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Agricultural technology for sustainable development: leaving no one behind

Report of the Secretary-General*

Summary

Agricultural technologies have the potential to accelerate transformative changes in agrifood systems, contributing to the achievement of multiple Sustainable Development Goals. Technological advancements in the areas of biotechnologies, protected cultivation, precision farming, sustainable agriculture mechanization, digital technologies including artificial intelligence, technologies for climate resilience, data collection and monitoring, and early warning systems for emergency response and building of resilience present opportunities to boost food production, improve nutrition, reduce environmental impact, benefit livelihoods and improve overall economic, social and environmental sustainability. Nevertheless, technology needs and risk assessment, knowledge-sharing, capacity development, enabling policies and regulatory frameworks, and investments are needed to ensure that new technologies are accessible and affordable in all countries and benefit rural communities, women, young people and Indigenous Peoples, leaving no one behind.

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I. Introduction

1. The present report has been prepared in response to General Assembly resolution 78/144, in which the Secretary-General was requested to submit to the General Assembly at its eightieth session, within existing resources, an action-oriented report that examines the current technological trends and key advances in agricultural technologies. The report provides illustrative examples of the transformative use of technologies at scale, with policy recommendations to assist Member States in accelerating the implementation of the 2030 Agenda for Sustainable Development.

2. For the purposes of the report, "agriculture" refers to the crop, livestock, fishery and forestry sectors. "Agrifood systems"[1] encompass the entire range of actors, and their interlinked value-adding activities, engaged in the primary production of food and non-food agricultural products, as well as in the storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, consumption and disposal of all food products, including those of non-agricultural origin. "Agricultural technologies" were defined in the previous report of the Secretary-General on the subject (A/78/228), which also emphasizes the application of science and knowledge to develop techniques to deliver a new product and/or service or to use a new process to deliver an established product or service that enhances the productivity and sustainability of agrifood systems.

II. Overview

3. The Secretary-General has consistently emphasized the vital role of science, technology and innovation in transforming food systems to achieve the Sustainable Development Goals. Since the United Nations Food Systems Summit in 2021, he has called for integrated national strategies that embed technological solutions to build sustainable and resilient food systems. In 2023, he reinforced the urgent need to scale up investments in research, data and technology-driven innovation to accelerate progress, and, in 2025, he reaffirmed the central role of technology, urging countries to adopt digital tools, data analytics and innovative approaches to enhance productivity, equity and environmental sustainability in global food systems. In his 2023 report (A/78/228), the Secretary-General observed that biotechnologies, digital technologies, renewable energy technologies, technologies for climate resilience, mechanization and data advancement presented opportunities to boost agricultural production, improve efficiency, minimize waste and reduce drudgery in agrifood systems, thus contributing to economic, social and environmental sustainability. He further highlighted the importance of governance and inclusive planning to ensure that new technologies would benefit vulnerable populations, including women and young people.

4. The present report falls under the Secretary-General's vision as conveyed at the Food Systems Summit and follow-up stocktaking moments and builds on the previous report with reference to the current state of food insecurity, climate risks, urbanization, food loss and waste, degradation of natural resources and transboundary pests and diseases that agricultural technologies can help to address. In the present report, the Secretary-General also advocates for the conduct of technology needs assessments, knowledge-sharing and capacity development to promote the adoption and scaling of agricultural technologies. In addition, he highlights opportunities for

[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.

engaging start-ups and the private sector through the Global Network of Digital Agriculture Innovation Hubs[2] and for promoting youth engagement with and employment in sustainable agrifood systems by leveraging emerging opportunities presented by new technologies for achieving the Sustainable Development Goals.

5. The report is aligned with the action-oriented Pact for the Future,[3] the Global Digital Compact[4] and foresight exercises on emerging technologies in agrifood systems, in which priority is given to unlocking the full potential of new technologies for bridging the digital divide (including artificial intelligence) and accelerating progress across the Sustainable Development Goals. In the report, the Secretary-General also considers the Global Alliance Against Poverty and Hunger[5] and the outcomes of the Fourth International Conference on Financing for Development. The report is relevant to the work of the United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals under the Technology Facilitation Mechanism, and its 2025 multi-stakeholder forum on science, technology and innovation for the Sustainable Development Goals, as well as to the work of the United Nations Food Systems Coordination Hub and the efforts of the United Nations resident coordinators and United Nations country teams with regard to food systems transformation.

6. The report relates to the work of the Secretary-General's Scientific Advisory Board for Independent Advice on Breakthroughs in Science and Technology, especially with regard to artificial intelligence and synthetic biology, and the Secretary-General's vision of a modernized United Nations system, with cutting-edge skills and a forward-thinking culture for stronger results, with a powerful fusion of innovation, data, digital, foresight and behavioural science skills, known as the United Nations 2.0 quintet of change.[6] In the report, the Secretary-General highlights recent technological trends in agriculture and emphasizes that agricultural technologies and their scaling-up need to be accompanied by a range of enabling policies, investment and social and institutional change. In addition, he highlights the need to identify and analyse opportunities, risks and trade-offs and to ensure the availability, accessibility and affordability of relevant technologies for small-scale producers and all actors of the agrifood systems.

III. Progress and challenges in the achievement of Sustainable Development Goal 2 and related goals

7. It is estimated that 673.2 million people in the world faced hunger in 2024, equivalent to 8.2 per cent of the global population. This marks a decrease of 15.2 million people compared with 2023. However, the global prevalence of moderate or severe food insecurity was 28 per cent in 2024, an increase of 335 million people since 2019, before the pandemic. Progress remains uneven: the global prevalence of stunting in children under 5 years of age in 2024 was 23.2 per cent, while an estimated 6.6 per cent of children under 5 years of age were affected by wasting in 2024. The latest updates on obesity in adults of 18 years of age and over show an increase from 2012 (12.1 per cent) to 2022 (15.8 per cent). In addition, 2.6 billion people, or 32 per cent of the global population, could not afford a healthy diet in 2024. While this represents a decrease of 48.8 million people from the previous year, affordability has worsened in Africa and in many low-income and lower-middle-income countries. In

[2] See www.fao.org/in-action/global-network-digital-agriculture-innovation-hubs/en.
[3] General Assembly resolution 79/1.
[4] Ibid., annex I.
[5] See https://globalallianceagainsthungerandpoverty.org/about/.
[6] See https://www.un.org/two-zero/en.

2024, the number of people affected by forced displacement linked with food crises continued to rise, reaching 95.8 million, a 4 per cent increase compared with 2023.[7] In addition, rapid urbanization is changing agrifood systems globally, which will affect rural livelihoods in multiple ways. Changes in large countries have had substantial regional and global impacts. These country-level dynamics underscore the importance of looking beyond global averages to understand regional disparities, and of adopting tailored approaches in different contexts.

8. Climate change and extreme climate events are disrupting agriculture, food production and supply chains, while increasing the spread of pests and diseases. The year 2024 was the warmest year in the 175-year observational record and temperatures continue to rise.[8] Drylands, home to over 2 billion people and rich in indigenous livestock and plant species, mostly in developing countries, face water scarcity and high climate vulnerability. Agricultural losses due to climate disasters made up an average of 23 per cent of the total impact of natural disasters across all sectors.[9] Furthermore, climate-driven shocks were the leading cause of acute food insecurity for nearly 72 million people in 18 countries, most of them fragile or conflict-affected,[10] and, in some cases, led to migration and movement of refugees.

9. While the rate of deforestation is slowing in some countries, the expansion of agricultural land continues to be the main driver of deforestation. Globally, almost 90 per cent of reported deforestation in the period 2000–2018 was due to agricultural expansion,[11] which is linked to outbreaks of zoonotic and vector-borne diseases, increasing water scarcity, land degradation and desertification. Loss of genetic diversity in trees and other woody plants continues, especially in tropical and subtropical regions.[12] While 80 per cent of the world's food comes from plants, the diversity of plant genetic resources for food and agriculture is under growing threat. Only nine crops accounted for over 60 per cent of production.[13]

10. Biodiversity for food and agriculture is among the Earth's most important resources yet is under threat of decline. In 2021, 64 per cent of assessed marine fish stocks were exploited within biologically sustainable levels and that percentage continues to decline.[14] In crops, replacement of farmers' varieties with improved varieties poses a threat to this important source of diversity. Results from a survey in 9 of 18 subregions were particularly alarming, with 18 per cent or more of farmers' varieties/landrace diversity reported as threatened.[15] In livestock, genetic diversity is also under threat.

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[7] Food Security Information Network and Global Network against Food Crises, *Global Report on Food Crises 2024* (Rome, 2024).

[8] World Meteorological Organization (WMO), *State of the Global Climate 2024* (Geneva, 2025). Available at: https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024.

[9] FAO, *The Impact of Disasters on Agriculture and Food Security 2023 – Avoiding and reducing losses through investment in resilience* (Rome, 2023).

[10] Food Security Information Network and Global Network against Food Crises, *Global Report on Food Crises 2024.*

[11] FAO, Global Remote Sensing Survey (Rome, 2021). Available at: https://openknowledge.fao.org/server/api/core/bitstreams/fe22a597-a39d-4765-8393-95fbcaed6416/content.

[12] FAO, Intergovernmental Technical Working Group on Forest Genetic Resources, Commission on Genetic Resources for Food and Agriculture, Eighth Session, 26–28 November 2024, Rome. Available at https://openknowledge.fao.org/server/api/core/bitstreams/7894bf28-6bc3-4e22-9337-cc5e960aa5ec/content.

[13] FAO Commission on Genetic Resources for Food and Agriculture Assessments, *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (Rome, FAO, 2025).

[14] FAO, *Review of the state of world marine fishery resources* (Rome, 2025).

[15] FAO Commission on Genetic Resources for Food and Agriculture Assessments, *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture*.

11. Approximately 13.2 per cent of the world's food is lost on an annual basis between harvest and the retail market. An estimated 19 per cent of food is wasted at the retail and consumer levels.[16] At the same time, globally, unsafe food is known to cause acute and chronic diseases, affecting vulnerable and marginalized people and their livelihoods. Rapid urbanization, together with income growth in low- and middle-income countries, is accelerating the dietary transition towards processed foods, adding pressure on natural resources.

12. Plant pests and diseases affect crop production, and cause 40 per cent of crops to be lost every year. Transboundary pests such as locusts and fall armyworm pose a particular threat to crops. The challenges encompass a wide range of spatial and temporal scales, transcend sectors, boundaries and international trade policies, and are linked with one another in complex and at times unanticipated ways. The global spread of transboundary pests and diseases has severely affected food and nutrition security and agricultural livelihoods.

13. Agrifood systems are responsible for 30 per cent of global energy consumption and 31 per cent of global greenhouse gas emissions.[17] The challenge is to decouple the development of efficient and inclusive food chains from the extensive use of fossil fuels, without compromising food security.

14. Digital technologies have high potential in agriculture sectors, but their adoption is hampered by a triple divide (digital, rural and gender). Without deliberate attention to equality and significant public investments, digitalization may exacerbate existing inequalities. Young people are disproportionately affected by limited access to education, training and decent rural employment, accelerating migration and weakening the resilience of agrifood systems. While progress has been made in reducing child labour, it is insufficient to meet targets on inclusive economic growth and decent work for all.[18] Young people and women are among those most affected by inadequate digital infrastructure in rural areas. About 36 per cent of working women work in agrifood systems, particularly in sub-Saharan Africa and Southern Asia, yet their access to resources and technologies still lags behind that of men. Although gender gaps in financial services and connectivity are narrowing, women farmers face intersecting digital, rural and gender divides.[19] Digital public goods can empower societies and digital public infrastructure has the potential to deliver services at scale. Indigenous Peoples and marginalized populations living in both rural and urban areas face compounded barriers to technology access and resources, including limited digital infrastructure, affordability challenges, lack of digital literacy and training, language and cultural obstacles and exclusion from decision-making processes. Women, in particular, face additional hurdles such as restrictive gender norms, limited device ownership and fewer opportunities in technology design. These barriers prevent equitable participation in the digital economy and limit the ability to benefit from innovations in agriculture and food systems, making targeted inclusion and tailored solutions essential to ensure no one is left behind in the digital transformation.

15. National strategies for agricultural development often fail to take account of the barriers to adoption of technologies and ways to scale their use through technology needs assessments, co-creation of technologies and capacity development of

[16] United Nations Environment Programme, *Food Waste Index Report 2024. Think Eat Save: Tracking Progress to Halve Global Food Waste* (Nairobi, 2024).

[17] FAO, *Greenhouse gas emissions from agrifood systems. Global, regional and country trends, 2000–2022* (Rome, 2024).

[18] FAO, *FAO framework on ending child labour in agriculture* (Rome, 2020).

[19] FAO, *The status of women in agrifood systems* (Rome, 2023). Available at https://openknowledge.fao.org/items/adc0741f-9de2-4d09-ae68-b19cc871601a.

agricultural innovation systems. Capacity development programmes are limited and often target men, and technologies themselves, such as mechanized tools, may not be ergonomically designed for women.[20] This underscores the need for gender-responsive innovation systems that prioritize inclusive design, equal representation and equitable access to technology.

IV. Technological trends and key advances

16. Agricultural biotechnologies include modern plant breeding techniques, such as marker-assisted selection, genome sequencing and editing technologies, especially clustered regularly interspaced short palindromic repeats (CRISPR/Cas9), and synthetic biology, which are increasingly applied in the genetic improvement of agricultural species. The contribution of artificial intelligence and digital sequence information in the development and application of biotechnologies for agriculture, nutrition, food safety, bioeconomy and the microbiome has increased exponentially.[21] Discussions are under way on multilateral platforms such as the Conference of the Parties to the Convention on Biological Diversity regarding access to genetic resources, including digital sequence information, and the fair and equitable sharing of benefits arising from their use.[22]

17. Protected cultivation that involves the use of structures and covering materials to create a favourable environment for crop growth and efficient use of natural resources is gaining in importance. Structures can be low in cost and use locally sourced materials, such as treated timber and bamboo, and biodegradable covering materials as an alternative to plastics, contributing to the expansion of protected cultivation systems.[23] Although the initial investment in protected cultivation may be high, the efficiency of the system and the possibility of off-season harvesting ensure a fast return on investment, leading to sustained economic gains.

18. Sustainable agricultural mechanization is used, inter alia, to enhance the efficiency of land preparation, seeding and planting, weed control, pest management, precise inputs application, harvesting, preparation for storage and value addition along the crop value chain.[24] Farmers who have access to improved agricultural tools and powered equipment can transition from subsistence farming to more market-oriented farming, reducing drudgery and the labour burden, thereby making the agricultural sector more attractive to rural youth.[25] Reduced losses during and after harvest as a result of mechanization-based solutions imply more efficient use of land and inputs, and reduced greenhouse gas emissions. Sustainable mechanization and digital technologies are increasingly being harnessed to boost productivity and reduce labour burdens.[26]

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[20] FAO, *The status of women in agrifood systems*.

[21] D. Smith, M.J. Ryan and A.G. Buddie, "The role of digital sequence information in the conservation and sustainable use of genetic resources for food and agriculture: opportunities and challenges", Background Study Paper, No. 73. Commission on Genetic Resources for Food and Agriculture (Rome, FAO, 2023). Available at https://doi.org/10.4060/cc8502en.

[22] See decision 16/2, adopted by the Conference of the Parties to the Convention on Biological Diversity at its sixteenth meeting.

[23] FAO, *Analysis of stakeholder submissions towards the development of a Voluntary Code of Conduct on the Sustainable Use and Management of Plastics in Agriculture* (Rome, 2024).

[24] See www.fao.org/sustainable-agricultural-mechanization/overview/what-is-sustainable-mechanization/en/.

[25] Ibid.

[26] See www.fao.org/gender/learning-center/thematic-areas/gender-and-innovative-and-labour-saving-technologies.

19. Digital technologies and information and communication technologies, precision agriculture, smart farming and remote sensing are revolutionizing agriculture. For example, artificial intelligence supports the achievement of Sustainable Development Goal 2 by enabling precision farming, environmental monitoring and animal tracking, helping to optimize resources, boost crop resilience and improve productivity while reducing the environmental impact.[27] By increasing transaction efficiency and cooperation among value chain actors, blockchain technology contributes to improving income by reducing transaction costs.

20. In some contexts, it may be necessary to prioritize basic mobile technologies, such as short message service (SMS) and voice-based systems, that operate without the need for Internet access. Building digital literacy – particularly among Indigenous people, women and young people – through tailored training and integration into extension services is also critical. Experiences in Latin America and the Caribbean show that rural extension services and digital literacy are needed.[28] Precision livestock farming utilizes a range of sensors to monitor individual animals or groups of livestock in order to improve animal health and productivity, collecting data by means of satellites, ground sensors or unmanned aerial vehicles. The ability to use sensors transmitting real-time data, on animals, in the field and in the soil, allows for cost-effective and accurate means of predicting animal and crop growth. Precision technologies can be applied throughout the value chain, improving efficiency at each stage. Real-time monitoring of supply chain activities also supports compliance with food safety standards and certification schemes.

21. Technologies provide opportunities to strengthen the resilience of agrifood systems while adapting to climate change and mitigating greenhouse gas emissions.[29] Models such as the Global Agro-Ecological Zoning framework are used to assess the potential of global agricultural resources and agricultural practices that have shown potential to optimize crop production. Such models with remote sensing can be used to determine agricultural parameters, monitor pests and diseases and conduct damage analysis (e.g. the global platform and mobile application for the Fall Armyworm Monitoring and Early Warning System and the Desert Locust Information Service of the Food and Agriculture Organization of the United Nations (FAO)).

22. The integration of renewable energy technologies and energy efficiency measures along agrifood value chains offers substantial synergies with the potential to enhance productivity, reduce greenhouse gas emissions and improve resilience. A wide range of renewable energy sources can be deployed to power key agricultural activities such as irrigation, and also transport. For example, solar-powered irrigation and cold chains can lower operational costs and reduce post-harvest losses, while off-grid renewable systems improve energy access in rural and remote areas. However, high upfront costs, lack of awareness, limited technical capacity and gaps in supportive policies and infrastructure are some barriers to adoption to be addressed.

23. Food processing technologies and technologies that track the movement of a food along the supply chain help to ensure food safety. In the case of an outbreak of a foodborne illness, efficient product tracing helps government agencies, producers and retailers to rapidly find the source and points of contamination. Tracking can also

[27] International Telecommunication Union, *AI for Good. Impact Report* (2024)

[28] Economic Commission for Latin America and the Caribbean, *Sistemas Mixtos de Extensión Rural: resumen de sus características y alcances* (Santiago, 2024).

[29] Technology Executive Committee and United Nations Climate Technology Centre and Network, "Technology and nationally determined contributions. Stimulating the uptake of technologies in support of nationally determined contribution implementation", (2023). Available at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/techandndc/4801dcaef1a74c5ca27f33360a6bd9d1/0aa460d277b54863a9fdbd51bf36aca5.pdf.

allow retailers to offer discounts on products nearing expiration, helping to reduce waste and promote more responsible consumption.

24. Several interconnected technological trends are transforming agrifood value chains, such as smart factories, intelligent, shortened and streamlined supply chains, online food retail and delivery services, financial technology (fintech), digital farming, education, extension and advisory services and market information and analytics. The rise of integrated digital platforms provides great potential to streamline the entire agrifood value chain, from input markets and smart farm management to financial and supply chain services, marketing, distribution and governance, fostering direct linkages among value chain actors. The synergistic integration of digital technologies is creating new economic opportunities, efficiency gains and sustainability across agrifood systems.

25. Monitoring and early warning systems related to food and agriculture are increasingly sourcing data and information from satellites, drones and automated systems for data collection and application for emergency operations and rapid response actions. These technologies are helpful for the timely monitoring of pests and disease outbreaks as well as for the promotion of environmentally sound management practices such as biological control, ultra-low volume pesticide application and integrated pest and disease management practices. Examples include the work of FAO in relation to its Emergency Centre for Transboundary Animal Diseases with the strengthening of early warning, disease reporting and surveillance activities, including the FAO Event Mobile Application, the Rift Valley fever decision support tool, which is integrated into the FAO Agro-informatics Platform, and the use of drones and portable polymerase chain reaction machines and DNA sequencers.

V. Technology needs assessment, knowledge-sharing and capacity development

26. Technology needs assessments[30] include prioritization, technology choice, the building of enabling environments, barriers analysis and technology action plans. They prioritize, for example, agriculture and water adaptation technologies such as the introduction of resilient crop varieties and animal breeds, water conservation and land management techniques. Assessments should take account of the entire value chain, be country-driven and action-oriented, and have a clear strategy for capacity development based on identified needs. The agriculture sector is consistently prioritized by developing country Parties to the United Nations Framework Convention on Climate Change in their technology needs assessments. Notably, 87 per cent of Parties identify agriculture, forestry and other land-use sectors as a priority for adaptation activities, while 35 per cent consider the agriculture sector for mitigation activities.[31]

27. There is strong demand to identify and assess drivers of and barriers to the development, transfer and uptake of technologies. Assessing the broader economic impact of technology adoption through comprehensive analytical approaches is critical to support evidence-based policymaking and strategic investment planning. In addition, foresight methodologies such as horizon scanning, scenario building and strategic planning are applied to address the knowledge gap surrounding emerging

[30] See https://unfccc.int/ttclear/tna.

[31] FAO and United Nations Framework Convention on Climate Change, *Climate technologies for agrifood systems transformation – Placing food security, climate change and poverty reduction at the forefront* (Rome, 2024).

agrifood technologies across different time horizons, ranging from 2030 to 2050 and beyond.[32]

28. Knowledge-sharing and capacity development initiatives at the global, regional and national levels for evidence-based decision-making leverage digital platforms, virtual reality simulations and artificial intelligence-powered knowledge hubs. These tools not only broaden access to cutting-edge research and best practices but also create interactive and adaptive learning environments. For instance, digital twins of value chains, in other words, a virtual representation of a physical supply chain network, allow policymakers and practitioners to simulate the outcomes of different policy or investment scenarios in real time, enabling more precise, data-informed decisions for transforming agrifood systems sustainably.

29. There are several ongoing efforts with regard to technology transfer and knowledge-sharing. For example, the World Intellectual Property Organization offers long-standing technical assistance to facilitate the transfer of appropriate technologies for addressing development needs in agriculture, in the least developed countries.[33] The World Meteorological Organization (WMO) has developed an online training course on drought monitoring and early warning systems. In these initiatives, the need to leverage traditional knowledge for the local development of technologies that improve food security and sustainability is emphasized.

30. Capacity development initiatives for rural youth are a priority for fostering the development and adoption of technologies. Initiatives such as the Youth Food Lab incubator programme developed by the World Food Forum Global Youth Action Initiative (Youth Initiative) can enhance young people's access to entrepreneurial and technological knowledge, supporting youth-led projects and business beginning at the ideas stage.[34] Similarly, networks of young scientists such as the Young Scientists Group – a global platform of emerging young researchers – support youth contributions to the transformation of agrifood systems.[35] Knowledge products aimed at rural communities can address the digital divide and advance pathways toward inclusive rural digitalization.[36] The United Nations Food Systems Coordination Hub, through its Youth Leadership Programme, established a global youth task force to amplify youth leadership in food systems transformation. This coalition united youth voices from various organizations, including the World Food Forum Youth Initiative, the United Nations children and youth major group, and the Stakeholders Engagement and Networking Advisory Group. Through their collaborative efforts, they coordinated youth engagement leading up to the second United Nations Food Systems Summit Stocktaking Moment in July 2025. The task force played an instrumental role in updating the Youth Declaration on Food Systems Transformation, reflecting the priorities and aspirations of young people worldwide.

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[32] Nevena Alexandrova-Stefanova and others, *Shaping sustainable agrifood futures: pre-emerging and emerging technologies and innovations for impact* (Rome, FAO, and Paris, Agricultural Research Centre for International Development (CIRAD), 2024).

[33] World Intellectual Property Organization, "Agrifood", Patent Landscape Report Series (Geneva, 2024).

[34] See https://youth.world-food-forum.org/news/detail/the-wff-youth-food-lab-incubator-programme-concludes-its-second-cycle/en.

[35] See www.fao.org/newsroom/detail/fao-and-the-world-food-forum-launch-young-scientists-group/en.

[36] Kevin Hernandez and others, *Towards digital inclusion in rural transformation* (Rome, FAO, 2024).

VI. Adoption and use of technologies at scale

Improving productivity, food security and nutrition

31. Biotechnologies play a critical role in the development of improved genetic varieties, breeds and strains for increasing productivity and enhancing nutritional quality. The CRISPR gene editing tool is used by government research institutions and start-ups in a wide range of applications from reducing waste to adapting plants and animals to climate change and improving productivity. Youth-led start-ups play a critical role in promoting the adoption and use of biotechnologies at scale. However, enabling environments such as rules and regulations governing development, approval and commercialization need to be strengthened in order to promote widespread adoption.

32. The FAO AquaGRIS platform,[37] launched in 2024, enhances aquaculture by cataloguing genetic resources of farmed and wild aquatic species. It supports biodiversity conservation, informs breeding programmes and aids the development of sustainable aquaculture through standardized data collection and monitoring. Standards are essential for building interoperable data systems and scaling solutions, and for ensuring that technologies such as artificial intelligence, the Internet of things and geospatial tools work effectively across sectors and borders. The United Nations Environment Programme plays a key role in connecting private sector data with public sector needs for standardized nature-related data in agrifood systems. Coordination among United Nations agencies is vital to harmonize practices, leverage synergies and prevent fragmentation in digital agriculture efforts.

33. Biofortification in crops through plant breeding and agronomic practices generates measurable improvements in vitamin and mineral nutritional status. Biofortification targeting key nutrients of public health concern as defined by the World Health Organization (i.e. vitamin A, iron and zinc) can reduce the risk of deficiency that adversely affects billions of individuals worldwide. HarvestPlus, for example, has developed more than 260 biofortified varieties in 30 countries.[38]

34. Precision agriculture, including precision fish farming, and smart farms, including vertical farms, hydroponics and aquaponics, are being adopted and scaled in various regions with a view to ending hunger and improving nutrition. Modern covering materials allow the plants to be screened from excessive heat, rain, cold, pests and diseases, especially in tropical and continental climates, thereby increasing overall efficiency and environmental health. Besides the huge advantages provided to soil-based systems, protected cultivation is the cornerstone for enhancing crop productivity.

35. The adoption and promotion of sustainable agricultural mechanization at scale allows productivity improvements and the creation of new and better jobs for mechanics, machine operators, agro-dealers and local machine manufacturers in rural communities. This represents an opportunity for unemployed rural youth to gain access to jobs, ensure food security and improve nutrition. The use of appropriate sustainable agricultural mechanization in harvest and post-harvest operations has a direct impact in reducing food losses and increases food security. FAO has launched a Global Innovation Accelerator to mainstream sustainable agricultural mechanization

[37] AquaGRIS is a global information system for aquatic genetic resources. See www.fao.org/fishery/aquagris/en.

[38] HarvestPlus, "Crop biofortification: The pathway to scaling up". Available at www.harvestplus.org/wp-content/uploads/2021/12/Crop-Biofortification_The-Pathway-to-Scaling-Up.pdf.

into farmer field schools. To ensure the sustainability of such interventions, mechanization support services should be scaled up in the targeted areas.

36. In recent years, integrated food production systems, including aquaculture technologies, have boosted efficiency and encouraged the use of best practices at scale. There is renewed interest in their capacity to maximize resource use, enhance incomes and support food security. Digitalization in that respect is transforming aquaculture by improving data collection, management, technological development and decision-making across the production cycle. It could further improve aquaculture development, strengthen value chain connections among farmers, suppliers and traders, and improve production transparency.

37. The coalitions of action developed in the context of the United Nations Food Systems Summit have leveraged technology to accelerate agricultural transformation and support sustainable food systems. The School Meals Coalition, for instance, utilizes digital platforms to streamline local procurement and integrate regenerative farming practices, enhancing both nutrition and climate resilience. Other coalitions, such as those focused on clean cooking and forest preservation, deploy data-driven tools to monitor impact, scale climate-smart agriculture and reduce environmental degradation. Collectively, these innovations enable more efficient, inclusive and sustainable food system interventions.

Adopting climate-resilient technologies at scale

38. Climate-resilient technologies, especially the development and promotion of climate-adapted crop varieties, livestock breeds and fish strains, are widely adopted. To scale them up, capacity development should be aligned with technology deployment, considering varying needs across income levels and institutional contexts, and should be tied to increased investment and financing, which are critical for low-income and smallholder actors in agrifood systems.

39. Start-ups play a crucial role in promoting climate technologies. FAO, through the Agrifood Systems Technologies and Innovations Outlook knowledge base and the Science, Technology and Innovation Portal, provides an overview of the innovation and technology ecosystem. Similarly, some start-ups provide real-time agricultural ecosystem intelligence platforms to enhance crop productivity while lowering water, fertilizer and energy expense.[39] Likewise, the integrated agro-industrial parks established with the support of the United Nations Industrial Development Organization (UNIDO), linking smallholder farmers with agroprocessing facilities and urban markets, promote investments in national and local research and development capacities, which are essential for fostering affordable, locally developed agricultural technologies and adapting to climate change.[40]

Managing natural resources and conserving biodiversity

40. There are multiple examples of increased support being provided to adopt and scale technologies for natural resources management and biodiversity conservation. For example, FAO has been supporting the Group of 20 initiative on bioeconomy to develop metrics, indicators, national policies and strategies for sustainable bioeconomy. UNIDO has implemented renewable energy technologies, such as mini- and small hydrosystems, solar irrigation, solar dryers, biogas systems and biomass-fuelled processing units in rural and agro-industrial settings, including pyrolysis systems for cogeneration of heat, power and biochar[41] to reduce dependence on fossil

[39] See, for example, https://senzagro.com/.
[40] See https://ipp.unido.org/portfolio/agro-industrial-parks.
[41] See https://a2dfacility.unido.org/web/node/12 and https://biocharvietnam.org/.

fuels. The Economic Commission for Africa has partnered with members to create the African Land Investment Portal, a decision support tool designed to assist Governments and investors in making informed agricultural investment choices.

41. The Economic and Social Commission for Western Asia, in collaboration with the Arab Fund for Economic and Social Development, launched a regional training programme on green technologies and business models to promote sustainable entrepreneurship across the Arab region and published a guideline showing the step-by-step process for mainstreaming circular practices in different sectors including agrifood systems. The International Trade Centre has developed a series of handbooks and scenario-based training modules that translate the complex requirements of environmental due diligence into concrete steps for exporters and cooperatives.

Scaling technologies for improving food quality and safety

42. Technologies contribute to improving food quality and safety through genome sequencing for epidemiologic surveillance, food testing and monitoring, as well as outbreak investigations. Artificial intelligence and blockchain can be used to effectively track and monitor food and ensure that it is authentic, safe and of good quality. Big data analytics, predictive modelling and digital labelling are increasingly being adopted to ensure that product information is accurate and up to date, and to track movements of food products. FAO is assisting its members in the strengthening of national food control systems in all respects, covering legal and scientific aspects, multi-stakeholder engagement, enforcement and trade policies. Such initiatives empower members to demonstrate an evidence-based growth path towards an improved food control system that attracts suitable financial support.

43. There are multiple initiatives that integrate digital technologies to improve food quality and safety across the whole value chain. Through initiatives such as whole genome sequencing, FAO further strengthens epidemiological surveillance and investigations of foodborne disease outbreaks by enabling precise identification of pathogens. These innovations help with the tracking of movements of food products and their ingredients, the early detection of contamination risks and the enhancement of food safety and control.

Reducing vulnerabilities and strengthening resilience to risks and shocks

44. Technologies help to reduce vulnerabilities and strengthen resilience through global monitoring, forecasting and early warning of pests and diseases and food insecurity. The FAO global animal disease information system (EMPRESi), a web-based application designed by the Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES) supports countries in their surveillance and early warning capacity. Risk forecasting has been advanced for Rift Valley fever and avian influenza, the latter representing a key global One Health challenge. Similarly, antimicrobial resistance in aquaculture, livestock and crops poses a significant One Health threat. This is being addressed by FAO-led initiatives such as the progressive management pathways for antimicrobial resistance and for aquaculture biosecurity and the national and regional aquatic organism health strategies, all of which improve global monitoring and involve the building of global knowledge networks to promote responsible antibiotic use and alternative disease management strategies.

45. Ongoing work at the global level continues to promote the adoption and scaling of technologies by advancing decision-making, enabling potential investments and providing real-time access to critical information. For example, the monitoring of crops, vegetation and droughts in real time with such tools as the FAO Agricultural

Stress Index System[42] helps to promote proactive decision-making. The FAO Food Price Monitoring and Analysis Domestic Market Prices tool provides the latest information on domestic prices of basic foods, mainly in developing countries. The WMO Integrated Drought Management Programme enhances drought monitoring, using indicators such as the Standardized Precipitation and Evapotranspiration Index. Satellite imagery, global navigation satellite systems and their integrated applications help with monitoring crop health, managing water resources, predicting weather patterns and responding to crises. Nevertheless, there is a need for greater international collaboration, capacity-building and policy innovation to maximize the benefits of space technology in agriculture.[43]

46. In order to enhance the resilience of agrifood systems and related livelihoods, a comprehensive assessment that uses data and technologies to analyse how drivers of food insecurity affect livelihoods is essential. In this regard, Data in Emergencies Monitoring conducted household monitoring in 27 countries in 2024 to deliver timely impact assessments following major crises (El Niño drought in Southern Africa, conflict in Lebanon, Sudan and Gaza, and floods in West Africa and elsewhere), using various data (e.g. remote sensing and household data) and delivering relevant outputs (e.g. livelihoods exposure, impacts, and damage and loss). Data in Emergencies Monitoring generated more relevant and timely evidence for programming by harnessing digital technologies, such as a trends analysis application, an events visualization in emergencies application for flood monitoring, and artificial intelligence-powered chatbots. The Desert Locust Information Service and the Fall Armyworm Monitoring and Early Warning System are used for the continuous surveillance of pest situations and the provision of guidance on response actions.[44]

Adoption and use of digital technologies for inclusive rural transformation

47. Digital services and information and communication technologies are further applied to achieve agrifood systems transformation. The FAO Digital Services Portfolio[45] promotes inclusive digital solutions, from low-cost tools such as SMS-based weather alerts and market updates to cutting-edge artificial intelligence. Digital technologies for financial inclusion, whereby consumers are reached through e-commerce, distributed ledger technologies for land titles and e-extension, among other technologies, are gaining in popularity. The expansion of rural financial inclusion is essential for creating decent employment and reducing poverty among women, young people and smallholders in agrifood systems. Digital financial services offer new entry points, particularly for remote and underserved clients, but their effectiveness depends on the digital and financial literacy divide being addressed, especially for young women.

48. Young people, who are more inclined to adopt digital technologies, can benefit from new entrepreneurship opportunities only if they have access to such technologies, adequate financing and training. Iterative skilling and re-skilling are crucial for a just transition. Mobile money platforms are being adopted at scale among young people in many countries[46] and free or affordable e-learning courses offered through platforms[47] can help resolve some of the challenges that young people face,

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[42] See https://asis.apps.fao.org/.

[43] FAO and United Nations Office for Outer Space Affairs, *Leveraging space technology for agricultural development and food security* (Vienna, 2025).

[44] FAO, *The Impact of Disasters on Agriculture and Food Security 2023.*

[45] See www.fao.org/digital-services/en.

[46] N. Benni, D. Berno and H. Ho, *Agricultural finance and the youth: prospects for financial inclusion in Kenya* (Rome, FAO, 2020).

[47] For example, FAO offers a free e-learning course entitled "Agripreneurship 101" for young agripreneurs. See https://elearning.fao.org/course/view.php?id=908.

including access to finance, education and training. Technologies also have the potential to address the root causes of child labour in agriculture, thereby promoting inclusive rural transformation. The FAO DIGICHILD initiative is aimed at exploring how geographic information systems can enhance traditional child labour monitoring methods. These advanced systems offer detailed georeferenced data, allowing for the identification of rural areas with key risk factors that contribute to the persistence of child labour.

VII. Conclusions and recommendations

Key recommendations for technology adoption and scaling

Adoption and scaling of technologies for sustainable agricultural development

49. Technologies are an important accelerator and enabler to make agrifood systems more efficient, inclusive, resilient and sustainable. However, the adoption and scaling of technologies requires long-term targeted finance. For example, out of 6,437 climate-resilient agrifood system technologies included in nationally determined contributions under the Paris Agreement, only 14 per cent have cost estimates and the potential for financing. The remaining 86 per cent may face financing constraints. Overall, nearly half of the technologies are fully dependent on external support for finance and technology transfer. In lower-income countries, around 80 per cent of climate technologies for agrifood systems need external support.[13] Finance flows to promote adoption of technology should be paired with capacity development strategies, as countries have varying needs based on income levels and institutional contexts. As a follow-up to events such as the World Without Hunger Conference,[48] the African Union and a number of financing initiatives, such as the Transformation Pathways Initiative,[49] aim to address the challenges of financing.[50]

Addressing risks and promoting equity, inclusion and access to technologies

50. The potential of digital technologies combined with other agricultural technologies should be better utilized to narrow digital divides in order to achieve the Sustainable Development Goals, while coordinated and more coherent global digital capacity development efforts are needed. Emerging technologies, including artificial intelligence, should be inclusive and serve all stakeholders, especially in the assessment of risks and opportunities to avoid exclusion. Advanced technologies that are used in monitoring, diagnosis and early warning of specific transboundary pests and diseases can be further expanded to cover the most vulnerable populations for better prevention and response, particularly in developing countries where agriculture is a primary livelihood.

51. Increasing numbers of youth- and women-led incubators are contributing to the co-development and promotion of technologies but they require further technical and entrepreneurial support. Competitions and collaborative platforms can help to engage and empower these groups to drive the next generation of technologies. However, the rapid push toward digitalization, without the availability of offline alternatives, risks deepening digital exclusion and reinforcing structural inequalities. It is also important to enhance the availability, access and affordability of technologies for small-scale producers, young people, women and other vulnerable groups. This can be achieved

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[48] See www.unido.org/world-without-hunger-conference.

[49] See www.unido.org/sub-sites/world-without-hunger-conference/day-2/wwhc-presentation-transformation-pathways-fund-tpf.

[50] See www.unido.org/sites/default/files/unido-publications/2025-03/Addis%20Ababa%20Global%20Call%20To%20Action.pdf.

by promoting inclusive policies and programmes that provide these groups with the necessary tools and resources to leverage technological advancements. Aligning education with actual labour market needs, particularly in rural areas, can also reduce child labour and encourage families to prioritize schooling over agricultural work.

Strengthening complementary enablers and policy frameworks for technology adoption and scaling

52. Complementary enablers including infrastructure, education, training, better science communication, foresight-driven technology exploration, testing, and scaling through technology hubs and knowledge-sharing platforms could improve adoption and use of technologies at scale. These efforts should ensure safety, acceptability, and gender and youth inclusion, and should bring low- and middle-income countries on board to avoid technological divides. It is essential to emphasize the strengthening of agricultural innovation systems, human capital and participatory policy development (e.g. technology policy laboratories). Significant investment in rural infrastructure, training and education is needed to enhance the availability, accessibility and affordability of technologies to small-scale producers and vulnerable groups.

53. Adequate and effective policies, incentives and regulatory frameworks should support these technologies, tailored to national contexts. Integrating innovative practices such as regenerative and climate-smart agriculture with advanced tools such as artificial intelligence requires careful evaluation. Participatory policy laboratories and dialogues for policy integration can help to combine a range of technologies. The Agrifood Systems Transformation Accelerator, co-led by FAO and UNIDO, offers a country-owned platform, open to all partners, to scale these solutions, aligning investments, policies and technologies for meaningful transformation on the ground.

Promoting multi-stakeholder engagement and partnerships for development, adoption and scaling

54. Co-development processes, adoption and scaling require multi-stakeholder engagement through agricultural innovation systems. The involvement of key agricultural stakeholders, including ministries of agriculture, research and extension institutions, producers' organizations and agripreneurs from the perspective of agricultural innovation systems is crucial for co-creation, adoption, scaling and sustainability of technological adoption. Strengthened public-private partnerships and the development of inclusive policies are needed to ensure broad participation in the technological landscape of agrifood systems. These stakeholders should be involved in shaping and monitoring pathways that promote decent work, youth engagement and rural employment. Platforms such as technology hubs can be catalysts of co-development, capacity development and knowledge-sharing.

The role of the United Nations in forging global collective action

55. The United Nations uses its unique convening power and broad partnerships beyond the United Nations system to promote technology adoption and scaling to deliver tangible benefits. This enables engagement with key stakeholders working to advance Sustainable Development Goal 2 and the 2030 Agenda in general. By reaching beyond traditional audiences, the United Nations strengthens collaboration and resource mobilization among partners, funders and Member States facing budget constraints and competing demands. There are a number of United Nations-led initiatives that foster knowledge-sharing and partnerships for the development and promotion of technologies for sustainable agricultural development. The Technology Facilitation Mechanism continues to bring together United Nations entities to share knowledge on science, technology and innovation. The action-oriented Pact for the

Future promotes technologies through the key elements related to science, technology and innovation.

56. Participants at the Food Systems Summit recognized the critical role of science, youth, finance and the private sector in accelerating transformation, and provided space for periodic review under the biannual Food Systems Summit stocktaking moments. The stocktaking process itself has emerged as a best practice, serving as a means of bringing together evidence, partnerships and political leadership, and offers a valuable mechanism for tracking progress up to 2030. The next stocktaking moment is expected to be convened in 2027, providing a further opportunity to align efforts, measure advances and sustain momentum.

57. In his call to action at the second United Nations Food Systems Summit Stocktaking Moment, the Secretary-General set out a clear and urgent agenda for State and non-State actors, as well as the broader international community, to drive bold, coordinated efforts toward food systems transformation. To implement the vision, the United Nations Food Systems Coordination Hub, supported by the Rome-based agencies and working in coordination with the wider United Nations system, facilitates the flow of knowledge, innovations and investment opportunities to drive integrated country-led action.

58. At the tenth annual multi-stakeholder forum on science, technology and innovation for the Sustainable Development Goals, held in 2025, the focus was placed on artificial intelligence as one of the most important elements contributing to agrifood systems transformation. Some other examples of initiatives with a similar focus on artificial intelligence include the Secretary-General's Road Map for Digital Cooperation and the work of the Secretary-General's Scientific Advisory Board, especially on artificial intelligence and synthetic biology. The second United Nations Food Systems Summit Stocktaking Moment, in July 2025, provided a platform for reflecting on progress, strengthening collaboration and unlocking finance and investments to accelerate agrifood systems transformation, in which technologies are expected to have a prominent role. The Secretary-General's United Nations 2.0 initiative, in particular the elements of the quintet of change (i.e. data, innovation, strategic foresight, digital and behavioural science), are directly contributing to enabling and scaling the adoption of technologies.

59. In his Road Map for Digital Cooperation, the Secretary-General aims to ensure that every person has safe and affordable access to the Internet by 2030. As reflected in the Organization's deep commitment to providing efficient mechanisms for multi-stakeholder engagement, enabling the achievement of Sustainable Development Goal 17 on partnerships for the Goals and collaborating to achieve common goals, United Nations agencies are collectively working to bridge the digital divide in rural areas by promoting accessible digital tools and capacity-building initiatives targeting smallholder farmers, women and youth. This work supports inclusive access to digital knowledge and services, directly contributing to rural connectivity and empowerment. The Road Map further promotes open, inclusive and rights-respecting digital public goods.

60. Capacity-building and knowledge-sharing, including by increasing digital skills for all people, should be pursued in order to strengthen the technology access and digital literacy of farmers, extension agents and policymakers. With the objective of fostering inclusive technology development and co-creation, engagement through multi-stakeholder technology platforms, innovation hubs and global partnerships should be sought on a continuous basis to promote responsible technology adoption through policy dialogues on the ethical use of technologies, especially artificial intelligence and other cutting-edge and emerging technologies. Systematic assessment of risks, opportunities and trade-offs is needed to ensure that smallholders, rural

women and youth are fully engaged in the entire spectrum of processes from technology development to adoption, scaling, monitoring, evaluation and learning.

61. Investment for effective implementation of agricultural technologies is critical for achieving the goals of the three Rio Conventions (Convention on Biological Diversity, United Nations Framework Convention on Climate Change, and United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa). The Technology Executive Committee of the United Nations Framework Convention on Climate Change highlighted the application of climate technologies in agrifood systems as an essential means for accelerating progress in adaptation and emission reduction.[51] Important building blocks for realizing their potential include building capacity and raising awareness – particularly for stakeholders in the least developed countries and small island developing countries – and scaling up finance. The development and implementation of technologies should be guided by careful consideration of potential risks and ethical implications for climate, biodiversity and society. Integrating local knowledge and ensuring equitable access to these technologies is also crucial for sustainable agriculture development. The Fourth International Conference on Financing for Development, held in 2025, is key to mobilizing resources to promote and adopt agricultural technologies for sustainable development.

[51] FAO and United Nations Framework Convention on Climate Change, *Climate technologies for agrifood systems transformation*.