Science for Transformation of Food Systems: Opportunities for the UN Food Systems Summit

By

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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.

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Summary
Food systems at the global level and in many countries and regions are failing to end hunger, don’t provide adequate nutritious foods for healthy diets, contribute to obesity and don’t assure safety of foods. How we produce and consume food is having 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 toward sustainability and equity.

We focus with this paper on the key role of science and research, as they are essential for innovations that accelerate the transformation to healthier, more sustainable, more equitable, and more 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 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 research and development of innovations with scientists that 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 toward reaching them, for instance by quantitative analyses and food systems modelling.

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 needed complex innovations will not be forthcoming.

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

Drawing on a comprehensive food systems framework, actions for seven science-driven innovations are elaborated in this paper:
1. Innovations to end hunger and increase 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 to facilitate inclusion of and empowerment and rights of women and youth, and Indigenous Peoples.

4. Biotechnology and digital innovations for improving peoples’ health, enhancing systems’ productivity, and restoring ecological wellbeing.

5. Innovations to keep – and where needed, regenerate -- productive soils, water and landscapes, and to 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 efficiency and inclusiveness of food systems and empowerment of youth and rural communities.

These innovations and their related goal-oriented actions do not exist in silos; there are synergies and trade-offs between them that must be considered in order 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; full inclusion of marginalized and vulnerable populations; gender equity; sound governance at all levels from 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, and that means there is an important role for innovation in financing. We propose, as a key food systems science policy target, that governments allocate at least 1% of their food and agriculture GDP to food systems science and innovation, with the perspective of exceeding that target. Least developed countries (LDCs) should be assisted in reaching quickly the equivalent of this target.

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, 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 scientific framework for constructive and evidence-based interaction for moving ahead, not just 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 for the complex area of food systems. The UNFSS may wish to
consider exploring a pathway toward a treaty on food systems. That should include innovation
and strengthening of the science-policy interfaces at local, national and international levels
where these interfaces get 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.
Science for Innovations of Food Systems: Opportunities for the UN Food Systems Summit

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 toward reaching them, for instance by quantitative and qualitative analyses and food systems modelling. This paper aims to address both of these contributions of science.

We note that science is not a panacea for the needed food systems innovations toward a sustainable system. Science like other actions can even have negative external effects, to be prevented by ethics and public policy. Yet, without accelerated interdisciplinary food systems science, the needed innovations for a sustainable food system will not be achieved. Science and innovation are critical for achieving food systems that serve people and 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 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 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). We in particular draw attention to the comprehensive contribution to knowledge about sustainable food systems by Indigenous Peoples\(^1\) and the opportunities of mutual learning between traditional knowledge and experience based systems and science systems 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 10\(^{th}\) person -
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 are 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. About 600 million people fall ill each year due to consumption of contaminated or unsafe foods. We are losing ground on the progress we have already made, and we face the prospect of severely compromising 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 getting entrenched. For many people, engaging in activities in the food system would seem to offer the most viable opportunities to escape poverty, and 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, to health, to safe water and sanitation, and to education continue to be violated. Ending poverty and gross inequalities remains essential for the achievement of the SDGs.

Food systems relate to the three basic dimensions of sustainability — social, economic, and environmental. 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 degradation of land and soil, water, and climate, as well as biodiversity loss. Climate change is more and more 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 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.

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. 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 and rural areas. This is likely to worsen inequalities and undernutrition, including child undernutrition, which can have life-long consequences. Modelling 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. COVID-19 further increases food insecurity and poverty, which may become much more serious if comprehensive policy responses are not implemented in a timely, and evidence-based manner.
Box: Conceptualizing Food Systems

“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”\(^\text{14}\). 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 human kind 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 delivery of health and well-being while being embedded in the transformation towards a sustainable circular bioeconomy. Science and innovation impact the functioning of the system as a whole and within its building blocks and the interconnections among them.\(^\text{15}\)

Figure 1: food systems conceptual framework\(^\text{16}\)

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.\(^\text{17}\)
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 on 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 paid now on how to make food systems more resilient to extreme weather events and other stressors induced by the changing climate\textsuperscript{18}. 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\textsuperscript{19}.

The changing state of the art of science and innovation and the important lessons 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, biosciences, earth sciences, social sciences, remote sensing, AI & 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 can also be involved in the design, implementation and monitoring of action, in order to learn and draw lessons for impact at scale\textsuperscript{20}. That includes also science that focuses on knowledge gaps, risks, uncertainties, and controversies. Many approaches from discovery research to implementation research and including both primary research and modelling 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, more equitable, and more resilient food systems\textsuperscript{21}. To enable full inclusion of poor and marginalized populations, including smallholder communities\textsuperscript{22}, in the process of and to 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\textsuperscript{23} knowledge systems, but recommends to invest more in programs exploring mutual learning and innovation across traditional and modern knowledge and science systems considering both on an equal footing.

The Scientific Group highlights the need for systems innovations, not only single-issue innovations, and calls for enhanced collaboration between and among different disciplines of sciences to this end. 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. 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 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 required levels of essential nutrients. 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. Policy innovations are needed to repurpose subsidies toward related supportive investments that facilitate a sustainable food system.

An important role of science here is also to identify their indirect effects. While efforts must be made to move closer to the true price of food, which should include external costs associated with climate change, biodiversity loss, and adverse health effects, capacities for internalizing such externalities are limited and thus cautious approaches are warranted to develop non-price instruments, including regulatory-based instruments, to help deal with such externalities. The true cost accounting approaches are to be pursued in the whole food system, and related capacities build up in the corporate and public sectors.

Measures that incentivize production and market supply of fruits and vegetables and consumption of healthy diets, and related innovations for increasing income of small holders address some of these challenges. Rising incomes of consumers do not, however, automatically lead to increasing consumption of healthy diets – even when accessibility and affordability are not constraints, consumption of healthy diets is not assured as people may still not change their consumption behaviour. 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

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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.
the blame for poor nutrition on consumer behaviour\textsuperscript{32}. Considerably more science is needed to understand the drivers in the processing, marketing and food environments. Moreover, 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\textsuperscript{33}. Dietary targets elaborated on by the World Health Organization (WHO), such as those related to adequate fruits and vegetable consumption, sweeteners, etc. should be considered accordingly.

Science intensive and promising opportunities such as the scaling up of sustainable cold chain technology to make perishable foods (especially vegetables and fruits) more available and affordable\textsuperscript{34} and at the same time reduce food loss and waste must be pursued, along with complementary investments in infrastructure to reduce transportation and other related costs and thereby lower food prices\textsuperscript{35}.

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 labelling, prohibition of trans-fats, regulation of 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\textsuperscript{36}. Research on the costs of acting versus not acting on the key drivers of diets and food systems change and the impact of these changes are 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.**\textsuperscript{37} 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\textsuperscript{38}, and in the armed conflicts\textsuperscript{39}. The implementation experiences of triple nexus approaches of humanitarian-peace-development nexus should be accompanied with evidence seeking social science. Science-based responses to catastrophes require preparedness. The capacity to understand, monitor, analyze, and communicate vulnerabilities, crises, and risks must be strengthened\textsuperscript{40}. Opportunities to expand and improve food security forecasting and monitoring must be seized. Local meteorological capacities must be expanded as accurate weather forecasting is of critical importance to farming communities.

Currently food prices 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 trade – both international and interregional -- can provide a more economical option for dealing with localized extreme weather events. Ensuring free and 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 41.

Climate change is the defining issue of our time 42. Agriculture, as well as forestry and related land use change are the single largest driver of multiple environmental pressures, and large 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 the promotion of sustainable food systems must be rewarded, with payments for ecosystem services as an option. 43 Boosting nature-based solutions 44 and nature-positive production calls for transforming soil management, farm input use, agronomy, 45 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 46; and protecting the agriculture- and forest-related genetic base 47. 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 reduction of monocultures 48. Similarly, bio-stimulants from land and marine sources that can replace chemical fertilizers in promoting soil plant growth and increasing yields can be further explored 49.

Novel insurance products and early warning mechanisms, and efficient social protection programs that include job creation and a variety of nutrition programs including school feeding programs strengthen resilience. 50 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. Future scientific and technological developments can increase the portfolio of bioproducts developed from local biodiversity, in keeping with a circular bioeconomy approach 51. Accelerating the reduction of food waste and loss calls for developing food processing, refrigeration, storage and warehouse technologies 52. It also calls for modifying consumption behaviors, life style choices, and perverse incentive to buy much more than needed. Moving quickly toward climate-positive and climate-resilient food systems should employ carbon pricing at appropriately high levels and incentives for technologies that facilitate adaptation and mitigation 53. 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 is only a very small proportion of climate finance, and that needs to increase\textsuperscript{54}.

Food systems need to become more prepared for and resilient not just 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\textsuperscript{55}, 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.

3.3. Innovations to overcome inefficient and unfair land, credit, labor, and natural resource use arrangements, and to facilitate inclusion of and empowerment and rights of women and youth and Indigenous Peoples\textsuperscript{56}. Poverty and hunger are interlinked and reducing extreme poverty directly impacts the elimination of hunger and all forms of malnutrition. Among the effective ways to sustainably eradicate poverty and inequality is to boost the opportunities and capacities of the poor and those living in situations of vulnerability, through ensuring more equitable access to resources and access to natural resources and economic assets. Providing and protecting land rights of smallholders – especially female smallholders -- is critical in that context, as is overcoming exploitative share tenancy.

Ensuring decent work is another 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 targeted asset building investments and programs, that empower poor people to build their asset base, offer promise. Yet, 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\textsuperscript{57}. Many food systems are unequal or breed inequalities through land and other asset ownership and market power relationships; 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 more equitable. The situation of the youth as well as of the elderly deserve 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 women and youth more fully and meaningfully in policymaking processes. Youth have the right and the responsibility to learn about food systems dynamics
and to be fully engaged in opportunities to transform the food systems they will inherit. Women who are cognizant of the needs and wants of women and of societal norms and issues, their voice in policymaking is critical for engagement in feeding families producing food and earning income. The inclusive transformation of smallholder farming will be imperative. 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. Bioscience and related digital innovations for peoples’ health, systems’ productivity, and ecological wellbeing. Adopting the One Health approach, i.e. health of soil, plants, animals, people, ecosystems and planetary processes, being one and indivisible, would make an important contribution. Specific science opportunities for innovations include genetic engineering, genome editing, alternative protein (including more plant-based and insect-derived protein) sources and essential micronutrient sources, cell factories, microbiome and soil and plant health technologies, plant nutrition technologies, animal production and health technologies, and aquatic food technologies. These advances in science and technology have great potential to meet food system challenges such as restoring soil health and functionality, improving resource efficiency of cropping systems, breeding orphan and underserved crops, and re-carbonization of the terrestrial biosphere. It must be acknowledged, however, that there are potential risks associated with science based innovations that must be considered within the science systems and with societal dialogues by transparency, ethical standards and reviews, biosafety measures, and where needed with regulatory policies.

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. However, bio- sciences increasingly benefit from digital innovations and artificial intelligence. Yet, these technologies sometimes run the risk of exclusion through 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 bioscience and digital innovations and ensuring that they, especially the potentially controversial technologies, contribute to sustainability is not sufficient – it will be important to adapt them to local conditions, to make them accessible and affordable to farmers, especially smallholders, and to 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 are able to better use the available technology and implement innovations. 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 biosciences and digital technologies, and get 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 to protect the agricultural genetic base and biodiversity. One-third of global land area is degraded. Soil degradation is being exacerbated by climate change along with land misuse and soil mismanagement. Water is becoming an increasingly scarce and polluted resource. Ecosystems services of land, forests, and water are being undermined. Primary forests are being over-exploited, including by non-sustainable expansion of agriculture. A sustainable food system must be based on sustainable soil, water and forest uses and on protection of ecosystems. Technology-based innovations are needed to support sustainable soil and agricultural water management, protect natural resources from degradation and restore degraded resources, and maintain and even increase biodiversity in agricultural settings. This underlines the need to advance knowledge in plant genetic diversity and microbial diversity, taking into account local climate variability. The use of modern hand-held digital devices for in-field measurement of soil carbon and remote sensing measurement of soil carbon can be of significant opportunity for both climate policy and productive plant nutrient management. This example highlights interconnectedness of technological and policy innovations.

Similarly, regenerative agricultural practices for resilient landscapes at scale offer opportunities that 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 needed. Innovations in agroforestry with trees and bushes and in agro-ecology can contribute to large-scale productive land use combined with ecological and climate-positive ecosystems services. Wild foods (e.g. berries and fruits) are important for food security and nutrition both for smallholder farmers and Indigenous Peoples. Food systems, including Indigenous Peoples’ food systems, need to better understood and protected when designing policies and measures to support forest systems.

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 include the aquatic food systems more fully. Science-based innovations for sustainable aquatic foods that protect and harness oceans and coastal areas can play a growing role in ending hunger and malnutrition and in building healthy, nature-positive and resilient food systems. 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\textsuperscript{83}.

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 for bringing the harvesting of oceans to sustainable levels and protecting biodiversity.

3.7. Engineering and digital innovations for efficiency and inclusiveness of food systems and empowerment of the youth and rural communities. Examples of digital innovations and engineering that hold much promise to make food systems more efficient, productive, and sustainable include artificial intelligence, big data analysis, remote sensing, robotics, digitization\textsuperscript{84}, mechanization, sub-surface drip irrigation with conservation agriculture, precision agriculture, vertical farming, indoor farming, and digitized food processing\textsuperscript{85}.

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. 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 connecting them to the wider economy. Noteworthy is also the growing role of digital innovations in science and technology processes that serve bio-chemical sciences and engineering of relevance for food systems.

Further development to make digital technologies affordable and accessible for small- and medium-sized farmers, as well as poor and vulnerable groups, is essential to avoid reducing their competitiveness even further.\textsuperscript{86} In this context, it would be timely to revisit and reinvigorate agricultural extension services. Attention to employment effects and a sharper focus on the poorest is also called for, as well as attention to ethical considerations. Investments are also needed to scale up infrastructure to enable universal access to digital technologies and key infrastructure, in particular access rural electrification wherever possible based on renewable energy sources.

Digitization in the food system is not necessarily enhancing equity, and 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. Of note is that digitization itself facilitates decentralized organization of science and research producing technological, policy and institutional innovations that are context-specific, and thereby offers extraordinary new opportunities to re-organize how science is undertaken, delivered, and used.

4. Modelling Synergies and Trade-offs Between Actions in Food Systems

Food systems do not operate in isolation. Achieving the food systems related SDGs and in particular SDG2 requires accelerated institutional and policy innovations as well as technology-based innovations that go beyond food systems, and that are coherently connected to transformations in health systems (One Health), in energy and environment systems (climate), and in economic systems (trade), as well as to evolving science and knowledge systems. **Strengthening interactions between food system scientists and health scientists, climate scientists, energy scientists and more will be paramount going forward** in order to generate the necessary expertise. Furthermore, partnerships (in research and with potential users) are needed to increase the probabilities of success. Supporting local innovations, developing co-creation of knowledge, participatory science and place-based living labs should be considered and explored at scale.

The above-mentioned innovations and actions do not exist in silos, they are connected and there are also synergies and trade-offs between them. Knowing about these synergies and trade-offs is of critical importance for maximizing the effectiveness and efficiency of proposed innovations and actions. A supposedly convincing “game changer” in one food systems domain may cause adverse effects in another domain, such as a hunger-reducing income transfer through a fertilizer subsidy may have adverse environmental effect if this leads to excessive nitrogen use. To avoid such incoherence and unintended consequences requires sound food systems modelling.

A recent review of the advanced global modelling literature found **strong synergies between SDG2 and other subsistence-related SDGs**. In particular, SDG1 (no poverty) is central for food security and can unlock many additional benefits across SDGs. SDG2 is also closely integrated with SDG3 (good health and well-being), due to the close link between malnutrition and maternal and child health, as well as the prevalence of diet-related mortality risk. Other socioeconomic SDGs have been shown to be key enablers for SDG2, including SDG4 (education), SDG5 (gender equality), SDG8 (decent work and economic growth), SDG10 (reduced inequality), SDG11 (sustainable cities and communities), SDH16 (peace, justice and strong institutions), and SDG17 (partnership) for the goals. These potential synergies merit greater attention and bridge-building across sectors for accelerating food systems transformation.
At the same time, trade-offs must be recognized. Agricultural production is substantially contributing to the risks of exceeding critical global sustainability thresholds in the domain of global warming, nutrient pollution, water quantity and quality, biodiversity loss and soil degradation. Climate action (SDG13) will require reducing or adapting production of greenhouse gas intensive products (meat, dairy, rice); achieving biodiversity on land (SDG15) will require further efforts to limit deforestation associated with agriculture expansion, as well as establishment of new conservation areas; environmental water flows (SDG6) will require decreasing water withdrawal for irrigation. Quantitative assessments show more efficient production systems and technologies, pricing of externalities, and integrated resource management can mitigate some of these trade-offs, but are unlikely to succeed in resolving these altogether.

In the face of all these challenges, forward-looking analyses indicate that deeper transformations of global food systems, combining both supply-side and demand-side measures, will be required to simultaneously achieve SDG2 targets and other goals. These will entail new supply-side investments, smoothly functioning trade and effective markets, as well as modified consumer behavior, with a fast transition towards more sustainable and healthy diets and sharp reductions in food losses and waste. These collective food system
transformations highlight the importance of SDG12 (responsible production and consumption), as a key supporting goal for the successful evolution of global food systems towards SDG2.

A comprehensive modelling concept as pursued by Laborde and Torero (2021)\textsuperscript{90} is depicted in stylized ways in Figure 3.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{	extit{An integrated modeling framework: The MIRAGRODEP CGE (source: Laborde and Torero, 2021)}}
\end{figure}

With this modelling framework, Laborde and Torero (2021) model six individual interventions similar to the ones presented in Figure 2, in terms of their impact on the food systems, prevalence of undernutrition and ecological effects in terms of GHG emissions, land and energy use, and use of chemical inputs. Due to synergies and complementarities between these scenarios, the authors also assess them as a package. The sensitivity to the results is also assessed under different governance principles, such as land use policies.\textsuperscript{2} The scenarios are listed in Table 1 and are organized around three main pillars: achievement of a more efficient and more 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 based on the baseline which is consisted with the State of Food Security and Nutrition in the World 2020 which by 2019 reported 690 million undernourished people and healthy diets were unaffordable for almost three billion people in the world.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Scenario & Description & Impact on Food Systems & Impact on Undernutrition & Impact on Ecological Effects \\
\hline
Scenario 1 & Increase in efficiency & Increase in food availability & Decrease in undernutrition & Decrease in GHG emissions \\
\hline
Scenario 2 & Increase in inclusiveness & Increase in access to healthy diets & Increase in well-being & Decrease in land use \\
\hline
Scenario 3 & Combination of Scenario 1 and 2 & Increase in food availability and access to healthy diets & Further decrease in undernutrition and increase in well-being & Further decrease in GHG emissions and land use \\
\hline
\end{tabular}
\caption{Comparison of different scenarios}
\end{table}

\textsuperscript{2} Other aspects of the global food systems such as trade policies are also analyzed to see how they interact with the main interventions considered.
A first key result is the confirmation that ending chronic hunger at a 5% level is reachable by 2030 with the right balance of interventions. While no intervention alone, at a realistic scale, could solve the problem, we see in Figure 4 that key structural interventions to increase the efficiency of the 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 in 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 well targeted programs, such as school feeding interventions, will be required. When adding such safety nets in the model by designing them
endogenously to left no one behind, it is possible to cover the 2.4 billion remaining people without economic access to healthy diets.

![Graph: Reduction in chronic undernourishment excluding safety nets and school feeding programs](image1)

**Figure 4:** Number of people (mio) removed from chronic undernourishment situation in 2030

Source: Preliminary results based on Laborde and Torero (2021)

![Graph: Beyond hunger: Reduction in healthy diets unaffordability excluding safety nets and school feeding programs](image2)

**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 resources mobilization, but the cost is manageable and represent 8 percent of the size of food markets\(^3\). Figure 6, provides the decomposition of this total cost by action (panel a) and the distribution by group of countries (panel b). The case of the actions referred to as “better choices” in Table 1, i.e. consumer incentives and farm subsidies re-purposing, don’t contribute to the total costs because they have been designed to be income neutral for the government, and to the producers (farm subsidies), or consumers (food tax/subsidies) for each country. The cost structure is dominated by the large structural investment in physical, human and knowledge capital of the innovation package impacting through value chains and the national economies (45 percent) and the social safety nets (36 percent). Of course, these two main items are different in nature since the latter involves recurrent spending every year and will have to be managed, and financed, by the governments alone. A critical finding of the analysis is the role of other interventions to minimize the cost of the safety nets. Indeed, to cover the income gap of the 3 billion people who – without action - could not afford healthy diets in 2030, countries will have to redistribute 1.4 trillion dollars (constant 2017) annually. By investing in the various programs, the value of the required safety nets drops by about two thirds (428 billion dollars globally) in 2030. Using safety nets to make sure that everyone could afford healthy diets is required, but if used alone they will be far too expensive.

Source: Preliminary results based on Laborde and Torero (2021)

*Figure 6: The cost of actions: magnitude and distribution*

\(^3\) 2030 spending and food market values, as estimated by the model to guarantee full consistency
The second panel in Figure 6 shows the distribution of the spending by region, i.e. where the money needs to be spent and/or invested. Since the needs are unevenly distributed globally, a significant effort in terms of global coordination, and even solidarity, will be required, especially to support the transformation of the food systems of low-income countries.

As previously shown, no single intervention could achieve the end of malnourishment, and that synergies are needed to tackle the various source causes of the problem but also to minimize the total cost of the package. However, their complementarity goes beyond their impacts on household food security and their cost-effectiveness, and therefore we also need to combine them to address heterogeneous environmental trade-offs.

![Environmental Trade-offs (selected)](Image)

Source: Preliminary results based on Laborde and Torero (2021)

Figure 7: Impacts of actions on environmental indicators

Finally, it is important to mention, that the actions modelled will generate tradeoffs in greenhouse gas emissions (GHG), agricultural land, increase of use of chemical inputs (index of chemical inputs per hectare), biodiversity (i.e. reduction of forest habitat) and in energy consumption as shown in Figure 7. As shown, the level of tradeoffs across all interventions are relatively small being the highest for the innovation and full package, and even being negative for the case of food loss and waste. However, this highlights the need for policies that stimulate investments in innovations for carbon farming (growing carbon in soil and trees as a tradable commodity) and related payment schemes for ecosystems services.
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; supportive global and national policies for public goods.\textsuperscript{91}

Enabling the food systems transformations requires constant \textit{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).\textsuperscript{92} Thousands of 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 innovative financing and capacity strengthening. Science systems have been decimated in many countries, especially in the global South. To tap the potentials of science, the public funding of food systems science and related research partnerships need to expand. Governments need to revisit 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 science investments in agriculture and food systems and \textbf{allocate at least 1\% of their food and agriculture GDP to food systems science and innovation with a perspective to substantially exceed this target}, while also accelerating investment in basic science that is becoming more and more relevant for food systems.\textsuperscript{93} Least developed countries (LDCs) should be assisted in reaching quickly the equivalent of this target. For instance, African ministers responsible for science and technology have already committed, about 20 years ago, to increase public expenditures on research and development to at least 1\% of GDP per annum.\textsuperscript{94}

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.\textsuperscript{95} Private sector here is a broad concept, ranging from semi-subsistence farmers to corporations. It is often overlooked, that the former are proven innovators too.\textsuperscript{96} Intellectual property rights protection issues require revisiting to align with sustainability expectations, especially for science opportunities that address overcoming hunger and malnutrition.\textsuperscript{97} New institutional arrangements may be discussed for sharing intellectual property that could directly reduce hunger and address sustainability concerns.

\textbf{Investments in capacity} for science and innovation need to expand. Of particular importance are investments for improving data, methods, models and tools for all food system components.
and actors, as well as for building or enhancing (shared) research infrastructures related to (research) data, modelling platforms, observation and monitoring networks to support the required advances in research and innovation, especially in the global South. 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. 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, 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. 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 can turn into local policy actions. This requires that science aligns with local policy agendas, which in turn calls for fostering greater collaboration between the science communities and the actors who are charged with making policies reality, including local communities. The proximity of science to decision making is important to connect timeliness and relevance of science where and when needed to policy. Similarly, the development of local infrastructure and local expertise to effectively link science to decision-making is important. It is also required that 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 transformation of farming, application of new technologies, promotion of 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 development of innovations and with scientists being more open to and collaborating on fair terms with start-ups.
The international sharing of science and participation of science in the follow up to the Food Systems Summit as part of implementation agendas are 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 knowledge of Indigenous Peoples’ knowledge) or are generated from new research – and this calls for investing in strengthening the skills of all food system actors, especially in developing countries where these skills tend to be limited and uneven in nature. In many instances, what is lacking is not more evidence but more actionable knowledge that may contribute to systemic changes, which requires supporting local innovations and encouraging and facilitating co-creation / co-design of knowledge. In support of that, leading research organizations from world regions could form networks (or alliances) to share science and develop actionable knowledge supporting food systems transformations.

Any 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 to mobilize the needed 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 toward investment for sustainable development and scale up and redesign of social safety nets; 3) 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)\textsuperscript{101}. 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.

6. Food Systems Governance and Science-policy Interface for Food Systems Innovation

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 all 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 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.

Related, food systems science and policy need a stronger scientific framework for constructive and evidence-based interaction for moving ahead, not just for the Food Systems Summit 2021 but for the long term.\(^{102}\) We call for strengthening the science-policy interfaces at national and international levels with strong international and independent voices for science-informed and evidence-based food systems policies. 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.\(^{103}\) We suggest to explore options for an inclusive, global Science-Policy Interface (SPI) for a sustainable food system that 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 that 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.\(^{104}\) Addressing these considerations requires a global mechanism that mobilizes the leading food systems scientists worldwide and across disciplines to support the Science-Policy Interface 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 Science–Policy Interface must be strengthened to enhance credibility, relevance and legitimacy. We call upon governments and UN agencies to initiate a process to explore options, existing\(^{105}\) as well as new, for a global Science-Policy Interface (SPI) for a sustainable food system. As such, this would be a concrete outcome of the UNFSS.

The assessment of the Summit outcomes is a matter of country and global actions. Science can play an important role with co-designing methods and tools to support and monitor the implementation of actions, with undertaking implementation research to accompany and learn from and scale up potential actions. Science and policy have a lot to gain from cooperation but the **independence of science must not be compromised** in order to address policy and institutional opportunities and failures with evidence-based insights. Yet, 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, and that sometimes irritates policy makers and practitioners. Science, adhering to responsible and ethical principles, must collaborate with a broad range of stakeholders. Helpful are improved quality and timeliness of science translation and communication for policymakers and non-technical audiences, 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 needed 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 on the following sources for its emerging recommendations


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)


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)


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 Mastes, Claudia Sadoff, Jean-François Soussana, Maria Cristina Tirado, Maximo Torero, Matthew Watkins
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)

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)
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**C. Actions for Equity, Inclusiveness and Nutrition and Health**

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D. Actions for Sustainable Resource Use and Foresight

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E. Investment, Finance, Trade and Governance actions

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F. Actions in Regions and Countries

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More than 200 sources, clustered by the generic Food Systems Concept


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

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


