Comment

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School children in Madagascar eat lunch provided as part of a nutrition initiative run by the World Food Programme.

Food systems: seven priorities to end hunger and protect the planet

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

Here's how the United Nations should harness science and technology to improve nutrition and safeguard the environment.

The world's food system is in disarray. One in ten people is undernourished. One in four is overweight. More than one-third of the world's population cannot afford a healthy diet. Food supplies are disrupted by heatwaves, floods, droughts and wars. The number of people going hungry in 2020 was 15% higher than in 2019, owing to the COVID-19 pandemic and armed conflicts[1].

Our planetary habitat suffers, too. The food sector emits about 30% of the world's greenhouse gases. Expanding cropland, pastures and tree plantations drive two-thirds of the loss in forests (5.5 million hectares per year), mostly in the tropics[2]. Poor farming practices degrade soils, pollute and deplete water supplies and lower biodiversity.

As these interlinkages become clear, approaches to food are shifting — away from production, consumption and value chains towards safety, networks and complexity. Recent crises around global warming and COVID-19 have compounded concerns. Policymakers have taken note.

In September, the United Nations secretary-general, António Guterres, will convene a Food Systems Summit. This is only the sixth UN summit on food since 1943, and the first with heads of states in the UN General Assembly. A group of leading scientists, known as the Scientific Group, has been tasked with ensuring that the science underpinning the 2021 summit is robust, broad and independent. We, the authors, are this group's chair and vice-chairs. Although such approaches are familiar in areas such as climate change and biodiversity, this marks the first time that scientists have been explicitly brought in to multilateral discussions around food (see *Nature* **595**, 332; 2021).

The global food system needs a revamp — in policies and institutions as well as on social, business and technology fronts[3]. Science is one lens for making sure that changes are integrated and collectively deliver better outcomes.

But the task is challenging. Food spans many disciplines — not least agriculture, health, climate science, artificial intelligence and digital science, political science and economics. The indirect, adverse effects of policies on climate change, biodiversity loss and health need to be factored in to the true costs of food; these are estimated to be about twice the current market value of food consumption globally[4]. A range of voices is crucial. The Scientific Group is engaging with hundreds of experts across civil society, including Indigenous peoples, producer and youth organizations and the private sectors.

Here we highlight the key roles that scientists should take to accelerate the transformation to healthier, more sustainable, equitable and resilient food systems. These seven priorities reflect the Scientific Group's evidence base, comprising more than 50 reports and briefs (see go.nature.com/3dtoazu).

Seven priorities

Science-driven advances are needed to address the following challenges.

End hunger and improve diets. Scientists need to identify optimal conditions and opportunities for investments to make healthy and nutritious foods more available, affordable and accessible. Measures that jointly improve more than one of these are most effective. For example, increased irrigation on small farms in Tanzania and Ethiopia has enhanced productivity, dietary diversity and farmers' incomes[5].

Three big game-changers are: enhancing research and development in agriculture and food to increase productivity in a sustainable way; slashing food waste and losses; and adding income and nutrition components to social-protection programmes. Research priorities to cut waste include scaling up solar energy and battery storage technologies to make food processing and preservation more affordable. New forms of packaging using recycled materials, coatings of nanomaterials and even edible films would keep foods fresh for longer. School feeding programmes, together with incentives to keep children in education (such as take-home rations for parents) have seen success in Mali, for example, where they increased school enrolment by 10 percentage points[6]. Under COVID-19 lockdowns, these types of programme became even more relevant.

Researchers also need to study behavioural barriers to healthy eating, such as snacking under stress. They should develop policy guidelines for educational food labels, and model the impacts of putting taxes and regulations on unhealthy foods (such as sugar and trans-fats). The health properties of fortified foods and cultivated meats must also be established.

De-risk food systems. The more global, dynamic and complex food systems become, the more open they are to new risks. Scientists need to improve how they understand, monitor, analyse and communicate such vulnerabilities. For example, droughts, the expansion of biofuels and financial speculation after the sudden imposition of trade barriers led to food price hikes in 2008 (ref. 7). The COVID-19 pandemic and armed conflicts have shaken food value chains across Africa this year, driving up food prices. Successful initiatives exist, combining on-the-ground observations of food systems and nutrition with forecasting. These include FEWS NET (https://fews.net) and the joint analyses from the UN Food and Agriculture Organization and the World Food Programme on early warnings of food insecurity[8].

Policies and economic solutions are needed. For example, new insurance products aided by remote sensing and weather forecasts would provide cover for lost crops and livestock. Solar-powered irrigation systems would reduce risk from drought. Smartphone apps would provide farmers with information on local crop pests, weather risks and market opportunities; these are already used in Kenya, Senegal, India and Bangladesh[9]. Payment schemes are needed to encourage farmers to manage and capture carbon in soils and trees, and to trade it.

"Protecting the land rights of smallholders, women and Indigenous peoples is paramount."

Protect equality and rights. Poverty and inequalities associated with gender, ethnicity and age restrict many people's access to healthy foods. Socio-economic researchers need to suggest inclusive ways to transform the more than 400 million smallholder farms worldwide. They must identify pathways out of inequitable and unfair arrangements over land, credit and labour, and empower the rights of women and youth. For example, if female-headed households in southern Ethiopia had the same resources as male-headed ones, their productivity in maize (corn) would increase by more than 40%, to match that of the latter[10].

Protecting the land rights of smallholders, women and Indigenous peoples is paramount. Technology can ensure transparency and efficiency. For example, using blockchain ledgers of ownership rights to allocate land could be an opportunity in Ghana[11]. At the transnational scale, the Land Matrix Initiative collects and shares data on big land acquisitions and investments in low- and middle-income countries; it covers deals in almost 100 nations worldwide. Similar solutions are needed to protect the land rights of Indigenous peoples[12]. Also required are efforts to build local research capacity, educational programmes around food and farming, and training and financing opportunities in rural areas.

Boost bioscience. Researchers need to find ways to restore soil health and improve the efficiency of cropping, crop breeding and recarbonizing the soil and biosphere. Linkages among all Earth systems must be considered together — known as a One Health approach (see go.nature.com/3jy7ekh).

Alternative sources of healthy protein need to be advanced, such as plant-based and insect-derived proteins, including for animal feed. Plant-breeding techniques that capture nitrogen from the air, to reduce the need for fertilizers and increase nutrients, should be investigated. Genetic engineering and biotechnology should be applied to increase the productivity, quality and resistance of crops to pests and drought. Recent examples include banana varieties that are resistant to Fusarium wilt fungal diseases, and pest-resistant *Bt* aubergines. To widen access to bioscience technologies, intellectual-property rights, skills and data sharing should be addressed.

Protect resources. Tools are needed to help people to manage soils, land and water sustainably. For example, hand-held digital devices and remote sensing can track concentrations of soil carbon and other nutrients. Artificial-intelligence systems and drones allow farmers to spot areas that need irrigation, fertilization and protection from pests. Soil microbes can be harnessed to improve soil structure, carbon storage and yields. Researchers need to adapt and scale up such technologies.

Biodiversity and genetic bases need to be protected. Seed varieties must be preserved, and their phenotypes and genotypes explored in the contexts of climate change and nutrition. Traditional food and forest systems, including those of Indigenous peoples, need to be better understood and supported in national agricultural research systems. Cooperation for mutual benefit should be explored, as has been done for climate adaptation in US Indigenous areas[13].

ANTON RAHARJO/NURPHOTO/GETTY

A seaweed farmer in Bali, Indonesia.

Sustain aquatic foods. Most of the focus on food so far has been on soil-based agriculture. Fish, shellfish and aquatic plants such as seaweed have much to offer nutritionally and environmentally. Aquatic foods need to be better integrated into the understanding of food systems[14]. Researchers should look for ways to increase nutritional diversity in aquatic foods and sequester carbon in marine and freshwater environments.

Ecological-science perspectives and global cooperation and institutions are needed to make harvesting of oceans, coastal waters and freshwater resources sustainable and protect biodiversity. The sustainability of fish-feeding systems needs attention; for example, by exploring the use of insect rearing, oil-rich modified legumes and micro-algae as fish feed.

Harness digital technology. Robots, sensors and artificial intelligence are increasingly used on farms: to harvest crops and milk cows, for example. Sensors can monitor the origin and quality of ingredients and products along the food-processing chain to reduce losses and guarantee food safety. But most farmers and producers still don't have access. To spread the benefits, devices need to become cheaper and easier to purchase and use. Rental services similar to Uber for farm machinery should be developed, as has been done with tractors in India. Rural electricity supplies will have to be expanded, along with IT training and education.

First steps

The 2021 Food Systems Summit is a great opportunity to end hunger by 2030 and set in train a sustainable food system. Previous summits have delivered change: creating the FAO (after 1943); strengthening the global food-research partnership CGIAR and founding the International Food Policy Research Institute (after 1974); accelerating the human right to food (2002); and establishing monitoring systems to warn of food-price crises (2009).

The breadth of the 2021 agenda could be a hindrance, however, to achieving its goals. To avoid failure, delegates should focus. They should prioritize establishing a guiding framework — for transforming diverse national and local food systems, as well as global networks, with the challenges of trade, finance, climate, innovation and governance.

Debates will be fierce. Food is a contentious topic. Disagreements abound over goals, pathways and speed of change, and the roles of science and technology, the private sector and the UN. For example, some see agroecology as the only acceptable way of farming; some view biotechnology and gene editing as dangers; others see opportunities. The Scientific Group has aimed to offer a scientific basis to this diversity of perspectives.

Actions and targets

Once plans are agreed, the UN Food Systems Summit will need to move to implementation. Here are our suggestions.

First, boost finance. On the research front, we propose that governments allocate to food research at least 1% of the proportion of their nations' gross domestic product that relates to food systems. Many countries spend only half of that. Least-developed countries should be given aid to reach a similar level. To end hunger for the poorest, we propose the establishment of a special fund. This would be supported by development-aid donors and bonds backed by the International Monetary Fund and World Bank. Research and modelling would be required on implementation and impacts.

Second, increase scientific capacity. The special fund could be used to strengthen research capacity in low- and middle-income countries, and expand research collaborations between the public and private sectors, and among farmers, start-up firms in food value chains and science communities. Sharing research infrastructure and data between the global south and global north would be a good start.

Third, strengthen science–policy interfaces. In stark contrast to many other fields, agriculture, food security and nutrition do not have an international agreement or convention to consolidate actions. We call on the UN Food Systems Summit and UN member states to explore an intergovernmental treaty or framework convention on food systems, analogous to the conventions on climate, biodiversity and desertification agreed on in Rio de Janeiro in 1992. The framework will need to include a strong independent scientific body that provides policy advice in the follow-up to the summit. We recommend that all science organizations and academies with food-relevant research be included in a preparatory process.

Bringing the tools of science to the table will help to transform the global food system to end hunger and achieve the UN Sustainable Development Goals by 2030.

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