. 2019. Hunger and Undernourishment. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/hunger-and-undernourishment.

[13] Food and Agriculture Organization, 2019. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. URL: http://www.fao.org/3/ca6030en/ca6030en.pdf, p. 1.

[14] Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., & Meybeck, A. 2011. Global food losses and food waste: FAO Rome.

median estimate for food waste of meat and animal products is 21%, fruits and vegetables 18% and cereals and pulses 10%.[15] Food loss and waste appear across the entire value chain and have varying causes. Pre-harvest and pre-slaughter losses are followed by harvesting loss, food loss (on site, transport, storage, dsitribution, prcessing and packaging) and food waste (retail and public and household consumption).[16]

While malnutrition and wastefulness are prevalent, so is obesity. There has been no progress to stem the rate of overweight in nearly 20 years."[17] Adult obesity is worsening in all sub regions of the world."[18] Word estimates of adult obesity establish an increase from 11.8% to 13.1% from 2012 to 2016. At the same period, adult obesity in North America increased by 2.6 percentage points, currently at about 35.5%. Other regions report the same trend (11.5% to 12.8% in Africa; 6.1% to 7.3% in Asia; 22.2% to 24.2% in Latin America; and 21.3% to 23.6% in Oceania). The future is not bright. In addition, child overweight is increasing across the board. Globally, the percent of child overweight increased from 5.3% to 5.6%. Similar increases are reported in Asia and Latin America while North America reports an increase of 0.9 percentage points and Australia and New Zealand report at increase of 4.5 percentage points.

In an ingenious and provocative report,[19] the costs of energy sufficient diet, nutrient adequate diet and health diet are compared across world regions. The cost of health diets are 4.7 times the cost of an energy sufficient diet and 1.6 times the cost of a nutrient adequate diet. The world uses on average 3.75 USD (2017), per person per day for a healthy diet but 79 cents for an energy sufficient diet and 2.33 USD for a nutrient adequate diet. In North America, Europe, and Oceania, healthy diets are almost 6 times more expensive than energy sufficient diets. In Africa, Asia and Latin American healthy diets are about 4 times more expensive than energy sufficient diets.

If we group countries by their respective income levels, residents of low-income countries will have to spend about 5.5 times more on a healthy diet in comparison to an energy sufficient diet while the rest of the world will need to spend, only, 4.5 times that amount. "The cost of a healthy diet exceeds the international poverty line (established at USD 1.90 purchasing power parity (PPP) per person per day), making it unaffordable for the poor. The cost also exceeds average food expenditures in most countries in the Global South: around 57 percent or more of the population cannot afford a healthy diet throughout sub-Saharan Africa and Southern Asia".[20]

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[15] Food and Agriculture Organization, 2019. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. URL: http://www.fao.org/3/ca6030en/ca6030en.pdf, p. 39.
[16] Food and Agriculture Organization, 2018. Methodological Proposal for Monitoring SDG Target 12.3: The Global Food Loss Index Design, Data Collection Methods and Challenges. Rome
[17] UNICEF, WHO and World Bank, 2020. Joint Child Malnutrition Estimates, March 2020 edition. URL: https://data.unicef.org/topic/nutrition/malnutrition/.
[18] FAO, IFAD, UNICEF, WFP and WHO, 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en
[19] Herforth, A., Bai, Y., Venkat, A., Mahrt, K., Ebel, A. & Masters, W.A. 2020. Cost and affordability of healthy diets across and within countries. Background paper for The State of Food Security and Nutrition in the World 2020. FAO Agricultural Development Economics Technical Study No. 9. Rome, FAO.
[20] FAO, IFAD, UNICEF, WFP and WHO, 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets, p. xvii. URL: https://doi.org/10.4060/ca9692en

Incentives and disincentives are also observed at the product level controlled predominantly by national states. Sugar, rice, as well as poultry-, pig-, sheep-, and bovine meat received tax and tariff breaks by around 30 countries each and at a nominal rate of protection in the years 2005-2016 ranging from 11% to 19%.[21] At the same time, the 10 most taxed products include bananas, nuts, seeds and beans.

Food plays a central role in our still increasing per capita health expenditure. Global health spending continues to rise rapidly – to US$ 7.8 trillion in 2017 or about 10% of GDP and $1,080 per capita – up from US$ 7.6 trillion in 2016.[22] At the same time, if we keep the status quo of our food systems, diet-related health costs are projected to increase by 1.3 trillion by 2030. The bulk part of the projected increase stems from increased coronary heart diseases and cancer.[23]

Some emerging trends

Economic (income, trade, prices, financial system), biophysical and environmental (natural resources, pollution and climate change), political (governance, public policies, conflicts), demographic (migration, urbanization and population growth), socio-cultural (cultures, rituals and social traditions) and innovation, technology and infrastructure drivers affect food systems.[24] Trends in each of these dimensions have the potential to both simplify and complicate food systems and the attainment of the SDGs. Cutting across these dimensions are megatrends. Megatrends are "large-scale social, economic, political, environmental or technological changes that are slow to form but which, once they have taken root, exercise a profound and lasting influence on many if not most human activities, processes and perceptions."[25]

Diets have the potential to influence both our health and the environment. Unhealthy diets and high body weight contribute significantly to premature mortality.[26] While "[F]ood systems contribute 19%–29% of global anthropogenic greenhouse gas (GHG) emissions, releasing 9,800–16,900 megatonnes of carbon dioxide equivalent (MtCO2e) in 2008. Agricultural

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[21] http://www.ag-incentives.org/indicator/nominal-rate-protection and FAO, IFAD, UNICEF, WFP and WHO (2020). The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en, p. 133.

[22] World Health Organization, 2019. Global Spending on Health: A world in Transition. p. 6. URL: https://www.who.int/health_financing/documents/health-expenditure-report-2019.pdf?ua=1.

[23] FAO, IFAD, UNICEF, WFP and WHO (2020). The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. URL: https://doi.org/10.4060/ca9692en. p. 101.

[24] Dury, S., Bendjebbar, P., Hainzelin, E., Giordano, T. and Bricas, N.,. 2019. ***Food Systems at risk: new trends and challenges.*** . Rome, Montpellier, Brussels,: FAO, CIRAD and European Commission. We refer the reader to a large literature on the topic. FAO. 2017b. Nutrition and food systems. Rome: FAO, Kennedy, E., Webb, P., Block, S., Griffin, T., Mozaffarian, D., & Kyte, R. 2020. Transforming Food Systems: The Missing Pieces Needed to Make Them Work. ***Current Developments in Nutrition***, 5(1).

[25] OECD. 2016. OECD Science, Technology and Innovation 2016: Megatrends affecting science, technology and innovation.

[26] Springmann, M., Godfray, C., Rayner, M., & Scarborough, P. 2016. Analysis and valuation of the health and climate change cobenefits of dietary change. ***Proceedings of the National Academy of Sciences***, 113: 201523119.

production, including indirect emissions associated with land-cover change, contributes 80%–86% of total food system emissions."[27] In a comparison of the 2050 effects of diets containing differing degrees of animal-sources food (e.g., Vegan, vegetarian,), Sprinmgmann et al. find that mortality rates are reduced relative to the reference diet by 6-10% and food-related greenhouse emissions are reduced by 29-70%. The economic value of the above amounts to 1-31 trillion US Dollars.[28]

The ongoing digitalization of the food system is affecting every aspect of the value chain: from irrigation control, precision agriculture including crop yield simulations, predictive models, drones and satellite data, digital labelling and food tracing, internet of things (e.g., tracking, monitoring, and quality control) to AI based autonomous farming machinery (e.g., Strawberry picking robots).[29] The latter is merely an example of the megatrends that slowly create the conditions under which unmanned gathering and packing of agriculture products will materialize. 3D food printing is projected to experience double digital growth in the coming years.[30] Meat Tech is an illustrative case. Meat Tech is developing an alternative to industrialized farming, circumventing the ethical and environmental issues surrounding conventional animal husbandry by developing an industrial cultured meat production process with integrated 3D printing technology.[31] It circumvents livestock's environmental, health, and ethical problems while addressing the increasing demands for protein. Overcoming the technological barriers will be a challenge to this industry, but political, economic, and societal challenges will have to be addressed as well.

Around the turn of the century, the motto of the telecommunication business was whatever goes by cable will go by air and vice versa. Two food megatrends follow this pattern. What we used to catch or cultivate at sea, will be cultivated on land, and vice versa. Aquaculture food systems are complex and have their fair share of environmental challenges. Atlantic Sapphire, for example, develops greenhouses where fish are given ideal condition to thrive, on land. By 2030, the facilities in Denmark and the US (Florida) will produce roughly 10% of the world demand for Salmon. Scaling up such innovations especially to low income counties where protein-energy malnutrition is among the 10 conditions contributing most to the reduced life expectancy in low income countries[32], is still an unsolved puzzle.

The race for the large-scale utilization of the seas for protein production has merely begun. Humans have been using the near-shore areas for seaweed and other protein rich sea

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[27] Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. 2012. Climate Change and Food Systems. ***Annual Review of Environment and Resources***, 37(1): 195-222. p. 195.

[28] Springmann, M., Godfray, C., Rayner, M., & Scarborough, P. 2016. Analysis and valuation of the health and climate change cobenefits of dietary change. ***Proceedings of the National Academy of Sciences***, 113: 201523119.

[29] See for example: https://www.roboticsresear.ch/articles/17565/strawberry-picking-robots-to-gather-enough-fruit-for-wimbledon

[30] There are multiple estimates but all predict CAGR of 15% and more. See for example: https://www.businesswire.com/news/home/20200624005366/en/Global-3D-Food-Printing-Market-Trends-2019-2020-2025---ResearchAndMarkets.com

[31] https://meatech3d.com/#about

[32] World Health Organization, 2019. World Health Statistics Indicators. p. 58.

products for centuries.[33] The industrialization of the oceans; large-scale, environmentally friendly cultivation and harvesting of marine aquacultures, can constitute a viable complementary strategy to the fish-on-land strategy. See Forbes for a summary of the potential embedded in exploring ocean crops[34], including the 220 economically viable seaweed types, ocean vegetables, fruits, and other crops. Similarly, the challenge of scaling-up currently expensive solutions to low- and medium-income countries remains.

Systems and change

Systems "are characterized by an assemblage or combination of parts whose relations make them interdependent."[35] Their elements are intertwined. Such interdependencies make system change problematic and infrequent. System change necessitates amendments of multiple system elements, including consumer behavior, business models, regulations, institutions, value chains, commons (rules and procedure for interaction)[36] and technologies. Systems have a clear tendency to reproduce known patterns in lieu of new and radical ones.[37]

Furthermore, a change in one part of the system is likely to have both intended and unintended consequences in another part of the system. In relation to food loss and waste, for example, reduction and delivery of "major societal benefits will require a careful analysis of the exact linkages between food loss and waste and food security, nutrition and environmental sustainability."[38] "Food systems will offer solutions to how we deal with ending hunger, with nutrition and how we ensure that we strengthen resilience for families and households. These are all things that are within our control. What has been lacking is how it all comes together with a real sense of purpose and ambition to get these things out of the way. It's how we prioritise these problems."[39]

To complicate the food system transition even further, "[I]t's how we look at them [food system problems] from a global perspective. It's not an African problem, it's not a European problem. What happened with Covid is a global problem, what happened before Covid with climate change is a global problem that impacts people very far removed from where some of these problems are happening. For the first time we understand how interconnected we are

[33] Schubel, J. R., & Thompson, K. 2019. Farming the Sea: The Only Way to Meet Humanity's Future Food Needs. ***GeoHealth***, 3(9): 238-244.
[34] https://www.forbes.com/sites/nishandegnarain/2020/07/29/ocean-crops-is-this-the-next-frontier-for-agriculture/?sh=420b109e5c95
[35] Scott, R., W. 2003. ***Organizations. Rational, natural, and open systems*** (5th ed.). New Jersey: Prentice Hall. p. 77.
[36] Fjeldstad, Ø. D., Snow, C. C., Miles, R. E., & Lettl, C. 2012. The architecture of collaboration. ***Strategic Management Journal***, 33(6): 734-750.
[37] Dosi, G. 1984. Technological paradigms and technological trajectories. ***Research policy***, 11: 147-162, March, J., G. 1991. Exploration and exploitation in organizational learning. ***Organization Science***, 2(1): 71-87.
[38] FAO. 2019. The State of Food and Agriculture 2019. Moving forward on food loss and waste reduction. Rome: FAO. p. 1.
[39] Agnes Kalibata, African Business, 4.9.2020 https://african.business/2020/09/agribusiness-manufacturing/agnes-kalibata-fixing-the-worlds-food-systems-a-problem-we-must-solve-together/

with these challenges and really being able to work through all this together as a globe and as a community is going to be the test of our time."[40]

"The dilemma of the global food system is a deeply existential one. On the one hand, we have a moral imperative to ensure an uninterrupted food supply, on the other, doing so based on the expansion of current practices will have devastating consequences for our natural environment, undermining the very basis of the food system's functioning. Most of the solutions proposed to resolve this dilemma focus on the expansion of arable lands and the increase of yields per hectare through the intensification of agricultural production. There is good reason to question whether or not this approach, which in many ways represents a continuation of existing trends, will result in a food system that sufficiently resolves the nexus of problems we face".[41] For a succinct exposition of transformation of food systems, element interdependency, and a discussion of the missing pieces, please see Appendix 1.

The way forward

The Secretary General António Guterres rocks worriedly in the rocking chair. The food systems do not work in tandem as the chair does. Against this backdrop, a global search for game changing solutions is in progress, especially amongst the young and creative. A 'game changing and systemic solution' is a feasible action, existing or new, based on evidence, best practice, or a thorough conceptual framework that would shift operational models or underlying rules, incentives, and structures that shape food systems, acting on multiple parts of – or across – the food system, to advance global goals which can be sustained over time (see Appendix 2 for further specification).[42]

To what extent will the 'young brains' manage to deliver game changing solutions that address economic, biophysical and environmental, political, demographic, socio-cultural and technological drivers [43] and deliver a better future?

[40] Agnes Kalibata, African Business, 4.9.2020 https://african.business/2020/09/agribusiness-manufacturing/agnes-kalibata-fixing-the-worlds-food-systems-a-problem-we-must-solve-together/

[41] Gladek, E., Fraser, M., Roemers, G., Muñoz, O. S., Kennedy, E., & Hirsch, P. 2017. The global food system: An analysis. The Netherlands: METABOLIC. p. 9.

[42] Shaping Solutions: Way forward for preparation of the UN Food System Summit, version 07.02.2021.

[43] Dury, S., Bendjebbar, P., Hainzelin, E., Giordano, T. and Bricas, N.,. 2019. ***Food Systems at risk: new trends and challenges.*** . Rome, Montpellier, Brussels,: FAO, CIRAD and European Commission. We refer the reader to a large literature on the topic. FAO. 2017b. Nutrition and food systems. Rome: FAO, Kennedy, E., Webb, P., Block, S., Griffin, T., Mozaffarian, D., & Kyte, R. 2020. Transforming Food Systems: The Missing Pieces Needed to Make Them Work. ***Current Developments in Nutrition***, 5(1).

Transforming Food Systems: The Missing Pieces Needed to Make Them Work

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ABSTRACT

Food systems lie squarely at the intersection of several overarching goals of the UN and member states, as embodied in the Sustainable Development Goals, including eliminating poverty, hunger, and malnutrition in all its forms, achieving good health and well-being, while promoting environmental sustainability. The need for radical transformation of current food systems is inescapable if the world is to achieve one, let alone all, of these goals. Meeting this challenge will inevitably be disruptive to current food systems, carry costs, and be politically onerous. But the projected benefits far outweigh these difficulties. This commentary spells out the complexity of issues that need to be tackled to design and implement food systems that improve diets, nutrition, and health in an equitable fashion, while simultaneously respecting planetary boundaries. Six critical domains are identified that must be addressed for the successful transformation of food systems: *1*) reinvent agriculture, *2*) transform food environments for healthy diets, *3*) mitigate climate change, *4*) productively engage the private sector, *5*) influence public policy priorities, and *6*) establish true cost accounting of food. Because science is crucial for each of these domains, a research-driven strategy, emphasizing a collaborative process, is outlined. Bold, new, but technically and politically feasible actions are needed to effectively transform current food systems. *Curr Dev Nutr* 2020;00:nzaa177.

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Abbreviations used: FBDG, food-based dietary guideline; GHG, greenhouse gas; NCD, noncommunicable disease; SDG, Sustainable Development Goal.

Introduction

The UN will host a Food Systems Summit in September 2021. The Summit will convene heads of state, senior country delegates, and business leaders as well as civil society and other stakeholders. One overarching issue for the summit is to develop game-changing strategies for a dramatic transformation of food systems to achieve healthy, sustainable diets that are produced with equitable access and will preserve or regenerate the natural environment. The Secretary General and other UN leaders are clear that bold new actions are required to transform the way food is produced and consumed to achieve dramatic progress in addressing the 17 Sustainable Development Goals (SDGs). The Summit will concentrate on developing specific, actionable, multistakeholder inputs into priorities, challenges, and opportunities to redesign food systems at the local, national, and international levels.

Current food and nutrition challenges

The statistics on food insecurity and malnutrition in all its forms are unequivocal in underscoring the scale of the challenges ahead. Poor diets are a main contributor to the global burden of disease, causing an estimated 8 million deaths, affecting about 1 in 7 people in 2019 (1, 2). Today, almost 1 billion people do not have access to enough calories, 2 billion are thought to be deficient in dietary sources of vitamins and minerals, and ~3 billion continue to consume suboptimal diets that significantly increase the risk of food insecurity, undernutrition, overweight and obesity, and associated diet-related noncommunicable diseases (NCDs) (1, 3, 4).

Food Systems at a Crossroads

Today's food systems were designed to address problems of the mid-20th century: to provide ample, cheap, shelf-stable, starchy calories for a growing world population, fortified with key micronutrients where feasible to prevent clinical nutrient deficiencies (5). Human and planetary concerns of the 21st century—the intersections of chronic diseases, improved but continuing food insecurity, undernutrition, and sustainability—require a fundamental transformation of food systems to meet evolving and future needs of consumers, producers, and the resource base on which all life depends.

The link between nutrition and sustainability is often understood in terms of the health and environmental impacts of diets. This construct is important but also unnecessarily narrow. In line with the SDGs, economic and societal outcomes are also components of the food system; income inequality, social discrimination, and constrained economic opportunities are concomitant with barriers to obtaining healthy diets, or in some cases, enough calories. In practical terms, this means seeking a much deeper understanding of the drivers of food choice in all contexts around the world. This goal goes far beyond seeking to "resolve hunger" through increased grain supply or by reducing greenhouse gas (GHG) emissions. As the global population increases in coming decades, coupled with rapid urbanization and increased incomes, patterns of dietary demand will change dramatically, and the ways in which food systems underpin such changes will be critical.

The complexity of food systems has been compounded by recent events. The coronavirus pandemic and associated policy responses have highlighted how vulnerable today's global, national, and local food systems are to disruptions, be they limiting agricultural labor and other inputs at the farm level, restricting transportation and processing, or affecting trade and consumers' purchasing power. At the same time, the pandemic has also underscored the significant negative environmental resource and climate impacts of the food we produce and how we choose to eat. Choices made by consumers (dietary patterns), market agents (involved in moving, storing, processing, and selling food), and producers (technologies and agricultural practices) affect and are affected by the climate and the evolution of the global burden of disease. This can have profound implications for planetary and human health, not just for vulnerable populations and communities, but for the entire planet. Thus, tackling the escalating costs associated with healthcare and productivity losses while better managing global emissions and natural resource degradation that threaten planetary boundaries, requires a laser-like focus on the urgent need to transform our food systems over the coming decade—one that is good for us and our planet.

Food Systems for Tomorrow

A major redesign in food systems is essential to combat food insecurity and malnutrition in all its forms within planetary boundaries (6). The UN decade of action on nutrition (2016–2025) led by FAO and WHO, has emphasized a redesign of food systems as 1 of 6 essential actions to achieve the SDGs, in particular: SDG 1, no poverty; and SDG 2, zero hunger (7). Seven other SDGs that can only be met by redesigned food systems include: SDG 3, good health and well-being; SDG 10, reduced inequalities; SDG 11, sustainable cities and communities; SDG 12, responsible consumption and production; SDG 13, climate action; SDG 14, life below water; and SDG 15, life on land.

To this end, several high-level reports have recently emerged emphasizing the urgency of reforming our food systems to achieve the SDGs (1, 6, 8). The Global Panel on Agriculture and Food Systems for Nutrition report (6) highlights that climate, globalization of diets, urbanization, income growth, and changing consumer trends have led to changing diets and consumer behavior and patterns for food; this report points out that our current food systems are imperfect and rely heavily on providing quantity without emphasizing the quality of food.

To achieve progress will require a "food systems approach" that encourages government and private sector stakeholders to coalesce to prioritize nutrition through high-quality diets while protecting the environment. Despite the similarity in findings from the recent food systems reviews, major questions still remain unanswered in considering food systems transformation. A critical gap is the lack of strong empirical evidence to guide policy decisions around nutrition, sustainable agriculture, and the environment.

To fill information gaps, each of these recent high-level reports calls for a multidisciplinary way of thinking using a "One Health" approach to establish sustainable practices in agriculture to improve the well-being of humans, animals, and the planet (see, e.g., www.tuftsctsi.org/research-series/one-health). To achieve this integrative thinking requires a perspective that explicitly rejects the traditional siloed approaches that viewed agricultural development as largely distinct from health and nutrition concerns, and the interaction of both with the environmental impacts. The upcoming UN Food Systems Summit in 2021 demonstrates the global community's growing awareness of the need for such integrative approaches to these complexly interconnected challenges.

The complexity of food systems is illustrated in **Figure 1** (8). The framework includes: biophysical and environmental drivers; innovation, technology, and infrastructure drivers; political and economic drivers; sociocultural drivers; and demographic drivers, as 5 distinct areas that influence changes in the food system. These drivers, in turn, affect the food environment, food supply chain, and consumer behavior, which ultimately determine the health, nutrition, social, and economic outcomes of the food systems.

Much media and political attention (largely driven by empty supermarket shelves) has been concentrated on enhancing the resilience of the global supply chains. Although that is important in the short term, the fundamental challenge is how to create transformational change that can tackle global problems via making healthy diets available and affordable (and desirable) to all through reconfigured sustainable food systems (9).

Food Systems: From Evidence to Action

It remains hard to convince many policymakers of the need to facilitate urgent, often radical, changes in food systems. The essence of this is captured from the following quote: "Evidence-based policy making is an important aspirational goal, but only a small proportion of research has the policy impact it might have. Most researchers are not trained to create policy impact from their work" (10). The inherent complexity of food systems with multiple stakeholders (including governments and the private sector) with conflicting interests and differing degrees of power and authority creates a situation in which there is no effective governance of food systems. Defining the priorities and the "how" remains hard. A new kind of policy thinking is needed, underpinned by new evidence of what can work, and how to manage a transition in which science, technology, business, and government are all united towards a common planetary goal.

A recent commentary (11) identified some of the priority actions that are critical for the transition of food systems towards sustainable, healthy diets (**Figure 2**). These policy questions are divided into 4

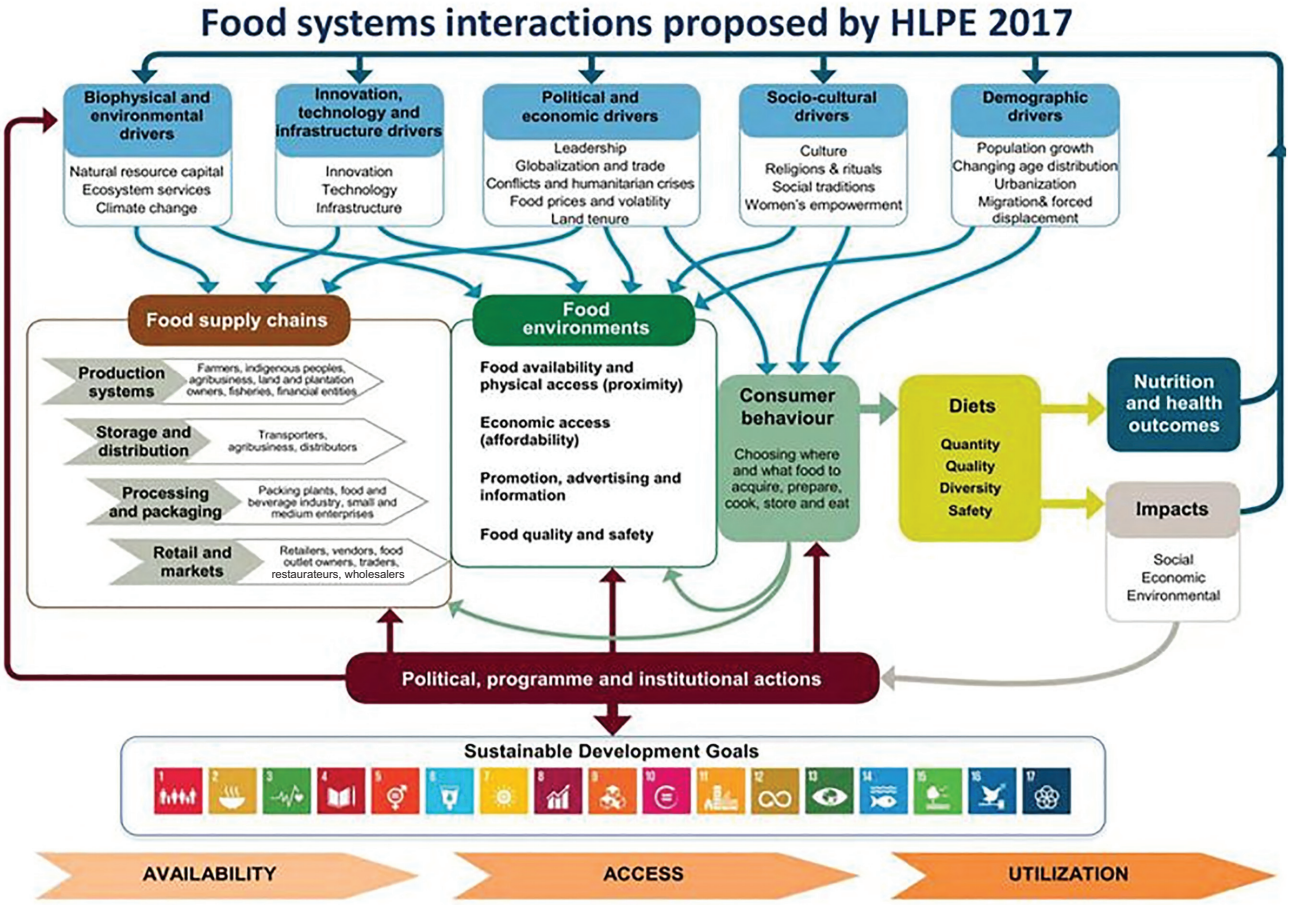

FIGURE 1 Food systems conceptual framework. HPLE, High Level Panel of Experts (on Food Security and Nutrition). Adapted from HLPE. Nutrition and Food Systems. FAO. 2017.

domains: availability, accessibility, affordability, and desirability. Within each of these domains a series of specific policies are identified. However, each of these domains contains unanswered issues that preclude advancing specific policy advice.

Although useful, the schematic does not address trade-offs *between* competing SDGs, nor the relative importance, practicality, and feasibility across the range of policy options available at the national and subnational levels. Two examples illustrate this conundrum. First, many countries, in their multisector nutrition plans, advocate for increased production of nutrient-rich foods (12). Thus, the recommendation in Figure 2 to "Promote production of a wide range of nutrient-rich foods" is consistent with many national-level plans. How to achieve this policy objective, however, is complicated. There is often an inconsistency between country-level agricultural goals and household-level priorities. For example, encouragement of an increased production of a variety of crops, although admirable, flies in the face of smallholder realities. Research on household decision making shows that smallholders put a premium on producing basic staples to ensure food security, over and above the cultivation of nutrient-dense fruits and vegetables (13). The case of Myanmar illustrates this further. The government has historically pursued what is termed a "Rice Bowl Policy," stressing an inordinate emphasis on rice production (13); here again, this has been a major challenge in encouraging a more diversified agricultural production in Myanmar.

Figure 2 also identifies "Define principles of engagement between public and private sectors." Here again, this goal is admirable, but thus far has been elusive to achieve in many countries. A summary of the challenges to advancing public-private sector collaborations within 24 low- and middle-income countries include: lack of trust, absence of demonstrated models for reaching SDG2, vested interests, and corruption, to name a few (12). This is not to suggest that public-private sector initiatives are unimportant but rather methods to achieve this collaboration have not been effectively developed and/or tested.

Upcoming debates on the design of future food systems will be fierce. There is an urgent need for an body like the Intergovernmental Panel on Climate Change dedicated to collation and translation of science relating to food systems. A significant deepening is needed of the scientific agenda relating to the politics and the economics of food systems: how production, trade, pricing, and procurement policies require us all to consider "who pays?" via health costs, climate externalities, income losses from shifting agricultural subsidies, and so much more. Economic models (food trade, prices, transportation logistics, demand) need to be fully articulated across the world, and fully integrated with

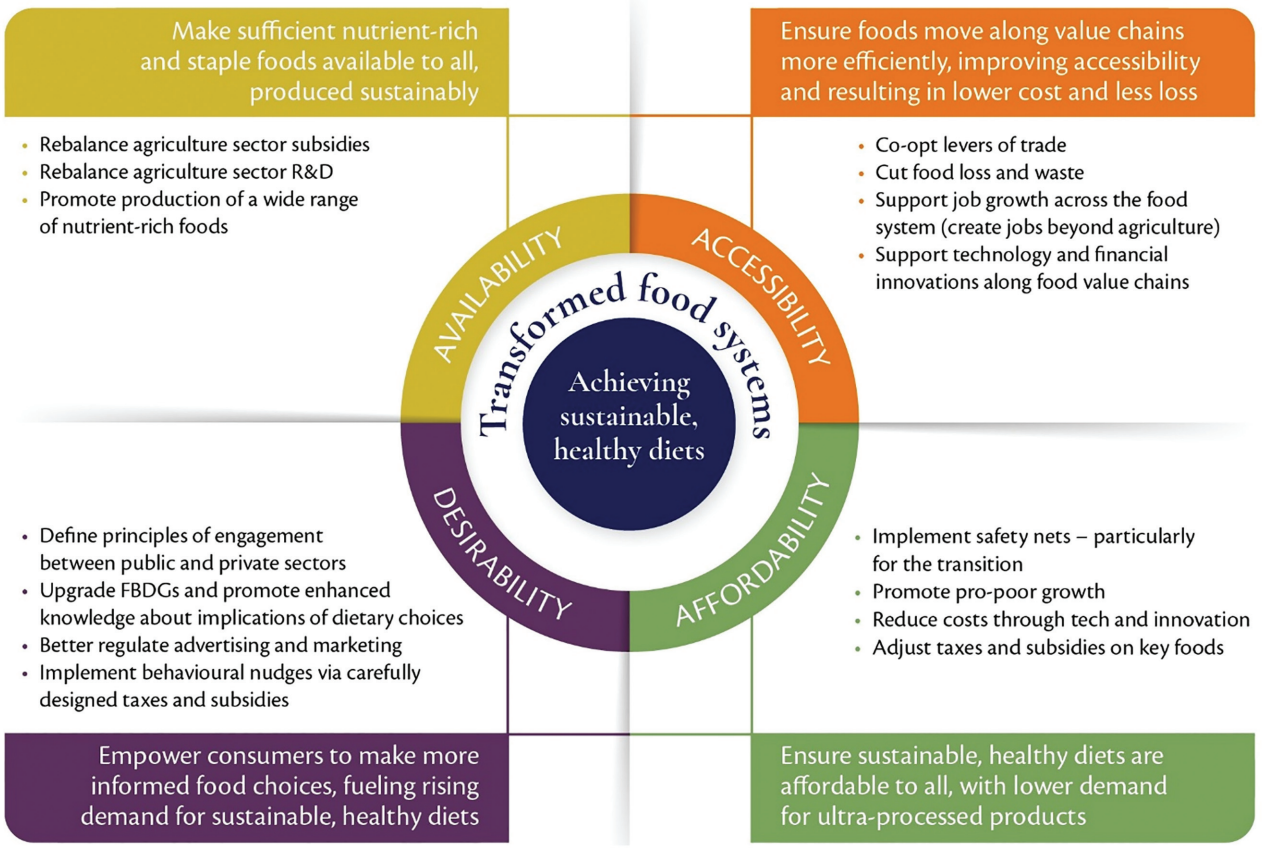

FIGURE 2 Policy priorities for a food system transformation. FBDG, food-based dietary guideline. Adapted from reference 11 with permission.

other complex dynamic modeling relating to climate change, on the one hand, and to natural resource depletion and degradation, on the other. Each of the above must be effectively integrated into an understanding of the many societal, economic, and political trade-offs associated with necessary action.

This is no small agenda. An improved coordination of the science and its messaging to policymakers and the business communities is needed to promote a clearer understanding and coherent public and private sector responses. The future for transformed food systems depends on collective action at the interface of science and policy. Many stakeholders will have roles in convening, facilitating, and catalyzing partnerships dedicated to the mobilization of a new science for serious but pragmatic change.

The Missing Pieces of the Food Systems Puzzle

There are many key questions posed for food systems that can only be addressed through transdisciplinary/multipartner efforts. These questions can be allocated into 6 broad categories: *1*) reinvent agriculture; *2*) transform food environments for healthy diets; *3*) mitigate climate change; *4*) engage the private sector; *5*) influence policy priorities; and *6*) establish true cost accounting. There are a range of questions in each of the 6 domains. The illustrative questions discussed below are only a small sample of the myriad issues that need to be addressed.

Reinvent agriculture

A key element of all food systems falls under the rubric of agriculture: food and nonfood product production, distribution, marketing of commodities, and livestock. The litmus test for successful agriculture is changing dramatically; agricultural policies will be judged against a much more complicated set of factors (13). The agriculture sector will be expected to increase output (quantity and quality) on the same amount of land and to do so in an environmentally sensitive manner.

Some policy options for agriculture are detailed in Figure 2. For example, the call for production of a wider range of crops is regularly discussed as a key policy option for agriculture. There are, however, huge gaps in our understanding of how to ensure an evidence-based approach to agricultural policies without a much better understanding of what works and in what local contexts. There are important questions, the answers to which require serious attention to research and development. Many countries are emphasizing farmers' uptake for production of nonstaple crops that have both nutrition and economic value. The "how" to achieve this goal is ambiguous given our current state of knowledge. Some other examples further illustrate this point. We need a much better understanding of how access in various types of markets (agricultural input, agricultural output) mediate differently

between agricultural production and diet and nutrition outcomes. The inability to provide evidence on some potentially impactful innovations in agriculture limits widespread adoption of revised policies. The success in reinventing agriculture to contribute to more effective food systems hinges on high quality data that respond to pertinent policy options.

Transforming food environments for healthy diets

It is the food environment that links agriculture to consumer food choices. There are a lot of theories, untested, about how the food environments can be improved to contribute to healthy diets. Typically, policy officials stress the promotion of food-based dietary guidelines (FBDGs) and/or consumer education as 2 tools to improve consumer choice. Do these tools work? Are there multiplier effects of combining the promotion of FBDGs and consumer education? How can commercial food companies be best incentivized to support healthy sustainable diet choices in line with national public health goals? It is important to identify effective methods for linking national public goals with commercial interests as a way to improve the food environment. These are just a few of many questions for which we need more data to better understand how to improve food choices and bring about effective behavior change for food choices and consumer behaviors.

Mitigate climate change

Climate is changing at an alarming rate. Climate change is a threat to agriculture and livelihoods, with wide-ranging current and future impacts including reduced agricultural productivity, increased frequency of natural disasters, and higher variability of water availability (13). Lack of research related to some critical questions precludes making significant progress in mitigating the effects of climate change. How do we reduce the climate impact due to the diets we consume while realizing the need for animal-sourced foods for improving the nutritional status of certain populations? How can we mitigate the risk associated with livestock ownership due to the relative risk of zoonotic diseases and implications for human health and nutrition?

Engage the private sector

Models of successful public-private sector partnerships historically, and even at the present time, are limited. Yet it is impossible to envision a successful transformation of food systems without an active involvement of the private sector across the whole food system. Here again, some critical questions need to be addressed. What kind of incentives/taxes and/or subsidies should be provided to improve access and availability of nutritious foods? Similarly, how can governments get buy-in from the private sector to reformulate products and standardize food labeling and packaging because these are elements that can influence consumer preferences? How can we leverage the supply chain networks of the private sector to improve access and availability of nutritious foods?

Influence policy priorities

There is universal agreement that evidence-based policies are critical. Policy formulation can be influenced if there is strong, consistent information on cost-effectiveness of different policy options. In many cases these data are not available. There are, however, unanswered questions. How might trade liberalization and globalization, particularly in low- and middle-income countries, affect sustainable production and consumption of energy-dense, highly processed foods? How do various instruments of trade policy affect the supply, price, and availability of nutrient-rich foods across rural markets?

Establish true cost accounting of food

An accurate accounting of costs and savings is necessary to evaluate the utility of various policy options in agriculture, food, and nutrition. Regrettably, these kinds of data are rarely available to guide policy choices. For example, what do we know about the costs and benefits of regenerative agricultural practices to sequester GHGs and reduce use of water, topsoil, and pesticides if widely implemented? What are the incentives in business innovations to create healthier processed and packaged foods that reduce NCDs when implemented?

Conclusions

Addressing the questions in the above 6 domains is an urgent priority. Practical solutions will necessarily be forced to grapple with difficult trade-offs among competing objectives, while exploiting synergies where possible. The challenge of balancing potential trade-offs among competing objectives is heightened by the competing economic and political interests of multiple stakeholders and the lack of mechanisms for global governance to coordinate the needed responses. Action cannot wait until the end of 2021; it must start today!

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Appendix 2: Game Changing Solution[44]

A **'game changing and systemic solution'** is a **feasible** action, existing or new, **based on evidence, best practice**, **or** a thorough **conceptual framework** that would **shift** operational **models or** underlying **rules**, **incentives**, **and structures** that shape food systems, acting **on multiple parts of – or across – the** food **system**, to advance global goals which can be sustained over time.

Game changing solutions can be a set of synergistic actions by various stakeholders, contributing to remove major bottlenecks towards more sustainable food systems. Roles and responsibilities may vary, between national governments and multistakeholders, and include partnerships. These game-changing solutions, seeking to promote **systemic behaviour change tailored to specific contexts**, can take the shape of **commitments** for new (public or corporate) policies, or the creation of partnerships, the launch of initiatives, announcement of funding, technology transfer, agreements.

These commitments and actions can be taken **(led and/or implemented) by all actors** (national governments, civil society (social movements, NGOs, consumer organisations), private sector, development partners.

These commitments should be **SMART** (specific, measurable, achievable, relevant and time-bound) and be accompanied by **operationalization and accountability provisions.**

Key criteria include:

(1) Impact potential at scale (incl. return on investment)
(2) Actionability (politics, capacity, costs)
(3) Sustainability (the ability to keep delivering to 2030 and beyond)

"Principles" for systemic solutions:

- Have positive effects on ensuring equitable livelihood opportunities, advancing human health, and regenerating environmental integrity, with focus on youth, women, marginalized and disabled populations
- Be a true departure from existing practices that address a long-term constraint, obstacle or trend
- Be ambitious and think big with concrete pathways and actions for long term systemic change
- Have deliberate impact pathways that account for/minimize/eliminate negative impacts, have co-benefits, or are mutually reinforcing on achieving the other Action Tracks' goals
- Be implementable at a sufficient scale to reach a large portion of the population with clear, timely and verifiable outcomes that produce significant impacts by 2030
- Be sustainable, in that it can persist in the medium- to long-term future
- Anticipate and prevent future lock-ins
- Promote gender equality and women's empowerment in food consumption and production systems

[44] Shaping Solutions: Way forward for preparation of the UN Food System Summit, version 07.02.2021.