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Agriculture technology for sustainable development: leaving no one behind

Report of the Secretary-General

Summary

In 2020, the burden of malnutrition in all its forms was already a challenge, and the impacts of the coronavirus disease (COVID-19) pandemic exacerbated pre-existing drivers of undernourishment. The application of science and technology in developing sustainable agricultural practices has the potential to accelerate transformative change in support of the 2030 Agenda for Sustainable Development. Technological advancements, in particular in the areas of biotechnologies, digital technologies, renewable energy, mechanization and data advancement, present opportunities to boost production, improve efficiency, minimize waste and reduce drudgery in agrifood systems, benefiting economic, social and environmental well-being. Good governance and inclusive planning are key to ensuring that new technologies benefit vulnerable populations rather than widen inequality gaps. Addressing the digital divide and gender inequality is also key to ensuring that no one is left behind.

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I. Introduction

1. The present report has been prepared in response to General Assembly resolution 74/215, in which the Assembly requested the Secretary-General to submit to it at its seventy-sixth session an action-oriented report that examines the current technological trends and key advances in agricultural technologies, provides illustrative examples of the transformative use of technologies at scale and includes recommendations that assist Member States in accelerating their efforts to implement the goals and targets of the 2030 Agenda for Sustainable Development.

2. For the purposes of the report, "agriculture" encompasses crops, livestock, fisheries, marine products, forestry and primary forestry products. The "agrifood system"[1] includes how food is grown, fished, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten and disposed of, as well as all of the people, activities, investments and choices that contribute to food and agricultural products. "Agricultural technologies" are considered in the report to include the application of scientific knowledge to develop techniques to deliver a product and/or service that enhances the productivity and sustainability of agrifood systems.

II. Overview

3. In his 2019 report on agriculture technology for sustainable development (A/74/238), the Secretary-General highlighted how agricultural technologies can be harnessed to advance sustainable, inclusive and resilient agrifood systems for achieving the Sustainable Development Goals. In the *Global Sustainable Development Report 2019*, the independent group of scientists appointed by the Secretary-General identified food systems and nutrition patterns as an entry point to implementing transformative change across the Goals. The group also identified science and technology as a key lever to advance systemic change.

4. In the present report, the Secretary-General analyses technological trends in agriculture and the potential benefits, risks and uncertainties surrounding emerging technologies. Examples are given of promising technologies that can help to move agrifood systems beyond business-as-usual operations to provide integrated solutions for achieving the Sustainable Development Goals. The Secretary-General also reiterates that agricultural technologies are not an end in themselves, but must be strategically aligned with sustainable development objectives.

5. The report serves to underscore that, to increase equitable access to nutritious foods, minimize environmental impacts across agrifood value chains and support decent work and sustainable livelihoods, the deployment of technologies needs to be accompanied by a range of enabling social, political and institutional factors. Poverty and marginalization often prevent vulnerable groups from benefiting from new technologies. Unless the root causes of poverty and marginalization are addressed, technological innovations risk bypassing the needs of vulnerable groups and thereby exacerbating inequalities.

[1] As defined in the report of the Council of the Food and Agriculture Organization of the United Nations (FAO) on its 166th session, report No. CL 166/REP (Rome, 2021). Available at www.fao.org/3/nf693en/nf693en.pdf.

III. Challenges

6. In 2020, between 720 and 811 million people were undernourished globally, as many as 161 million more than in 2019.[2] The impacts of the coronavirus disease (COVID-19) pandemic, protracted conflict and weather extremes are exacerbating pre-existing drivers of undernourishment. In 2020, 155 million people across 55 countries and territories experienced acute food insecurity at crisis levels or worse, an increase of around 20 million people from 2019.[3]

7. A healthy diet costs far more than the international poverty threshold of $1.90 per day (ranging from approximately $3.27 to $4.57 per day,[4] and a staggering 3 billion people cannot afford one.[5] Moreover, the global obesity rate continues to grow; undernutrition coexists with overweight, obesity and other diet-related non-communicable diseases. Globally, more than 1.9 billion adults are overweight,[6] and 11 million deaths were attributable to dietary risk factors in 2017.[7] In 2020, 149 million children under the age of 5 were stunted, 45 million affected by wasting and 39 million overweight.[8] If current consumption patterns continue, diet-related health costs linked to non-communicable diseases and their mortality are projected to exceed $1.3 trillion per year by 2030.[9]

8. At the same time, almost one third of the global food produced is lost or wasted, including approximately 14 per cent at the post-harvest level[10] and 17 per cent at the consumer and retail levels.[11] Unsafe food is known to cause acute and chronic diseases, with the burden of unsafe food disproportionally affecting vulnerable and marginalized people.

9. Existing methods of food production, distribution and consumption are not fully aligned with the global agendas of food security, the Sustainable Development Goals or the Paris Agreement. Food systems are responsible for 34 per cent of total anthropogenic greenhouse gas emissions, with the majority of the emissions associated with agriculture and land use or land-use change activities.[12] Climate change is amplifying existing risks and creating new ones. The growing frequency and intensity of extreme weather and climate events and associated disasters is

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[2] FAO, International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organization (WHO), *The State of Food Security and Nutrition in the World 2021: Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All* (Rome, FAO, 2021).

[3] Food Security Information Network and Global Network Against Food Crises, *Global Report on Food Crises 2021: Joint Analysis for Better Decisions* (Rome, 2021). Crisis-level or worse is measured as Integrated Food Security Phase Classification phases 3–5.

[4] Anna Herforth and others, "Cost and affordability of healthy diets across and within countries", background paper (Rome, FAO, 2020).

[5] FAO, IFAD, UNICEF, WFP and WHO, *The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Health Diets* (Rome, FAO, 2020).

[6] See www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

[7] Ashkan Afshin and others "Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017", *The Lancet*, vol. 393, No. 10184 (2019).

[8] UNICEF, WHO and World Bank, "Levels and trends in child malnutrition: key findings of the 2021 edition" (Geneva, WHO, 2021).

[9] FAO, IFAD, UNICEF, WFP and WHO, *The State of Food Security and Nutrition in the World 2020: Transforming Food Systems for Affordable Health Diets.*

[10] FAO, IFAD, UNICEF, WFP and WHO, *The State of Food Security and Nutrition in the World 2019: Safeguarding against Economic Slowdowns and Downturns* (Rome, FAO, 2019).

[11] United Nations Environment Programme (UNEP), *Food Waste Index Report 2021* (Nairobi, 2021).

[12] Monica Crippa and others, "Food systems are responsible for a third of global anthropogenic GHG emissions", *Nature Food*, vol. 2, No. 3 (2021).

devastating livelihoods and jeopardizing agrifood systems. Food security faces a range of unprecedented biological hazards, such as desert locust swarms of magnitudes previously unseen.

10. Food production occupies half of the habitable land on the planet.[13] The expansion of agricultural land continues to be the main driver of deforestation, increasing water scarcity, land degradation and desertification. Biodiversity is under severe threat, with nearly 1 million species at risk of extinction.[14] Agricultural land expansion and animal trade increase the risks of zoonotic and transboundary animal and plant diseases. Antimicrobial resistance further threatens to undermine human health.

11. The intersecting crises of climate change, biodiversity loss, pollution and the COVID-19 pandemic have increased risks and vulnerabilities for agrifood systems.[15] Between 2008 and 2018, agriculture absorbed 26 per cent of the overall economic impact of medium- to large-scale natural hazard-induced disasters, with disaster-related loss in crop and livestock production valued at $280 billion.[16]

12. Approximately 1.3 billion people across the world live in multidimensional poverty.[17] Extreme income poverty is rising on account of the pandemic for the first time in decades, with women, young people, indigenous peoples and other vulnerable groups at particularly high risk. COVID-19 mitigation measures have caused disruptions to livelihoods, constrained access to food and increased food prices.[18] In remote rural areas and some border regions, vulnerable groups have suffered from disruptions in food supply chains, trade and seasonal migration.

13. Agrifood systems directly employ over 1 billion people and provide livelihoods to another 3.5 billion. There is an increasing proportion of female labour in agriculture, but with persistent gender inequality women are often marginalized from the development and use of technologies. The pandemic is further aggravating their marginalization, poverty and food insecurity, including by increasing their care burden.[19] Furthermore, the prevalence of food insecurity is higher among women than among men globally. This is true not only in humanitarian circumstances, but also in non-crisis households in which women are culturally expected to eat last and least, even if they are pregnant or breastfeeding.[20]

14. In sub-Saharan Africa and South Asia, the youth population is growing rapidly; but young people in rural areas of low-income countries face a variety of challenges in terms of access to resources, capacity development and technologies.[21] In the

[13] UNEP, *Global Environment Outlook 6: Healthy Planet Healthy People* (Cambridge, United Kingdom of Great Britain and Northern Ireland, 2019).

[14] Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, "The global assessment report on biodiversity and ecosystem services: summary for policymakers" (Bonn, Germany, 2019).

[15] UNEP, *Making Peace with Nature: A Scientific Blueprint to Tackle the Climate, Biodiversity and Pollution Emergencies* (Nairobi, 2021).

[16] FAO, *The Impact of Disasters and Crises on Agriculture and Food Security 2021* (Rome, 2021).

[17] United Nations Development Programme and Oxford Poverty and Human Development Initiative, *Global Multidimensional Poverty Index 2020: Charting Pathways out of Multidimensional Poverty – Achieving the SDGs* (2020).

[18] International Food Policy Research Institute, *2021 Global Food Policy Report: Transforming Food Systems after COVID-19* (Washington, D.C., United States of America, 2021).

[19] Titan Alon and others, "The impact of COVID-19 on gender equality", National Bureau of Economic Research Working Paper Series, No. 26947 (Cambridge, Massachusetts, United States, 2020).

[20] FAO, "Gendered impacts of COVID-19 and equitable policy responses in agriculture, food security and nutrition" (Rome, 15 May 2020).

[21] FAO, *Youth and Agriculture: Key Challenges and Concrete Solutions* (Rome, 2014).

absence of decent work opportunities, young people join the flow of internal and international migrants. Agriculture can be an important source of decent employment, with technologies potentially changing how young people see agricultural employment.[22]

15. The share of people living in urban areas is projected to increase from 54 per cent in 2015 to 68 per cent in 2050.[23] Rapid urbanization accelerates the dietary transition towards higher consumption of meat, fruits and vegetables, as well as highly processed foods, sugars and comestible oils, relative to cereals, requiring commensurate shifts in production, which further strains natural resources.[24] Such consumption patterns also change the structure of value chains, leading to the proliferation of supermarkets, consolidation and highly mechanized processes.[25]

16. Technological change presents new opportunities to eradicate poverty and reduce inequality, and strong governance is critical to achieving these goals. In the absence of appropriate policies, some technical solutions can exacerbate the exclusion of small-scale, marginalized and informal actors, who may be left behind.[26]

17. These challenges are complex and interconnected, transcending sectors and boundaries. A systems approach to technology and innovation is fundamental for ensuring sustainability, resilience and inclusion. The key is to develop and promote integrated and holistic programmes, policies, investment plans, institutional arrangements and platforms to facilitate intersectoral and interdisciplinary approaches.

IV. Technological trends and key advances

18. When used appropriately, agricultural technologies can contribute to the transformation to more efficient, inclusive, resilient and sustainable agrifood systems for achieving better production, nutrition, environment and life, leaving no one behind.

Biotechnologies

19. Based on the definition of biotechnology in the Convention on Biological Diversity,[27] "agricultural biotechnologies" encompass a broad suite of technologies, from those that are considered low-tech, such as artificial insemination, fermentation techniques, biofertilizers and mutation induction, to high-tech ones involving advanced RNA- and DNA-based methodologies, including genetic modification, whole genome sequencing, genome editing and synthetic biology. Agricultural biotechnologies can provide benefits in a range of areas, such as the genetic improvement of plants and animals to increase their yields, efficiency or resilience; the conservation of genetic resources for food and agriculture; and the prevention of plant and animal diseases.

20. Institutional and human capacity have steadily advanced in the application of agricultural biotechnologies to boost food security and nutrition. Genome editing

[22] See www.fao.org/fsnforum/cfs-hlpe/discussions/youth_engagement_employment-v0.

[23] See https://ourworldindata.org/urbanization.

[24] Anthony Fardet and Edmond Rock, "Ultra-processed foods and food system sustainability: what are the links?", *Sustainability*, vol. 12, No. 15 (2020).

[25] Ndeyapo Nickanor and others, "The supermarket revolution and food security in Namibia", African Food Security Urban Network Urban Food Security Series No. 26 (2017).

[26] Stephen Wegren, "The 'left behind': smallholders in contemporary Russian agriculture", *Journal of Agrarian Change*, vol. 18, No. 4.

[27] Biotechnology is defined as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use".

allows researchers to quickly, cheaply and accurately change the DNA of nearly any organism. However, policies and legislation to govern these technologies and harmonize governance across countries has been lagging. A major issue is the lack of agreement as to whether genome-edited organisms are genetically modified organisms and thus subject to the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. In addition, these technologies have been slower to spread to developing countries.

21. Next-generation sequencing refers to the various high-throughput massive parallel processing approaches to DNA sequencing, and the ensuing data are generally referred to as digital sequence information. Access and benefit-sharing regimes for the use of digital sequence information are being discussed intensely. Next-generation sequencing allows for the assessment of genetic variation and the expansion of DNA sequence databases and bioinformatics tools. These in turn can support genomic selection based on specific traits, microbial surveillance and diagnostics to prevent illness in livestock.

22. The broad range of applications that are described by the term "synthetic biology" include "the de novo synthesis of genetic material and an engineering-based approach to develop components, organisms and products".[28] While the potential of synthetic biology is undeniable, the enabling policy regimes to address safety and equity concerns are lacking.

Digital technologies

23. Digital technologies have the potential to increase agricultural productivity and access to markets, improve cost efficiency, enhance communication and inclusivity and optimize resource planning.[29] They have contributed to reducing the impact of the COVID-19 pandemic on farmers[30] and informing pandemic response measures in agriculture more broadly.[31] Innovative retail and distribution systems have provided solutions to ensure access to food for vulnerable people. When deployed effectively, digital technologies can support education (both formal and informal), public services and targeted poverty reduction programmes.

24. There is strong evidence[32] that the adoption of improved inputs and the acquisition of knowledge boost agricultural productivity and farm income. However, small-scale producers often lack access to inputs, information or the finances to procure these amenities. The proliferation of digital technologies and the penetration of mobile phones in low- and middle-income countries, coupled with advances in cloud computing, remote sensing, the Internet of things, artificial intelligence, machine learning and data analytics, have created opportunities for innovation in small-scale agriculture.

25. Digitization also contributes to the development of citizen science, an approach that combines the Internet, smartphones and social media with low-cost sensor networks to provide extensive real-time information to improve community resilience, in particular in developing countries. Citizen science can also educate and empower communities and stakeholders that might not have access to professional

[28] Secretariat of the Convention on Biological Diversity, "Synthetic biology", Convention on Biological Diversity Technical Series No. 82 (2015).

[29] World Bank, *What's Cooking: Digital Transformation of the Agrifood System* (Washington, D.C., United States, 2021).

[30] FAO, "Enabling agriculture innovation systems to promote appropriate technologies and practices for farmers, rural youth and women during COVID-19" (Rome, June 2020).

[31] See www.fao.org/land-water/overview/covid19/digital.

[32] FAO, "The economic lives of smallholder farmers: an analysis based on household data from nine countries" (Rome, 2015).

knowledge streams. For example, the Agroclimate Impact Reporter is an online citizen science application designed for the collection and reporting of weather and climate impacts on farm operations across Canada.

26. Mobile telephones can increase access to financial and other digital services for small-scale producers.[33] During the COVID-19 pandemic, there has been a surge in the registration and use of digital financial services in low- and middle-income countries to address mobility restrictions and bank closures. Technologies such as blockchain, Quick Response Codes and radio frequency identification improve the traceability of food, facilitate efficient recalls when needed, reduce food waste and increase transparency across value chains.

27. The Internet of things, artificial intelligence, machine learning, big data and next-generation technologies such as 5G/6G and quantum computing can provide small-scale producers and other stakeholders with real-time data and advanced analytics to inform decision-making, improve productivity and provide weather alerts to increase climate resilience. Digital technologies have revolutionized livestock production through the identification and tracking of animal behavioural patterns in real time.[34] These technologies can predict and prevent diseases, while promoting optimal nutrient composition. Digital technologies can be a key driver for rural transformation.[35] However, if not managed appropriately, they can cause market concentration, technological dependence or environmental harm because of data errors. Some technologies also shift labour markets by demanding different skill sets.[36]

28. The digital divide continues to be an issue, in particular among populations in remote areas who fall outside data collection processes. Almost half of the world's population, 3.7 billion people, are currently offline, the majority of them women and people in developing countries.[37] Some of the challenges in scaling up digital technologies in low- and middle-income countries include limited connectivity, lack of awareness, regulatory gaps, data governance issues and cultural or contextual challenges. Persistent gender inequality is reinforced by the digital divide, with women facing higher barriers in terms of access to and use of digital technologies.[38]

29. Data privacy presents another core risk. The surge in digital finance use in low- and middle-income countries is providing Governments, technology companies and financial institutions with a massive amount of personal and financial data from clients, many of whom may not understand the implications. The use (or misuse) of such data, especially when triangulated with other sources of data such as geotagging and travel logs, raises the risk of surveillance creep and abuse of citizens' privacy. Furthermore, in many low- and middle-income countries, there is a lack of digital financial consumer protection, leaving consumers vulnerable to fraud, scams, predatory lending and data theft.

[33] FAO and African Rural and Agricultural Credit Association, *Agricultural Value Chain Finance Innovations and Lessons: Case Studies in Africa* (Rome, 2020).

[34] J. L. Ellis and others, "Review: synergy between mechanistic modelling and data-driven models for modern animal production systems in the era of big data", *Animal*, vol. 14, No. S2 (2020).

[35] Lisha Ye and Huiqin Yang, "From digital divide to social inclusion: a tale of mobile platform empowerment in rural areas", *Sustainability*, vol. 12, No. 6 (2020).

[36] See https://wfpinnovation.medium.com/hello-tractor-innovating-in-the-agri-sharing-economy-85b9de3e8688.

[37] United Nations, "With almost half of world's population still offline, digital divide risks becoming 'new face of inequality', Deputy Secretary-General warns General Assembly", press release, 27 April 2021.

[38] OECD, "Bridging the digital gender divide. include, upskill, innovate" (Paris, 2018).

Renewable energy and other green technologies

30. Food systems currently consume 30 per cent of the world's available energy,[39] and energy use is responsible for about 35 per cent of greenhouse gas emissions from agrifood chains, excluding those from land-use change.[40] An estimated one third of the food produced is lost or wasted, and with it the energy used to produce it, estimated at about 38 per cent of energy consumed in food systems. Modern agrifood systems are heavily dependent on fossil fuels. At the same time, approximately 3 billion people still rely on traditional biomass for cooking and heating, with adverse effects on health, the environment and economic development.

31. Transitioning towards energy-smart agrifood systems that optimize the use of efficient and sustainable energy is crucial. Energy-smart agrifood systems not only conserve energy but can even produce it to leverage the dual relationship between energy and food.[41] For example, rainwater harvesting, solar food dryers, green fertilizers and food bioconservation help to conserve water and energy and reduce waste. This is increasingly important as countries face accelerating impacts of climate change.

32. The links between bioenergy and food security are complex because, while they have synergies, they also compete for resources, including land. Land, resources and bioenergy are critical inputs to both food and non-food uses, with an impact on food security, energy security, rural development and climate. An integrated approach is required to address these links and sustainably promote both food and fuel, with efficient and sustainable resource allocation.[42]

Mechanization

33. Mechanization includes farming and processing technologies ranging from basic hand tools to more sophisticated and motorized equipment. Sustainable agricultural mechanization can reduce drudgery, relieve labour shortages, create new jobs, improve productivity, reduce harvest costs, improve resource efficiency and enhance market access.[43]

34. Since individual small-scale producers cannot often afford specialized machinery, there have recently been some examples of beneficial investments and digital service solutions. For example, Hello Tractor in Nigeria and TROTRO Tractor in Ghana[44] are digital platforms designed to enable access to tractors by increasing the coverage of machines and services. Limited Internet access and language barriers, however, remain a challenge.

35. Mechanization can also provide solutions for livestock and poultry, as it can play an important role in the prevention and control of zoonoses. Mechanization helps to eliminate pathogens, block transmission routes and enhance biosafety. The COVID-19 pandemic has highlighted the importance of addressing zoonotic diseases, in particular in the Asia-Pacific region, where there has historically been a higher incidence. Mechanization solutions can also increase breeding efficiency and improve the quality of livestock products.

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[39] FAO, "Energy-smart food for people and climate", issue paper (Rome, 2011).

[40] Monica Crippa and others, "Food systems are responsible for a third of global anthropogenic GHG emissions".

[41] See www.fao.org/energy/home.

[42] See www.fao.org/energy/bioenergy.

[43] See www.fao.org/sustainable-agricultural-mechanization.

[44] FAO, "Use of information and communications technology tools for tractor hire services in Africa: opportunities and challenges", Integrated Crop Management No. 25 (Rome, 2020).

Food processing technologies

36. Consumer awareness of health, sustainability and social responsibility is driving demand for nutritious, sustainably produced food. Food processing technologies can support such demands by minimizing the degradation of food components that support good health and well-being.

37. Compliance with sustainability principles is imperative for the food processing sector to ensure resource efficiency, minimize waste and use environmentally friendly packaging materials. Processing must rigorously ensure food safety, with rapid and high throughput safety evaluation techniques. Sensor technology, cold plasma technology, sustainable packaging, refrigeration climate control, non-thermal pasteurization and sterilization and nano- and micro-technology are examples of recent innovations in emerging technologies that integrate considerations for sustainability into food design.[45]

38. Strategic approaches to ensure sustainability are focused on healthy product composition, the development of novel preservation alternatives, extending the shelf-life of fresh products, resource-efficient processing methods, plant-based meat alternatives and innovative processes and bioprocesses to utilize by-products.

V. Transformative use of technologies at scale

39. Numerous technologies are available spanning the entire agrifood system to address the challenges identified in section III. An exhaustive list of relevant technologies is beyond the scope of the present report, but indicative examples are provided below.

Ending hunger and improving nutrition and human health

40. The diversification of production systems towards safe, nutrient-dense crops enhances resilience to climate and price shocks, diversifies food consumption and reduces seasonal income fluctuations. This includes the production of horticultural crops and pulses, neglected and underutilized species, small-scale fisheries and aquaculture.

41. Smartphone applications are increasingly used across the globe to help in the fight against hunger. ShareTheMeal[46] supports operations ranging from resilience-building and school feeding programmes to providing food assistance in emergencies. Wefarm,[47] a farmer-to-farmer digital network, allows farmers to connect to other farmers in various parts of the world, allowing them to more effectively share knowledge and combine their buying and selling power.

42. Chilling, freezing and canning operations help to preserve the shelf-life of perishables and make foods available year-round, rather than on a seasonal basis. This helps to reduce food loss and waste.

43. Biotechnologies have reduced time in breeding cycles and enabled targeted improvements in varieties and breeds. Biofortification of crops, for example, measurably improves human nutrition and health outcomes. There have been 211 biofortified crop varieties released in 30 countries, with an estimated 7.6 million

[45] José Teixeira, “Grand challenges in sustainable food processing”, *Frontiers in Sustainable Food Systems*, vol. 2, No. 19 (2018).

[46] See https://innovation.wfp.org/project/sharethemeal.

[47] See https://about.wefarm.com.

farming households growing them.[48] Mutation breeding mimics the natural process of spontaneous mutation and has long been used to develop novel and improved varieties with desired traits.

44. In the Andean region, for example, finding ways to improve the productivity and yield stability of quinoa is important for food and nutrition security. Through a combination of mutation breeding for improved varieties and isotope tracing and water control using a water-absorbing polymer, in conjunction with good soil and water management practices, farmers have seen an enormous increase in yield – from 1.1 to 3.1 tons per hectare – while simultaneously reducing their fertilizer purchases by 30 per cent and water use by 40 per cent.[49]

45. The genetic development of farmed types of aquatic species is lagging and there is a huge opportunity to improve the production efficiency and sustainability of aquaculture by adopting appropriate genetic improvement approaches such as selective breeding.[50]

46. Precision agriculture in the context of crops, livestock and fisheries can increase efficiency by optimizing conventional production systems. In India, an artificial intelligence-based sowing application providing small-scale producers with precision agro-advisory services for a host of crops increased yield by 10 to 30 per cent.[51] Precision fish farming uses real-time monitoring of biomass, water quality and aquatic animal behaviour, as well as smart control of aeration, automated feeding and exchange of water, among other things, to optimize the use of energy and input resources while reducing waste in water.[52]

47. Smart farms are more resilient to external variables. Vertical farms and soil-less farming have expanded agriculture into new frontiers and provide alternative solutions to land degradation. Through the H2Grow project, currently being implemented in nine countries, communities in Chad were able to produce 340 tons of hydroponically grown animal feed in 2020.[53] Digital and precision agriculture technologies are key to optimizing and regulating inputs, including water, fertilizer and crop protectant.

Addressing climate change

48. Extreme weather and climate events and associated disasters are making it more difficult for small-scale producers to grow crops, raise animals and earn a decent income in rural areas across the world. At the same time, there is an urgent need to scale up technological innovations to mitigate and adapt to climate change in line with the Sustainable Development Goals and the Paris Agreement.

49. Small-scale producers need to deploy species, breeds, varieties and strains that are well adapted to local conditions. Climate change exacerbates the challenge as regions experience unprecedented combinations of stressors, such as climatic pressures, pests and diseases, and new food safety concerns. Recent developments in

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[48] HarvestPlus, "Catalyzing biofortified food systems: 2018 annual report" (Washington, D.C., United States, 2018).

[49] See www.iaea.org/newscenter/news/quinoa-farmers-increase-yields-using-nuclear-derived-farming-practices.

[50] FAO, *The State of the World's Aquatic Genetic Resources for Food and Agriculture* (Rome, 2019).

[51] See https://news.microsoft.com/en-in/features/ai-agriculture-icrisat-upl-india.

[52] Fearghal O'Donncha and Jon Grant, "Precision aquaculture", *IEEE Internet of Things Magazine*, December 2019.

[53] See https://innovation.wfp.org/project/h2grow-hydroponics.

molecular genetics are allowing faster and more targeted development of climate-adapted plant varieties and animal breeds.

50. Greenhouse gas emissions due to land-use changes, such as converting forests to agricultural land, have been decreasing over the past 20 years, while emissions related to food production have increased.[54] Discussions at recent international forums demonstrate a general consensus among Governments, experts and civil society that both agrifood systems and forests will play a key role in solving the confluence of climate, economic and health crises plaguing the world today.

51. Forest protection initiatives have been insufficient to stop land conversion for agricultural use. Innovative technologies to increase agricultural productivity, maximize resource efficiency and minimize waste can reduce the amount of land and resources needed for agriculture.

52. Remote sensing technology can monitor water productivity and advanced water stress detection through WaPOR.[55] The establishment of the proposed Next Generation Agricultural Stress Index System will enable countries with a high risk of drought to better safeguard the agricultural livelihoods and food security of vulnerable households by analysing satellite images to detect drought hotspots.[56]

53. Isotope techniques can also quantify the amount of nitrogen taken up by crops from fertilizers to prevent overuse, which contributes to greenhouse gas emissions. Blockchain technologies can support a worldwide network of reliable carbon data and serve as a tool for the monitoring and evaluation of climate change mitigation activities and the development of carbon markets.[57] Fallout radionuclides have been used as a tracer to measure the rate of soil erosion and to validate the efficiency of conservation methods.[58]

Sustainable management of natural resources, including biodiversity

54. Technologies can support the sustainable use of natural resources, including by enabling more targeted and efficient use of pesticides and fertilizers and harnessing biodiversity to provide services such as pest control and improved plant nutrition. For measurement and monitoring, the System for Earth Observation Data Access, Processing and Analysis for Land Monitoring of the Food and Agriculture Organization of the United Nations (FAO) helps countries to measure, monitor and report on forests and land use by using advanced cloud computing, artificial intelligence and machine learning to detect changes in forests, such as those associated with illegal or unsustainable timber harvesting.[59] The United Nations Global Platform has launched an artificial intelligence tool to support countries in implementing the recently adopted international standard for natural capital accounting, the System of Environmental-Economic Accounting Ecosystem Accounting.[60]

55. Developments in biotechnologies help to keep a range of domesticated genetic resources available to meet the changing needs of producers. For example, the African

[54] Francesco Tubiello, "Greenhouse gas emissions from food systems: building the evidence base", *Environmental Research Letters*, vol. 16, No. 6 (2021).

[55] See https://wapor.apps.fao.org/home/WAPOR_2/1.

[56] Oscar Rojas, "Next Generation Agricultural Stress Index System (ASIS) for agricultural drought monitoring", *Remote Sensing*, vol. 13, No. 5 (2021).

[57] Lan van Wassenaer, Mireille van Hilten and Marcel van Asseldonk, "Applying blockchain for climate action in agriculture: state of play and outlook", background paper (Rome and Wageningen, Netherlands, FAO and Wageningen University and Research, 2021).

[58] See www.iaea.org/newscenter/news/nuclear-techniques-reveal-depth-of-soil-erosion-in-uganda.

[59] See www.fao.org/3/CA1085EN/ca1085en.pdf.

[60] See https://aries.integratedmodelling.org/un-bc3-launch-the-first-ai-tool-for-rapid-natural-capital-accounting-the-aries-for-seea-explorer.

Orphan Crops Consortium[61] is aimed at improving the productivity and adaptability of 101 underutilized African crops by sequencing their genomes and developing breeding capacity. DNA barcoding can be used to control the intentional or unintentional introduction of exotic species and for the identification of commercial fish fraud involving the replacement of high-value species with low-value species.[62]

56. Indigenous peoples' knowledge systems and territorial management practices can advance strategies for the conservation of natural resources and climate change mitigation. Such methods can complement new technologies for monitoring and measurement. Indigenous peoples have reiterated their interest in new technologies, with the assertion that their cosmogonies, self-determination and rights to free, prior, and informed consent are respected to avoid risks.

57. In Panama, for example, an innovative social project merges the traditional knowledge of indigenous peoples with digital technologies. This allows indigenous peoples to self-monitor and map their territories and gather data on natural resources using drones fitted with radio navigation technology. The monitoring system has strengthened indigenous peoples' technicians and traditional authorities in forest management and governance, allowing them to determine effective actions to preserve, protect and manage the forest.[63]

58. The sterile insect technique uses irradiation to sterilize mass-reared male insects so that they cannot produce offspring, which results in pest population reduction over time. It has been used to suppress pests in many countries worldwide and enables pest control without introducing invasive insect species into ecosystems with threats to biodiversity. In combination with other complementary measures, the technique has boosted fruit trade in Argentina, allowing exports with no quarantine restrictions to many countries, including Chile, China, Mexico and the United States of America, representing $27.2 million in revenue for cherries alone in the 2019/20 growing season.[64]

Tackling transboundary animal and plant pests and diseases

59. Animal and plant pests and diseases present major challenges owing to their changing distribution on account of climate change, intensification and globalization, increased pathogen evolution and increasing impacts on food emergencies. Efficient monitoring, reporting, forecasting and early warning of such threats are paramount for improving preparedness and minimizing losses. New technologies, including mobile-based technologies, help to map and monitor the spread of infectious diseases across sectors and regions on the basis of real-time field data. For example, the Event Mobile application[65] strives to strengthen real-time reporting of animal disease events.

60. Rift Valley fever is a climate-sensitive disease that affects both humans and livestock. An early warning decision support tool has been developed that integrates near real-time risk maps of Rift Valley fever with expert knowledge on its eco-epidemiology.[66] The tool has enhanced the capacity to identify high-risk areas and issue alerts for prevention and control and has contributed to an improved state of vigilance and preparedness in Eastern Africa.

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[61] See http://africanorphancrops.org/about.

[62] Bárbara Calegari and others, "DNA barcode authentication reveals highly fraudulent Cod commerce in Porto Alegre, Brazil", *Forensic Science International*, vol. 2 (2020).

[63] See www.fao.org/3/I8760EN/i8760en.pdf.

[64] See www.iaea.org/newscenter/news/argentinas-newly-recognized-fruit-fly-free-areas-expedite-fresh-fruit-exports-to-china.

[65] See www.fao.org/publications/card/fr/c/CA7122EN.

[66] See www.fao.org/in-action/kore/good-practices/good-practices-details/en/c/1203903.

61. Increased livestock production and international trade in response to growing consumer demand for meat products has resulted in higher rates of transboundary animal diseases.[67] Markets are considered a hotspot of disease amplification because they facilitate the mixing of a high volume of species from different origins in a single location.[68] With limited resources, countries require enhanced capacities to conduct targeted, risk-based disease surveillance and control. The FAO epidemiology value chain platform uses online applications to facilitate biosecurity profiling of high-traffic value chain points, map animal mobility and visualize trade network movements.[69]

62. Technologies support locust detection, surveillance and treatment, helping countries to respond to the ravaging desert locust crisis. The Desert Locust Information Service uses big data to closely monitor the global desert locust situation.[70] Locust-affected countries transmit data to FAO, which in turn carries out an analysis in conjunction with weather and habitat data and satellite imagery to assess the current locust situation, provide forecasts and issue warnings. Biopesticides, a promising alternative to chemical pesticides, are used to treat desert locust outbreaks in fragile ecosystems, including in a 36,000 hectare area in Somalia.[71]

Improving food quality and safety

63. The Codex Alimentarius, the joint FAO and World Health Organization food standards programme,[72] provides global food safety standards and guidelines. However, real gains in global food safety require strong national food control systems, bolstered by intersectoral collaboration, public-private partnerships and a data-driven, science-based approach to food safety management.[73] Encouraging food business operators to self-regulate and enhancing consumer education also help to advance food safety.[74] New hygiene practices implemented during the COVID-19 pandemic provide an opportunity to instil a food safety culture across society. There is also a need to strengthen official food control systems, including food testing.

64. Innovative technologies, such as the use of whole genome sequencing, can provide a strategic option for identifying and tracing foodborne pathogens around the globe. This helps in supporting national efforts to strengthen food surveillance and testing capacities. Over 22 countries have employed whole genome sequencing in their food safety regulatory frameworks,[75] and it is widely effective in outbreak investigations.[76]

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[67] OECD and FAO, *OECD-FAO Agricultural Outlook 2020–2029* (OECD Publishing and FAO, Paris and Rome, 2020).

[68] Ming Wang and others, "Food markets with live birds as source of avian influenza", *Emergency Infectious Diseases*, vol. 12, No. 11 (2006); and Xiu-Feng Wan, "Indications that live poultry markets are a major source of human H5N1 influenza virus infection in China", *Journal of Virology*, vol. 85, No. 24 (2011).

[69] See www.fao.org/food-chain-crisis/resources/success-stories/detail/en/c/1234560.

[70] See www.fao.org/locusts/en.

[71] See www.fao.org/fao-stories/article/en/c/1267098.

[72] See www.fao.org/fao-who-codexalimentarius/en.

[73] FAO, "Food fraud: intention, detection and management", food safety technical toolkit for Asia and the Pacific, No. 5 (Bangkok, 2021).

[74] FAO and WHO, "Food control system assessment tool" (Rome, 2019).

[75] Raquel García Fierro and others, "Outcome of EC/EFSA questionnaire (2016) on use of Whole Genome Sequencing (WGS) for food- and waterborne pathogens isolated from animals, food, feed and related environmental samples in EU/EFTA countries", *European Food Safety Authority Journal*, vol. 15, No. 6 (2018).

[76] Bas Oude Munnink and others, "Rapid SARS-CoV-2 whole-genome sequencing and analysis for informed public health decision-making in the Netherlands", *Nature Medicine*, vol. 26 (2020).

65. Initiatives to improve traceability, food inspection and certification systems increase food supply transparency, helping to mitigate fraud and improve safety.[77] These tools stabilize food trade and protect consumers while facilitating the identification and recall of implicated foodstuffs throughout the supply chain, reducing disease and mitigating industry-wide economic repercussions, excessive food waste and damage to consumer confidence. It will be important to establish an international agreement providing a standard format for quick and efficient data exchange to ensure that increasingly global agrifood systems continue to operate with minimal disruption.

Boosting resilience to vulnerabilities, shocks and stress, including the coronavirus disease and the need to build forward better

66. Boosting resilience to multiple risks and vulnerabilities can help the industry to mitigate, adapt to and bounce back from shocks. Furthermore, resilience implies the capacity not only to respond to shocks, but also to leverage these changes to strengthen learning, innovation and transformation towards sustainable development.[78]

67. For over a decade, the multi-partner Integrated Food Security Phase Classification system[79] has been the global gold standard for the classification of acute food insecurity and malnutrition, including in the declaration of famines. While continuing to consolidate its country-level work, the system is also leveraging advanced technologies and artificial intelligence to meet the needs of national, regional and global Integrated Food Security Phase Classification analysts with systematized, automated processes, enabling more comprehensive and frequent coverage. These innovations are designed to support human-led analysis to detect and forecast food crises, including the risk of famine, early enough for countries to take action in mitigating and responding to them.

68. Faced with the multiple crises of the COVID-19 pandemic, climate change, biodiversity loss and environmental degradation, innovation and new technologies can help to inform evidence-based policies and strategies for more resilient and equitable systems. For example, investing in jobs and technologies that support the transition to renewable energy promotes a green recovery that fuels resilience and sustainable growth in the wake of the pandemic.

Addressing food loss and waste

69. Technologies have considerable potential to improve efficiency, reduce food waste and enable the monitoring of supply chains. The Internet of things plays a key role in this regard, by allowing stakeholders at each level of the food supply chain to have access to key data on the supply, production and management of food.[80] Food sensing technologies for food safety, quality and traceability help to track the freshness of food. Blockchain improves supply chain traceability and transparency, enhancing safety and facilitating recalls.[81] Mobile applications facilitate the recovery, redistribution and resale of food, reducing food waste. Mobile and digital marketplaces that connect small-scale producers to traders and consumers also offer tremendous opportunities to reduce on-farm food losses in low- and middle-income countries.

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[77] Yajie Wang, “Food safety traceability method based on blockchain technology”, *Journal of Physics: Conference Series*, vol. 1634.

[78] United Nations common guidance on helping build resilient societies.

[79] See www.ipcinfo.org.

[80] Hermione Dace, *Technology to feed the World* (London, Tony Blair Institute for Global Change, 2020).

[81] World Economic Forum, “Innovation with a purpose: the role of technology innovation in accelerating food systems transformation” (2018).

70. Innovations are reducing the negative environmental impacts of food packaging. The development of sustainable active packaging is particularly promising as it enhances the safety, security and sustainability of food from production to consumption.[82]

71. Sustainable cooling technologies, such as solar refrigeration, as part of cold chain storage can significantly reduce food loss and waste in perishables in low- and middle-income countries. Furthermore, the use of real-time data to monitor environmental conditions, such as temperature and humidity, improves transparency across the food supply chain and helps to reduce energy consumption and food loss and waste.[83]

72. Food irradiation can improve the safety and extend the shelf-life of foods. The commercial use of irradiation as a phytosanitary measure to prevent the spread of pests is enabling trade in agricultural products that would otherwise be restricted owing to risk-based controls on shipments of fresh commodities. For example, the irradiation of premium quality fruits has guaranteed Viet Nam exports worth $20 million a year to the United States.[84]

Generating decent rural employment opportunities and reducing rural poverty

73. Digital innovation can boost financial inclusion by tackling bottlenecks faced by small-scale producers seeking access to financial systems.[85] Blockchain and advanced data analytics can improve supply chains by enabling faster delivery of products, enhancing product traceability, improving collaboration between supply chain partners and aiding access to markets, finance and investment opportunities, including for small-scale producers and micro-, small and medium-sized enterprises.[86] However, there is a need for greater regulation of data privacy to protect vulnerable stakeholders.

74. Mobile financial services allow previously unbanked individuals to save, borrow, pay and transfer money remotely, thus promoting rural financial inclusion, poverty alleviation and economic growth. Together with other technologies, mobile applications can be used to analyse customer data, develop credit profiles, set up farm-gate prices, make online payments and facilitate market linkages between producers and consumers.

75. Online platforms enable producers to sell directly to consumers, leading to increased profits, improved supply chain efficiency, reduced wastage and better financial inclusion. They can potentially rebalance power along value chains, improving equity for small-scale producers and middle traders. During the COVID-19 pandemic, open-air markets, such as the Mutrah fish market in Oman, transitioned to a digital platform, bringing together retailers and fishers in auctions to deliver the catch to restaurants, hotels, supermarkets and countries in the region.[87]

76. In Guatemala, the Chispa Rural digital platform[88] allows young people in rural areas to have access to and share targeted information and multimedia content that can inspire and improve their production, marketing and entrepreneurial endeavours.

[82] Joana Kleine Jäger and Laura Piscicelli, "Collaborations for circular food packaging: the set-up and partner selection process", *Sustainable Production and Consumption*, vol. 26 (2021); and K. Schroen and others, "Technology options for feeding 10 billion people: options for sustainable food processing", (Brussels, European Union, 2013).

[83] See https://packagingeurope.com/digitalization-food-waste.

[84] See www.iaea.org/newscenter/news/irradiation-secures-viet-nams-fruit-exports.

[85] See www.fao.org/partnerships/south-south-cooperation/news/news-article/en/c/1339051.

[86] See www.fao.org/3/ca9941en/CA9941EN.pdf.

[87] See www.fao.org/neareast/news/view/en/c/1294228.

[88] See https://chisparural.gt.

It provides them with access to services, capacity development and funding opportunities while helping them to attain visibility as they develop their businesses and generate jobs in their communities.

77. Green technologies and practices address climate change while providing decent employment opportunities that contribute to rural poverty reduction.[89] It has been estimated that the transition to a green economy could generate 15 million to 60 million jobs,[90] including decent green jobs throughout agrifood systems. To achieve impact at scale, it is critical to ensure that young people have access to the relevant education and skills needed for the green economy. The United Nations Environment Programme Green Jobs for Youth initiative is aimed at increasing demand for green jobs in the workforce, enhancing green entrepreneurship and building capacity through skills training and education.[91]

78. Solar-powered sustainable irrigation is an increasingly popular solution to sustainably enhance agricultural productivity for small-scale producers. Women constitute around 70 per cent of agricultural labour in the Niger, but their participation in decision-making has been limited. The involvement of rural women in the Dimitra community listeners' clubs improved their empowerment and well-being and ultimately boosted rural technology diffusion, with increases in the uptake and maintenance of solar irrigation technologies.[92]

VI. Recommendations

79. Technology and innovation solutions must be context-specific and must work together; no one solution can serve as a silver bullet. Technologies must be disseminated in coordination with other levers of change, including governance, human capital, business and finance. Both individual and collective actions can make agrifood systems more sustainable, equitable and resilient. Data and analysis can help to indicate which technologies can have the biggest impact in terms of social, economic and environmental gains.

80. Strengthening national agricultural innovation systems and their functional capacities can help to unlock the potential of innovation, foster investment in agricultural research and participatory technology development and facilitate the sharing of knowledge and best practices. To be truly inclusive and avoid top-down interventions, assessments must serve to identify the needs and demands of small-scale producers and vulnerable groups and incorporate them into the design and application of agricultural technologies. Small-scale producers, including women, young people and indigenous peoples, should be actively involved in decision-making on research, development and innovation as co-creators of solutions. Technology-based interventions that are people-centred and rights-based can ensure that no one is left behind.

81. As countries recover from the COVID-19 crisis, closing the digital as well as the gender divide will be more important than ever. Rapid technological uptake without an inclusive approach risks further widening gaps. Digital inclusion requires identifying and changing exclusionary policies, establishing gender-responsive extension and advisory services, optimizing labour-saving technologies and services and

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[89] Hans Herren and others, "Green jobs for a revitalized food and agriculture sector" (Rome, FAO, January 2012).

[90] See www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_181795/lang--en/index.htm.

[91] See www.unep.org/explore-topics/education-environment/what-we-do/green-jobs-youth.

[92] Olumide Adisa, "Rural women's participation in solar-powered irrigation in Niger: lessons from Dimitra Clubs", *Gender and Development*, vol. 28, No. 3 (2020).

improving overall digital literacy. Reinforcing collective action through producer- and community-based organizations can also enhance access to technologies. Existing digital solutions can help rural women to obtain access to relief services, technology-enabled social protection services and income-generation opportunities in the aftermath of the pandemic.

82. Effective policy frameworks, incentives, regulatory measures and economic and legal instruments will be critical to creating an enabling environment for agricultural technologies that advance the achievement of the Sustainable Development Goals. Technology-based interventions that include a strong governance component, such as property rights, non-discrimination and accountability mechanisms, will achieve more equitable results. For technologies that use personal data, better regulations and accountability are crucial to protect privacy and prevent data misuse, including more sophisticated competition frameworks that adequately regulate competition between traditional financial institutions and telecommunications companies in the digital finance space.

83. Technology-based interventions should utilize human rights-based monitoring approaches, including the collection of disaggregated data to measure impacts on, or unintended consequences for, all population groups. Inclusion seeks to enhance marginalized peoples' participation in governance processes while also creating a policy environment that prioritizes the reduction of inequalities and dimensions of exclusion, such as poverty and discrimination.

84. Innovative technologies must be embedded within agroecological and other sustainable agriculture approaches, including conservation agriculture, climate-smart agriculture, agroforestry and organic agriculture, building on and benefiting from local and traditional knowledge. For example, the use of neglected and underutilized species may introduce positive environmental and nutritional outcomes. Similarly, animal and crop production ventures can be integrated into farming systems that ensure the circularity of input and output and optimize nutritional outcomes of the whole system.

85. Technological innovations must be linked to financial innovations. Blended finance can play a particularly important role in financing the investments needed for transforming agrifood systems. In recent years many impact funds have been set up to finance solutions addressing the challenges mentioned above, including the AGRI3 Fund[93] and the Land Degradation Neutrality Fund,[94] which promote sustainable management of natural resources, while the aim of the Althelia Climate Fund[95] is to address climate change by investing in sustainable land-use practices.

86. Ongoing monitoring and evaluation activities as well as scenario-building exercises must assess the impacts of agricultural technologies at temporal and spatial scales. Models must examine potential risks and vulnerabilities. Understanding the systemic nature of risk requires in-depth analysis of how multiple risks interact at different levels in a highly dynamic and fluid environment.

87. Policies, investments and partnerships must help in realizing the potential of technologies to transform agrifood systems to tackle intersecting global crises. They should prioritize solutions that help to address the root causes of vulnerability and risk. Public, private and community actors should design, implement and track progress on a suite of complementary and mutually supportive risk and crisis management interventions. These may include solutions to agroclimatic and disaster risk and food security and nutrition information systems; multi-hazard early warning

[93] See https://agri3.com/about.

[94] See www.eib.org/en/products/equity/funds/land-degradation-neutrality-fund.

[95] See www.eib.org/en/projects/pipelines/all/20100720.

systems; governance and finance structures to address crises; risk transfer mechanisms (social protection and insurance); vulnerability reduction measures and the promotion of good practices, technologies and innovations, including livelihood diversification; emergency preparedness, anticipatory action and response; risk-proofing of infrastructure along the food value chain; nature-based solutions; food loss and waste reduction; and inclusive, resilient and sustainable diets.

88. Lastly, technological advancements are not enough without diffusion. Each innovation has to be adapted to the local agroecological conditions. United Nations system entities, the CGIAR System Organization, the Association of International Agricultural Research Centers and the International Service for the Acquisition of Agri-biotech Applications are key in facilitating technology transfer and knowledge-sharing to different parts of the world. National agricultural research systems and national agricultural extension and advisory services play a vital role in communicating and sharing location-specific and demand-driven technologies and innovations with small-scale agricultural producers at the country level.

Role of the United Nations in forging global collective action

89. Established under the Addis Ababa Action Agenda of the Third International Conference on Financing for Development (see General Assembly resolution 69/313, annex) and the 2030 Agenda for Sustainable Development, the Technology Facilitation Mechanism[96] is aimed at supporting the achievement of the Sustainable Development Goals. It has four components: a multi-stakeholder forum on science, technology and innovation for the Goals;[97] an online platform called 2030 Connect[98] acting as a gateway for information on existing science, technology and innovation initiatives, mechanisms and programmes; a group of 10 high-level representatives appointed by the Secretary-General; and the United Nations inter-agency task team on science, technology and innovation for the Goals and its 10 workstreams.[99] The workstream on science, technology and innovation policy frameworks, action plan and road maps promotes policy and planning tools leading to actions that can accelerate the attainment of the Goals. The Technology Facilitation Mechanism exemplifies how United Nations entities can work together to promote science, technology and innovation for the benefit of Member States. In response to a United Nations call for technology solutions for addressing the COVID-19 pandemic and its impacts, launched by the Mechanism, over 180 submissions were received, including on food and agriculture. The selected solutions were made available through the 2030 Connect platform.[100]

90. It is important for Governments and the United Nations to engage in public-private-partnerships that enable data-sharing and analysis for public benefit. The United Nations can facilitate sustainable research collaborations, while the private sector can help to fund user-friendly technology solutions using sustainable business models that encourage marginalized stakeholders to reclaim their data ownership and gain autonomy. Governments and the United Nations must direct more efforts towards developing data science capacities in agrifood systems.

91. In the road map for digital cooperation (A/74/821), the Secretary-General laid out a vision in which all stakeholders could play a role in advancing a safer and more equitable digital world. Digital technologies and data must be harmonized to enable stakeholders throughout agrifood systems to have access to and review relevant data

[96] See https://sdgs.un.org/tfm.
[97] See https://sdgs.un.org/tfm/sti-forum.
[98] See https://sdgs.un.org/tfm/online-platform.
[99] See https://sdgs.un.org/tfm/interagency-task-team.
[100] See https://tfm2030connect.un.org/covid-19.

and models. Governments, the United Nations and other actors must ensure that application programming interfaces and data standards speak the same "Sustainable Development Goal language" in order to fully integrate and prioritize sustainability considerations. For example, the FAO Hand-in-Hand geospatial platform[101] and its Data Lab[102] enable data access in countries with limited national capacity and support, including those facing humanitarian crises.

92. In the context of open and improved data-driven systems, strong data governance based on the principles of respect for human rights and fundamental freedoms will be essential.[103] The International Platform for Digital Food and Agriculture, hosted by FAO, will serve to enhance international cooperation and provide structured and strategic policy recommendations on the digitization of food and agriculture.

93. The Climate Technology Centre and Network, the operational arm of the Technology Mechanism under the United Nations Framework Convention on Climate Change, is hosted by the United Nations Environment Programme and the United Nations Industrial Development Organization and promotes the accelerated transfer of environmentally sound technologies for low-carbon and climate-resilient development at the request of low- and middle-income countries.[104] The Commission on Science and Technology for Development, for which the United Nations Conference on Trade and Development serves as the secretariat, launched the CropWatch Innovative Cooperation Programme for Agricultural Monitoring, which offers developing countries technical assistance for crop monitoring and food security early warning. Regional initiatives, including the Centre for Sustainable Agricultural Mechanization and the Arab Regional Food Systems Dialogue, help to address context-specific agricultural opportunities and challenges.

94. The forthcoming United Nations Food Systems Summit[105] is an important occasion to bring together science communities, policymakers and other stakeholders for engaged knowledge production and identification of innovative evidence-based solutions. Other forthcoming opportunities include the fifteenth session of the Conference of the Parties to the Convention on Biological Diversity, which will adopt a global biodiversity framework, and the twenty-sixth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, which presents important opportunities to raise collective ambition and drive action to tackle the unfolding climate emergency. In Katowice, Poland, the parties adopted the technology framework under the Paris Agreement that plays a strategic role in improving the effectiveness and efficiency of the work of the Technology Mechanism by addressing the transformational changes envisioned in the Agreement and the long-term vision for technology development and transfer. Agrifood systems play an important role in negotiations for the twenty-sixth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change; the Koronivia joint work on agriculture should ultimately result in a decision on how Governments will integrate the sector as part of their climate commitments.

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[101] See www.fao.org/hih-geospatial-platform.
[102] See www.fao.org/datalab/website/web/home.
[103] See https://unsceb.org/privacy-principles.
[104] See www.ctc-n.org.
[105] See www.un.org/en/food-systems-summit.