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Harnessing digital solutions for agrifood systems transformation

Executive Summary

This background document explores how digital technologies can drive a balanced transformation of agrifood systems in Europe and Central Asia, enhancing productivity while supporting environmental sustainability and social inclusion. It presents a range of digital solutions and highlights that access and adoption remain uneven, with barriers such as limited digital infrastructure, high costs, low digital literacy, and gender-based exclusion particularly affecting smallholders and marginalized communities. The document highlights the need for coherent policies, inclusive innovation ecosystems and investment strategies that embed digitalization within broader agricultural and rural development efforts. It concludes with actionable policy recommendations and outlines a potential role for FAO in supporting Members through technical assistance, capacity building, governance support and regional coordination to ensure that digital transformation is inclusive, sustainable and farmer-centred.

Guidance Sought

Members are invited to review this document and provide feedback on its analysis, results and proposed recommendations. Members should consider translating the recommendations into national action plans, allocating sufficient resources, and strengthening institutional mechanisms for coordination and delivery. Members also are encouraged to foster regional dialogue and cross-country knowledge exchange to accelerate progress and scale good practices. These actions are essential to ensuring that digital transformation delivers on its potential to build productive, inclusive, resilient and environmentally sustainable agrifood systems across the region.

I. Introduction

1. Digital solutions are key enablers of agrifood systems transformation, driving productivity while supporting sustainable resource use, climate resilience and adaptation, and environmental stewardship. Modern technologies such as artificial intelligence (AI), remote sensing and big data analytics, among others, support precise agriculture through climate-smart, data-driven insights that optimize inputs, reduce environmental impacts and enable predictive decision-making. This priority is consistent with global commitments, including with the 2024 United Nations Pact for the Future, which emphasizes digital cooperation and sustainable development, and with the FAO Regional Conference for Europe (ERC), with

sessions progressively reinforcing the role of digitalization in agriculture.[1] While ERC 2018 first called for inclusive digital innovation to address productivity gaps,[2] ERC 2024 deepened the agenda by linking digital tools with sustainability. The present paper builds on these processes by contextualizing those commitments, identifying actionable policy recommendations for Members.

2. Yet, without ensuring social and financial sustainability alongside environmental goals, digital transformation risks reinforcing existing inequalities. Women, smallholders and marginalized communities often face barriers – e.g. limited connectivity, affordability and digital literacy – in accessing digital technologies.

3. To unlock the full potential of digital agricultural transformation, policies and investments must embed inclusion – through integrated digital strategies, rural connectivity, inclusive innovation, and user-centred services rooted in local contexts. This background document explores these themes in Europe and Central Asia, outlining key solutions, adoption challenges and strategies for equitable and sustainable digital transformation. The following chapter highlights digital solutions that improve efficiency, sustainability and resilience, drawing on insights from the FAO AgriTech Observatory.[3] Chapter three explores barriers to inclusive adoption, whereas chapter four outlines policy and investment strategies to drive inclusive transformation. The final chapter provides actionable recommendations to embed inclusion, expand rural infrastructure and strengthen digital governance.

II. Digital technologies balancing productivity and sustainability

4. Digital solutions are already delivering tangible benefits across Europe and Central Asia, offering practical responses to the region's dual challenge of enhancing agricultural productivity while safeguarding environmental and social sustainability.

5. In many parts of the region, the overuse and inefficient management of water and fertilizers contribute to soil degradation and pose risks to long-term agricultural productivity. Intensive farming has led to significant soil erosion and a decline in soil health across the continent.[4] This underscores the urgent need for more resource-efficient agricultural methods. A growing set of precision agriculture solutions powered by in-field soil sensors, drone surveillance and satellite imagery offers tailored insights to optimize input use. These systems do not require farmers to process complex data themselves; instead, they deliver practical, location-specific guidance on when and how much to irrigate or fertilize. Some systems incorporate AI or machine learning to enhance accuracy over time, while others rely on rule-based models calibrated to local crop and climate data. In either case, they help identify nutrient deficiencies, soil moisture needs, signs of crop stress and climate trends early enough to take corrective action. More recently, advances in large language models have enabled interactive advisory tools that provide farmers with instant, context-sensitive guidance on about crop management, pest control and weather risks through chatbots or virtual assistants, generating accessible responses and effectively bridging knowledge gaps.[5]

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[1] **FAO.** 2024. *Report of the 34th FAO Regional Conference for Europe (ERC/24/REP).* Chisinau, Republic of Moldova, 14–17 May 2024. Rome, FAO. https://openknowledge.fao.org/items/a0c7a838-754d-4334-b22c-3e70a6f2967e

United Nations. 2024. *Pact for the Future. Outcome document of the Summit of the Future,* New York, September 2024. United Nations, New York. https://www.un.org/en/summit-of-the-future/pact-for-the-future

[2] **FAO.** 2018. *Report of the 31st Session of the FAO Regional Conference for Europe (ERC/18/REP).* Voronezh, Russian Federation, 16–18 May 2018. Rome, FAO. https://openknowledge.fao.org/items/e6e1166c-3a92-4c57-8dd8-a9459f214241

[3] The FAO AgriTech Observatory is available online at https://agritechobservatory.fao.org.

[4] **FAO.** 2022. *Overview of land degradation neutrality (LDN) in Europe and Central Asia.* Rome. https://doi.org/10.4060/cb7986en

[5] Examples of such technology include:

- Famio: a cloud-based, internet of things-enabled software and mobile application, used in indoor farming in Türkiye. Learn more at https://agritechobservatory.fao.org/famio.

6. Labour shortages, outdated equipment and inefficient practices constrain productivity across many farms in Europe and Central Asia. The use of ageing, heavy machinery exacerbates soil compaction and erosion, while the lack of precision in planting, tillage and harvesting limits yield potential and resource efficiency.[6]

7. Advanced machinery solutions – particularly global navigation satellite system-guided tractors and AI-based farm equipment – support more sustainable and data-informed field operations. These technologies enable accurate route planning, input application and soil management, helping reduce waste, minimize environmental harm and potentially increase productivity per hectare. In parallel, digital platforms that facilitate the sharing of machinery among farmers and cooperatives are improving access to such technologies, reducing idle time and operational costs, especially in contexts where individual ownership remains unfeasible.[7,8]

8. With the exception of well-integrated European Union markets, agrifood markets across the region often lag in their supply chains and suffer from fragmentation, restricting producers' access to formal marketplaces and aggregators. This worsens during crises such as the war in Ukraine, disrupting essential import and export logistics.[9] To address gaps, digital supply chain tools optimize logistics coordination, track product movement and support inventory and storage management across chain nodes. These include digital systems for transport scheduling, cold chain monitoring and traceability – technologies that help reduce spoilage, enhance transparency and ensure compliance with safety and quality standards. In parallel, digital market access platforms – such as online marketplaces or producer-consumer apps – support farmers' visibility and direct sales opportunities while also improving consumers' access to diverse, locally

- AssistAgro: a Russian digital platform for the management of weed and plant diseases in crops. Learn more at https://agritechobservatory.fao.org/assistagro.
- OneSoil Scouting: a Swiss mobile application that helps farmers remotely monitor crops, increase yields and reduce seed and fertilizer costs used in the whole region, among others. Learn more at https://agritechobservatory.fao.org/onesoil-scouting.
- Agricolus: a cloud based decision support system in Italy that uses satellite data, sensors in the field, GIS mapping and machine learning to provide farmers, agricultural cooperatives and agronomists with forecasting models for crop phenology and health, irrigation and pest outbreaks, helping reduce excessive water, fertilizer and pesticide use. Learn more at https://agritechobservatory.fao.org/agricolus.

[6] **FAO.** 2022. *The State of Food and Agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/98a4c80a-b4d3-403c-8557-d8536c8316ee.

[7] **FAO.** 2023. *The State of Food and Agriculture 2023: Revealing the true cost of food to transform agrifood systems.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/1516eb79-8b43-400e-b3cb-130fd70853b0.

[8] Examples include:

- GeoInnovus Automated Control System: a North Macedonian high-precision guidance solution for agricultural machinery that enables tractors, harvesters and sprayers to follow pre-programmed routes without manual steering, enhancing efficiency in planting, fertilizing and pesticide application. Learn more at https://agritechobservatory.fao.org/geoinnovus.
- Agrobot Lala: a Serbian autonomous ground robot that collects and analyses georeferenced soil samples for nitrates in real time, using AI and cloud-based tools to generate multilayer fertilization maps for precision agriculture. Learn more at https://agritechobservatory.fao.org/agrobot-lala.
- Bakus: French autonomous electric vineyard robots for pruning, weeding and pesticide application, offering remote operation to enhance worker safety and hygiene. The robots are supported by a universal platform compatible with various smart tools and devices. Learn more at https://agritechobservatory.fao.org/bakus.
- Unmanned Systems Group: develops Supercam unmanned aerial vehicles (UAVs) for precision agriculture, combining encrypted data transmission, multispectral imaging and georeferenced mapping to monitor crop health, support land and resource management and enhance agricultural decision-making through detailed field analysis. Learn more at https://agritechobservatory.fao.org/supercam-uav.

[9] **FAO.** 2023. *FAO in Europe and Central Asia 2022.* Budapest. https://doi.org/10.4060/cc5252en

produced and nutrient-rich foods. In doing so, they help build more inclusive and nutrition-sensitive agrifood systems.[10]

9. In addition, the lack of transparency in food supply chains – e.g. data inaccuracies, interoperability issues and fragmented records – creates vulnerabilities in food safety and traceability.[11] Digital traceability systems, QR code tagging, blockchain-based ledgers and digital certificates are increasingly being used to address this issue by enabling transparency and compliance across the supply chain, leading to improved food safety and reduced risk of fraud.[12] These technologies work by recording key information – such as origin, batch number, processing steps and transport data – at each point along the supply chain, creating a digital footprint that can be instantly verified by regulators, retailers and consumers. For example, digital alert systems provide real-time data on food safety incidents, enabling rapid government and consumer response to contamination or fraud, thus protecting both human and animal health.[13]

10. Each year, substantial food is lost or wasted during processing, distribution, retail and consumption due to inadequate handling, poor storage and weak inventory management.[14] AI-powered sorting systems, intelligent cold chain infrastructure and real-time storage monitoring technologies have the potential to

[10] Examples include:
- Local Food Nodes: an app developed in Sweden and applied throughout Europe that acts as a bridge between food producers and local consumers. Learn more at https://agritechobservatory.fao.org/local-food-nodes.
- Agromap: an application that connects farmers, processors and agrifood businesses in Georgia by digitally mapping over 20 categories of local actors. Learn more at https://agritechobservatory.fao.org/agromap.
- Farmer Expert (Uzman Çiftçi): a free e-commerce app in Türkiye that serves as a blockchain-based marketplace. Learn more at https://agritechobservatory.fao.org/uzman-ciftci.
- Fuori di Zucca: an Italian organization that coordinates a Solidarity Purchasing Group (GAS in Italian) in the centre of the city of Perugia, Italy. Learn more at https://agritechobservatory.fao.org/fuori-di-zucca.
- Socleo: a French software partner that supports short supply chains within the agricultural and food distribution sectors. Learn more at https://agritechobservatory.fao.org/socleo.

[11] **Astill, J., Dara, R. A., Campbell, M., Farber, J. M., Fraser, E. D. G., Sharif, S. & Yada, R.Y.** 2019. Transparency in food suply chains: A review of enabling technology solutions. Trends in Food Science & Technology, 91, 240–247. doi: 10.1016/j.tifs.2019.07.024.
Sarkar, H., Davis, M. & Burke, D. 2023. How supply chain visibility and traceability can drive a sustainable food industry. In: *SupplyChainBrain*. https://www.supplychainbrain.com/articles/37184-how-supply-chain-visibility-and-traceability-can-drive-a-sustainable-food-industry

[12] **Nguyen, T. H. N., Yeh, Q. & Huang, C.** 2021. Understanding consumer' switching intention toward traceable agricultural products: push-pull-mooring perspective. *International Journal of Consumer Studies*, 46(3), 870-888. https://doi.org/10.1111/ijcs.12733
Westerlund, M., Nene, S., Leminen, S. & Rajahonka, M. 2021. An exploration of blockchain-based traceability in food supply chains: on the benefits of distributed digital records from farm to fork. *Technology Innovation Management Review*, 6-18. https://doi.org/10.22215/timreview/1446.

[13] Examples include:
- Trade Control and Expert System (TRACES) : an online platform operated by the European Union for the tracking of animal and plant health certification. Learn more at https://agritechobservatory.fao.org/traces.
- National Animal Identification and Traceability System (NAITS) in Georgia: Learn more at https://agritechobservatory.fao.org/naits.
- Rapid Alert System for Food and Feed (RASFF): an e-notification and communication system for food quality control used by European Union Member States to prevent harm to European consumers and consumers of products originating in the European Union. Learn more at https://agritechobservatory.fao.org/rapid-alert-system-for-food-and-feed.
- pOsti: an Italian blockchain-based app and mobile app that facilitate the complete traceability of all stages of a product's value chain. Learn more at https://agritechobservatory.fao.org/posti.
- Trusty: helps producers and retailers share agrifood products' journeys and their safety and sustainability standards with final consumers. Learn more at https://agritechobservatory.fao.org/trusty.

[14] **FAO.** 2019. *The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/11f9288f-dc78-4171-8d02-92235b8d7dc7/content

significantly reduce post-harvest losses. These innovations continuously track food condition and location, predict spoilage risks and enable timely interventions such as optimized storage or redistribution. They enhance food quality assurance, lower spoilage rates and improve inventory and logistics efficiency, resulting in reduced greenhouse gas emissions and greater food system resilience.[15,16]

11. Numerous farmers in the region, especially small and medium-sized ones, continue to face barriers in accessing formal finance services. Credit is often expensive, rejection rates are high, and informal lending is preferred, which limits producers' ability to invest in new technologies, inputs or infrastructure.[17] Digital financial instruments – such as mobile wallets, credit scoring, index-based insurance and carbon finance – are helping farmers access capital and insurance.[18] These tools use alternative data such as satellite imagery, transaction histories and weather patterns to assess creditworthiness or determine payouts, expanding access to underserved farmers lacking traditional collateral or credit histories. Some solutions leverage AI-driven risk models to evaluate borrowers rapidly and more accurately, while others use remote sensing and climatic models to automate insurance claims or assess carbon sequestration potential. In both cases, digital tools reduce transaction costs for service providers and offer more timely, accessible and tailored financial products to farmers.[19,20]

[15] **FAO**. 2023. *The State of Food and Agriculture 2023: Revealing the true cost of food to transform agrifood systems.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/1516eb79-8b43-400e-b3cb-130fd70853b0

[16] Examples include:

- Comerso: a French circular economy platform that helps stores manage, sell and donate unsold goods through logistics support, donation tracking and environmental impact assessment tools to reduce food waste and optimize resource use. Learn more at https://agritechobservatory.fao.org/comerso.
- CozZo: a Bulgarian all-in-one food management app that helps reduce waste by tracking inventory and expiry dates, with real-time household syncing, meal planning and integrated messaging for streamlined kitchen coordination. Learn more at https://agritechobservatory.fao.org/cozzo.
- Eatme: a Russian website and app that helps reduce food waste by allowing customers to buy unsold meals from caterers at up to 80 percent off, with real-time notifications, online ordering and scheduled pickup from participating restaurants and cafes. Learn more at https://agritechobservatory.fao.org/eatme.
- Karma: a Swedish mobile app that connects consumers with restaurants and grocery stores that have surplus food to sell at discounted prices. Learn more at https://agritechobservatory.fao.org/karma.

[17] **FI-compass.** 2020. *Financing gap in the EU agricultural and agri-food sectors.* https://www.fi-compass.eu/library/market-analysis/financing-gap-eu-agricultural-and-agri-food-sectors

[18] While digital financial services can support financial inclusion, they are not a standalone solution. Their effectiveness depends heavily on enabling conditions such as regulatory reform, financial sector capacity, digital infrastructure and trust. In the absence of these, digital tools alone cannot overcome the structural limitations of financial systems. This theme is further explored under the subtopic "Unlocking sustainable and inclusive finance and strengthening public–private partnerships for agrifood system transformation" at the Forty-fourth Session of the European Commission on Agriculture.

[19] **Benni, N.** 2023. *Fintech innovation for smallholder agriculture – A review of experiences.* Rome, FAO. https://openknowledge.fao.org/server/api/core/bitstreams/96182efa-1c8e-4588-a40c-1f65d4b6a01e/content

[20] Examples of such technology are:

- Agrio: a fintech platform for credit, cash and resource management solutions targeting agricultural production actors that help contracted farming companies in Türkiye manage their production, contracts, inventory flow and treasury through different services such as digital point-of-sale systems for merchants, e-wallets for farmers and payment networks for mediatory businesses. Learn more at https://agritechobservatory.fao.org/agrio.
- CARD AgroCredit: an Armenian online app designed to guide farmers and other crucial stakeholders on the intricacies of loans, detailing the conditions, prerequisites and application procedures. Learn more at https://agritechobservatory.fao.org/card-agrocredit.
- AgroApp: a Ukrainian online platform for agribusiness finance, connecting farmers with input suppliers and banks to simplify and accelerate the process of obtaining a loan for farmers for the purchase of fertilizers, seeds and plant protection products. Learn more at https://agritechobservatory.fao.org/agroapp.

12. Lastly, traditional agricultural monitoring systems are often reactive, limiting timely responses to fast-evolving challenges such as climate events, pests or market shocks[21] Emerging applications of AI and big data analytics are enabling a shift towards more predictive, real-time decision-making frameworks across agrifood systems. These technologies integrate high-frequency data streams – from weather stations, remote sensors, drones and satellites – to model and forecast variables and risks across production, logistics and market planning in agrifood systems. This enables a more proactive and predictive framework for decision-making in agrifood systems and better positions them to meet the speed and scale of challenges and achieve sustainable production.[22,23]

13. These examples from across the region demonstrate that digital innovations can simultaneously enhance productivity and sustainability. However, realizing their full potential requires addressing persistent gaps in equitable access, financing, skills and policy support – issues explored in the following section.

III. Key challenges to equitable access and inclusive adoption – evidence from the region

14. **Truly sustainable agrifood systems must work for all participants – economically, socially and environmentally**.[24] In practice, this means no group – women, youth or smallholders – can be left behind. Alluding to Sustainable Development Goal 8 on economic growth, FAO notes that an inclusive digital transition is "not just an opportunity – it is a necessity for sustainable agriculture and rural development".[25] Conversely, exclusion from opportunities offered by digital technologies translates into persistent productivity gaps, limited market participation, heightened vulnerability to climate and economic shocks, lost incomes and, ultimately, agrifood systems that fail to deliver economic viability, social equity and environmental sustainability for all participants. Smallholder farmers, rural women and other vulnerable groups in agrifood systems face overlapping obstacles to adopting digital solutions.

15. **While European Union Member States have generally achieved high levels of connectivity**, with 94 percent of households having internet access in 2024,[26] **a significant digital divide persists across the broader Europe and Central Asia region**. The Western Balkans are gradually improving yet still lag

- Zypl: Tajik software that leverages AI to determine creditworthiness. https://agritechobservatory.fao.org/zyplscore.

[21] **FAO.** 2022. *The State of Food and Agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems.* Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/items/98a4c80a-b4d3-403c-8557-d8536c8316ee.

[22] **Golubev, I.G.** 2021. Digitalization and use of artificial intelligence technologies in technical modernization of the agro-industrial complex. *E3S Web of Conferences*, 291, 04006. https://doi.org/10.1051/e3sconf/202129104006
Wu, J. 2024. Digitizing agriculture: strategic insights into traditional challenges and modern management solutions. *Advances in Economics, Management and Political Sciences,* 121(1), 215-219. https://doi.org/10.54254/2754-1169/121/20242631

[23] Examples include:

- AI Forecasting System: From the European Centre for Medium-Range Weather Forecasts (ECMWF), the AI Forecasting System has improved predictive weather accuracy by approximately 20 percent compared to traditional methods. Learn more at https://www.ecmwf.int/.
- AgroScout: from Israel, AgroScout provides AI-powered crop monitoring solutions using drones and remote sensing technologies to detect and predict diseases, pests and nutrient deficiencies. Learn more at https://agritechobservatory.fao.org/agro-scout.

[24] **FAO.** 2018. *Sustainable food systems: Concept and framework.* Rome. https://openknowledge.fao.org/handle/20.500.14283/ca2079en

[25] **FAO.** 2025. *FAO Statements UNECE Regional Forum 2–3 April 2025. Statement for the Closing.* https://regionalforum.unece.org/sites/default/files/2025-04/FAO%20Statements_UNECE%20RFSD%202025_2%20April.pdf

[26] **Eurostat.** 2024. Share of households with internet access. In: *Eurostat*. https://ec.europa.eu/eurostat/databrowser/view/TIN00134

behind European Union averages, particularly in rural areas,[27] while in the Caucasus, connectivity varies widely.[28] Meanwhile, many countries in Central Asia continue to face severe limitations in internet coverage, speed and affordability,[29] especially in mountainous or sparsely populated areas.[30] This digital divide limits access to vital information and keeps agritech companies from developing and scaling solutions tailored to these communities due to perceived low market viability. This creates a reinforcing barrier and undermines economic viability, social inclusion and the environmental benefits that digital technologies can enable.

16. **Upfront investment costs for digital tools – such as sensors, drones and weather stations – remain a widespread barrier to adoption, particularly for smallholder farmers**. High purchase, maintenance and software subscription costs limit uptake globally.[31] In Tajikistan, for example, farmers report being able to pay as little as USD 50 for a technology solution overall, but they are willing to pay only if they are confident that it directly addresses their challenge.[32] This affordability constraint is further reinforced by limited access to formal credit channels among smallholder farmers and agrifood small and medium enterprises (SMEs) that lack collateral or credit history, preventing them from investing in technologies that that are essential for long-term environmental, economic and social resilience. In addition, small agribusinesses, agri-cooperatives and food processors often lack scale or funding to digitize. Research shows that agri-cooperatives lag behind other firms in the adoption of information and communications technology.[33] In general, smaller enterprises cite the same cost, skills and applicability barriers as farmers.[34]

17. **Limited digital literacy and insufficient training hinder effective use of information and communications technology** in agriculture across Europe and Central Asia. Farmers – particularly female, older or less-educated individuals – often lack the skills to operate new tools or perceive their benefits.[35] In some countries, the absence of robust, state-run extension and advisory services exacerbates this issue, leaving farmers without guidance on modern farming technologies and techniques. In other countries, advisory services are delivered by private contracting firms, resulting in uneven reach and quality. But the challenge of limited digital literacy affects not only farmers but also extension agents and local authorities

[27] **Tintor, V., Jovanović, N., Bocarova, V. & Bugarski, M.** 2022. *Western Balkans Digital Economy Society Index. WB DESI 2022 Report.* https://www.rcc.int/files/user/docs/43a521a624cf08523a2268a67a7be2ff.pdf.

[28] **World Bank.** 2020. COVID-19 Prompts Urgency of Bridging Digital Divide in Central Asia. Press Release, 2 December 2020. In: *World Bank Group.* https://www.worldbank.org/en/news/press-release/2020/12/02/urgency-of-bridging-digital-divide-in-central-asia-increases-as-a-result-of-the-covid-19-pandemic.

[29] **GSMA.** 2024. Mobile Connectivity Index: Global Rankings 2024. In: *GSMA.* [Cited 14 July 2025]. https://www.mobileconnectivityindex.com/index.html#year=2024&globalRankings=overall&globalRankingsYear=2024.

Speedtest. 2024. Global Index – Mobile Internet Speeds by Country. In: *Speedtest Global Index.* https://www.speedtest.net/global-index#mobile.

[30] According to surveys conducted by FAO with 618 farmers in Uzbekistan in 2023 and with 1423 farmers in Tajikistan in 2024. Unpublished.

[31] **McFadden, J., Casalini, F. & Antón, J.** 2022. Policies to bolster trust in agricultural digitalisation: Issues note. *OECD Food, Agriculture and Fisheries Papers*, No. 175. Paris, OECD Publishing. https://doi.org/10.1787/5a89a749-en.

[32] According to surveys conducted by FAO with 618 farmers in Uzbekistan in 2023 and with 1423 farmers in Tajikistan in 2024. Unpublished.

[33] **EU CAP Network.** 2023. *Guidelines: Evaluating the AKIS Strategic Approach in CAP Strategic Plans.* Brussels, Directorate-General for Agriculture and Rural Development. https://eu-cap-network.ec.europa.eu/publications/guidelines-evaluating-akis-strategic-approach-cap-strategic-plans_en.

[34] **McFadden, J., Casalini, F. & Antón, J.** 2022. Policies to bolster trust in agricultural digitalisation: Issues note. *OECD Food, Agriculture and Fisheries Papers*, No. 175. Paris, OECD Publishing. https://doi.org/10.1787/5a89a749-en

[35] **Belacin, M., Iacovone, L., Izvorski, I. & Kasyanenko S.** 2025. Accelerating Growth through Entrepreneurship, Technology Adoption, and Innovation. ECA Economic Update (Spring), Washington, DC: World Bank. DOI: 10.1596/978-1-4648-2233-9.

responsible for facilitating digital adoption.[36] This systemic barrier means that simply improving digital literacy in isolation, without linking it to practical agricultural applications and supportive institutional frameworks, will not lead to meaningful adoption or impact.

18. **Many digital solutions, and especially advanced technologies, are designed for large-scale or high-input operations, and small farms and agribusinesses find them mismatched to their needs**. The relevance and appropriateness of currently offered solutions – particularly for smallholders – remains a major obstacle to adoption.[37] The recent European Union Farmtopia project[38] highlights that small farms face "solutions incompatible with their needs" and report uncertain return on investment from pilot tools.[39] The mistrust of opaque algorithms and concerns over data privacy also slow uptake.[40] Surveys conducted by FAO in Uzbekistan (2023) and Tajikistan (2024) reveal that farmers tend to prefer traditional methods when the benefits of digital technologies remain unclear or unproven. The underdeveloped innovation ecosystems across the region hinder technology providers' ability to fully grasp the real needs and challenges of smallholder farmers. Consequently, many digital solutions designed for smallholders either become obsolete or fail to achieve scalable adoption.

19. **Women can face additional structural barriers to accessing and using digital technologies**. Despite the highest gender parity in internet use in the region,[41] normative structural issues coupled with social behavioural practices still limit the impact of digital tools. One key issue is the lack of land ownership and collateral, a widespread problem across the region,[42] which often excludes women from credit and investment opportunities necessary to adopt digital solutions. Surveys conducted by FAO in Uzbekistan (2023) and Tajikistan (2024) show that women have significantly lower ownership of digital devices than men and less awareness of available digital technologies for agriculture and face entrenched social norms that restrict both ownership and use. In some cases, exclusion is institutionalized, as extension and advisory services primarily engage with men through formal channels such as local authorities, religious leaders and farmers' associations – spaces where men typically dominate – leaving women disconnected from information, services and innovation opportunities critical for productive and sustainable agrifood systems.

20. **Digital agriculture governance in Europe and Central Asia shows wide disparities**. European Union Member States, for instance, integrate digitalization as a cross-cutting priority in their Common Agricultural Policy (CAP) Strategic Plans 2023–2027, explicitly linking it to productivity, sustainability, nutrition and resilience objectives.[43] Similarly, Agricultural Knowledge and Innovation Systems are now central to the European Union; the 2023–2027 CAP explicitly frames these systems as the backbone of

[36] **European Commission.** 2021. Empowering smallholder farmers to access digital agricultural extension and advisory services. In: *European Commission.* https://knowledge4policy.ec.europa.eu/publication/empowering-smallholder-farmers-access-digital-agricultural-extension-advisory-services_en

[37] **FAO.** 2020. *Enabling smallholders and family farmers to access appropriate innovation, information and advisory services for sustainable agrifood systems.* Document COAG/2020/15. 27th Session of the FAO Committee on Agriculture, Rome, 28 Sept – 2 Oct 2020. Rome, FAO. https://openknowledge.fao.org/handle/20.500.14283/nd410en

[38] For more information, please see https://farmtopia.eu/.

[39] **EU CAP Network.** 2023. *Guidelines: Evaluating the AKIS Strategic Approach in CAP Strategic Plans.* Brussels, Directorate-General for Agriculture and Rural Development. https://eu-cap-network.ec.europa.eu/publications/guidelines-evaluating-akis-strategic-approach-cap-strategic-plans_en

[40] **McFadden, J., Casalini, F. & Antón, J.** 2022. Policies to bolster trust in agricultural digitalisation: Issues note. *OECD Food, Agriculture and Fisheries Papers*, No. 175. Paris, OECD Publishing. https://doi.org/10.1787/5a89a749-en

[41] **International Telecommunication Union (ITU).** 2024. *Measuring Digital Development: Facts and Figures 2024.* https://www.itu.int/dms_pub/itu-d/opb/ind/d-ind-ict_mdd-2024-4-pdf-e.pdf

[42] **FAO.** 2025. *FAO Statements UNECE Regional Forum 2–3 April 2025. Statement for the Closing.* https://regionalforum.unece.org/sites/default/files/2025-04/FAO%20Statements_UNECE%20RFSD%202025_2%20April.pdf

[43] **European Commission.** 2025. Digitalisation of agriculture and rural areas in the EU. Directorate-General for Agriculture and Rural Development. In: *Digitalisation*. Brussels, European Commission. https://agriculture.ec.europa.eu/overview-vision-agriculture-food/digitalisation_en

modernization and digitalization in farming.[44] In contrast, many non-European Union countries in the region still lack comprehensive and up-to-date digital agriculture strategies and policies on data governance, interoperability, e-government, electronic trade, partnerships and networks for innovation.[45] Nevertheless, there are signs of growing momentum. Tajikistan has adopted its National Programme for Digitalization of Agriculture in 2025,[46] while other countries in the Balkans are advancing efforts to develop similar strategies.[47] Still, the absence or fragmentation of policies and the underdeveloped nature of innovation ecosystems pose a direct challenge to achieving an inclusive digital transition, leaving smallholders, entrepreneurs and other stakeholders without the institutional backing required to adopt and benefit from digital technologies.

21. Addressing these complex multidimensional challenges goes beyond equitable access to technology – it is essential for building agrifood systems that are environmentally sustainable, economically viable and socially inclusive. Closing the gap between productivity and sustainability calls for a more systemic approach that tackles both structural and infrastructural issues, integrates behavioural insights to shift norms and practices – including gender-related barriers – and strengthens trust. Long-term, anticipatory and evidence-based policies – aligned with the vision of United Nations 2.0 and informed by foresight – are needed to ensure that digital innovation goes beyond short-term gains and contributes to agrifood systems that are efficient, resilient, inclusive and sustainable.

IV. Policy and investment strategies for sustainable digital transformation – Insights from across the region

22. A sustainable and inclusive digital transformation of agrifood systems in Europe and Central Asia requires coherent policy frameworks, investment in infrastructure, and support mechanisms that address economic, social and environmental goals. Several core strategic pillars emerge as essential.

23. Reliable internet access remains a primary enabler of digital transformation. Countries such as Kazakhstan and Serbia have begun investing in targeted rural broadband initiatives under public–private partnerships.[48] The European Commission's 2030 Digital Compass sets a clear benchmark, aiming for

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[44] **EU CAP Network.** 2023. *Guidelines: Evaluating the AKIS Strategic Approach in CAP Strategic Plans.* Brussels, Directorate-General for Agriculture and Rural Development. https://eu-cap-network.ec.europa.eu/publications/guidelines-evaluating-akis-strategic-approach-cap-strategic-plans_en

[45] **ITU and FAO.** 2020. *Status of Digital Agriculture in 18 countries of ECA.* Geneva, Switzerland. https://openknowledge.fao.org/items/fde1f47d-64ad-49cf-b932-609b06a83ffb

McFadden, J., Casalini, F. & Antón, J. 2022. Policies to bolster trust in agricultural digitalisation: Issues note. *OECD Food, Agriculture and Fisheries Papers*, No. 175. Paris, OECD Publishing. https://doi.org/10.1787/5a89a749-en

[46] **FAO.** 2025. Tajikistan adopts programme for the digitalization of the agricultural sector, with FAO support. In: *FAO Europe News*. https://www.fao.org/europe/news/detail/tajikistan-adopts-programme-for-the-digitalization-of-the-agricultural-sector-with-fao-support/en

[47] **FAO.** 2024. *Report of the 34th FAO Regional Conference for Europe (ERC/24/REP).* Chisinau, Republic of Moldova, 14–17 May 2024. Rome, FAO. https://openknowledge.fao.org/items/a0c7a838-754d-4334-b22c-3e70a6f2967e

FAO. 2024. Kosovo launches the development of the Digital Agriculture Programme and Action Plan, with FAO support. In: *Digital Villages Initiative in Europe and Central Asia.* [Cited 17 July 2025]. https://www.fao.org/digital-villages-initiative/europe/news-and-articles/news-and-articles-detail/kosovo-launches-the-development-of-the-digital-agriculture-programme-and-action-plan-with-fao-support/en

[48] **Astana Times.** 2025. Kazakhstan to provide 99 percent of rural areas with internet by 2027. In: *The Astana Times.* [Cited 17 July 2025]. https://astanatimes.com/2025/06/kazakhstan-to-provide-99-of-rural-areas-with-internet-by-2027/

European Bank for Reconstruction and Development (EBRD). 2021. EBRD and WBIF support Serbia to expand broadband to rural areas. In: *News and events.* [Cited 17 July 2025]. https://www.ebrd.com/home/news-and-events/news/2021/ebrd-and-wbif-support-serbia-to-expand-broadband-to-rural-areas.html

gigabit connectivity for all European Union households, including rural ones, by 2030.[49] These efforts show that investing in rural connectivity is technically feasible and socially necessary. Expanding such initiatives region-wide is essential to closing rural–urban divides and ensuring that all actors of agrifood systems, including agricultural producers, can fully participate in digital food systems.

24. Many countries in Europe and Central Asia have already begun prioritizing building robust agrifood innovation systems (AIS) as critical for scaling inclusive agricultural innovation and enhancing digital capacities in agriculture. This illustrates that capacity building for digital skills must go hand in hand with strengthening extension services, research and collaboration among actors. Scaling these approaches across the region can help ensure that innovation is farmer centred, context specific and inclusive of marginalized groups. In other words, AIS can serve as the bridge between digital innovation and sustainability by linking research, advisory services and farmers in a system that both accelerates the adoption of productivity-enhancing technologies and ensures that these technologies are tailored to local needs, environmental stewardship and long-term resilience.

25. Experience across Europe and Central Asia shows that designing digital solutions for local realities and scaling them through trusted intermediaries can drive more inclusive uptake. The government-led National Animal Identification and Traceability System (NAITS) in Georgia exemplifies this approach by combining digital registration and traceability tools with outreach via veterinarians, cooperatives and local authorities to ensure broad participation among rural livestock keepers. This strategy has increased system adoption and enhanced food safety, animal health management and market access for smallholders who might otherwise be excluded.

26. There is growing recognition that digitalization must be systematically integrated into national agricultural and rural development strategies or addressed through dedicated digital agriculture strategies, programmes or action plans. This approach aligns with European Union guidance for Member States, and countries such as Spain and Tajikistan already have taken concrete steps by developing their own national digital agriculture road maps.

27. In addition, establishing clear policies on data governance, interoperability standards and safeguards for data privacy and responsible AI use is increasingly critical, especially as trust concerns remain a barrier to digital adoption.[50] Since trust is also a behavioural issue, behaviourally informed policies and actions – such as designing services that account for different risk perceptions, cultural norms and gender dynamics – can play a decisive role in enhancing confidence and accelerating the inclusive uptake of digital innovation.

28. Equally important is ensuring financial mechanisms that support smallholder participation in digital transformation: public incentives, inclusive credit schemes and subsidized investment to support digital adoption by farmers and agrifood SMEs, particularly those facing structural barriers such as limited access to capital or digital infrastructure. Promotion efforts should prioritize technologies that deliver clear income gains for farmers, whether through resource optimization, yield increases, reduced input and labour costs or improved risk management, thereby making adoption both attractive and sustainable.

29. As highlighted in the discussions at ERC 2018 and ERC 2024, supporting platforms and tools that are openly available, interoperable and designed to benefit smallholders and marginalized groups can lower entry barriers, reduce dependency on proprietary systems and ensure broader participation in the digital transformation of agrifood systems. Open-source and open-innovation approaches, including the

[49] **European Commission.** 2023. Europe's Digital Decade: digital targets for 2030. In: *A Europe fit for the digital age.* https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[50] **McFadden, J., Casalini, F. & Antón, J.** 2022. Policies to bolster trust in agricultural digitalisation: Issues note. *OECD Food, Agriculture and Fisheries Papers*, No. 175. Paris, OECD Publishing. https://doi.org/10.1787/5a89a749-en

development and use of Digital Public Goods, offer scalable and cost-effective pathways to ensure that digital transformation benefits are equitably shared across the Europe and Central Asia region.

30. Beyond on-farm technologies, governments in the region are actively leveraging data, registries, e-government systems and predictive AI systems to strengthen agrifood sector monitoring, administration and forecasting. For instance, the Ukraine State Agrarian Registry system, supported by FAO, illustrates how e-government systems and public services help farmers access subsidies, market information and crisis support during conflict.[51] Predictive AI systems – such as the European Union Joint Research Centre's AI-driven climate hazard detection solution[52] – directly contribute to food system resilience. Investing in integrated digital governance – from registries to more advanced monitoring and forecasting systems – is fundamental to building transparent, adaptive and resilient agrifood systems across Europe and Central Asia.

V. Policy recommendations

31. To achieve a sustainable and inclusive digital transformation of agrifood systems that balances agricultural productivity with environmental sustainability and social inclusion, Members are encouraged to prioritize these key areas while leveraging FAO's technical expertise and support for implementation:

A. Promote the use and scaling of digital solutions and services that promote climate-smart, resource-efficient practices – such as precision input use, soil and water monitoring, and early warning systems – to simultaneously increase yields and reduce environmental impacts.
B. Expand affordable, high-quality rural connectivity through public–private partnerships to close the digital rural divide and ensure equitable access to digital services across all agrifood actors.
C. Strengthen Agrifood Innovation Systems, research and education by funding advisory services that prioritize farm productivity and environmental sustainability, innovation hubs and farmer networks, alongside building digital skills for farmers and extension agents and involving them in knowledge co-creation to foster scalable, context-specific innovations.
D. Mainstream digital agriculture within national policies, with a clear focus on both productivity gains and environmental outcomes, while establishing robust data governance and AI ethics frameworks guided by foresight.
E. Embed gender- and age-sensitive and socially inclusive approaches in digital strategies to ensure that women, youth and marginalized communities can benefit equally from new technologies, finance and services. This should include behaviourally informed approaches to shift norms and practices and strengthen trust while overcoming gender-related barriers.
F. Develop inclusive financial mechanisms and investment tools to enable smallholders and marginalized groups to participate fully in the digital transformation by lowering the cost of adopting digital technologies with sustainability co-benefits, such as subsidies for digitally enabled water-saving tools or other climate-smart solutions.
G. Support on-farm experimentation with new digital technologies via farmer-led trials and demonstration plots aligned with long-term environmental stewardship, lowering adoption costs

[51] **FAO.** 2023. *Ukraine: EU-FAO partnership to ensure recovery and development of agricultural value chains.* https://www.fao.org/newsroom/detail/ukraine-eu-fao-partnership-for-recovery-of-agricultural-value-chains-040123/en

[52] **European Commission.** 2025. AI tool to help detect growing climate hazards for EU agriculture. In: *The Joint Research Centre: EU Science Hub.* [Cited 18 July 2025]. https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/ai-tool-help-detect-growing-climate-hazards-eu-agriculture-2025-04-07_en

and partnering with research institutions and extension services to generate localized evidence on their benefits and usability.

H. Design digital solutions and public services, including early warnings, that are farmer centric and locally adapted, disseminating them through trusted intermediaries such as cooperatives and community leaders to maximize uptake and impact among diverse users.

I. Invest in integrated e-government systems, including registries and AI-driven forecasting, to enhance transparency, food safety and resilience against systemic shocks, including in redirecting agriculture subsidies towards innovation and the building of rural ICT infrastructure.

J. Promote open-source and open-innovation approaches, including the development and use of Digital Public Goods, to close inclusivity gaps.

K. Establish monitoring and evaluation systems to track both the adoption of digital technologies and their sustainability outcomes – including effects on productivity, input efficiency and environmental performance – to inform adaptive policy and ensure accountability.

32. As a trusted partner in the region, FAO is well positioned to support countries in designing and implementing digital transformation pathways that balance productivity, sustainability and inclusion. Moving forward, FAO could focus on strengthening national capacities to integrate digitalization into agricultural and rural development policies, including the development of dedicated digital agriculture strategies and action plans. This may involve technical support for mainstreaming climate-smart digital solutions, developing inclusive financing mechanisms, and enhancing Agrifood Innovation Systems to deliver sustainability-focused digital advisory services. FAO also can support the design and delivery of targeted digital skills programmes for farmers, extension agents and local and national institutions to ensure meaningful and equitable adoption. In addition, FAO can provide technical assistance in designing e-government systems and digitalizing public services in a farmer-centric and inclusive manner, ensuring that they are accessible, trusted and responsive to user needs. FAO also can play a key role in convening multistakeholder innovation platforms that foster collaboration among governments, the private sector and rural communities. These efforts would contribute directly to FAO's Strategic Framework and provide a strong programmatic foundation for its work in the 2026–2027 biennium.