Scientific Group for the
United Nations Food Systems Summit 2021
https://sc-fss2021.org/

draft for discussion
August 2, 2021

Science for Transformation of Food Systems:

Opportunities for the UN Food Systems Summit

by

Joachim von Braun, Kaosar Afsana, Louise O. Fresco, Mohamed Hassan

with the Scientific Group for the UN Food Systems Summit

The authors are Chair and Vice-Chairs, respectively of the Scientific Group. They developed this draft paper in close collaboration with the Scientific Group of the UN Food Systems Summit, which has engaged extensively with science communities around the world including the partners and contributors of more than 40 reports and briefs prepared specifically for the Scientific Group's evidence-based contributions to the Summit. The authors thank the participants of Science Days for their thoughtful input and comments on the draft paper, as well as all others who shared comments and suggestions.

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 thatunderpins the Summit and its outcomes.

Joachim von Braun (Germany) Chair of the Scientific Group. Director of the Center for Development Research (ZEF), Bonn University, and Professor for economic and technological change.

Kaosar Afsana (Bangladesh) Vice Chair of the Scientific Group. Professor Public Health, BRAC University.

Louise Fresco (Netherlands) Vice Chair of the Scientific Group. President of the Executive Board, Wageningen University & Research.

Mohamed Hassan (Sudan) Vice Chair of the Scientific Group. President of The World Academy of Sciences for the advancement of science in developing countries (TWAS).

Mario Herrero Acosta (Costa Rica) Chief Research Scientist of Agriculture and Food, The Commonwealth Scientific and Indus- trial Research Organisation (CSIRO).

Ousmane Badiane (Senegal) Chairperson of Akademiya2063, former Africa Director for the International Food Policy Research Institute (IFPRI).

Patrick Caron (France) Vice President of the University of Montpellier, President of Agropolis International and Director of the Montpellier Advanced Knowledge Institute on Transitions

Martin Cole (Australia) is Professor for Agriculture and Food within the Commonwealth Science and Industrial Research Organisation (CSIRO). Chairperson of the HLPE Steering Committee of CFS.

Ismahane Elouafi (Morocco) Chief Scientist, Food and Agriculture Organization of the United Nations (FAO).

Frank A. Ewert (Germany) Scientific Director, Leibniz Centre for Agricultural Landscape Research (ZALF).

Sheryl L. Hendriks (South Africa) Professor of Food Security & Director, Institute for Food, Nutrition and Well-being, University of Pretoria.

Thomas W. Hertel (USA) Professor of Agricultural Economics at Purdue University and Executive Director of the Global Trade Analysis Project (GTAP).

Jikun Huang (China) Professor at School of Advanced Agricultural Sciences and Director of China Center for Agricultural Policy (CCAP), Peking University.

Marta Hugas (Spain) Chief Scientist at European Food Safety Authority (EFSA).

Elizabeth Hodson de Jaramillo (Colombia) Professor Em. School of Sciences of the Pontificia Universidad Javeriana, and member of Inter American Network of Academies of Sciences (IANAS).

Andrew Kambugu (Uganda) Executive Director Infectious Diseases Institute (IDI), College of Health Sciences, Makerere University. Co-founder of the Researchers for Global Health (R4GH) initiative.

Kaoru Kitajima (Japan) Professor at Kyoto University Graduate School of Agriculture; a forest ecologist, especially in tropical America and Asia.

Rattan Lal (USA) Distinguished University Professor of Soil Science, Director CFAES Rattan Lal Center for Carbon Management and Sequestration at the Ohio State University. World Food Prize Laureate 2020.

Hoesung Lee (South Korea) Chair, Intergovernmental Panel on Climate Change (IPCC), Professor at Korea University Graduate School of Energy and Environment, Seoul.

Uma Lele (India) is President of the International Association of Agricultural Economists (IAAE).

Lynnette M. Neufeld (Canada) incoming President of the International Union of Nutrition Scientists (IUNS), Director Know- ledge Leadership, Global Alliance for Improved Nutrition (GAIN).

Urs Niggli (Switzerland) Scientist focusing on sustainable farming systems, from 1990 to 2020 he led the Research Institute of Organic Agriculture (FiBL)

Claudia Sadoff (USA) Executive Management Team Convener and Managing Director, Research Delivery and Impact, of the Consultative Group on International Agricultural Research

Lisa Sennerby Forsse (Sweden) past President, Royal Swedish Academy of Agriculture and Forestry (KSLA) and was the vice-chancellor of the Swedish University of Agricultural Sciences 2006-2015.

Jean-François Soussana (France) is Vice-President for international at the French national research institute for agriculture, food and environment (INRAE).

Morakot Tanticharoen (Thailand) Professor and Senior Advisor to the President of the National Science and Technology Development Agency (NSTDA), research in microbiology and biotechnology.

Maximo Torero (Peru) ex-officio Member Chief Economist, Food and Agriculture Organization of the United Nations (FAO).

Aman Wirakartakusumah (Indonesia) Professor Em. at Department of Food Science and Technology and Senior Scientist at SEAFAST Center, Bogor Agricultural University (IPB), President-Elect, International Union of Food Science and Technology.

David Zilberman (Israel, USA) Professor in the Department of Agricultural and Resource Economics, University of California at Berkeley. One of the Founders of the International Consortium of Applied Bio-economy Research (ICABR).

Table of Contents

Summary

Food systems at the global level and in many countries and regions are failing to end hunger, they do not provide adequate nutritious foods for healthy diets, they contribute to obesity and do not assure safety of foods. How we produce and consume food has profound implications for the health of people, animals, plants, and the planet itself. A change in world views in support of a range of actions is needed to re-orient food systems dynamics. A central element of such change is a much greater emphasis on science for innovation to transform food systems towards sustainability and equity.

In this paper, we focus on the key role of science and research, as they are essential for innovations that accelerate the transformation to healthier, more sustainable, equitable, and resilient food systems. The problems of food systems are to a significant extent due to long delays between scientific warnings and policy responses, innovation-stifling regulatory regimes, low levels of science investments, and a lack of effective communication by science communities themselves. Moreover, inclusive research in many fields of food systems offers opportunities, where local communities are co-creators in the research and development of innovations with scientists who are open to related collaboration.

Science offers many important contributions to achieve the Food Systems Summit goals based on the SDGs, of which we highlight two here: first, science generates the basic inputs for innovations, i.e. policy and institutional innovations (incl. social and business innovations) as well as technology-based innovations to catalyze, support, and accelerate food systems transformation; and second, science scrutinizes actions, i.e. assessing ambitions, targets and actions on pathways towards reaching them, for instance through quantitative analyses and food systems modeling.

We stress that policy innovations, institutional innovations, and technology innovations are closely connected and actually need to be pursued in an integrated approach. Science alone is not a panacea to cure the diseases of the food system, but without science the necessary complex innovations will not be forthcoming.

We note the need for systems innovations rather than only single-issue innovations, and call on the science communities to commit to enhanced collaboration among all relevant different disciplines of sciences for this purpose. This includes recognition of and cooperation with knowledge systems of Indigenous Peoples. Moreover, science is not naïve vis á vis power relations, and social sciences explicitly uncover them and must identify options for innovations that help to overcome adverse effects.

Drawing on a comprehensive food systems framework, actions for seven science-driven innovations are elaborated in this paper, each with some concrete examples:

1. Innovations to end hunger and increase the availability and affordability of healthy diets and nutritious foods: this bundle partly draws on the six science and innovation actions below.
2. Innovations to de-risk food systems and strengthen resilience, in particular for negative emission farming and drawing on both advanced science as well as traditional food system knowledge.

3. Innovations to overcome inefficient and unfair land, credit, labor, and natural resource use arrangements, and facilitate the inclusion, empowerment and rights of women and youth, and Indigenous Peoples.
4. Bio-science and digital innovations for improving people's health, enhancing systems' productivity, and restoring ecological well-being.
5. Innovations to keep – and where needed, regenerate – productive soils, water and landscapes, and protect diversity of the agricultural genetic base and biodiversity.
6. Innovations for sustainable fisheries, aquaculture, and protection of coastal areas and oceans.
7. Engineering and digital innovations for the efficiency and inclusiveness of food systems and the empowerment of youth and rural communities.

These innovations and their related goal-oriented actions do not exist in silos; rather, there are synergies and trade-offs between them that must be considered to maximize the system-wide effectiveness and efficiency of proposed innovations and actions while ensuring equity and sustainability.

Fundamental conditions essential to enable and leverage food systems transformation to achieve the objectives include peace and security, and related diplomatic and security policies guided by the humanitarian-peace-development nexus, the full inclusion of marginalized and vulnerable populations, gender equity, sound governance at all levels from the community to local, national and international, and supportive global and national policies for public goods, such as climate policies and trade regimes.

Food systems transformations require private and public investments at scale, which means that there is an important role for innovation in financing. As a key food systems science policy target, we propose that governments allocate at least 1% of their food systems-related GDP to food systems science and innovation, with the perspective of exceeding that target. Least developed countries (LDCs) should be assisted in reaching this target quickly.

Investments in capacity for science and innovation need to expand, with more attention to strengthening local research capacities, developing more inclusive, transparent, and equitable science partnerships, promoting international research cooperation and addressing intellectual property rights issues where they hinder innovations that can serve food and nutrition security, food safety, and sustainability goals.

Food systems science and food systems policy need a stronger framework for constructive and evidence-based interaction for moving ahead, not only for the Food Systems Summit 2021 but for its follow-up and in the long term. In contrast to the other subjects of global concern that were agreed upon at the Earth Summit in Rio in 1992, agriculture, food, and nutrition do not have an international agreement or convention to consolidate actions as for climate, biodiversity and desertification. The time has come to consider such a set of agreements and mechanisms. The UNFSS may wish to consider exploring a pathway towards a treaty on food systems. This should include innovation and strengthening the science-policy interfaces at the local, national and international levels where these interfaces are connected and can be served with strong, trusted, and independent voices for science-informed and evidence-based food systems actions. We call upon governments and UN agencies to initiate a process to explore options – existing as well as new – for a strengthened global science-policy interface for a sustainable food system. As such, this could be a concrete outcome of the UNFSS.

1. Objectives of the Paper

Science offers many important contributions to the Food Systems Summit, two of which we highlight here. First, science has an intrinsic role in generating new insights and the basis for new technologies and policy and institutional innovations (incl. social and business innovations). These are critical to catalyze, support, and accelerate food systems transformation to achieve the Food Systems Summit goals based on the SDGs. Second, science serves the Food Systems Summit's policy-makers to identify ambitious targets and actions for pathways towards reaching them, for instance by quantitative and qualitative analyses and food systems modeling. This paper aims to address both of these contributions of science.

We note that science is not a panacea for the necessary food systems innovations towards a sustainable system. Like other actions, science can even have negative external effects, to be prevented by ethics and public policy. Nonetheless, without accelerated interdisciplinary food systems science, the necessary innovations for a sustainable food system will not be achieved. Science and innovation are critical for achieving food systems that serve people and the planet.

The Food Systems Summit is the opportunity to address and resolve food system problems and failures. The aim of the Food Systems Summit is to help countries and stakeholders to maximize the co-benefits of a food systems approach across the entire 2030 SDG Agenda and address the challenges of climate change, soil degradation, and biodiversity loss. Action agendas defined in the Summit processes need to be evidence based.

It is not the purpose of this paper to develop an action agenda for the Summit, but rather to highlight the critical roles of science in a transformative agenda. This paper draws on the wealth of information generated by food systems-related science communities, including new syntheses by the Scientific Group and its research partners and many others (see references in the annex and end notes). In particular, we draw attention to the comprehensive contribution to knowledge about sustainable food systems by Indigenous Peoples[1] and the opportunities of mutual learning between traditional- and experience-based knowledge and science for innovation.

2. Framing the Food Systems Context and Concepts

Food systems at the global level and in many countries and regions are failing to end hunger, provide adequate nutritious foods for healthy diets, or deliver safe foods. Between 720 million and 811 million people face hunger and are undernourished – that is every tenth person – 150 million children under five years of age are stunted (short for their age), and two billion people are overweight or obese. These numbers have been high and/or growing for a number of years now, and with COVID-19 disproportionately impacting poor and food-insecure populations, they are continuing to rise with an estimated 118 million more people facing hunger in 2020 than in 2019.[2,3] About 600 million people fall ill each year due to the consumption of contaminated or unsafe foods.[4] **We are losing ground on the progress that we have already made**, and we face the prospect of severely compromising the achievement of the SDGs and the 2030 Agenda.

Besides escalating hunger and all forms of malnutrition (micronutrient deficiencies, underweight, overweight/obesity and related NCDs), poverty and inequalities between and within countries are widespread and becoming entrenched. For many people, engaging in activities in the food system would seem to offer the most viable opportunities to escape poverty, yet they are being left out of earning their fair share of the benefits from engaging in food systems, and are condemned to jobs that do not provide livable wages and decent working conditions and livelihoods. Fundamental human rights to food, health, safe water and sanitation, and education continue to be violated. Ending poverty and gross inequalities remains essential for achieving the SDGs.

Food systems relate to the three basic dimensions of sustainability: social, economic, and environmental.[5] Many food systems are based on production and distribution systems that are simply not sustainable. Scientific assessments indicate that many aspects of current food production systems drive the degradation of land and soil, water, and climate, as well as biodiversity loss.[6,7] Climate change is increasingly adversely impacting food security. The global food system emits about 30% of global greenhouse gases, contributes to 80% of tropical deforestation, and is a main driver of soil degradation[8] and desertification, water scarcity, and biodiversity decline. Climate change along with soil and environmental degradation are partly caused by – and have negative impacts – on the food system. It is very clear that **how we produce and consume food has profound implications for the health of people, animals, plants, and the planet itself.**[9]

The Food Systems Summit is taking place in the midst of the COVID-19 pandemic, which has revealed the close intertwining of food, ecological, and health systems.[10] The pandemic is having a significant impact on the global commodity markets and trading systems, economic growth, incomes, and poverty levels, with disproportionate burdens on vulnerable communities in both urban[11] and rural areas. This is likely to worsen inequalities and undernutrition, including child undernutrition, which can have life-long consequences. Modeling projects that COVID-19 could result in an additional 9.3 million children wasted (low weight for height) and 2.6 million children stunted (low height for age) by 2022.[12] COVID-19 further increases food insecurity and poverty, which may become much more serious if comprehensive policy responses – especially equal global vaccination coverage – are not implemented in a timely, and evidence-based manner.[13]

Conceptualizing Food Systems [14]

"Food systems embrace the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal (loss or waste) of food products that originate from agriculture (including livestock), forestry, fisheries, and food industries, and the broader economic, societal, and natural environments in which they are embedded…". "A *sustainable food system* is one that contributes to food security and nutrition for all in such a way that the economic, social, cultural, and environmental bases to generate food security and nutrition for future generations are safeguarded". Its sustainability is not to be realized internally and in isolation with the food systems serving humanity, but depends upon its relationships with nature and ecological systems of which humankind is a part, with its destructive impacts that need to be overcome by food systems transformations.

Food systems are connected to other systems such as health, ecology and climate, economy and governance, and science and innovation (see Figure 1). A conceptual framework of food and nutrition systems should capture the delivery of health and well-being while being embedded in the transformation towards a sustainable circular bio-economy. Science and innovation impact the functioning of the system as a whole and within its building blocks and the interconnections among them.

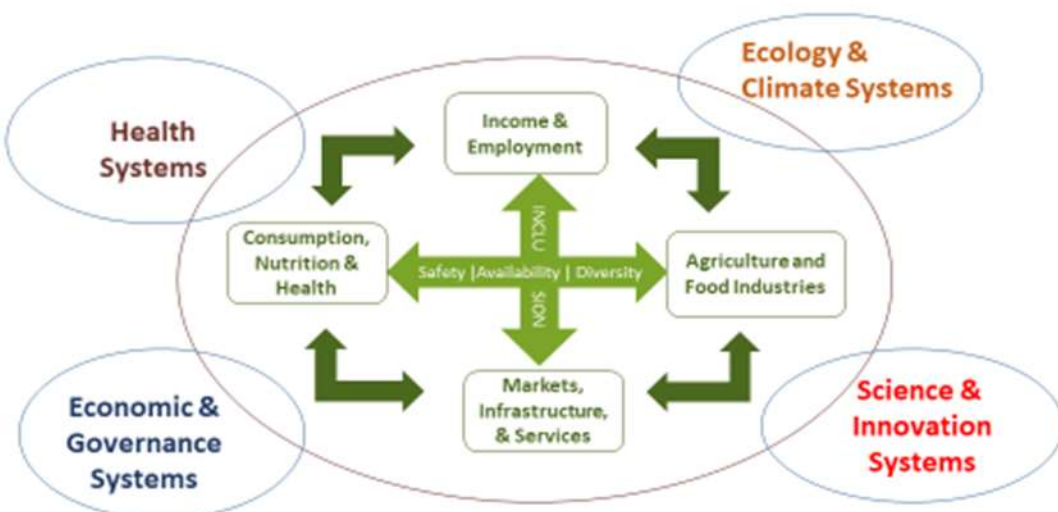


Figure 1: Food systems conceptual framework.[14]

An integrated approach with which Indigenous Peoples look at food systems and the elements that compose them, weaves the different elements into systemic practices, generate foods while preserving biodiversity.[1]

Science needs to explore the root causes of emerging zoonotic diseases, and closely engage with policy innovations, including related to land use and animal production. Going forward, it is abundantly clear that **more attention will need to be paid to how to make food systems more resilient to health shocks and pandemics, associated economic shocks and slowdowns, and violent conflicts and other crises**, just as more attention is being now paid to how to make food systems more resilient to extreme weather events and other stressors induced by the changing climate.[15] This will require integrated approaches that create greater synergy across government efforts to deal with health and other social services as well as food system failures in rural areas and other marginal communities.[16]

The changing state of the art of science and innovation and the important lessons that they offer for food systems transformation need to be recognized. As noted earlier, science has at least two important roles for food systems: first, science generates new breakthroughs that can become innovations in food systems (e.g. genomics, plant nutrition, animal production and health, bio-sciences, earth sciences, social sciences, remote sensing, AI and robotics, digitization, remote sensing, big data, health and nutrition science, behavioral research, etc.); and second, science helps to inform and shape decisions, investments, policies and institutions and it can also be involved in the design, implementation and monitoring of action to learn and draw lessons for impact at scale.[17] This also includes science that focuses on knowledge gaps, risks, uncertainties, and controversies. Many approaches from discovery research to implementation research and including both primary research and modeling techniques can contribute valuable evidence.

3. Opportunities for Science and Innovation to Achieve the Food Systems Summit Goals

Science and research are fundamental drivers of innovation. All three – science, research, and innovation – are essential to accelerate the transformation to healthier, more sustainable, equitable, and resilient food systems.[18] To enable the full inclusion of poor and marginalized populations – including smallholder communities[19] – in the process of and benefit from food systems transformation, investments in technology-based innovations must be accompanied by institutional innovations (incl. social, business and policy innovations), underpinned by science: basic sciences and applied sciences, natural sciences and social sciences. The Scientific Group underlines not only its respect for Indigenous Peoples[1] knowledge systems but recommends investing more in programs exploring mutual learning and innovation across traditional and modern knowledge and science systems considering both on an equal footing. This may include documenting this knowledge and jointly studying it scientifically.

The Scientific Group highlights the **need for systems innovations rather than only single-issue innovations**, and calls for enhanced collaboration between and among different disciplines of sciences for this purpose. The Scientific Group suggests a focus on seven science-driven innovations to catalyze, support, and accelerate food systems transformation to achieve the Food Systems Summit goals and thereby the SDGs and SDG2 in particular. These innovations emerge from our conceptual framework and the building blocks and linkages therein (see Box). We hasten to emphasize that technology-based innovations and policy and institutional innovations are in synergy among each other: in other words, many technology-based innovations need policy and institutional innovations to fully realize their potential (for instance, innovative financing mechanisms), and similarly many policy and institutional innovations need technology-based innovations to be properly implemented and monitored (for instance, information systems). Further, in many instances, food systems innovations must be place-based, adapted to the local contexts and capacities. We provide ***examples of science-based innovations in the seven action areas below, identifiable in cursive format***. Alignment of technological change with sustainability concerns certainly requires attention and joint engagement by researchers from all areas of the food systems-related sciences (including social sciences) guiding innovation arrangements.

3.1. Innovations to end hunger and increase the availability and affordability of healthy diets and nutritious foods.

More than 3 billion people cannot afford healthy diets, and more than 1.5 billion people cannot even afford a diet that only meets the required levels of essential nutrients.[2,20] The contribution of science and innovation here relates to identifying optimal context-specific investment opportunities and their implementation. Broadly speaking, the investment opportunities include productivity enhancement, people's skills and empowerment, agricultural research, social protection, nutrition programs, etc.[21] Policy innovations are needed to *repurpose subsidies towards related supportive investments that facilitate a sustainable food system.*[22]

Food is undervalued. The value of food from a cultural, social and economic perspective needs revisiting. An important role of science here is also to identify their indirect effects, while efforts must be made to embrace the true value of food.[23] External costs associated with climate change,[24] biodiversity loss, and adverse health effects need to be considered. *True cost accounting* approaches are to be pursued in the whole food system, and related capacities built up in the corporate and public sectors. Capacities for internalizing such externalities are limited.[1] Cautious approaches are warranted to develop price and non-price instruments, including regulatory-based instruments, to help deal with such externalities. Fostering positive externalities of the food systems such as by carbon farming and biodiversity-enhancing land use should be considered and tested where justified.[25] Nonetheless, if food prices were to reflect true costs, food healthy diets may become unaffordable for low-income consumers, and social safety nets would need to be put in place.

Healthy diet concepts benefit from a stronger science basis.[26] Measures that incentivize the production and market supply of fruits and vegetables and related innovations enhance consumption and can increase the income of small holders.[27] However, rising incomes of

[1] It should be noted that lower food prices – if they come about in the short term – might have adverse income effects for producers, and discourage them from investing to protect the ecosystem, especially if ecosystem services related to food systems are not incentivized, but more relevant is the avoidance of extreme price volatility, because that reduces incentives to invest and hurts farm households.

consumers do not automatically lead to the increasing consumption of healthy diets: even when accessibility and affordability are not constraints, the consumption of healthy diets is not assured as people may still not change their consumption behavior. Approaches to create demand for healthy diets and nutrition must be explored. At the same time, we have to be careful not to put all of the blame for poor nutrition on consumer behavior.[28] Considerably more science is needed to understand the drivers in the processing, marketing and food environments. Science-intensive and promising opportunities such as *scaling up sustainable cold chain technology* to make perishable foods (especially vegetables and fruits; potatoes) more available and affordable[29] and at the same time reducing food loss and waste must be pursued, along with complementary *investments in infrastructure to reduce transportation and other related costs* and thereby reduce food prices.[30]

Nutrition science – like all science – is conflicted and much of our real understanding of these nutrition issues is only starting to emerge. More research is needed to identify the most adequate healthy diets and their affordability and environmental sustainability across different contexts.[31] *Dietary targets* elaborated by the World Health Organization (WHO) – such as those related to adequate fruits and vegetable consumption, sweeteners, etc. – should be considered accordingly. A potentially very significant contribution to deepened insights in health aspects of diets is *the "Periodic Table of Food Initiative (PTFI)*", a global effort to create a public database of the bio-chemical composition and function of the food that we eat using the latest mass spectrometry technologies and bioinformatics.[32] If further combined with *micro-biome science of human nutrition,*[33] the perspectives on healthy diets may further be shifting and related health and information actions can become more concrete, including for the prevention of obesity.

We need to better understand how to *design and implement policies that enable healthy food environments, especially for children*, such as through taxes on foods whose excessive consumption should be avoided, limitations on advertisements of unhealthy foods, information by *educational food labeling,* prohibition of trans-fats, and regulation of the use of high-fructose corn syrup. Sound implementation of nutrition education is likewise required. Information about health properties from industrial fortification and biofortification of certain foods should also be considered.[34,22] Research on the costs of action versus no-action regarding the key drivers of diets and food systems change and the impact of these changes is required for effective decision-making.

3.2. Innovations to de-risk food systems and strengthen resilience, in particular for negative emission farming and drawing on both advanced science as well as traditional food system knowledge.[35]

As food systems become more global, dynamic, and complex, they also become more vulnerable to new, challenging, and systemic risks, as evidenced by the food price crisis in 2008, the ongoing COVID-19 pandemic,[36] and in armed conflicts.[37] The implementation experiences of *triple nexus approaches of the humanitarian-peace-development nexus* should be accompanied with evidence-seeking social science.[38] Science-based responses to catastrophes require preparedness. The capacity to understand, monitor, analyze, and communicate vulnerabilities, crises, and risks must be strengthened.[39] Opportunities to expand and *improve food security forecasting and monitoring with web-based approaches* must be seized. Local *meteorological capacities must be expanded* as accurate weather forecasting is of critical importance to farming communities. De-risking food systems by *solar powered small-scale irrigation* and affordable *smart phones with location-specific soil and weather data* are concrete innovations that can be scaled.

Food prices currently show fast upward movements, and increased volatility. Such tendencies on top of the income losses due to COVID-19 add to food security dangers for the poor. Care must be taken to avoid erratic policies, especially trade policies. While *strategic food reserves can play a role* in ensuring resilience to supply shocks, open rule-based trade – both international and interregional – can provide a more economical option for dealing with localized extreme weather events. Ensuring *free and rule-based open food trade* will require a rejuvenation of multilateral trade negotiations. In addition, to avoid panic-induced world price spikes, transparent information on production, stocks and government interventions around the world are critical and must be made widely available. The Agricultural Market Information System (*AMIS) is an important step* in this direction.[40]

Climate change is the defining issue of our time.[41] Agriculture as well as forestry and related land use change are the single largest drivers of multiple environmental pressures, and major contributors to greenhouse gas emissions. While they are part of the overall climate change problems, they must also be part of the solutions. Good resource management practices for soil and water that contribute to promoting sustainable food systems must be rewarded, with *payments for ecosystem services* as an option.[42] In some countries, there is a need to reduce the over-use of chemical fertilizers that leads to a large environmental pollution and climate change. Boosting nature-based solutions[43] and nature-positive production calls for *transforming soil management, farm input use, agronomy*,[44] and livestock and aquatic food systems in ways to sustainably boost production to meet current and future food demands, *protecting and using biodiversity through biophysical and ecological practices,*[45] rapid reduction of the use of pesticides in intensive crop production, of antibiotics and steroids, and protecting the agriculture- and forest-related genetic base.[46] Of critical importance in this context is the *rapid reduction of the use of antibiotics and steroids in livestock and aquatic food* production systems. Greater emphasis must also be given to the development of green technologies that deploy ecologically suitable trees and indigenous perennial species to boost nature-positive production, and the reduction of large monocultures.[47] Similarly, *organic fertilizers and bio-stimulants from land and marine sources that can replace chemical fertilizers in promoting soil plant growth* and increasing yields can be further explored.[48] *Novel insurance products* and *efficient social protection programs* that include job creation and a variety of nutrition programs including school-feeding programs strengthen resilience.[49]

Future scientific and technological developments can increase the portfolio of bioproducts developed from local biodiversity, in keeping with a *circular bio-economy* approach.[50] Accelerating the reduction of food waste and loss calls for developing *food processing, refrigeration, storage and warehouse technologies.*[51] It also calls for *modifying consumption behaviors, lifestyle choices*, and the perverse incentive to buy much more than needed. Moving quickly towards climate-positive and climate-resilient food systems should employ *carbon pricing at appropriately high levels* and incentives for technologies that facilitate adaptation and mitigation.[22] Initiatives for *carbon farming* (growing carbon in soil and trees as a tradable commodity) and related payment schemes should be explored. Climate finance for adaptation has important ecological opportunities in the food system and is also pro-poor. It only currently accounts for a very small proportion of climate finance, which needs to increase.[52]

Food systems need to become more prepared for and resilient not only to extreme weather events and climate shocks, but to market and inflationary shocks, health shocks, natural disaster shocks, political/governance shocks, cyber shocks, and other emerging shocks. The characteristics, scale and impact of risks continue to evolve,[53] and food-related crises are rising in likelihood and severity. Science also has a growing role in developing a common language to converge multiple knowledge systems and shared goals under emerging risks and uncertainties and how to prepare for and manage them.

Rigorous implementation research is needed to strengthen the fit-to-context design and delivery of such programs and thereby strengthen the resilience of chronically vulnerable communities and their food systems.

3.3. Innovations to overcome inefficient and unfair land, credit, labor, and natural resource use arrangements, and facilitate the inclusion, empowerment and rights of women and youth and Indigenous Peoples.

[22] Poverty and hunger are interlinked and reducing extreme poverty directly impacts the elimination of hunger and malnutrition. Among the effective ways to sustainably eradicate poverty and inequality is boosting the opportunities and capacities of the poor and those living in situations of vulnerability, through ensuring more equitable access to resources, i.e. to natural resources and economic assets. *Providing and protecting land rights* of smallholders – especially female smallholders, and Indigenous Peoples – is critical in this context, as is overcoming exploitative share tenancy. *Inclusive approaches are more possible, affordable and controllable through block chain ledgers of land ownership and credit*.

Ensuring decent work is a key area and calls for regulation and value chain transparency. The potential for significantly expanding green jobs within food systems must be vigorously pursued. *Pro-poor asset sharing investments and programs that empower poor people to build their asset base* offer promise. Nonetheless, eliminating poverty alone does not make healthy diets affordable for all. Changing food systems need to ensure that people with low incomes can access a healthy diet by *enabling them to earn living wages and have access to social safety nets*.

The roles of **women** are very important for productive, healthy and sustainable food systems.[44] Many food systems are unequal or breed inequalities through land and other asset ownership and market power relationships, whereby power imbalances are a common phenomenon. Besides gender inequalities, overall inequalities across classes, regions, rural-urban contexts, and social groups also influence whether food systems will transform to be healthier, more sustainable, and equitable. Women's voices in policy-making – being cognizant of the needs and wants of women and societal norms and issues – is critical.
The situation of the **youth** as well as the elderly deserves particular attention. Key innovations include policies to transform land tenure in equitable ways, provide more and better education investments that enable and empower youth and women and allow them unfettered access to knowledge and information, facilitate job training and education programs, provide affordable financial services, and include youth more fully and meaningfully in policy-making processes. *Vocational training with multi-facetted curricula relevant for rural economic space and food systems are to be scaled up.* Youth have the right and responsibility to learn about food systems dynamics and to be fully engaged in opportunities to transform the food systems that they will inherit. The inclusive transformation of smallholder farming will be imperative for youth. Smallholders are not a homogenous group, and transformation of the small farm economy around the world will call for different policies to address the heterogeneity of smallholders.

3.4. Bio-science and related digital innovations for people's health, food systems' productivity,[54] and ecological well-being.[41, 55]

Specific science opportunities for innovations here include *genetic engineering, genome editing, alternative protein (including more plant-based and insect-derived protein) sources*[56] *and essential micronutrient sources, cell factories, microbiome and soil and plant health technologies, plant nutrition technologies,*[57] *animal production and health technologies*. These advances in science and technology have great potential to meet food system challenges such as restoring soil health and functionality,[58] improving the resource efficiency of cropping systems[59], breeding orphan and underserved crops,[60] and re-carbonization of the terrestrial biosphere. *Modern plant breeding techniques that allow plants to capture nitrogen from the air reduce the need for fertilizers and improve nutritional qualities.*
However, it must not be neglected that there are potential risks associated with science-based innovations that need to be considered within the science systems and with societal

dialogues through transparency, ethical standards and reviews, biosafety measures, and – where needed – with regulatory policies. Adopting the *One Health approach*, i.e. the health of soil, plants, animals, people, ecosystems and planetary processes, being one and indivisible, would make an important contribution.[61]

Translating bio-science innovations into reality does not happen automatically: property rights, skills, and data are key for the translation and management of scientific innovations in practice.[62] However, b*io-sciences increasingly benefit from digital innovations and artificial intelligence.*[63] Nonetheless, these technologies sometimes run the risk of exclusion through the creation of monopolies that need to be prevented by anti-trust regulations. Hence, *innovations in governance structures* are needed to ensure that access to bio-science and digital technologies is not hindered. Furthermore, developing these bio-science and digital innovations and ensuring that they – especially the potentially controversial technologies – contribute to sustainability is not sufficient; rather, it will be important to *adapt them to local conditions*, make them accessible and affordable to farmers, especially smallholders, and use them to enhance local and traditional knowledge. It will also be important to have open information sharing so that users are aware of the opportunities, costs and benefits of new innovations and able to better use the available technology and implement innovations.[64] To ensure that poor communities are not left behind, governments of countries in the global South need to invest in the *creation of capacities and expertise to develop and utilize bio-sciences and digital technologies and receive support for that from development partners.* It is important that Indigenous Peoples and local people in general receive the benefits of their interactions and information sharing with scientists that result in innovations.

3.5. Innovations to keep – and where needed, regenerate – productive soils, land and water, and protect the agricultural genetic base and biodiversity.

One-third of global land area is degraded.[65] Soil degradation is being exacerbated by climate change along with land mis-use and soil mismanagement.[66] Water is becoming increasingly scarce and polluted.[67] Ecosystems services of land, forests, and water cycles are being undermined.[68] Technology-based innovations are needed to support sustainable soil, agricultural, and water management, protect natural resources from degradation and restore degraded resources, and maintain and even increase biodiversity in agricultural settings.[69,70] This underlines the need to advance knowledge in plant genetic diversity and microbial diversity, taking local climate variability into account.[71] *Harnessing soil microbes to add to depleted soils to improve structure, carbon capture and yields are promising innovation opportunities.* The use of *modern hand-held digital devices for in-field measurement of soil carbon* and *remote sensing measurement of soil carbon* can become significant opportunities for both climate policy and productive plant nutrient management. These examples highlight the interconnectedness of technological and policy innovations, because the technologies can facilitate the increased feasibility of payments for ecosystems services.

Similarly, agro-ecology and other regenerative *practices for resilient landscapes* at scale promise opportunities. They need long-term accompanying science. An integrated approach for sustainable soil management should be considered and incentivized. Locally-adapted sustainable intensification of existing agricultural systems is also needed.[72]

Primary forests are over-exploited, including due to the non-sustainable expansion of agriculture. *Innovations in agroforestry* with trees and bushes and in landscape contexts can contribute to large-scale productive land use combined with ecological and climate-positive ecosystems services.[73] Wild foods (e.g. berries and fruits) are important for food security and nutrition for both smallholder farmers and Indigenous Peoples.[74] Traditional food and forest systems – including Indigenous Peoples' food systems – need to be better understood and protected, when designing policies.[75]

3.6. Innovations for sustainable fisheries, aquaculture, and protection of coastal areas and oceans.

There is a tendency to think of food systems as terrestrial systems only. Given the tremendous current and future potential of wild and farmed seafood and seaweed to help assure healthy diets, it is critical to broaden the understanding of food systems to more fully include the aquatic food systems.[76]

Institutional innovations are needed to overcome the mis-use of oceans as commons. We are approaching tipping points in harvesting from nature, and unless we *stop treating the oceans as commons that can be exploited* for perpetuity, we will accelerate species extinction among other irreversible changes. Ecological science perspectives and global cooperation and institutions are needed to bring the harvesting of oceans to sustainable levels and protect biodiversity.

Science-based innovations for sustainable aquatic foods that protect, and harness oceans and coastal areas can play a growing role in reducing hunger and malnutrition and building healthy, nature-positive and resilient food systems.[77] Innovations must support aquatic foods "to increase nutritional diversity, reduce waste, address environmental change and management failures, improve livelihoods of fishing and coastal communities, and capitalize on opportunities to sequester carbon in the marine environment".[78] Of critical importance are innovations in fish feeding systems: *using insect rearing and oil rich modified legumes as fish feed in improved aquaculture to avoid depletion of oceans can become options. Enhancing the use of organisms of lower trophic levels for human consumption, e.g. micro-algae and seaweed can also evolve as foods.*

3.7. Engineering and digital innovations for efficiency and inclusiveness of food systems and empowerment of the youth and rural

communities. Digital innovations and engineering that hold much promise to make food systems more efficient, productive, and sustainable are touching on all components of food systems. Examples include *artificial intelligence, big data analysis, remote sensing, and robotics,*[79] *mechanization, sub-surface drip irrigation with conservation agriculture, precision agriculture, vertical farming, indoor farming, and digitized food processing.*[80] The use of *sensors to monitor origin and quality of products and ingredients all along the food chains* to reduce losses, guarantee safety and reduce unnecessary "in-transparencies".

Some of the ways in which digital innovations can be put to work to optimize agricultural production processes include using *drones and advanced analysis of image data to identify pests and diseases in real time*. With improved access to biotic (pests and diseases) or physical (meteorological, SAT early warning systems) information and remote sensing, producers can use their mobile phones to strengthen their agricultural practices and make better use of inputs and resources.

Digitization in the food system is not necessarily enhancing equity, and it may even benefit large-scale farming and processing at the expense of smallholder farming. Thus, appropriate *governance structures* are needed to ensure that access to digital technologies is not hindered and that data collected from smallholders are appropriately protected so that smallholders are not "data-exploited". Inequitable access to digital technologies could significantly impede the transition to equitable food systems. Easing information access for women is particularly important. Strengthening the *e-commerce ecosystem* could transform rural livelihoods, providing *platforms* to reach the last-mile households and better connect them to the wider economy.

The growing role of *digital innovations in science and technology processes* that serve bio-chemical sciences and engineering of relevance for food systems is also noteworthy.
it is of note that digitization itself facilitates decentralized organization of science and research producing technological, policy and institutional innovations that are context-specific, and thereby it offers extraordinary new opportunities to re-organize how science is undertaken, delivered, and used in participatory ways.

Further development to make digital technologies affordable and accessible for small- and medium-sized farmers is essential to avoid even further reducing their competitiveness.[81] In this context, revisiting and reinvigorating *agricultural extension services with digital options* is called for. Attention to employment effects is also called for, as well as attention to ethical considerations of data use and data ownership. Investments are also needed to scale up universal access to digital technologies and key infrastructure, in particular access to rural electrification, wherever possible based on renewable energy sources.

4. Modeling Synergies and Trade-Offs Between Actions in Food Systems

The sets of innovations and actions mentioned above are connected, and there are synergies and trade-offs among them. Understanding these synergies and trade-offs is critical in maximizing the effectiveness of innovations and actions. A convincing game-changing action in one food systems domain may cause adverse effects in another domain. For example, a fertilizer subsidy that increases income and reduces hunger may have an adverse environmental effect if this leads to excessive nitrogen use. To avoid such unintended consequences, food systems modeling is essential.

Furthermore, food systems do not operate in isolation. Innovations go beyond food systems and are connected to transformations in health systems ("One Health"), energy and environment systems (climate), economic systems (trade), and evolving science and knowledge systems. Strengthening the interactions among scientists specializing in food systems, health, climate, and energy will make it possible to generate the required expertise. Furthermore, researchers and users of research need to work together to increase the chances of achieving food systems-related SDGs. Supporting local innovations, creating knowledge, participatory science, and living labs should be explored at scale.

A recent review of the advanced quantitative global modeling found **strong synergies between SDG2 and other related SDGs**. These synergies and trade-offs are illustrated in Figure 2. In particular, SDG1 (no poverty) is central for food security and can unlock many additional benefits across the SDGs. SDG2 is closely integrated with SDG3 (good health and well-being) due to the close link between malnutrition and maternal and child health, as well as deaths associated with poor diet. Other socioeconomic SDGs — including SDG4 (education), SDG5 (gender equality), SDG8 (decent work and economic growth), SDG10 (reduced inequality), SDG11 (sustainable cities and communities), SDG16 (peace, justice and

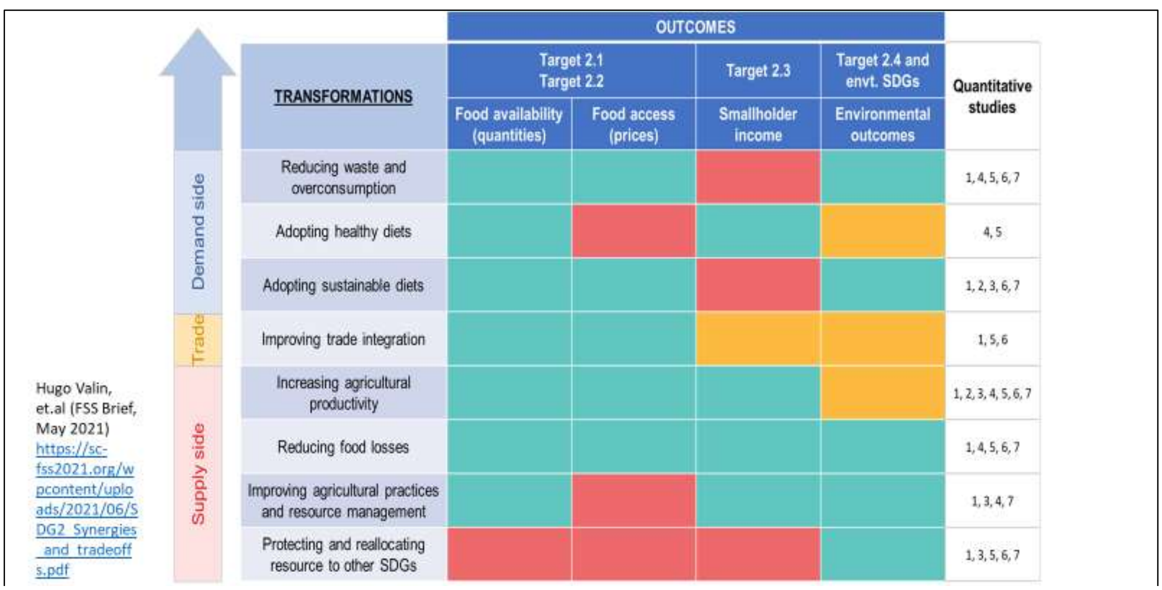


Figure 2: Key transformations implemented in global analyses and their typical impact for relevant indicators (Valin et al., 2021).

strong institutions), and SDG17 (partnership) — are key enablers for SDG2. These potential synergies merit greater attention for accelerating food systems transformation.

The importance of trade-offs must also be recognized. Agricultural production substantially contributes to global warming, nutrient pollution, degradation of water quantity and quality, biodiversity loss, and soil degradation. Climate action (SDG13) requires curtailing greenhouse gas-intensive products (meat, dairy, rice). Achieving biodiversity on land (SDG15) requires limiting deforestation associated with agriculture expansion and establishing new conservation areas. Achieving environmental water flows (SDG6) requires reducing water withdrawal for irrigation. Quantitative assessments show more efficient production systems and technologies and pricing of externalities. Additionally, integrated resource management can mitigate some of these trade-offs, although they are unlikely to succeed in addressing them altogether.

Forward-looking analyses indicate that to achieve the SDG2 targets and other goals, deeper transformation of food systems at the global level will be required, combining supply- and demand-side measures. Such transformation entails new supply-side investments, effective trade and markets, and modified consumer behavior, with a fast transition towards more sustainable and healthy diets and sharp reductions in food loss and food waste. SDG12 (responsible production and consumption) is a key goal for the successful transformation of global food systems to achieve SDG2.

With an integrated modeling framework – illustrated in Figure 3 – Laborde and Torero (2021) model six individual interventions similar to those presented in Figure 2 with respect to their impact on the food systems, the prevalence of undernutrition, ecological effects in terms of GHG emissions, land and energy use, and the use of chemical inputs. Given the synergies and complementarities between these scenarios, the authors assess them as a package. The sensitivity to the results is also assessed under different governance principles, such as land use policies.[2]

The scenarios are listed in Table 1 and organized around three main pillars: achievement of a more *efficient* and *inclusive* system, allowing consumers and producers to make *better choices*. Only preliminary findings from Laborde and Torero (2021) are summarized here. The results of the different scenarios are consistent with the baseline of *The State of Food Security and Nutrition in the World 2020*, namely that in 2019 there were 690 million undernourished people in the world and healthy diets were unaffordable for almost 3 billion people.

[2] Other aspects of the global food systems, like trade policies, are also analyzed to see how they interact with the main interventions.

Figure 3: An integrated modelling framework: The MIRAGRODEP CGE (source: Laborde and Torero, 2021).

Escenarios	Title	Description
More Justice	#1 Social safety net: healthy diets for everyone	Provide food stamps (income transfer that should be spent on food products) to eliminate the "poverty gap" between the per capita income of each household and the affordability of healthy diets cost line. The cost is initial calibrated on SOFI 2019 and updated based on model dynamics.
More Justice	#2 School Feeding Program	All kids between 6 and 11 years old have access to school feeding programs 200 days a year. Daily per capita ration includes 320 grams of fruits, 102 grams of grains, 51 grams of animal proteins (meat, fish, eggs), 480 grams of milk, and 100 grams of vegetables.
Better Choices	#3 Farm Subsidy Repurposing	All farm subsidies (outputs, inputs, others) are redistributed in the form a a subisdy to farmer revenue. The rate of support is computed endogenous by the model to maintain farm subsidy budget constant, but a sectoral bias is introduced. Nutrious and low-emissions products are subsidised at twice the average rate, while products with low nutrition value and high emissions are subsidised at half the average rate.
Better Choices	#4 Consumer's incentive reform	Taxation of red meat products in High Income and Middle Income countries. The level of tax is computed by the model to obtain a reduction of consumption of 15 percent in HIC (and UMIC in Europe), and 7.5 percent in UMIC (exc. Africa). The group of countries have been constructed by computing an index of "excess" consumption by comparing average daily intake with a sustaibale and healthy diet reference (i.e. Flexitarian diet in this case, but alternative diets give the same ranking of countries)
More Efficiency	#5 Innovation, Technology and Knowledge for Farmers	This package of interventions is aimed at increasing farm level productivity, while reducing environmental footprints. It has three components Increased/or Improved **Irrigation** systems. % of each country cropland benefits from new investments by 2030. For regions with high rate of irrigated land (all Asian regions), we consider only an upgrade of existing materials, leading to no change in yield but a reduction in water inefficiency. For other regions, we consider an increase of water use (for irrigation, but with an improved average efficiency) but also a yield increase Increased **livestock** genetics and better practices for higher productivity [Z%]and lower emissions per unit of output. % of the the herd of each country is improved by 2030. Extension services and farmer **training** to increase all farm productivity (total factor productivity, TFP). % of farmers in each country are covered. TFP is increased. In addition, carbon sequestration in soil is increased.
More Efficiency	#6 Reducing Food Waste and Loss	Reduction of 25% in all countries of food waste and food losses, including for left-on-the field
Combined actions	All except Safety Nets	Include actions 2 to 6. Since the Safety Net is computed to provide enough income to everyone to be able to afford healthy diets, it is important to consolidate all the other actions before this one.
Combined actions	All including Safety Nets	All actions, 1 to 6. While this package will take care of all vulnerable people, showing the consolidated impact on environmental and economic indicators is important (trade-off lens)
Combined actions	Everything with land use regulation	In this consolidated scenario, we do not allow for land use change (fixed amount of agricultural land) by considering a stronger land governance.

Table 1: Scenario definitions (source: Laborde and Torero, 2021).

The finding confirms that ending chronic hunger at a 5% level is feasible by 2030 with the appropriate balance of interventions. While no intervention alone could solve the problem, Figure 4 shows that key interventions to increase the efficiency of food systems — through increased *farm productivity* and reduction of *food loss and waste* — will reduce the number of people in chronic hunger by 314 million by 2030. Beyond hunger, 568 million people will be able to afford healthy diets, as shown in Figure 5. To target the remaining population, *safety nets* and targeted programs like *school-feeding* interventions are required. When adding such safety nets in the model, it is possible to cover the 2.4 billion remaining people without access to healthy diets.

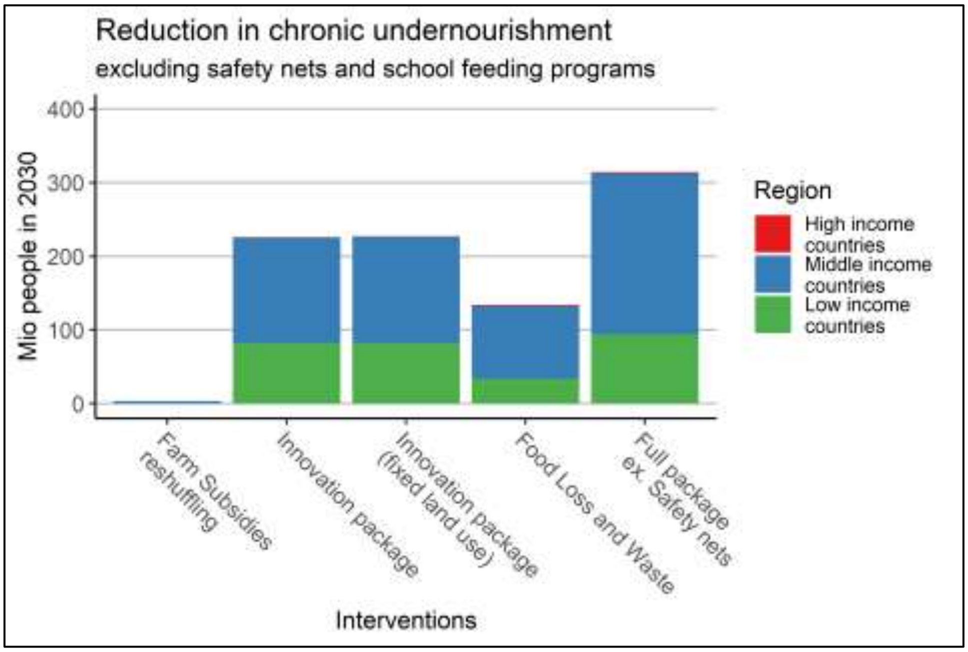


Figure 4: Number of people (mio) removed from chronic undernourishment situation in 2030 (source: Preliminary results based on Laborde and Torero, 2021).

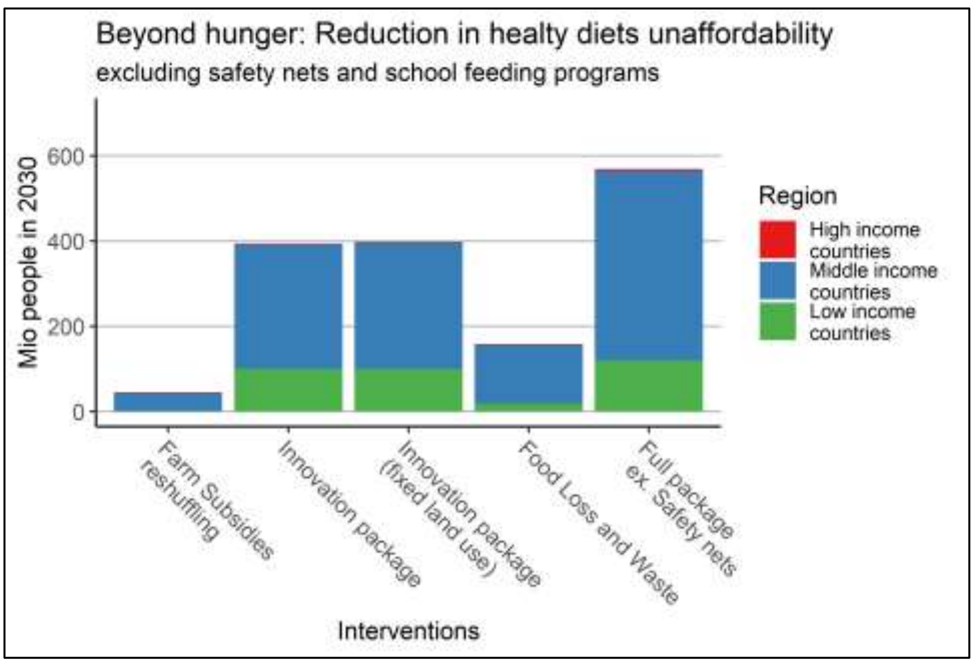


Figure 5: Number of people (mio) removed from not being able to access healthy diets by 2030 (source: Preliminary results based on Laborde and Torero, 2021).

Achieving the end of widespread hunger requires significant *resource mobilization*, representing 8% of the size of food markets.[3] Figure 6 provides the breakdown of this total cost from all sources, public and private, by action (Panel A) and the distribution by group of countries (Panel B). The actions – referred to as "better choices" in Table 1 – including *consumer incentives* and *farm subsidies re-purposing*, do not contribute to the total costs because they are designed to be cost-neutral for the government and producers (farm subsidies) as well as consumers (food tax/subsidies) in each country. A related analysis of environmental effects of consumption change is provided by FABLE (2021).[82] The cost structure is dominated by the large investment in innovations for productivity, and in people, which impact the value chains and national economies (45%), and the social safety nets (36%). Clearly the two main items are different since the latter involves recurrent spending every year and will have to be managed and financed by governments alone.

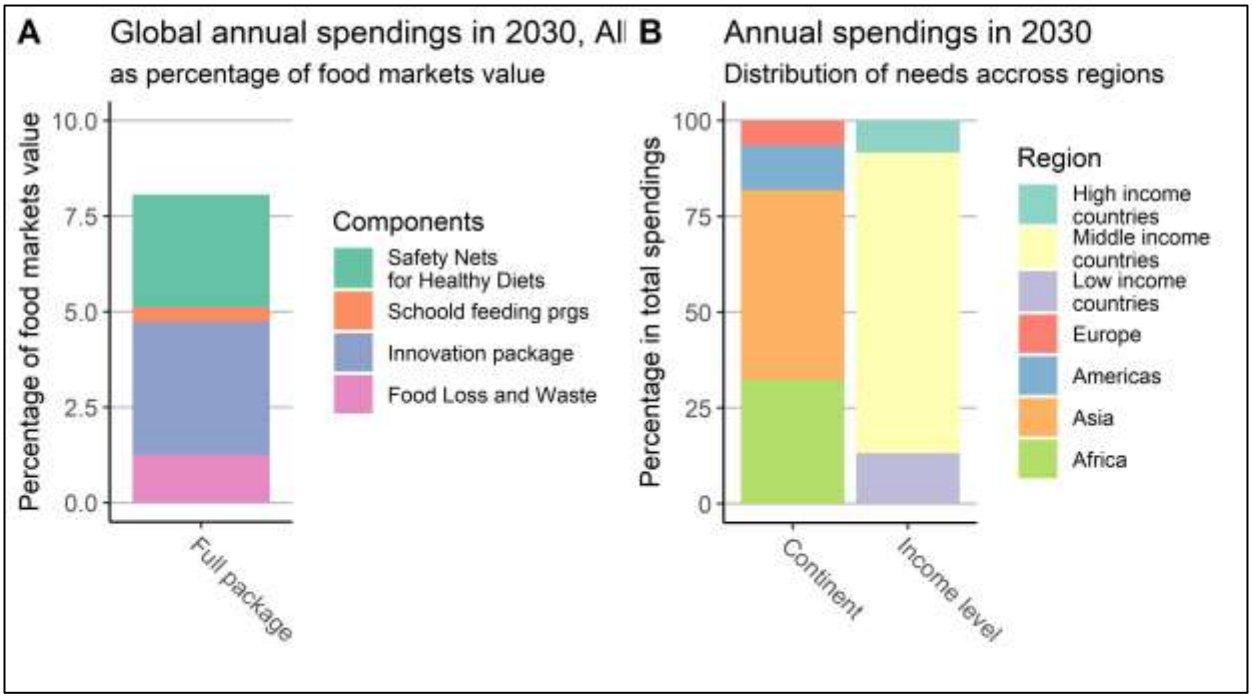


Figure 6: The cost of actions: magnitude and distribution (source: Preliminary results based on Laborde and Torero, 2021).

[3] 2030 spending and food market values, as estimated by the model to guarantee full consistency.

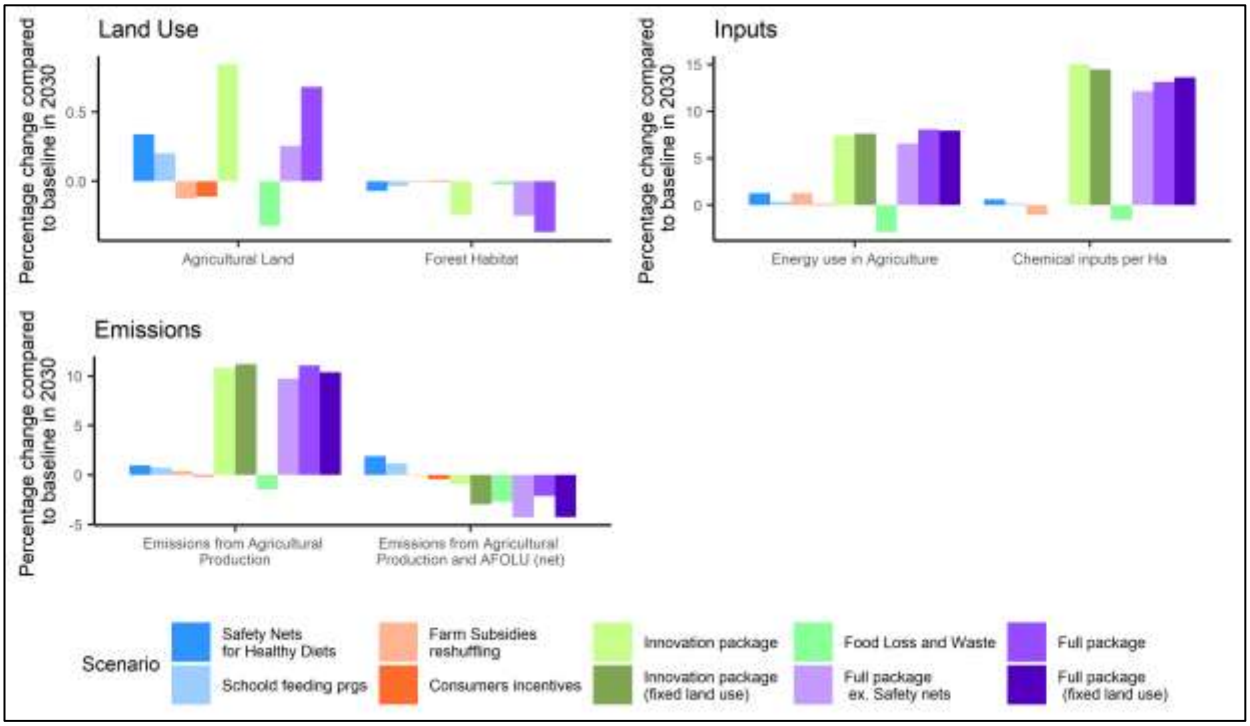


Figure 7: Impacts of actions on environmental indicators (source: Preliminary results based on Laborde and Torero, 2021).

The second panel in Figure 6 shows the distribution of the costs by region and hemispheres. Since the needs are unevenly distributed globally, a significant solidarity effort is required for global coordination, especially to support the transformation of food systems in low-income countries. As previously shown, no single intervention can end malnourishment. The actions modeled will generate trade-offs in greenhouse gas emissions (emissions from agricultural production and net emissions from agriculture, forestry, and other land use, or AFOLU), chemical inputs (increased use of chemical inputs per hectare), biodiversity (reduction of forest habitat and agricultural land) and energy consumption. As shown in Figure 7, the levels of trade-offs across all interventions are relatively small.

The effects indicate environmental improvement as a consequence of reducing food loss and waste. However, when it comes to net agricultural emissions and AFOLU, the effect is negative as is the case for forest land. This highlights the need for policies that can stimulate investments in innovation for carbon farming — growing carbon in soil and trees as a tradable commodity — and related payment schemes for ecosystems services, as indicated in section 3.5 concerning science and innovation actions above.

5. Enabling Food Systems Transformation

Transformation of food systems that are under way do not guarantee that the food-related SDGs – especially SDG2 – will be achieved. There are fundamental conditions that are essential to enable and leverage food systems transformation to achieve desired objectives, including *facilitating peace and security, and conflict resolution, full inclusion of marginalized and vulnerable populations, gender equity, sound governance at all levels from community to local to regional to national and international,* and *supportive global and national policies for public goods.* [83] Modes of implementation need to especially focus on **finance, capacity, and governance.**

Finance: Enabling food systems transformations requires constant **investment in science** that has the potential to serve positive change in systems. In 2018, the world science "output" in terms of peer-reviewed publications was 4.04 million, and of these 14% related to agricultural and biological sciences (about 298,000) and environmental sciences (about 273,000). [84] Thousands of potentially game-changing insights are generated by the world science communities every year. More attention is needed to identify actionable insights for innovations and that requires strengthening capacity and innovative financing.
Science systems have been decimated in many countries, especially in the global South. To tap the potentials of science, public funding of food systems science and related research partnerships need to expand. Governments need to change their low levels of spending on food systems-related research and innovation. We call on governments – especially in the global South – to review the level of their investments in food systems science and **allocate at least 1% of their food systems-related GDP to food systems science and innovation with a perspective to substantially exceed this target.** LDCs should be assisted in quickly reaching the equivalent of this target. About 20 years ago, African ministers responsible for science and technology had already committed to increase public expenditures on research and development to at least 1% of GDP per annum.[85] As basic sciences – for instance, *bio-chemical and nutrition and health sciences* – are becoming increasingly relevant for food systems, the investment in these must also be accelerated and systems of sharing of sciences for food systems expanded.[86] There are important new opportunities for engaging private sector science to address public goods in food systems innovations, particularly in partnership with the public sector.[87] The private sector here is a broad concept, ranging from semi-subsistence farmers to large corporations. It is often overlooked that the former are also proven innovators.[88] The knowledge of Indigenous Peoples is another important component of local food systems' innovation landscape. Intellectual property rights protection issues require revisiting to align with sustainability expectations, especially for science opportunities that address overcoming hunger and malnutrition.[22] New institutional arrangements may be discussed for sharing intellectual property that could directly reduce hunger and address sustainability concerns.

The Food Systems Summit agenda needs to consider how the investments in the identified priority actions may be financed, and that is where **innovative finance** approaches shall be considered that economics research can explore. Research suggests that mobilizing the necessary financial resources may include a combination of actions, such as 1) additional – actually doubling – international development funds (ODA) to agricultural and rural development, food and nutrition security; 2) reallocation of agricultural subsidies towards investment for sustainable development and scaling up and redesigning social safety nets; 3) the initiation of a new dedicated “end hunger” fund, perhaps through expanded IDA; and 4) possibly financing innovative financial mechanisms such as “End Hunger Bonds” through support from incremental special drawing rights (SDRs).[89] The private sector should be part of the resource mobilization, expecting long-term returns from a more prosperous society. Research shall identify what combinations of finance may contribute to a sustainable financing of the food systems transformation.

Capacity: Of particular importance are investments for *improving data, methods, models and tools for all food system components* and actors, as well as building or *enhancing (shared) research infrastructures related to (research) data, modeling platforms, observation and monitoring networks* to support the required advances in research and innovation, especially in the global South.[90] Integrated *global food system models* are needed as existing models do not have consistent global coverage and are not designed to assess the impacts of all elements of food systems.[14] Besides global foresight work, strengthening national and – where possible – subnational/local, policy scenarios and foresight work is also necessary. More attention needs to be paid to strengthening local research capacities, *expanding research collaboration among public and private sector research, and indigenous systems*, sharing research infrastructure and data, developing more inclusive and equitable science partnerships and follow-up mechanisms, systematically learning what works and what can be scaled up and translating that knowledge into action, improving the efficiency in the way knowledge is generated and shared, and *addressing intellectual property rights issues when they hinder innovations* that can serve food and nutrition security, food safety, and sustainability goals.[18] With the increased recognition of their central role to achieving many development goals, food systems will be expected to perform a more complex set of activities, and this requires new and more appropriate holistic metrics. Protecting the freedom of science to innovate and experiment while adhering to ethical standards needs to be continually reinforced.

Because significant components of food systems are local, the Summit has to ensure that its outcomes and deliverables turn into positive local actions. This requires **science aligning with national and local agendas for implementation actions.** The proximity of science to decision-making is important to connect the timeliness and relevance of science to policy where and when it is needed. Similarly, the development of national and local infrastructure and expertise to effectively link science to decision-making is important. The science underpinning food systems transformation becomes more inter- and trans-disciplinary, more open to a wide range of innovations and their diverse stakeholders, and more appropriately configured and scaled to different contexts. Relatedly, it would be important to innovate and *improve the methods for* *analyzing the performance of food systems* (e.g. analyzing their impact on health, nutrition and sustainability goals) at different levels (local, national, global).

Transformation is not possible without science, and in many instances citizen participation in research and implementation can be very supportive for the transformation of farming, the application of new technologies, shifting to healthy diets, and other key elements of successful food systems transformation. **Citizen science** has an important role to play in inclusive food systems transformation, especially with farmers as co-designers directly participating in the development of innovations and with scientists being more open to and collaborating on fair terms with start-ups. **Indigenous Peoples knowledge systems** should be partnered with in such approaches.

The international sharing of science and participation of science in the follow-up to the Food Systems Summit as part of implementation agendas is vital. Proposals for international collaboration include supporting low- and middle-income countries to build and sustain capacities to acquire and deploy technologies through joint research, education and training programs. Beyond investing in capacities to undertake research, it will be important to also invest in capacities to act upon research: in other words, to put to effective use the knowledge and innovations that already exist (e.g. traditional and indigenous knowledge) or are generated from new research. This calls for investing in *strengthening the skills of all food system actors*, especially in emerging economies where these skills tend to be more limited. In many instances, what is lacking is actionable knowledge that may contribute to systemic changes, which requires supporting local innovations and encouraging and facilitating the co-creation/co-design of knowledge. In support of this, *leading research organizations from world regions could form networks (or alliances)* to share science and develop actionable knowledge supporting food systems transformations.

Governance and science-policy interface: In contrast to other subjects of global concern that were agreed upon at the Earth Summit in Rio in 1992, agriculture, food security and nutrition do not have an international agreement or convention to consolidate actions. Climate, biodiversity and desertification have their dedicated conventions and ensuing subsidiary bodies, secretariats and further protocols. Fueled by regular meetings of the conference of parties and underpinned by a solid science-policy interface, they have made enormous progress. Thus, we believe that the time has come to consider such a set of agreements and mechanisms for the complex area of food systems, obviously fully recognizing existing efforts and agents. The UNFSS may wish to consider opening a process for *exploring a treaty on food systems*. In a related manner, food systems science and policy need a stronger scientific framework for constructive and evidence-based interaction for moving ahead, not only for the Food Systems Summit 2021 but also for the long term.[91] At the national level, coherent national food systems research policies need to be better integrated into national development policies, such that countries develop their own context-specific food systems policies and strategies. At the international level, some have proposed strengthening the contribution of science to policy-making for transformational food systems with an Intergovernmental Scientific Advisory Panel, while others advocate strengthening and better connecting existing mechanisms.[92,17] We suggest exploring **options for an inclusive, global science-policy interface** (SPI) for a sustainable food system that connects national and global food systems concerns and will assist in an evidence-based follow-up to the proposed Summit actions and for the long term. This proposition is based on three considerations: (1) the growing complexity of food value chains from resource use to human nutrition and their increasing globalization, which urgently requires a new integrated approach drawing on all related science for sustainable agriculture, food and nutrition systems; (2) the absence of a comprehensive and timely system to collect, analyze and assess data on the diagnosis and technical, economic and social solutions to create long-term sustainable, affordable, nutritious and safe food systems; and (3) the limited or non-existent translation and traceability of scientific data and experiences into evidence-based policy that precludes the application of experiences across countries and regions.[93] Addressing these considerations requires a global mechanism that mobilizes the leading food systems scientists worldwide and across disciplines to support the SPI through co-production, open access, and communication of knowledge. The effective and independent participation of research communities from low-income countries and emerging economies in the SPI must be strengthened to enhance credibility, relevance and legitimacy. We call upon governments and UN agencies to *initiate a process to explore options – existing[94] as well as new – for a global SPI* for a sustainable food system. As such, this would be a concrete outcome of the UNFSS.

Science and policy have a lot to gain from cooperation but the independence of science must not be compromised to address policy and institutional opportunities and failures with evidence-based insights. Nonetheless, science that produces new insights also needs to constantly earn the trust of society, and in view of the cultural sensitivity of all matters related to food, policies and rules must assure confidence in scientific endeavors. Anti-science sentiments exist in parts of society. While pursuing new insights and truths, there are many issues on which scientists themselves do not agree, which sometimes irritates policy-makers and practitioners. Adhering to responsible and ethical principles, science must collaborate with a broad range of stakeholders. The improved quality and timeliness of science translation and communication for policy-makers and non-technical audiences are helpful, along with attention to ethics, peer review, scientific integrity and excellence, transparency and declarations of interest in science.

In closing, science, innovation, and technologies play critical roles among the measures to achieve food systems transformations. All sciences – natural sciences and social sciences, basic sciences and applied sciences – in collaboration with diverse traditional knowledge systems must deliver the innovations and make significant contributions for the necessary food systems transformation to achieve the SDGs, especially SDG2, and the complete 2030 Agenda.

Annex

Sources of contributions by Scientific Group and its partners as well as other relevant references

The Scientific Group draws on the science backgrounds of its members who are leaders in Food Systems related Science and the following sources for its emerging recommendations

1. The peer-reviewed background papers by the Scientific Group https://sc-fss2021.org/materials/scientific-group-reports-and-briefs/

2. The about 40 Food Systems Summit Briefs on Big Cross Cutting Themes and Strategic Innovations by Partners of the Scientific Group (see list of completed and ongoing Briefs at https://sc-fss2021.org/wp-content/uploads/2021/05/FSS_ScG_Briefs_list_3-May-2021.pdf)

3. The Wealth of Recent Most Relevant Publications on Food Systems Related Research and Knowledge Community: More than 200 sources, clustered by the generic Food Systems Concept and Action Track Concept (https://sc-fss2021.org/materials/publications-and-reports-of-relevance-for-food-systems-summit/)

*4. The Scientific Group engages in **peer review and evaluations of propositions by the Action Tracks** and insights from that also enter the Scientific Group's emerging conclusions. (see peer reviews on and by Scientific Group at (https://sc-fss2021.org/wp-content/uploads/2021/05/Evaluation_Peer_Review_and_Science_Advisory.pdf)*

Re 1. Peer-reviewed background papers by the Scientific Group *https://sc-fss2021.org/materials/scientific-group-reports-and-briefs/*

Food Systems – Definition, Concept and Application for the UN Food Systems Summit
by Joachim von Braun, Kaosar Afsana, Louise O. Fresco, Mohamed Hassan, Maximo Torero
doi.org/10.48565/scfss2021-re63

Healthy diet – A definition for the United Nations Food Systems Summit 2021
by Lynnette M Neufeld, Sheryl Hendriks, Marta Hugas (March 2021)
doi.org/10.48565/scfss2021-e072

The True Cost and True Price of Food
by Sheryl Hendriks, Adrian de Groot Ruiz, Mario Herrero Acosta, Hans Baumers, Pietro Galgani, Daniel Mason-D'Croz, Cecile Godde, Katharina Waha, Dimitra Kanidou, Joachim von Braun, Mauricio Benitez, Jennifer Blanke, Patrick Caron, Jessica Fanzo, Friederike Greb, Lawrence Haddad, Anna Herforth, Danie Jordaan, William Masters, Claudia Sadoff, Jean-François Soussana, Maria Cristina Tirado, Maximo Torero, Matthew Watkins
https://sc-fss2021.org/wp-content/uploads/2021/06/UNFSS_true_cost_of_food.pdf

Achieving Zero Hunger by 2030 – A Review of Quantitative Assessments of Synergies and Tradeoffs amongst the UN Sustainable Development Goals
by Hugo Valin, Thomas Hertel, Benjamin Leon Bodirsky, Tomoko Hasegawa, Elke Stehfest (May 26, 2021)
doi.org/10.48565/scgr2021-2337

***Action Track 1** – Ensuring Access to Safe and Nutritious Food for All Through Transformation of Food Systems*
by Sheryl Hendriks, Jean-François Soussana, Martin Cole, Andrew Kambugu, David Zilberman
doi.org/10.48565/scfss2021-wg92

***Action Track 2** – Shift to Healthy and Sustainable Consumption Patterns*
by Mario Herrero, Marta Hugas, Uma Lele, Aman Wira, Maximo Torero (April 2021)
doi.org/10.48565/scfss2021-9240

***Action Track 3** – Boost Nature Positive Production*
by Elizabeth Hodson, Urs Niggli, Kaoru Kitajima, Rattan Lal, Claudia Sadoff (April 2021)
doi.org/10.48565/scfss2021-q794

***Action Track 4** – Advance Equitable Livelihoods*
by Lynnette M. Neufeld, Jikun Huang, Ousmane Badiane, Patrick Caron, Lisa Sennerby Forsse (March 2021)
doi.org/10.48565/scfss2021-tw37

***Action Track 5** – Building Resilience to Vulnerabilities, Shocks and Stresses*
Thomas W. Hertel, Ismahane Elouafi, Frank Ewert and Morakot Tanticharoen (March 2021)
doi.org/10.48565/scfss2021-cz84

Re 2. The Food Systems Summit Briefs on Big Cross Cutting Themes and Strategic Innovations by Partners of the Scientific Group

(see list of completed and ongoing Briefs at https://sc-fss2021.org/wp-content/uploads/2021/05/FSS_ScG_Briefs_list_3-May-2021.pdf)

A particularly important ongoing task is Modelling the Food Systems and exploring impacts of related policy actions

Already on the web:

A. Modelling and Strategizing Food Systems Transformations

The Bioeconomy and Food Systems Transformation
by Eduardo Trigo, Hugo Chavarria, Carl Pray, Stuart J. Smyth, Agustin Torroba, Justus Wesseler, David Zilberman, Juan F. Martinez (February 17, 2021)
doi.org/10.48565/scfss2021-w513

The Transition Steps Needed to Transform Our Food Systems
by Patrick Webb, Derek J. Flynn, Niamh M. Kelly, and Sandy M. Thomas on behalf of the Global Panel on Agriculture and Food Systems for Nutrition (April 26, 2021)
doi.org/10.48565/scfss2021-hz63

Cost and Affordability of Preparing a Basic Meal around the World
by William A. Masters, Elena M. Martinez, Friederike Greb, Anna Herforth, Sheryl L. Hendriks (May 2021)
https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Cost_of_Basic_Meals.pdf

---

B. Science, Technology, and Innovation Actions

The Role of Science, Technology and Innovation for Transforming Food Systems Globally
by Robin Fears, Claudia Canales (April 2021)
doi.org/10.48565/scfss2021-q703

How could science–policy interfaces boost food system transformation?
by Etienne Hainzelin, Patrick Caron, Frank Place, Arlène Alpha, Sandrine Dury, Ruben Echeverria, Amanda Harding (May 14, 2021)
doi.org/10.48565/scfss2021-4y32

Food System Innovations and Digital Technologies to Foster Productivity Growth and Rural Transformation
by Rui Benfica, Judith Chambers, Jawoo Koo, Alejandro Nin-Pratt, José Falck-Zepeda, Gert-Jan Stads, Channing Arndt (May 2021)
doi.org/10.48565/scfss2021-6180

Leveraging data, models & farming innovation to prevent, prepare for & manage pest incursions: Delivering a pest risk service for low-income countries
by Taylor, B; Tonnang, HEZ; Beale, T; Holland, W; Oronje, M; Abdel-Rahman, EM; Onyango, D., Finegold, C; Zhu, J; Pozzi, S, Murphy, ST (April 15, 2021)
doi.org/10.48565/scfss2021-ty56

Food Systems Innovation Hubs in Low-and-Middle-Income Countries
by Kalpana Beesabathuni, Sufia Askari, Madhavika Bajoria, Martin Bloem, Breda Gavin-Smith, Hamid Hamirani,

Klaus Kraemer, Priyanka Kumari, Srujith Lingala, Anne Milan, Puja Tshering, Kesso Gabrielle van Zutphen, Kris Woltering (March 26, 2021)
doi.org/10.48565/scfss2021-fh72

A New Paradigm for Plant Nutrition
by Achim Dobermann, Tom Bruulsema, Ismail Cakmak, Bruno Gerard, Kaushik Majumdar, Michael McLaughlin, Pytrik Reidsma, Bernard Vanlauwe, Lini Wollenberg, Fusuo Zhang, Xin Zhang (February 10, 2021)
doi.org/10.48565/SCFSS2021-HG55

A Whole Earth Approach to Nature Positive Food: Biodiversity and Agriculture
by Fabrice A.J. DeClerck, Izabella Koziell, Tim Benton, Lucas A. Garibaldi, Claire Kremen, Martine Maron, Cristina Rumbaitis Del Rio, Aman Sidhu, Jonathan Wirths, Michael Clark, Chris Dickens, Natalia Estrada Carmona, Alexander K. Fremier, Sarah K. Jones, Colin K. Khoury, Rattan Lal, Michael Obersteiner, Roseline Remans, Adrien Rusch, Lisa A. Schulte, Jeremy Simmonds, Lindsay C. Stringer, Christopher Weber and Leigh Winowiecki
https://sc-fss2021.org/wp-content/uploads/2021/07/FSS_Brief_Nature_Positive_Agriculture.pdf

Delivering climate change outcomes with agroecology in low- and middle-income countries: evidence and actions needed
by Sieglinde Snapp, Yodit Kebede, Eva Wollenberg, Kyle M. Dittmer, Sarah Brickman, Cecelia Egler, Sadie Shelton (May, 17, 2021)
doi.org/10.48565/scfss2021-2420

C. Actions for Equity, Inclusiveness and Nutrition and Health

A review of evidence on gender equality, women's empowerment, and food systems
by Jemimah Njuki, Sarah Eissler, Hazel Malapit, Ruth Meinzen-Dick, Elizabeth Bryan, and Agnes Quisumbing (May 11, 2021)
doi.org/10.48565/scfss2021-1q69

Marginal areas and indigenous people – Priorities for research and action
by Sayed Azam-Ali, Hayatullah Ahmadzai, Dhrupad Choudhury, Ee Von Goh, Ebrahim Jahanshiri, Tafadzwanashe Mabhaudhi, Alessandro Meschinelli, Albert Thembinkosi Modi, Nhamo Nhamo, Abidemi Olutayo (April 5, 2021)
[doi.org/10.48565/fd4f-rk35](doi.org/10.48565/fd4f-rk35)

The White/Wiphala Paper on Indigenous Peoples' food systems
by Members of Global-Hub and of the technical editorial committee. Danny Hunter (Alliance of Bioversity International and CIAT); Gam Shimray (Asian Indigenous Peoples Pact); Thomas Worsdell; (Asian Indigenous Peoples Pact); Anne Brunel (FAO Indigenous Peoples Unit); Gennifer Meldrum (FAO Indigenous Peoples Unit); Ida Strømsø (FAO Indigenous Peoples Unit); Luisa Castañeda (FAO Indigenous Peoples Unit); Mariana Estrada (FAO Indigenous Peoples Unit); Mikaila Way (FAO Indigenous Peoples Unit); Yon Fernandez de Larrinoa (FAO Indigenous Peoples Unit); Charlotte Milbank (FAO Indigenous Peoples Unit, University of Cambridge); Tania Martinez (Greenwich University, Natural Resources Institute); Harriet Kuhnlein (McGill University, Centre for Indigenous Peoples' Nutrition and Environment); Bhaskar Vira (University of Cambridge)
[doi.org/10.4060/cb4932en](doi.org/10.4060/cb4932en)

Priorities for inclusive urban food system transformations in the Global South
by Paule Moustier, Michelle Holdsworth, Dao The Anh, Pape Abdoulaye Seck, Henk Renting, Patrick Caron, Nicolas Bricas (May 10, 2021)
[doi.org/10.48565/3xdb-qq20](doi.org/10.48565/3xdb-qq20)

Secondary Cities as Catalysts for Nutritious Diets in Low- And Middle-Income Countries
by Kesso Gabrielle van Zutphen, Dominique Barjolle, Sophie van den Berg, Breda Gavin-Smith, Klaus Kraemer, Capucine Musard, Helen Prytherch, Johan Six, Simon Winter, Kris Woltering (April 2021)
https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Secondary_Cities.pdf

The Future of Small Farms: Innovations for Inclusive Transformation
by Xinshen Diao, Thomas Reardon, Adam Kennedy, Ruth S. DeFries, Jawoo Koo, Bart Minten, Hiroyuki Takeshima, and Philip Thornton (April 2021)
https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Small_Farms.pdf

Fruits and vegetables for healthy diets: Priorities for food system research and action
by Jody Harris, Bart de Steenhuijsen Piters, Stepha McMullin, Babar Bajwa, Ilse de Jager, and Inge D. Brouwer (March 2021)
doi.org/10.48565/scfss2021-ys30

Safeguarding and using Fruit and Vegetable Biodiversity
by Maarten van Zonneveld, Gayle M. Volk, M. Ehsan Dulloo, Roeland Kindt, Sean Mayes, Marcela Quintero, Dhrupad Choudhury, Enoch G. Achigan-Dako, Luigi Guarino (April 2021)
doi.org//10.48565/scfss2021-rz27

Addressing Food Crises in Violent Conflicts
by Birgit Kemmerling, Conrad Schetter, Lars Wirkus (April 2021)
doi.org/10.48565/scfss2021-h009

COVID-19 and Food Systems: Rebuilding for Resilience
by Patrick Webb, Derek J. Flynn, Niamh M. Kelly, Sandy M. Thomas, and Tim G. Benton on behalf of the Global Panel on Agriculture and Food Systems for Nutrition (May 2021)
doi.org/10.48565/scfss2021-g940

In the age of pandemics, connecting food systems and health: a Global One Health approach
by Gebbiena M. Bron, J. Joukje Siebenga, Louise O. Fresco (February 15, 2021)
doi.org/10.48565/scfss2021-z850

D. Actions for Sustainable Resource Use and Foresight

Pathways to Advance Agroecology for a Successful Transformation to Sustainable Food Systems
by Urs Niggli, Martijn Sonnevelt, Susanne Kummer (June 2021)
doi.org/10.48565/scfss2021-wf70

Water for Food Systems and Nutrition
by Claudia Ringler, Mure Agbonlahor, Kaleab Baye, Jennie Barron, Mohsin Hafeez, Jan Lundqvist, J.V. Meenakshi, Lyla Mehta, Dawit Mekonnen, Franz Rojas-Ortuste, Aliya Tankibayeva, Stefan Uhlenbrook May 2021)
doi.org/10.48565/scfss2021-tq56

Crop Diversity, its Conservation and Use for Better Food Systems. The Crop Trust Perspective
by Stefan Schmitz, Rodrigo Barrios, Hannes Dempewolf, Luigi Guarino, Charlotte Lusti, Janet Muir (April 2021)
doi.org/10.48565/scfss2021-j983

Climate Change and Food Systems
by Alisher Mirzabaev, Lennart Olsson, Rachel Bezner Kerr, Prajal Pradhan, Marta Guadalupe Rivera Ferre, Hermann Lotze-Campen (May 2021)
https://sc-fss2021.org/wp-content/uploads/2021/05/FSS_Brief_Climate_Change_and_Food_Systems.pdf

Reduction of Food Loss and Waste – The Challenges and Conclusions for Actions Findings and Recommendations for Actions of an international Conference by the Pontifical Academy of Sciences with the Rockefeller Foundation by Joachim von Braun, Marcelo Sánchez Sorondo and Roy Steiner (February 15, 2021)
doi.org/10.48565/scfss2021-dw50

Livestock and sustainable food systems: Status, trends, and priority actions
by Mario Herrero, Daniel Mason-D'Croz, Philip K. Thornton, Jessica Fanzo, Jonathan Rushton, Cecile Godde, Alexandra Bellows, Adrian de Groot, Jeda Palmer, Jinfeng Chang, Hannah van Zanten, Barbara Wieland, Fabrice DeClerck, Stella Nordhagen, Margaret Gill (July 2021, draft)
https://sc-fss2021.org/wp-content/uploads/2021/07/FSS_Brief_Livestock_Sustainable_Food_Systems.pdf

The Vital Roles of Blue Foods in the Global Food System
by Jim Leape, Fiorenza Micheli, Michelle Tigchelaar, Edward H. Allison, Xavier Basurto, Abigail Bennett, Simon R. Bush, Ling Cao, Beatrice Crona, Fabrice DeClerck, Jessica Fanzo, Jessica A. Gephart, Stefan Gelcich, Christopher D. Golden, Christina C. Hicks, Avinash Kishore, J. Zachary Koehn, David C. Little, Rosamond L. Naylor, Elizabeth R. Selig, Rebecca E. Short, U. Rashid Sumaila, Shakuntala H. Thilsted, Max Troell, Colette C.C. Wabnitz (April 15, 2021)
doi.org/10.48565/scfss2021-bq71

E. Investment, Finance, Trade and Governance actions

Ending Hunger by 2030 – policy actions and costs
by Joachim von Braun, Bezawit Beyene Chichaibelu, Maximo Torero Cullen, David Laborde, Carin Smaller (March 4, 2021; reprint from Oct.13, 2020)
doi.org/10.48565/scfss2021-kz31

Financing SGD2 and Ending Hunger
by Eugenio Díaz-Bonilla (May 11, 2021)
doi.org/10.48565/scfss2021-ba75

Trade and Sustainable Food Systems
by Andrea Zimmermann and George Rapsomanikis (June 8, 2021)
doi.org/10.48565/scfss2021-zq03

F. Actions in Regions and Countries

Policy options for food systems transformation in Africa – from the perspective of African universities and think tanks
by Fadi Abdelradi, Assefa Admassie, John Asafu Adjaye, Miltone Ayieko, Ousmane Badiane, Katrin Glatzel, Sheryl Hendriks, Mame Samba Mbaye, Fatima Ezzahra Mengoub, Racha Ramadan, Tolulope Olofinbiyi, Simbarashe Sibanda (April 2021)
doi.org/10.48565/scfss2021-6h10

The Role of Science, Technology, and Innovation for Transforming Food Systems in Africa
by Sheryl L. Hendriks, Endashaw Bekele, Thameur Chaibi, Mohamed Hassan, Douglas W. Miano and John H. Muyonga (April 2021)
doi.org/10.48565/scfss2021-a948

The Role of Science, Technology and Innovation for Transforming Food Systems in Latin America and the Caribbean
by Elizabeth Hodson de Jaramillo, Eduardo J. Trigo and Rosario Campos (April 2021)
doi.org/10.48565/scfss2021-6w45

The Role of Science, Technology, and Innovation for Transforming Food Systems in Asia
by Paul J Moughan, Daniel A Chamovitz, S Ayyappan, Morakot Tanticharoen, Krishan Lal, Yoo Hang Kim (April 2021)
doi.org/10.48565/scfss2021-tf41

The Role of Science, Technology, and Innovation for Transforming Food Systems in Europe
by Claudia Canales, Robin Fears (April 2021)
doi.org/10.48565/scfss2021-qb52

Transforming Chinese Food Systems for both Human and Planetary Health
by Shenggen Fan, Jikun Huang, Fusuo Zhang, Wenhua Zhao, Hongyuan Song, Fengying Nie, Yu Sheng, Jinxia Wang, Jieying Bi and Wenfeng Cong (April 18, 2021)
doi.org/10.48565/scfss2021-vq06

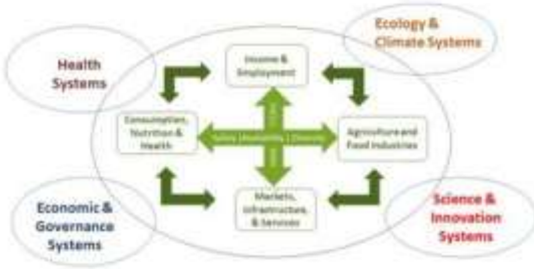
Key Areas of the Agricultural Science – Development in Russia in the Context of Global Trends and Challenges
by a Group of Russian Scientific Experts under the Supervision of the Institute of Agricultural Research of the Higher School of Economics (April 2021)
doi.org/10.48565/scfss2021-6265

Food System in India. Challenges, Performance and Promise
by Ashok Gulati, Raj Paroda, Sanjiv Puri, D. Narain, Anil Ghanwat (March 30, 2021)
doi.org/10.48565/scfss2021-b823

Re 3. Drawing on the Wealth of New Science Based Findings of Recent Most Relevant Publications of the Food Systems Related Research and Knowledge Community:

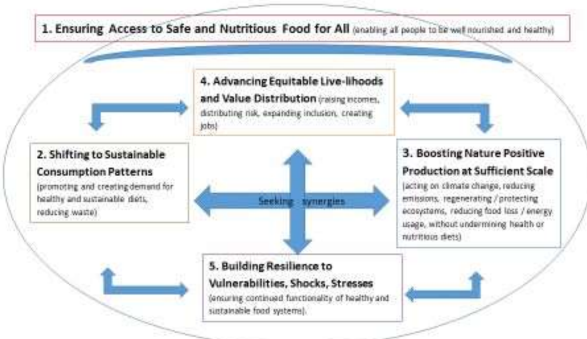
<u>More than 200 sources</u>, clustered by the generic Food Systems Concept

https://sc-fss2021.org/materials/publications-and-reports-of-relevance-for-food-systems-summit/



1. Food systems research
2. (broadly sorted by systems' components – only sources after 2016 considered)
3. Systems-wide research: Modelling Food Systems transformations- Synergies, Tradeoffs; Foresights – Policy Implications
4. Agriculture and Food Industries
5. Markets, Infrastructure and Services
6. Consumption, Nutrition and Health
7. Income and Employment

by the Action Track based Food Systems concept



1. Ensuring Access to Safe and Nutritious Food for All
2. Shifting to Sustainable Consumption Patterns
3. Boosting Nature Positive Production at Sufficient Scale
4. Advancing Equitable Livelihoods and Value Distribution
5. Building Resilience to Vulnerabilities, Shocks, Stresses

[1] FAO. (2021) *The White/Wiphala Paper on Indigenous Peoples' food systems*. Rome. https://doi.org/10.4060/cb4932en

[2] FAO, IFAD, UNICEF, WFP and WHO. 2021**. The State of Food Security and Nutrition in the World 2021.** Rome, FAO. http://www.fao.org/3/cb4474en/online/cb4474en.html

[3] Klassen, S., & Murphy, S. (2020). **Equity as both a means and an end: Lessons for resilient food systems from COVID-19.** *World Development*, *136*, 105104. https://doi.org/10.1016/j.worlddev.2020.105104

[4] WHO (2020). **Dietary recommendations: Nutritional requirements; Establishing human nutrient requirements for worldwide application.** WHO, Geneva. https://www.who.int/news-room/fact-sheets/detail/food-safety

[5] Dury S.**,** Bendjebbar P.**,** Hainzelin E.**,** Giordano T.**,** Bricas N. 2019. **Food systems at risk. New trends and challenges.** Rome: FAO-CIRAD-European Commission, 132 p. ISBN 978-2-87614-751-5https://doi.org/10.19182/agritrop/00080; FAO. 2018. **The future of food and agriculture – Alternative pathways to 2050**. Summary version. Rome. 60 pp. http://www.fao.org/3/CA1553EN/ca1553en.pdf

[6] IPBES (2019): **Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.

[7] HLPE (2017) **Nutrition and food systems. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security**, Rome 152 p. http://www.fao.org/3/a-i7846e.pdf

[8] Food and Land use Coalition (2019): https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf

[9] Bron, G. M., Siebenga, J. J., & Fresco, L. O. (2021). **In the age of pandemics, connecting food systems and health: A Global One Health approach.** *Food Systems Summit Brief by Partners of Scientific Group*. https://dx.doi.org/10.48565/scfss2021-z850

[10] Webb. P, Flynn. D.J, Kelly. N.M, Thomas. S.M, & Benton, T.G, (2020), **COVID-19 and Food Systems: Rebuilding for Resilience,** *Food Systems Summit Brief by Partners of Scientific Group.* https://dx.doi.org/10.48565/scfss2021-g940

[11] Moustier, P., Holdsworth, M., Seck, P. A., Renting, H., Caron, P., & Bricas, N. (2021). **Priorities for inclusive urban food system transformations in the Global South.** *Food Systems Summit Brief by Partners of Scientific Group.* doi.org/10.48565/3xdb-qq20

[12] Osendarp, S., Akuoku, J., Black, R., Headey, D., Ruel, M., Scott, N., ... & Heidkamp, R. (2020). **The potential impacts of the COVID-19 crisis on maternal and child undernutrition in low- and middle-income countries.** Preprint under consideration at a Nature Portfolio Journal. https://doi.org/10.21203/rs.3.rs-123716/v1

[13] von Braun, J., Zamagni, S., & Sorondo, M. S. (2020). **The moment to see the poor**. *Science*, *368*(6488), 214. https://doi.org/10.1126/science.abc2255

[14] J.von Braun, K.Afsana, L.O. Fresco, M.Hassan, M.Torero. (2021) **Food Systems – Definition, Concept and Application for the UN Food Systems Summit. Scientific Group Report for the Food Systems Summit.** doi.org/10.48565/scfss2021-re63

[15] Webb, P., Benton, T. G., Beddington, J., Flynn, D., Kelly, N. M., & Thomas, S. M. (2020). **The urgency of food system transformation is now irrefutable**. Nature Food, 1(10), 584–585. https://doi.org/10.1038/s43016-020-00161-0;

Mushtaq, S., Kath, J., Stone, R. et al. **Creating positive synergies between risk management and transfer to accelerate food system climate resilience.** Climatic Change 161, 465–478 (2020). https://doi.org/10.1007/s10584-020-02679-5

[16] Allen, S., O. Badiane, L. Sene, and J. Ulimwengu. 2014. Government Expenditures, **Health Outcomes, and Marginal Productivity of Agricultural Inputs: The Case of Tanzania**. *Journal of Agricultural Economics.* Vol. 65, No. 3, 637-661; Wouterse, F. and O. Badiane. 2019. **The role of health and educational attainment in agricultural production: Evidence from smallholders in Burkina Faso**. Agricultural Economics, Volume 50, 4.

[17] Hainzelin, E., Caron, P., Place, F., Dury, S., Echeverria, R., & Harding, A. (2021). **How could science-policy interfaces boost food system transformation?** *Food Systems Summit Brief by Partners of Scientific Group* https://dx.doi.org/10.48565/scfss2021-4y32

[18]Fears. R, & Canales. C, (2021). **The Role of Science, Technology and Innovation for Transforming Food Systems Globally.** *Food Systems Summit Brief by Partners of Scientific Group*. http://doi.org/10.48565/scfss2021-q703

[19] Diao, X., Reardon, T., Kennedy, A., DeFries, R.S., Koo, J., Minten, B., Takeshima,H & Thornton, P (2021), **The Future of Small Farms: Innovations for Inclusive Transformation,** *Food Systems Summit Brief by Partners of Scientific Group*. https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Small_Farms.pdf

[20] Masters, W.A, Martinez,E.M, Greb, F, Herforth, A & Hendriks, S **(2021). Cost and Affordability of Preparing a Basic Meal around the World** *Food Systems Summit Brief by Partners of Scientific Group.* https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Cost_of_Basic_Meals.pdf

[21] Center for Development Research (ZEF) of the University of Bonn in cooperation with the Food and Agriculture Organization of the United Nations (FAO). (2020). **Investment Costs and Policy Action Opportunities For Reaching a World Without Hunger (SDG 2)** http://www.fao.org/documents/card/en/c/cb1497en

[22] Hendriks, S, Soussana, J.-F., Cole, M., Kambugu, A. & Zilberman, D. (2021**) Ensuring Access to Safe and Nutritious Food for All Through Transformation of Food Systems Paper on Action Track 1**. doi.org/10.48565/scfss2021-wg92

[23] Hendriks, S., de Groot Ruiz, A., Acosta, M.H., Baumers, H., Galgani, P., Mason-D'Croz, P., Godde, C., Waha, K.,…. &, Watkins, M (June 1, 2021). **The True Cost and True Price of Food,. Scientific Group Report for the Food Systems Summit.** **https://sc-fss2021.org/wp-content/uploads/2021/06/UNFSS_true_cost_of_food.pdf**

[24] Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., ... & Campbell, B. (2019). **Climate risk management and rural poverty reduction.** Agricultural Systems, 172, 28-46. https://doi.org/10.1016/j.agsy.2018.01.019

[25] Miller, V., Yusuf, S., Chow, C. K., Dehghan, M., Corsi, D. J., Lock, K., Popkin, B., Rangarajan, S., Khatib, R., Lear, S. A., Mony, P., Kaur, M., Mohan, V., Vijayakumar, K., Gupta, R., Kruger, A., Tsolekile, L., Mohammadifard, N., Rahman, O., … Mente, A. (2016). **Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: Findings from the Prospective Urban Rural Epidemiology (Pure) study**. *The Lancet. Global Health*, *4*(10), e695-703. https://doi.org/10.1016/S2214-109X(16)30186-3

[26] Jaacks, L. M. 2019. **Taxes on saturated fat, salt, and sugar improve the healthiness of grocery purchases, but changes are frustratingly small**. *The Lancet Public Health, 4*(8): e363–e364. https://doi.org/10.1016/S2468-2667(19)30110-0 ;

Micha, R., Karageorgou, D., Bakogianni, I., Trichia, E., Whitsel, L. P., Story, M., Peñalvo, J. L., & Mozaffarian, D. (2018). **Effectiveness of school food environment policies on children's dietary behaviors: A systematic review and meta-analysis**. *PLOS ONE, 13*(3), e0194555. https://doi.org/10.1371/journal.pone.0194555;

Schreinemachers, P., Baliki, G., Shrestha, R. M., Bhattarai, D. R., Gautam, I. P., Ghimire, P. L., Subedi, B. P., & Brück, T. (2020). **Nudging children toward healthier food choices: An experiment combining school and home gardens**. *Global Food Security, 26*, 100454. https://doi.org/10.1016/j.gfs.2020.100454

[27] Zilberman, D., Lu, L., & Reardon, T. (2019). **Innovation-induced food supply chain desig**n. *Food Policy, 83,* 289–297. https://doi.org/10.1016/j.foodpol.2017.03.010 ;

Zarnowiecki, D., Mauch, C. E., Middleton, G., Matwiejczyk, L., Watson, W. L., Dibbs, J., Dessaix, A., & Golley, R. K. (2020). **A systematic evaluation of digital nutrition promotion websites and apps for supporting parents to influence children's nutrition**. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 17. https://doi.org/10.1186/s12966-020-0915-1

[28] Herrero, M., Hugas, M., Lele, U., Wira, A., & Torero, M. (2021). **Shift to Healthy and Sustainable Consumption Patterns. Scientific Group Report for the Food Systems Summit: A Paper on Action Track 2.** *The Scientific Group for the UN Food System Summit 2021* https://dx.doi.org/10.48565/scfss2021-9240

[29] Harris, J., Piters, B. D. S., McMullin, S., Bajwa, B., de Jager, I., & D Brouwer, I. (2021). **Fruits and vegetables for healthy diets: Priorities for food system research and action**. *Food Systems Summit Brief by Partners of Scientific Group* https://dx.doi.org/10.48565/scfss2021-ys30

[30] van Zutphen, K.G., Barjolle, D., van den Berg, S., Gavin-Smith, B, Kraemer, K., Musard, C., Prytherch, H., Six, J., Winter, S & Woltering K **Secondary Cities as Catalysts for Nutritious Diets in Low- And Middle-Income Countries.** . *Food Systems Summit Brief by Partners of Scientific Group.* https://sc-fss2021.org/wp-content/uploads/2021/06/FSS_Brief_Secondary_Cities.pdf

[31] Hirvonen, K., Bai, Y., Headey, D., & Masters, W. A. (2020). **Affordability of the EAT–Lancet reference diet: a global analysis.** *The Lancet Global Health, 8*(1), e59–e66. https://doi.org/10.1016/S2214-109X(19)30447-4 ,

Headey, D. D., & Alderman, H. H. (2019). **The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents**. *The Journal of Nutrition, 149*(11), 2022-2033. https://doi.org/10.1093/jn/nxz158

[32] See at https://foodperiodictable.org/about/

[33] Kau, A., Ahern, P., Griffin, N. *et al.* **Human nutrition, the gut microbiome and the immune system.** *Nature* 474, 327–336 (2011). https://doi.org/10.1038/nature10213

[34] Downs, S., & Demmler, K. M. (2020). **Food environment interventions targeting children and adolescents: A scoping review**. *Global Food Security, 27*, 100403 https://doi.org/10.1016/j.gfs.2020.100403 .

[35] Mirzabaev, A., Olsson, L., Kerr, R. B., Pradhan, P., Guadalupe, M., Ferre, R., & Lotze-Campen, H. **Climate Change and Food Systems***. Food Systems Summit Brief by Partners of Scientific Group.* *https://sc-fss2021.org/wp-content/uploads/2021/05/FSS_Brief_Climate_Change_and_Food_Systems.pdf*

[36] Sperling, F., Havlik, P., Denis, M., Valin, H., Palazzo, A., Gaupp, F., & Visconti, P. (2020). **Transformations within reach: Pathways to a sustainable and resilient world-Resilient Food Systems**. http://pure.iiasa.ac.at/16822

[37] Kemmerling, B., Schetter, C. & Wirkus, L. (2021) **Addressing Food Crises in Violent Conflicts.** *Systems Summit Brief by Partners of Scientific Group*. https://dx.doi.org/10.48565/scfss2021-h009

[38] Sultan Barakat, Sansom Milton. 2020. Localisation Across the Humanitarian-Development-Peace Nexus. Journal of Peacebuilding & Development. Vol 15, Issue 2, 2020 https://doi.org/10.1177/1542316620922805

[39] Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., Webb, P., Lartey, A., & Black, R. E. (2013). **Evidence-based interventions for improvement of maternal and child nutrition: What can be done and at what cost?** *The Lancet, 382*(9890), 452–47; Hidrobo, M., Hoddinott, J., Kumar, N., & Olivier, M. (2018). **Social Protection, Food Security, and Asset Formation.** *World Development, 101*, 88–103. Ruel, M. T. &, Alderman, H., & Maternal and Child Nutrition Study Group. (2013). **Nutrition-sensitive interventions and programmes: How can they help to accelerate progress in improving maternal and child nutrition?** *The Lancet*, *382*(9891), 536-551.

[40] Zimmermann, A & Rapsomanikis, G (2021) **Trade and Sustainable Food Systems.** *Food Systems Summit Brief by Partners of Scientific Group. http://doi.org/10.48565/scfss2021-zq03*

[41] Hodson, E., Urs, N., Kaoru, K., Lal, R., Sadoff, C (2021), **Boost Nature Positive Production: A paper on Action Track 3**. *The Scientific Group for the UN Food System Summit 2021, 2021.* https://dx.doi.org/10.48565/scfss2021-q794;

Hertel, T W., Elouafi, I., Frank, E., Morakot, T, (2021), **Building Resilience to Vulnerabilities, Shocks and Stresses: A paper on Action Track 5**. *The Scientific Group for the UN Food System Summit 2021.* https://dx.doi.org/10.48565/scfss2021-cz84

[42] Daily, G. C., & Polasky, S. (2019). **How do we stem biodiversity loss?** In *Biological Extinction: New Perspectives* (pp. 332-357). Cambridge University Press. https://doi.org/10.1017/9781108668675.015;

Rahman, H. M., & Hickey, G. M. (2019). **What does autonomous adaptation to climate change have to teach public policy and planning about avoiding the risks of maladaptation in Bangladesh?** Frontiers in Environmental Science, 7, 2. https://doi.org/10.3389/fenvs.2019.00002

[43] Jensen, E.S., Carlsson, G. & Hauggaard-Nielsen, H. **Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis.** *Agron. Sustain. Dev.* **40,** 5 (2020). https://doi.org/10.1007/s13593-020-0607-x

[44] Neufeld, L M., Jikun. H., Ousmane, B., Patrick C., Forsse, L.S, (2021) **Advance Equitable Livelihoods: A paper on Action Track 4**. The Scientific Group for the UN Food System Summit 2021. https://dx.doi.org/10.48565/scfss2021-tw37;

Lal, R. (2017**). Improving soil health and human protein nutrition by pulses-based cropping systems**. Advances in Agronomy, 145, 167-204. https://doi.org/10.1016/bs.agron.2017.05.003

[45] van Zonneveld, M., Volk, G. M., Dulloo, M. E., Kindt, R., Mayes, S., Quintero, M., ... & Guarino, L. (2021). **Safeguarding and using fruit and vegetable biodiversity.** *Food Systems Summit Brief by Partners of Scientific Group* https://dx.doi.org/10.48565/scfss2021-rz27

[46] Schmitz, S., Barrios, R., Dempewolf, H., Guarino, L., Lusti, C., & Muir, J. (2021**). Crop Diversity, its Conservation and Use for Better Food Systems. The Crop Trust Perspective**. *Food Systems Summit Brief prepared by Research Partners of the Scientific Group for the Food Systems Summit.* https://dx.doi.org/10.48565/scfss2021-j983

[47] Niggli, U., Sonnevelt, M., & Kummer, S. (2021**). Pathways to advance agroecology for a successful transformation to sustainable food systems.** *Food Systems Summit Brief prepared by Research Partners of the Scientific Group* doi.org/10.48565/scfss2021-wf70;

Snapp, S., Kebede, Y., Wollenberg, E., Dittmer, K. M., Brickman, S., Egler, C., & Shelton, S. (2021). **Delivering climate change outcomes with agroecology in low-and middle-income countries: evidence and actions needed**. **.** *Food Systems Summit Brief prepared by Research Partners of the Scientific Group.* http://doi.org/10.48565/scfss2021-2420

[48] Alae-Carew, C., Nicoleau, S., Bird, F. A., Hawkins, P., Tuomisto, H. L., Haines, A., ... & Scheelbeek, P. F. (2020). **The impact of environmental changes on the yield and nutritional quality of fruits, nuts and seeds: a systematic review**. Environmental Research Letters, 15(2), 023002. https://doi.org/10.1088/1748-9326/ab5cc0

[49] Donald Bundy, Susan Horton, Dean Jamison, George Patton, Nilanthi de Silva (editors). 2018. **Re-Imagining School Feeding: A High Return Investment in Human Capital and Local Economies.** DCP3 and WFP. http://www.dcp-3.org/schoolfeeding

[50] Trigo, E., Chavarria, H., Pray, C., Smyth, S. J., Torroba, A., Wesseler, J., Zilberman, D., Martinez, J.F. (2021) **The Bioeconomy and Food Systems Transformation**: *Food Systems Summit Brief prepared by Research Partners of the Scientific Group* http://doi.org/10.48565/scfss2021-w513

[51] Dobermann, A., Bruulsema, T., Cakmak, I., Gerard, B., Majumdar, K., McLaughlin, M., Reidsma, P., Vanlauwe, B., Wollenberg, L., Zhang, F., Zhang, X. **A New Paradigm for Plant Nutrition**: *Food Systems Summit Brief prepared by Research Partners of the Scientific Group.* http://doi.org/10.48565/SCFSS2021-HG55

[52] Van der Ploeg, J. D., Barjolle, D., Bruil, J., Brunori, G., Madureira, L. M. C., Dessein, J., ... & Wezel, A. (2019). **The economic potential of agroecology: Empirical evidence from Europe.** Journal of Rural Studies, 71, 46-61. https://doi.org/10.1016/j.jrurstud.2019.09.003

[53] World Economic Forum. 2021. The Global Risks Report 2021. http://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2021.pdf

[54] Fuglie, K., Gautam, M., Goyal, A., & Maloney, W.F. (2020). **Harvesting Prosperity: Technology and Productivity Growth in Agriculture.** Washington, DC: World Bank. doi:10.1596/978-1-4648-1393-1

[55] Smith, P., Calvin, K., Nkem, J., Campbell, D., Cherubini, F., Grassi, G., Korotkov, V., Le Hoang, A., Lwasa, S., McElwee, P., Nkonya, E., Saigusa, N., Soussana, J., Taboada, M. A., Manning, F. C., Nampanzira, D., Arias-Navarro, C., Vizzarri, M., House, J., … Arneth, A. (2020). **Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification?** *Global Change Biology, 26*(3), 1532–1575. **https://doi.org/10.1111/gcb.14878**

[56] van Vliet, S., Kronberg, S. L., & Provenza, F. D. (2020). **Plant-Based Meats, Human Health, and Climate Change**. *Frontiers in Sustainable Food Systems, 4*, 128. https://doi.org/10.3389/fsufs.2020.00128

[57] Jensen ES, Carlsson G and Hauggaard-Nielsen H (2020) **Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global- scale analysis.** *Agronomy for Sustainable Development, 40*(1), 5. https://doi.org/10.1007/s13593-020-0607-x

[58] Lal, R. (2017). **Improving soil health and human protein nutrition by pulses-based cropping systems**. In Advances in Agronomy (Bd. 145, S. 167–204). Elsevier. https://doi.org/10.1016/bs.agron.2017.05.003
[59] Pretty, J., Benton, T.G., Bharucha, Z.P. *et al.* **Global assessment of agricultural system redesign for sustainable intensification**. *Nat Sustain* **1,** 441–446 (2018). https://doi.org/10.1038/s41893-018-0114-0
[60] Padulosi S., Phrang Roy and Francisco J. Rosado-May (2019). **Supporting Nutrition Sensitive Agriculture through Neglected and Underutilized Species - Operational Framework.** Bioversity International and IFAD, Rome, Italy. 39 pp.
[61] Lal, R. (2020). **Managing Organic Matter Content for Restoring Health and Ecosystem Services of Soils of India,** Journal of the Indian Society of Soil Science, Vol. 68, No. 1, pp 1-15 (2020) DOI: 10.5958/0974-0228.2020.00001.8
[62] Webb, P., Flynn, D. J., Kelly, N. M., & Thomas, S. M. (2021). **The Transition Steps Needed to Transform Our Food Systems**. *Food Systems Summit Brief prepared by Research Partners of the Scientific Group.* http://doi.org/10.48565/scfss2021-hz63
[63] Benfica, R., Chambers, J., Koo, J., Nin-Pratt, A., Falck-Zepeda, J., Stads, G. J., & Arndt, C. (2021). **Food System Innovations and Digital Technologies to Foster Productivity Growth and Rural Transformation.** *Food Systems Summit Brief prepared by Research Partners of the Scientific Group* https://dx.doi.org/10.48565/scfss2021-6180
[64] Thornton, P. K., Kristjanson, P., Förch, W., Barahona, C., Cramer, L., & Pradhan, S. (2019). **Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge?** *Global Environmental Change, 52*, 37-48. https://doi.org/10.1016/j.gloenvcha.2018.06.003
[65] Le Q.B., Nkonya E., Mirzabaev A. (2016) **Biomass Productivity-Based Mapping of Global Land Degradation Hotspots**. In: Nkonya E., Mirzabaev A., von Braun J. (eds) **Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development**. Springer, Cham. https://doi.org/10.1007/978-3-319-19168-3_4
[66] IPCC, 2019: **Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems** [P.R. Shukla et l., (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf
[67] Ringler, C., Agbonlahor, M., Baye, K., Barron, J., Hafeez, M., Lundqvist, J., ... & Uhlenbrook, S. (2021). **Water for Food Systems and Nutrition**. *Food Systems Summit Brief prepared by Research Partners of the Scientific Group. doi.org/10.48565/scfss2021-tg56*
[68] Mirzabaev, A., et al 2019: **Desertification. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems** [P.R. Shukla, et al. (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/06_Chapter-3.pdf
[69] Shukla, et al (2019). **Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Intergovernmental Panel on Climate Change**. https://www.ipcc.ch/site/assets/uploads/sites/4/2020/02/SPM_Updated-Jan20.pdf
[70] Smith, P. et al. 2019: **Interlinkages Between Desertification, Land Degradation, Food Security and Greenhouse Gas Fluxes: Synergies, Trade-offs and Integrated Response Options. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems** [P.R. Shukla, et al., (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/09_Chapter-6.pdf
[71] Guerra, C.A., Heintz-Buschart, A., Sikorski, J. et al. **Blind spots in global soil biodiversity and ecosystem function research**. Nat Commun 11, 3870 (2020). https://doi.org/10.1038/s41467-020-17688-2
[72] Bernard, B., Lux, A. **How to feed the world sustainably: an overview of the discourse on agroecology and sustainable intensification.** Reg Environ Change 17, 1279–1290 (2017). https://doi.org/10.1007/s10113-016-1027-y;

Pretty, J., Benton, T.G., Bharucha, Z.P. et al. **Global assessment of agricultural system redesign for sustainable intensification.** Nat Sustain 1, 441–446 (2018). https://doi.org/10.1038/s41893-018-0114-0

HLPE. 2019. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. http://www.fao.org/3/ca5602en/ca5602en.pdf

[73] Olsson, L. et al. (2019) **Land Degradation. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems** [P.R. Shukla, et al., (eds.). https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/07_Chapter-4.pdf
[74] Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., ... & Wunder, S. (2014). **Environmental income and rural livelihoods: a global-comparative analysis**. *World development*, *64*, S12-S28. https://doi.org/10.1016/j.worlddev.2014.03.006
[75] Azam-Ali, S., Ahmadzai, H., Choudhury, D., Goh, E. V., Jahanshiri, E., Mabhaudhi, T., ... & Olutayo, A. (2021**). Marginal areas and indigenous people–Priorities for research and action**. *Food Systems Summit Brief Prepared by Partners of the Scientific Group* https://dx.doi.org/10.48565/fd4f-rk35
[76] Leape, J., Micheli, F., Tigchelaar, M., Allison, E. H., Basurto, X., Bennett, A., Bush, S. R., Cao, L., ..., & Wabnitz, C. C.C. 2021**. The Vital Roles of Blue Foods in the Global Food System, - Protect and develop the potential of blue foods to help end malnutrition,** *Food Systems Summit Brief Prepared by Partners of the Scientific Group* https://dx.doi.org/10.48565/scfss2021-bg71

[77] Costello, C., L. Cao, S. Gelcich et al. 2019. *The Future of Food from the Sea*. **Capture Fisheries: Current status and trends**, Washington, DC: World Resources Institute. Available online at www.oceanpanel.org/future-food-sea

[78] International Food Policy Research Institute. 2020. *2020 Global Food Policy Report: Building Inclusive Food Systems*. Washington, DC: International Food Policy Research Institute. - **Reshaping Food Systems** https://doi.org/10.2499/9780896293670

[79] Taylor, B; Tonnang, HEZ; Beale, T; Holland, W; Oronje, M; Abdel-Rahman, EM; Onyango, D., Finegold, C; Zhu, J; Pozzi, S, Murphy, ST (2021) **Leveraging data, models & farming innovation to prevent, prepare for & manage pest incursions: Delivering a pest risk service for low-income countries.** *Food Systems Summit Brief Prepared by Partners of the Scientific Group.* https://dx.doi.org/10.48565/scfss2021-ty56

[80] Lal, R. **Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic.** *Food Sec.* **12,** 871–876 (2020). https://doi.org/10.1007/s12571-020-01058-3

[81] Malabo Montpellier Panel (2019). **Byte by Byte: Policy Innovation for Transforming Africa's Food System with Digital Technologies**, Dakar. June 2019. DOI: https://doi.org/10.2499/9780896296848

[82] FABLE (2021). Environmental and agricultural impacts of dietary shifts at global and national scales. FABLE Policy Brief July 2021. Paris: Sustainable Development Solutions Network (SDSN).

[83] Global Panel on Agriculture and Food Systems for Nutrition. (2020). **Future Food Systems: For people, our planet, and prosperity**. https://www.glopan.org/foresight2/; International Food Policy Research Institute (IFPRI). (2020). **Global Food Policy Report: Building Inclusive Food Systems**. https://doi.org/10.2499/9780896293670

[84] Scimago journal and country rankings for 2018

[85] Declaration of the first NEPAD Ministerial conference on Science and Technology, 7 November 2003, Johannesburg, South Africa https://sarpn.org/documents/d0000614/index.php

[86] Beintema, N., Pratt, A. N., & Stads, G.-J. (2020). **Key Trends in Global Agricultural Research Investment. ASTI Program Note**. https://www.asti.cgiar.org/sites/default/files/pdf/Global-update-ASTI-note.pdf; von Braun, J. (2020) "**Transforming Food Systems – the challenges of food security, malnutrition, climate change, ecosystems degradation, well-being**" Presentation at the European Union - FAO Strategic Dialogue (May 06, 2021) https://sc-fss2021.org/wp-content/uploads/2021/05/EU_FAO_JvonBraun_Keynote_6-5-2021.pdf

[87] Herrero, M., Thornton, P.K., Mason-D'Croz, D. *et al.* **Innovation can accelerate the transition towards a sustainable food system.** *Nat Food* **1,** 266–272 (2020). https://doi.org/10.1038/s43016-020-0074-1

[88] Tambo, J.A. T. Wünscher. (2017) Farmer-led innovations and rural household welfare: Evidence from Ghana. Journal of Rural Studies, 2017

[89] von Braun, J., Bezawit C., Torero M. C., Laborde, D., & Carin, S (2021). **Ending Hunger by 2030 – policy actions and costs**, *Food Systems Summit Brief prepared by Research Partners of the Scientific Group for the Food Systems Summit* 2021 https://dx.doi.org/10.48565/scfss2021-kz31;

Díaz-Bonilla, E. (2021). **Financing SGD2 and Ending Hunger**. *Food Systems Summit Brief prepared by Research Partners of the Scientific Group for the Food Systems Summit 2021* https://dx.doi.org/10.48565/scfss2021-ba75

[90] Inter-Academy Partnership. (2018). **Opportunities for future research and innovation on food and nutrition security and agriculture: The Inter-Academy Partnership's global perspective**. https://www.interacademies.org/sites/default/files/publication/iap_fnsa_global_web_complete_28nov.pdf

[91] von Braun, J. (2018). **Global Institutions: Governance Reform for Food, Nutrition, and Agriculture.** 2018 Global Food Policy Report, 62–71 https://doi.org/10.2499/9780896292970_08;

[92] Inter-Academy Partnership. (2018). **Opportunities for future research and innovation on food and nutrition security and agriculture: The Inter-Academy Partnership's global perspective**.

von Braun, J., & Kalkuhl, M. (2015). **International Science and Policy Interaction for Improved Food and Nutrition Security: Toward an International Panel on Food and Nutrition (IPFN).** ZEF Working Paper Series, 142(October).

[93] Hendriks, S. L., Bekele, E., Chaibi, T., Hassan, M., Miano, D. W., & Muyonga, J. H. (2021). **The Role of Science, Technology, and Innovation for Transforming Food Systems in Africa.** doi.org/10.48565/scfss2021-a948;

Hodson de Jaramillo, E., Trigo, E. J., & Campos, R. (2021). **The Role of Science, Technology and Innovation for Transforming Food Systems in Latin America and the Caribbean.** doi.org/10.48565/scfss2021-6w45;

Moughan, P. J., Chamovitz, D. A., Ayyappan, S., Tanticharoen, M., Lal, K., & Kim, Y. H. (2021). **The Role of Science, Technology, and Innovation for Transforming Food Systems in Asia.** doi.org/10.48565/scfss2021-tf41;

Fan, S., Huang, J., Zhang, F., Zhao, W., Song, H., Nie, F., ... & Cong, W. (2021). **Transforming Chinese Food Systems for both Human and Planetary Health.** doi.org/10.48565/scfss2021-vq06;

Serova, E., Orlova, N., Popov, V., Petukhova, M., Osmakova, A., Kobiakov, O., ... & Tolmachev, P. (2021). Key Areas of the Agricultural Science Development in Russia in the Context of Global Trends and Challenges. doi.org/10.48565/scfss2021-6265;

Gulati, A., Paroda, R., Sanjiv, P., Narain, D., & Ghanwat, A. (2021). **Food System in India: Challenges, Performance and Promise**. doi.org/10.48565/scfss2021-b823, *Food Systems Summit Brief prepared by Research Partners of the Scientific Group for the Food Systems Summit 2021*

[94] Including the CGIAR (https://www.cgiar.org/), the Global Forum on Agricultural Research and Innovation (GFAR) https://www.gfar.net/), the High Level Panel of Experts on Food Security and Nutrition (HLPE) (http://www.fao.org/cfs/cfs-hlpe), and the InterAcademy Partnership (IAP) (https://www.interacademies.org/)