EU CAP NETWORK



# Assessing digitalisation under the CAP Strategic Plans

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# Abbreviations

| | |
|---|---|
| AI | Artificial Intelligence |
| AKIS | Agricultural Knowledge and Innovation Systems |
| AMS | Area monitoring system |
| API | Application programming interfaces |
| CAP | Common Agricultural Policy |
| CCO | CAP Cross-Cutting Objective |
| CEADS | Common European Agricultural Data Space |
| CEF | Connecting Europe Facility |
| CLMS | Copernicus Land Monitoring Services |
| COOP | Cooperation type of interventions |
| CSRD | Corporate Sustainability Reporting Directive |
| DE4AFS | Data Economy for Agri-Food Systems |
| DEA | Data envelopment analysis |
| DESI | Digital Economy and Society Index |
| DIB | Disaggregated data on interventions and beneficiaries |
| DMA | Digital maturity assessment |
| DME | Data for monitoring and evaluation |
| DNA | Digital Networks Act |
| EAFRD | European Agricultural Fund for Rural Development |
| EEA | European Environmental Agency |
| EDIH | European Digital Innovation Hubs |
| EIP | European Innovation Partnership |
| ENVCLIM | Environmental, climate-related and other management commitments |
| EO | Earth observation |
| ESA | European Space Agency |
| FADN | Farm Accountancy Data Network |
| FMIS | Farm management information systems |
| FSDN | Farm Sustainability Data Network |
| GHG | Greenhouse gas |
| GPS | Global positioning system |
| IACS | Integrated administration and control system |
| ICT | Information and communication technology |
| IFS | Integrated farm statistics |
| INVEST | Investment type of interventions |
| INVRE | Investments in tangible and intangible assets, research and experimental and innovative production methods |
| IoT | Internet of Things |
| ISIC | International Standard of Industrial Classification |
| JRC | Joint Research Centre |
| KNOW | Knowledge exchange and dissemination of information |
| LCA | Life cycle assessment |
| LPIS | Land-parcel identification system |
| NGEU | Next Generation EU |
| NUTS | Nomenclature of territorial units for statistics |
| OECD | Organisation for Economic Co-operation and Development |
| PMEF | Performance Monitoring and Evaluation Framework |
| PPP | Plant protection product |
| S3 | Smart Specialisation Strategy |
| SME | Small and medium-sized enterprises |
| SO | CAP Specific Objective(s) |
| TTMU | Trans-theoretical model of perceived usefulness |

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# Introduction

The 2023-2027 CAP gives more attention to digitalisation as Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 [1], foresees that Member States will elaborate **digital strategies** to develop a strategic approach towards digitalisation in agriculture and rural areas. These strategies should show the way for the increased adoption of digital technologies in agriculture and rural areas and the use of those technologies **to improve the effectiveness and efficiency** of the CAP Strategic Plan interventions.

Furthermore, this regulation has several specific provisions explicitly referring to digitalisation. At the level of objectives, digitalisation is not regarded only as a means to modernise agriculture and rural areas (CAP Cross-cutting Objective (CCO)) [2], but also as a specific area to focus on for increasing farm competitiveness (Specific Objective 2) [3], through enhancing market orientation and farm productivity. As regards horizontal aspects, farm advisory services must cover digital technologies in agriculture and rural areas [4], as well as the sustainable management of nutrients with the use of digital applications [5]. At the intervention level, the types of interventions in the wine sector include tangible and intangible investments in innovative processes for the digitalisation of the processes and technologies to produce wine products [6]. In addition, a number of investments in the installation of digital technologies in agriculture, forestry and rural areas, such as investments in precision farming, smart villages, rural businesses, and information and communications technology infrastructures, are considered as contributing to the CCO [7]. Finally, other types of interventions, such as cooperation, including LEADER, as well as knowledge exchange and dissemination of information, may also contribute to digitalisation.

Regarding the evaluation of digitalisation, Annex I of Commission Regulation 2022/1475 of 6 September 2022 [8], includes the **digital strategy** as one of the key elements that **must be assessed when evaluating the effectiveness of the CCO.** Finally, digitalisation can play a central role in the delivery of the policy and its simplification, and this is an aspect that must be analysed when Member States assess the efficiency of their CAP Strategic Plans [9].

The monitoring and evaluation of digitalisation in the 2023-2027 CAP requires, first of all, a mechanism for the identification of digitalisation-related interventions in the CAP Strategic Plans, which may allow not only the development of a sound intervention logic but also the establishment of a baseline and the consequent tracking of the adoption and intensity of digitalisation. To this end, the report:

- Develops a conceptual framework for the role of digitalisation under the CAP Strategic Plans, including in the delivery of interventions and administrative simplification.
- Analyses the set of indicators that can be used to monitor and assess digitalisation in CAP Strategic Plans, focusing on existing data sources and proposing improvements, where needed.
- Proposes a methodology to better identify CAP Strategic Plans interventions related to digitalisation, based on a detailed classification system.

Building on these, the report analyses the main considerations for assessing both the cross-cutting contribution of CAP support to fostering digitalisation and the contribution of digitalisation to the CAP's specific objectives.

This report serves three primary audiences, each with distinct needs regarding the assessment of digitalisation. **Managing Authorities and other administrative bodies** delivering digitalisation interventions may gain an understanding of the role of digitalisation across the agri-food sector's value chain and in rural areas, as well as how the CAP Strategic Plans and other funding sources can be leveraged to enable and drive change, overcoming barriers. Moreover, they will find practical solutions for systematic identification of digitalisation activities across their CAP Strategic Plans and beyond, and for preparing and structuring evaluations that demonstrate how their digitalisation-related interventions contribute to sustainable farm productivity and modernisation of agriculture and rural areas.

**Evaluators** conducting assessments during the design and implementation, and after the completion of digitalisation-related interventions, gain a structured methodology for measuring digitalisation adoption and impacts, with clear linkages between the identification of digitalisation-specific interventions, evaluation questions and data sources. The report provides key considerations for establishing baselines and attributing effects to specific interventions, while the proposed survey modules and analytical strategies offer practical tools for enriching the existing evidence base.

[1] Article 114(b) of Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulations (EU) No 1305/2013 and (EU) No 1307/2013. OJ L 435, 6.12.2021, p. 1–186. ELI: http://data.europa.eu/eli/reg/2021/2115/oj.

[2] Paragraph 2, Article 6, Regulation (EU) 2021/2115.

[3] Paragraph 1(b), Article 6, Regulation (EU) 2021/2115.

[4] Paragraph 4(f), Article 15, Regulation (EU) 2021/2115.

[5] Paragraph 4(g), Article 15, Regulation (EU) 2021/2115.

[6] Paragraph 1(e), Article 58, Regulation (EU) 2021/2115.

[7] Recital 78, Regulation (EU) 2021/2115.

[8] Commission Implementing Regulation (EU) 2022/1475 of 6 September 2022 laying down detailed rules for implementation of Regulation (EU) 2021/2115 of the European Parliament and of the Council as regards the evaluation of the CAP Strategic Plans and the provision of information for monitoring and evaluation. OJ L 232, 7.9.2022, p. 8–36. ELI: http://data.europa.eu/eli/reg_impl/2022/1475/oj.

[9] Paragraph 3, Article 1, Regulation (EU) 2022/1475.

Finally, the **European Commission** may benefit from a harmonised approach that enables consistent and future-oriented monitoring of digitalisation progress across Member States, facilitating aggregate analysis of CAP Strategic Plans' contribution to the Digital Decade targets [10].

### How to read this report

It must be stressed that this is a thematic report with the purpose of providing some tools and key considerations, but not exhaustive guidance for assessing digitalisation under the CAP Strategic Plans. This is because the contribution of digitalisation to the CAP specific objectives can, in general, be approached the same way as any other intervention, and therefore, many aspects have already been addressed by other publications, including those by the EU CAP Network. This report highlights the dimensions specific to digitalisation and is structured in five sections. Section 1 discusses the general role of digitalisation in modern agriculture and rural areas by analysing two parallel and complementary value chains: the classical agri-food value chain and the agri-food data economy value chain. Section 2 takes a more specific approach and presents a theoretical framework for digitalisation under the CAP Strategic Plans, discussing drivers and barriers to digitalisation and the role of CAP Strategic Plans and other EU policies towards leveraging these drivers and overcoming the barriers. Based on this theoretical framework, Section 3 discusses the development of a generic intervention logic under the CAP Strategic Plans by developing a definition of digitalisation under the CAP Strategic Plans and discussing its key components, and by presenting ways to identify digitalisation related interventions, including through a three-tier classification system. Finally, Section 4 discusses the structuring elements, the available data sources and the key considerations that must be taken into account for the assessment of the contribution of CAP support towards fostering digitalisation and the assessment of the contribution of digitalisation towards the CAP specific objectives. The first two sections set the theoretical basis and are addressed to all audiences. Evaluators and evaluation managers may focus more on Section 3 and 4 and consult Sections 1 and 2 when they need to understand the theoretical background.

# 1. Role of digitalisation in modern agriculture and rural development

## 1.1. Digitalisation in the agri-food value chain and rural areas

Agriculture is currently confronted by multiple, interrelated pressures including climate change, natural resource depletion and global food security concerns. At the same time, society demands safe and sustainable food produced transparently and ethically. In response, digitalisation in agriculture may help to address these challenges by providing more accurate information for decision-making, thereby improving efficiency, resilience and sustainability [11]. Importantly, digital transformation is not only about on-farm improvements; it also fosters rural development by improving access to services and knowledge for communities outside urban centres.

In essence, digitalisation means using data-driven approaches (e.g. by leveraging sensors, analytics, automation, connectivity) to inform decisions at every stage of production and distribution, as well as to contribute to a sustainable and inclusive development of rural areas. By adopting such technologies, stakeholders can overcome traditional barriers, strengthen linkages between producers, processors and consumers, and unlock new opportunities for growth. In the following sections, we examine the role of digitalisation.

Developed by Michael Porter and used throughout the world for nearly 30 years [12], the value chain provides a solid framework for illustrating the role of digitalisation and discussing how it can contribute to a more sustainable, data-driven agri-food sector and rural areas. Adapted to the agri-food sector and rural areas, Porter's value chain includes:

- **primary activities**, such as upstream logistics, on-farm operations, downstream logistics, marketing and after sales operations; and
- **support activities**, the main components of which are farm management, knowledge and advisory services, and rural infrastructures.

### 1.1.1. Upstream and on-farm operations

Digitalisation can support farmers even before the seeds are sown – for instance, through data-driven planning tools and smart farm equipment that **optimises inbound logistics and input inventories**. These tools allow for tighter inventory control and ensure timely purchase and delivery of inputs and the reduction of waste.

[10] Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030. OJ L 323, 19.12.2022, pp. 4-26. ELI: http://data.europa.eu/eli/dec/2022/2481/oj.

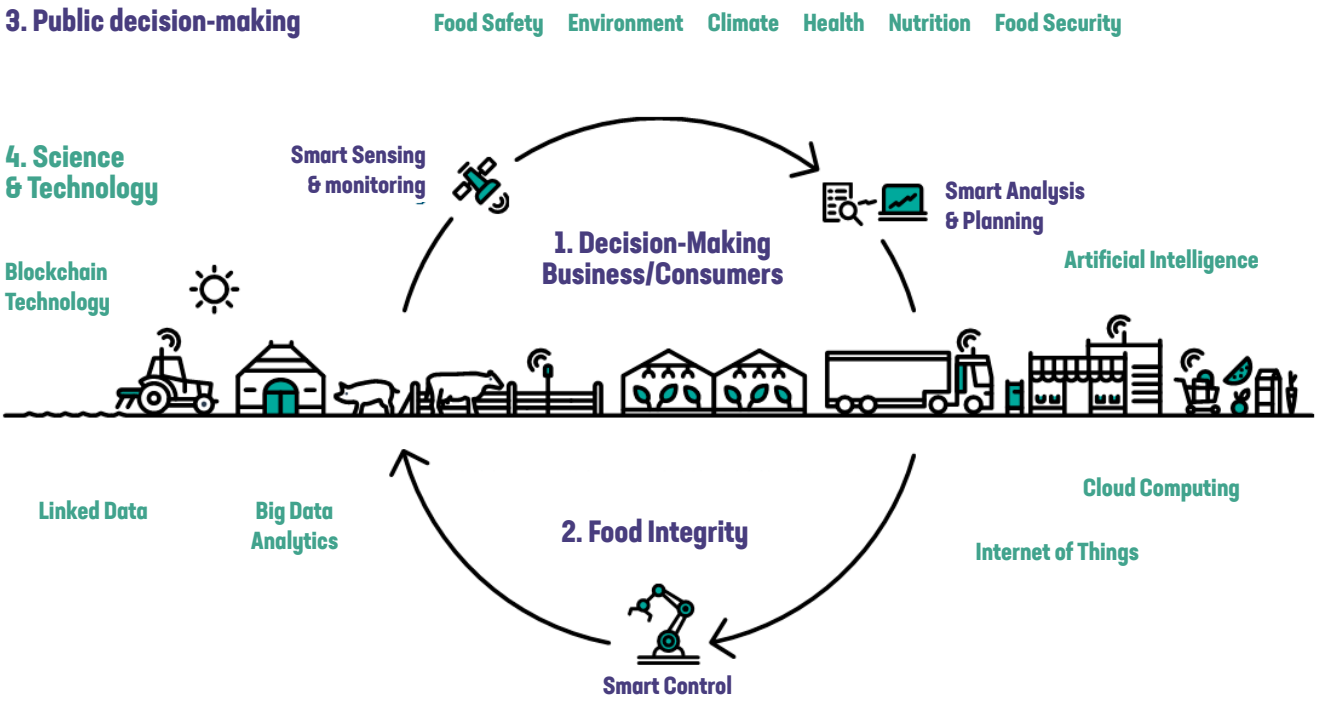
[11] Balasundram, S. K., Shamshiri, R. R., Sridhara, S., Rizan, N., *The role of digital agriculture in mitigating climate change and ensuring food security: an overview*, Sustainability, 15(6), 2023, 5325. https://doi.org/10.3390/su15065325 and Charlebois, S., Latif, N., Ilahi, I., Sarker, B., Music, J., Vezeau, J., *Digital traceability in Agri-Food Supply Chains: A Comparative analysis of OECD member countries*, Foods, 13(7), 2024, 1075. https://doi.org/10.3390/foods13071075.

[12] Porter, M. E., *Competitive advantage: creating and sustaining superior performance*, New York, Free Press, 1985. https://id.lib.harvard.edu/alma/99000473683020394l/catalog.

As regards on-farm operations, several key enabling technologies, such as Internet of Things (IoT), cloud computing, blockchain, and artificial intelligence (AI) [13], drive the shift from traditional precision agriculture toward **smart agriculture** [14]. Whereas precision agriculture focuses primarily on location-based management, smart agriculture integrates contextual and situational awareness into continuous data streams. This allows digital technologies to detect and interpret environmental and biological signals in real-time [15], and effectively respond to sudden changes in operational conditions, such as weather or disease alerts. At the core of smart agriculture are reconfiguration features that transform precision, one-off interventions into an intelligent, resilient and continuously learning agricultural system [16]. For example, soil moisture sensors linked to an irrigation system may allow real-time adjustments, applying water only where and when needed. Similarly, drone imagery and satellite data feed into crop models that guide variable-rate fertiliser applications. Beyond crops, livestock operations also benefit. For instance, smart sensors track animal health and welfare, providing early alerts and improving care.

This closed-loop – sensing, analysis, decision and actuation – enables farming to become more data-driven and precise, with minimal human intervention in routine tasks. Figure 1 illustrates this development by the **cyber-physical management cycle**, which includes: (i) smart sensing and monitoring, (ii) smart analysis and planning, and (iii) smart control. 'Smart' refers to intelligent devices, often connected to the cloud or edge computing, that manage agri-food production systems. These smart devices enhance traditional tools (e.g. rain gauges, ploughs, harvesters, notebooks) by incorporating sensors, built-in intelligence, and the capability to perform autonomous actions or operate remotely. Machines are equipped with various sensors that measure environmental data, which influences their behaviour. This ranges from simple feedback mechanisms, like a thermostat regulating temperature, to advanced deep learning algorithms used for implementing optimal crop protection plans. These technologies are further enhanced by integrating external big data sources, such as weather forecasts, market data and benchmarking with other farms.

**Figure 1. The cyber-physical management cycle**




Source: Wolfert et al., (2024) [17]

[13] For definitions of AI, cloud computing and IoT, see Eurostat's Digital economy and society glossary: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Category:Digital_economy_and_society_glossary. For blockchain technology, see the European Blockchain Service Infrastructure (EBSI) Glossary: https://ec.europa.eu/digital-building-blocks/sites/spaces/EBSI/pages/492240899/Glossary.

[14] Assimakopoulos, F., Vassilakis, C., Margaris, D., Kotis, K., Spiliotopoulos, D., *AI and Related Technologies in the Fields of Smart Agriculture: A Review*, Information, 16(2), 2025, 100. https://doi.org/10.3390/info16020100 and Wolfert, S., Ge, L., Verdouw, C., Bogaardt, M.-J., *Big Data in Smart Farming – A review*, Agricultural Systems, 153, 2017, pp. 69-80. https://doi.org/10.1016/j.agsy.2017.01.023.

[15] Saha, G., Shahrin, F., Khan, F. H., Meshkat, M. M., Azad, A. A. M., *Smart IoT-driven precision agriculture: Land mapping, crop prediction, and irrigation system*, PLOS ONE, 20(3), 2025, e0319268. https://doi.org/10.1371/journal.pone.0319268; Sharma, V., Tripathi, A. K., Mittal, H., *Technological revolutions in smart farming: Current trends, challenges & future directions*, Computers and Electronics in Agriculture, 201, 2022, 107217. https://doi.org/10.1016/j.compag.2022.107217 and Wolfert, J., Sørensen, C. G., Goense, D., *A future internet collaboration platform for safe and healthy food from farm to fork*, in Global Conference (SRII), 2014 Annual SRII, pp. 266-273, IEEE, 2014. https://doi.org/10.1109/SRII.2014.47.

[16] Feng, Y., Gao, G., Wang, P., Zhang, Z., Liu, K., *Introducing reconfigurable manufacturing systems to agriculture*, Flexible Services and Manufacturing Journal, 2024, pp. 1-53. https://doi.org/10.1007/s10696-024-09559-5 and Verdouw, C., Tekinerdogan, B., Beulens, A., Wolfert, S., *Digital twins in smart farming*, Agricultural Systems, 189, 2021, 103046. https://doi.org/10.1016/j.agsy.2020.103046.

[17] Wolfert, S., Giesbers, E., Adema, H., Bogaardt, *M.-J., Farm Data Sharing: current practices and principles,* in Van der Sloot, B., Van Schendel, S. (eds.), The boundaries of data, Amsterdam University Press, 2024, pp. 83-98. https://doi.org/10.2307/jj.12124947.

Robotics plays an increasingly important role in smart control, such as in autonomous weeding [18]. With the advancement of AI, human involvement in analysis and planning is expected to be increasingly supported by algorithms, making the cyber-physical management cycle nearly fully autonomous [19]. While this is already a reality in some modern greenhouses, fully automated solutions are being tested in open-field agriculture as well [20]. However, humans will always be part of the food production process, but their role may evolve to focus on higher-level intelligence tasks, leaving most operational activities to autonomous machines [21]. The result is optimised production as well as safer work conditions: farmers can make better decisions, fine-tune operations, and raise productivity while using fewer inputs and reducing waste and environmental impact. It also leads to increased security within the company, management and improved mental health for farmers by increased safety controls.

In conclusion, data-driven technologies are playing a crucial and reciprocal role in on-farm operations and management. Table 1 provides a brief overview of different examples of data-driven technologies along the cyber-physical management cycle across different types of farming.

**Table 1. Examples of digital technologies and data applications in different types of farming**

| Cyber-physical management cycle and data | Field crops farming | Livestock farming | Horticulture |
|---|---|---|---|
| Smart sensing and monitoring | Robotics and sensors | Biometric sensing, GPS tracking | Robotics and sensors (temperature, humidity, $CO_2$, etc.), greenhouse computers |
| Smart analysis and planning | Seeding, planting, Soil typing, crop health, yield modelling | Breeding, monitoring | Lighting, energy management |
| Smart control | Precision farming | Milk robots | Climate control, Precision control |
| Role of data | Earth observation<br>Weather/climate data, yield data,<br>Soil types,<br>Market information, agricultural census data | Livestock movements | Weather/climate, market data, social media data |

Source: Wolfert et al., (2017)

### 1.1.2. Downstream supply chain, processing and marketing

Digital innovations continue to add value as agricultural products move beyond the farm gate. In processing and downstream logistics, automation and IoT devices help **monitor storage conditions and streamline handling of produce**, reducing spoilage.

Most visibly, digitalisation can **increase transparency and traceability** throughout the supply chain. Using technologies like blockchain and cloud databases, each step – from harvest and transport to processing and retail – can be recorded and verified. This creates an auditable digital record for food products, assuring quality and safety. For example, a blockchain-based system can log every transaction or movement of a batch of grain or a crate of vegetables, preserving information about its origin and journey. This traceability helps agribusinesses and regulators ensure food integrity (e.g. confirming organic or geographic origin), and it builds consumer trust by allowing shoppers to know the farm-to-fork story of what they buy. These digital tools improve transparency in the value chain, enabling consumers to make more informed choices about sustainable and high-quality food.

[18] Lytridis, C., Pachidis, T., *Recent advances in agricultural robots for automated weeding,* AgriEngineering, 6(3), 2024, pp. 3279-3296. https://doi.org/10.3390/agriengineering6030187.
[19] Heuvelink, E., Hemming, S., Marcelis, L. F., *Some recent developments in controlled-environment agriculture: on plant physiology, sustainability, and autonomous control*, The Journal of Horticultural Science and Biotechnology, 2025, pp. 1-11. https://doi.org/10.1080/14620316.2024.2440592.
[20] Al-Amin, A., Lowenberg-DeBoer, J., Franklin, K., Behrendt, K., *Economic Implications of Field Size for Autonomous Arable Crop Equipment*, unpublished manuscript, 2021. DOI: 10.22004/ag.econ.316595.
[21] Adamides, G., Edan, Y., *Human-robot collaboration systems in agricultural tasks: A review and roadmap*, Computers and Electronics in Agriculture, 204, 2023, 107541. https://doi.org/10.1016/j.compag.2022.107541.

Digital platforms can **connect producers more directly with markets**. For example, ecommerce marketplaces and mobile apps let farmers sell products to buyers online, often improving farm gate prices and expanding market access for rural producers. These marketing innovations can shorten supply chains and empower farmers, including smallholders, by reducing middlemen and transaction costs.

Additionally, real-time data analytics helps agri-food companies **manage inventory and respond better to demand**. By analysing sales trends or logistics data, producers and retailers can better match supply with consumer demand and minimise waste (e.g. adjusting planting or shipping based on predictive analytics).

In sum, digitalisation of the downstream segments leads to a more agile, transparent, and customer-responsive agri-food chain, while upholding food safety and reducing losses.

### 1.1.3. Supporting services and rural community benefits

Alongside primary value-chain activities, digitalisation strengthens supporting services in agriculture and rural economies. One key area is **knowledge and advisory services**: digital platforms (web portals, mobile advisory apps, e-learning) allow the dissemination of best practices and weather or market information to farmers and other rural actors instantly. This improves their access to expertise and continuous learning, which is crucial for innovation. In parallel, **farm advisory services** start being delivered via digital means. For example, advisory chatbots and remote-consultation platforms facilitate the provision of extension services to hard-to-reach farmers and remote villages. Moreover data-driven advisory tools such as the farm sustainability tool [22] guide farmers in sustainable practices by analysing farm-specific data.

**Farm management information systems** (FMIS) have emerged as foundational tools in modern agriculture, serving as integrated digital platforms that collate, analyse and report data across all aspects of farm activity. At their core, FMIS enable farmers and advisors to centralise agronomic, environmental, financial and logistical information in a single repository. This holistic data integration supports evidence-based decision-making, allowing users to compare historical performance, model scenarios (e.g. yield projections under alternative input regimes) and monitor key performance indicators in real time. By linking modules for field mapping, input management, machinery scheduling and financial accounting, FMIS can streamline operations while generating the records and reports required for both internal management and external compliance.

A particularly salient function of FMIS is the electronic record-keeping of plant protection product (PPP) applications in compliance with Commission Implementing Regulation (EU) 2023/564 of 10 March 2023 [23]. Under this regulation, from 1 January 2026 all professional users of PPPs must record digitally, for each application: the product's trade name and active substance; the dose rate; the date and time of application; the identity of the operator; the equipment used; meteorological conditions; the precise field or plot location; and the treated area or volume. FMIS can capture these details either through manual recording or, where available, via direct interfaces with application machinery that log date, time and geo-coordinates. These digital records ensure conformity with EU law, facilitate audit and inspection processes by national authorities, and reduce the risk of transcription errors inherent in paper-based systems.

At the same time, advancements in data science will increasingly depend on data generated throughout the entire agri-food supply chain. This creates a mutual dependency: scientific and technological progress relies on agri-food system data, while improvements in those systems benefit from data-driven developments in science and technology. Thus, the same data could be used for multiple purposes, which is also encouraged by the recently published Commission's Vision for Agriculture and Food [24]. However, in practice, this is not always obvious or simple, because each purpose has different requirements for data attributes such as quality, density and confidentiality. As a result, this may hinder system interoperability, limiting the adoption of digital solutions and the simplification of administrative processes. This can ultimately increase administrative burden.

Another support factor is **rural infrastructure and services**. Reliable broadband connectivity and cellular networks form the backbone of digital agriculture. High-speed internet in rural areas enables all these smart farming and e-services to function. Improving rural connectivity is a foundational step to closing the urban-rural digital divide. With connectivity in place, rural communities can also leverage digital tools to improve local services and quality of life. For example, digital platforms can be used for telemedicine, online education, or virtual marketplace for local products. The European Long-Term Vision for Rural Areas [25] emphasises making rural areas 'connected' and 'prosperous', with digitalisation as a key enabler.

The overall effect of these support-level digital solutions can empower rural people and enterprises with information, services and market linkages similar to the ones available in urban centres. This inclusive rural digitalisation helps ensure that benefits of the digital age are shared broadly, reducing rural isolation. It also helps agriculture indirectly by attracting young farmers and entrepreneurs to rural areas (when modern amenities and opportunities are available), thus strengthening the human capital for the agri-food sector.

[22] For more information, see: https://fastplatform.eu.

[23] Commission Implementing Regulation (EU) 2023/564 of 10 March 2023 as regards the content and format of the records of plant protection products kept by professional users pursuant to Regulation (EC) No 1107/2009 of the European Parliament and of the Council. OJ L 74, 13.3.2023, pp. 4-9. ELI: http://data.europa.eu/eli/reg_impl/2023/564/oj.

[24] European Commission, *A Vision for Agriculture and Food: shaping together an attractive farming and agri-food sector for future generations* (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions), Brussels, 2025. Vision for Agriculture and Food - European Commission.

[25] For more information, see: https://rural-vision.europa.eu/index_en.

As analysed above, digitalisation enhances operational efficiencies. At the same time, the proliferation of data not only transforms decision-making processes for all value chain actors but also paves the way for the development of the data economy. This emerging data economy complements the traditional agricultural value chain with new opportunities for efficiency, sustainability and innovation. For instance:

1. Digital data is becoming **crucial for decision-making at all levels of the agri-food supply chain**, including farmers, logistics providers, food processors and consumers.
2. Data sharing throughout the supply chain is essential for **ensuring food integrity**, providing assurance to consumers and other stakeholders about the safety, authenticity, and quality of food [26].
3. **Public decision-making on societal challenges** such as food security, climate change and healthy nutrition can benefit from these data, although it is currently mostly based on separate censuses and statistics, often leading to administrative burden for all actors in the food chain.
4. This digitalisation is **driven by rapid advancements in science and technology**, such as artificial intelligence, the IoT and blockchain technology.

Smart devices, and the data they generate, can be applied in various areas, although the extent of their effectiveness depends on the level of data sharing. Business models and governance mechanisms play crucial roles in these data-driven developments, reshaping the entire agricultural ecosystem [27]. Therefore, the transition towards a data economy, as described in the next section, is an important future development that should be considered. Although this may not be entirely in the current scope of the CAP Strategic Plans, it may be relevant in view of future developments.

## 1.2. Towards a data economy for agri-food systems

Initially, isolated applications supported individual processes, such as pest control and fertiliser application. Gradually, these applications expanded through FMIS to interconnected systems that aim to integrate entire supply chains and data ecosystems. This shift is now progressing towards data sharing initiatives and federated data spaces, which facilitate real-time information exchange, predictive analytics and collaborative innovation. For example, farmers, distributors, retailers and service providers traditionally operate in silos with limited visibility into each other's operations. These participants can create a collaborative network where real-time information flows seamlessly between parties while maintaining control over sensitive proprietary data [28]. Weather forecasting services share climate predictions, agricultural producers provide crop status updates, logistics companies contribute transportation data, and retailers offer demand patterns, creating a comprehensive information ecosystem that enables rapid response to changing conditions and market dynamics.

This collaborative framework generates substantial value through predictive analytics and innovation opportunities that emerge from the synthesis of diverse data sources. The shared information enables sophisticated forecasting models that can anticipate supply disruptions, optimise resource allocation and identify emerging market trends with unprecedented accuracy. Furthermore, the collaborative environment fosters innovation as participants discover unexpected correlations and opportunities for cooperation. The federated approach ensures that while valuable insights are generated from collective data, each organisation maintains sovereignty over its critical business information. Each participant retains control over their sensitive data (such as profit margins or secret growing techniques) but shares just enough information to make the entire system work better.

Such a transition supports the emergence of a parallel value chain, alongside the traditional one of the agri-food sector. At the core of this value chain is a cohesive digital framework, the data economy for agri-food systems (DE4AFS), unlocking new opportunities for efficiency, sustainability and resilience [29]. The DE4AFS is emerging as a key component of the digital transformation, encompassing an ecosystem where digital data serves as both a resource and a driver of value creation [30]. It is characterised by the production, distribution and utilisation of digital data as a primary asset [31]. Unlike traditional economic goods, data is non-rival and non-depletable; its value often grows when aggregated, analysed and applied in diverse contexts. However, not all of them are public goods due to controlled access and ownership. These unique characteristics position **data as a significant factor of production, complementing labour and physical capital** [32]. The data economy for agri-food systems involves complex value chains where actors, including individuals, businesses, and governments, simultaneously produce and consume data. These actors collaborate within a digital ecosystem, facilitated by intermediaries, data-sharing initiatives and governance frameworks [33].

[26] Minnens, F., Lucas Luijckx, N., Verbeke, W., *Food supply chain stakeholders' perspectives on sharing information to detect and prevent food integrity issues,* Foods, 8(6), 2019, 225. https://doi.org/10.3390/agriengineering6030187.

[27] Wolfert, S., Verdouw, C., van Wassenaer, L., Dolfsma, W., Klerkx, L., *Digital innovation ecosystems in agri-food: design principles and organizational framework,* Agricultural Systems, 204, 2023, 103558. https://doi.org/10.1016/j.agsy.2022.103558.

[28] Šestak, M., Copot, D., *Towards Trusted Data Sharing and Exchange in Agro-Food Supply Chains: Design Principles for Agricultural Data Spaces,* Sustainability, 15(18), 2023, 13746. https://doi.org/10.3390/su151813746.

[29] The Data Economy for Agri-Food Systems is currently being defined by the Horizon Europe funded project Data4Food2030 (www.data4food2030.eu).

[30] Scelta, G., Rashid, H., Cheng, H. W. J., LaFleur, M., Parra-Lancourt, M., Julca, A., Hunt, N., Islam, S., Kawamura, H., *Frontier Technology Quarterly January 2019: Data Economy – radical transformation or dystopia?*, United Nations, 2019. https://www.un.org/development/desa/dpad/publication/frontier-technology-quarterly-january-2019/.

[31] Rix, C., Stein, H., Chen, Q., Frank, J., Maass, W., *Conceptualizing Data Ecosystems for Industrial Food Production*, in *2021* IEEE 23rd Conference on Business Informatics *(CBI)*, 1-3 September 2021. doi: 10.1109/CBI52690.2021.00031.

[32] See footnote 30 for Scelta et al., (2019).

[33] See footnote 27 for Wolfert et al., (2023).

Data-driven innovation enables the development of new business models, enhances food security, and supports sustainability. Value is created through (i) direct use (e.g. precision agriculture tools), (ii) in context by the integration and application of a specific set of resources that is relevant to the specific location and time of a beneficiary and (iii) in exchange – monetary or non-monetary – by interaction among ecosystem actors that function in specific institutional and governance arrangements. Unlike conventional ecosystems, data sharing and co-creation now occur across heterogeneous stakeholders, necessitating sophisticated governance structures and collaboration mechanisms [34]. Box 1 provides an illustrative example of a case study from the Data4Food2030 project. Although this project has not been supported by the CAP, it illustrates the complexity but also the benefits of data sharing and co-creation.

## Box 1. Illustrative case study 'PigLink'

Case study: PIGLink – from farmers to consumers

PIGLink aims to address digital gaps on pig farms by promoting data interoperability through an open normative framework. It facilitates seamless data exchange between farm equipment (e.g., weighing scales, water meters) and management tools (e.g., analysis software) using standardised web application programming interfaces (APIs). This ensures secure, breeder-supervised data sharing, reducing redundant entries and enabling unified dashboards. By normalising diverse data formats, PIGLink enhances data valorisation, enriching dashboards with key breeding indicators. Over time, it enables benchmarking to assess animal health, welfare, and farm performance, empowering farmers and stakeholders with actionable insights to improve productivity and decision-making.

PIGLink is promoting data interoperability to:

- facilitate the flow of data between equipment and managing tools,
- facilitate the day-to-day management of the farmer, and
- enable the farmer to comply with specifications in response to consumer expectations.

Type of stakeholders:

- Farmer organisation
- Representatives of technical advisors
- Veterinarian
- Equipment manufacturers (approx. 6)
- Farmers (approx. 10)
- Inter-professional association

Data4Food2030 project [35]

While DE4AFS offers several opportunities for sustainable development, significant challenges are (i) *accessibility and equity*, bridging the digital divide to ensure small farmers and underserved communities also benefit, (ii) *trust and governance*, addressing privacy, ownership, and ethical concerns through robust governance mechanisms, and (iii) *environmental impacts*, balancing the benefits of digital transformation with its resource and energy demands. Currently, there are, at least, two data economy scenarios confronting each other: one is a 'vertical dominance' scenario, based on private and corporate led data spaces, and the other one is the 'open data space' scenario, where – also as an effect of the Data act [36] – actors of the system can freely share their data through neutral data intermediaries. Thus, the emerging DE4AFS requires a shift from firm-centric approaches to ecosystem-driven strategies. Digital platforms or data sharing initiatives facilitate the co-creation of innovative services and business models, integrating stakeholders from start-ups to incumbent firms and supporting collaborations between them [37].

In conclusion, the data economy for agri-food systems (DE4AFS) closely supports the objectives of the CAP by enabling a more efficient, sustainable and digitally integrated agri-food sector. Through the development of federated data spaces and interoperable systems, DE4AFS facilitates the digital transition promoted by the CAP, helping to simplify administrative processes and reduce the burden on farmers, but also reducing stress and hence increasing well-being. By treating data as a key production factor, alongside labour and capital, DE4AFS enhances competitiveness and fosters innovation across the value chain. It also encourages collaboration among diverse stakeholders, from start-ups to established firms, aligning with the CAP's emphasis on inclusive rural development and effective governance. Moreover, DE4AFS addresses equity by aiming to bridge the digital divide, ensuring that small and medium-sized farms can also benefit from digital advancements. In doing so, it reinforces the CAP's broader goals of supporting fair income, environmental care and vibrant rural communities.

After this broad introduction of the role of digitalisation in modern agriculture and rural areas, the next section will present a theoretical framework that describes the enablers, drivers and barriers influencing digitalisation and the role of CAP Strategic Plans and other EU policies in addressing them.

[34] Rong, K., Hu, G., Lin, Y., Shi, Y., Guo, L., *Understanding business ecosystem using a 6C framework in Internet-of-Things-based sectors*, International Journal of Production Economics, 159, 2015, pp. 41-55. https://doi.org/10.1016/j.ijpe.2014.09.003.

[35] For more information, see: https://data4food2030.eu/project/piglink/.

[36] Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828. OJ L, 2023/2854, 22.12.2023, ELI: http://data.europa.eu/eli/reg/2023/2854/oj.

[37] Piot-Lepetit, I., *Digitainability and open innovation: how they change innovation processes and strategies in the agrifood sector?*, Frontiers in Sustainable Food Systems, 7, 2023, 1267346. https://doi.org/10.3389/fsufs.2023.1267346.

# 2. Theoretical framework for digitalisation under the CAP Strategic Plans

Having outlined the broad significance of digitalisation within modern agriculture and rural areas, we now shift our attention to how the CAP Strategic Plans, working in concert with other EU policies, can actively foster the uptake of digital tools and practices.

The Digital Decade policy programme 2030 serves as the overarching strategic framework for digitalisation, establishing concrete targets and objectives for Europe's digital transformation by 2030. It operates through four cardinal points:

- a digitally **skilled population and highly skilled digital professionals**, with the aim of achieving gender balance,
- secure, resilient, performant and sustainable **digital infrastructures**,
- the **digital transformation of businesses**, and
- the **digitalisation of public services**.

This section discusses a theoretical framework about how CAP Strategic Plans can contribute to promoting enablers, leveraging drivers and overcoming barriers to effectively contribute to the digital decade targets. Where relevant, other policies that may work together with the CAP will also be presented. This theoretical framework will allow us to better define digitalisation and set the basis for developing an intervention logic and assessing the effectiveness of CAP Strategic Plans towards digitalisation.

## 2.1. Drivers, enablers and barriers to digitalisation in agriculture and rural areas

Digitalisation in agriculture and rural areas is enabled and driven by a combination of technological advancements, policy support and market demands, but it also faces significant barriers that need to be addressed for widespread adoption [38].

### 2.1.1. Drivers and enablers

As explained in Section 1.1, the primary drivers and enablers of digitalisation include the **rapid development of advanced technologies** enabling precise data collection, real-time analysis, and automated decision-making, which can significantly enhance sustainable productivity. This development is highly supported by research and innovation (R&I), in which agricultural R&I can greatly benefit from cross-domain interactions to develop new digital tools, methodologies, and systems that can address the evolving challenges European agriculture faces. Cutting-edge technologies largely come from other domains such as high-tech industries, healthcare and the public sector. Many examples of this can be found in Horizon Europe and Horizon 2020 projects, such as IOF2020, ATLAS, DEMETER, SMARTAGRIHUBS, ICT-AGRI-FOOD and AGROBOFOOD AGRIDATAVALUE, CERBERUS, FARMTOPIA, SPADE and STELLA [39]. These initiatives contribute to breakthroughs in precision farming, remote sensing, artificial intelligence, big data management, and robotics tailored to the agricultural context [40]. While some projects are more research-oriented, specifically the innovation action type of projects, support large-scale uptake of digital technologies.

However, research and technological innovation alone do not guarantee a transformative impact. Without practical application and adoption on farms, these advancements risk remaining confined to academic and experimental spaces. This recognition underpins the emphasis within the CAP Strategic Plans on creating stronger connections between research outputs, their application and actual uptake.

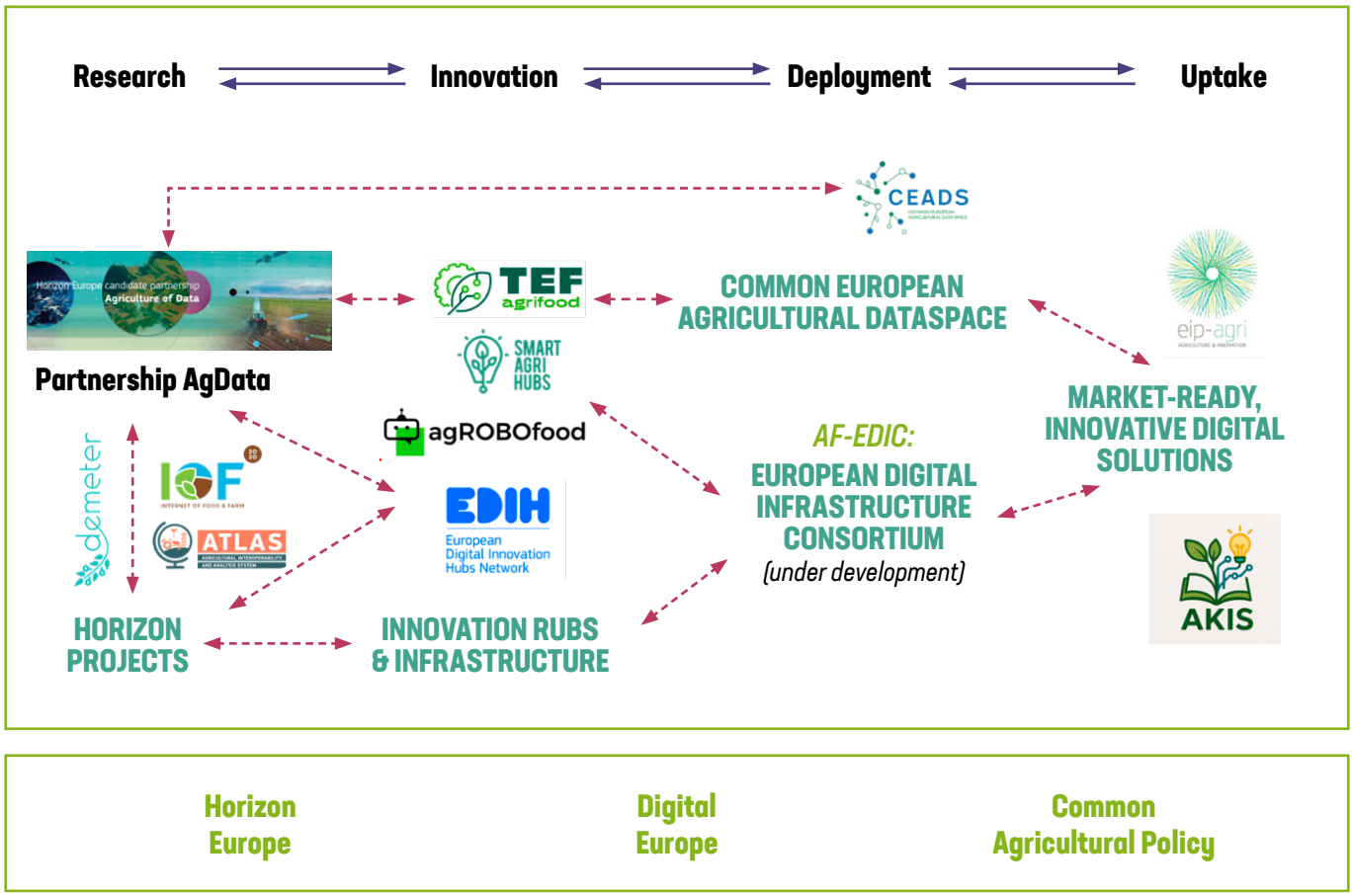
Figure 2 explains how actions in R&I are complemented by deployment actions to ensure the scaling of innovative solutions, bringing them to market, and uptake by end-users, respectively. It should be noted that, although the figure suggests a linear process from left to right, in reality, there is a lot of interaction between all these stages and the actors involved.

[38] Ferrari, A., Bacco, M., Gaber, K., Jedlitschka, A., Hess, S., Kaipainen, J., Koltsida, P., Toli, E., Brunori, G., *Drivers, barriers and impacts of digitalisation in rural areas from the viewpoint of experts*, Information and Software Technology, 145, 2022, 106816. https://doi.org/10.1016/j.infsof.2021.106816.

[39] European Commission, *Digitalisation of the European Agricultural Sector: Activities in Horizon 2020*, Brussels, 2023, available at: https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture-horizon-2020.

[40] Ibid.

**Figure 2. A strategic approach to bring research and innovation towards deployment and uptake in agri-food digitalisation**




Source: Adapted from: European Commission. Digitalisation the EU agricultural Sector Shapes Europe's Digital Future [41]

**Market demand for sustainable and efficient agricultural practices** is also driving digitalisation [42]. Consumers are increasingly concerned about the environmental impact of food production and are demanding transparency and traceability in the supply chain. Digital technologies can help meet these demands by providing detailed information about the origin, production methods and environmental footprint of agricultural products.

Additionally, the agricultural industry is under pressure to **increase productivity and contribute to sustainability goals.** It must reduce costs (not only economic, but also environmental and social costs) in the face of growing global food demand and limited natural resources. The Corporate Sustainability Reporting Directive (CSRD) significantly impacts agricultural supply chains by enhancing transparency and accountability in sustainability practices. To comply with CSRD, companies need to collect accurate and comprehensive data on their environmental impact. This often involves leveraging digital solutions to monitor and report on sustainability metrics effectively.

Another group of drivers and enablers relates to DE4AFS. **Effective governance frameworks** and supportive policies facilitate digital transformation and ensure consistency across regulations. By **addressing ethical, legal and social implications,** they can ensure fair access, data privacy, transparency, and equitable benefits for all stakeholders. Building on these enablers, innovative, **data-driven business models** leverage data to create value, optimise operations, reduce costs, and increase profitability.

In addition to the drivers and enablers specific to agriculture, rural areas benefit from a broader set of digitalisation enablers that support inclusive development and community resilience. One key driver is the **expansion of digital public services**, which improves access to healthcare, education, and administrative services for rural populations. e-government platforms and telemedicine services reduce the need for physical travel and enhance service delivery in remote areas [43].

[41] For more information, see: Digitalising the EU agricultural sector.
[42] Finger, R., *Digital innovations for sustainable and resilient agricultural systems,* European Review of Agricultural Economics, 50(4), 2023, pp. 1277-1309. https://doi.org/10.1093/erae/jbad021.
[43] Woods, L., Martin, P., Khor, J. *et al.*, *The right care in the right place: a scoping review of digital health education and training for rural healthcare workers,* BMC Health Services Research, 2024, p. 1011. https://doi.org/10.1186/s12913-024-11313-4.

**Rural entrepreneurship** is another important enabler, supported by digital tools that facilitate business creation, access to markets, and financial services. Digital platforms allow rural entrepreneurs to engage in e-commerce, manage logistics, and connect with customers beyond their immediate locality. These tools [44] are particularly valuable for small and medium-sized enterprises (SMEs) operating in rural contexts.

The **smart villages initiative** also plays a crucial role in promoting integrated rural development strategies that leverage digital technologies. The CAP provides a supportive framework for rural communities and funding opportunities for the preparation and implementation of smart village strategies [45]. Under rural development interventions, Member States have the opportunity to design relevant interventions for supporting the emergence of smart villages. These strategies combine infrastructure investments with community-led innovation to improve quality of life and economic opportunities. Smart villages [46] foster collaboration among local stakeholders, including municipalities, civil society and private sector actors, to co-create tailored digital solutions.

Finally, **community-based innovation ecosystems** are emerging as powerful enablers of rural digitalisation. These ecosystems include local innovation hubs, digital training centres, and cooperative platforms that empower rural residents to co-develop and adopt digital solutions. By building local capacity and fostering digital literacy, these initiatives ensure that the benefits of digitalisation are equitably distributed across rural areas [47].

### 2.1.2. Barriers

Despite these enablers and drivers, several barriers hinder the widespread adoption of digital technologies in agriculture. One of the main barriers is the **high cost of digital tools and technologies.** Large and capital-intensive enterprises are more likely to implement new technologies in production practices, especially if they are led by younger and more educated managers who are more open to modern technologies and are more willing to take risks [48]. However, many small and medium-sized farms, which make up a significant portion of the agricultural sector, may not have the financial resources to invest in expensive digital equipment and software.

Additionally, the complexity of digital technologies can be a barrier for farmers who may **lack the technical skills and knowledge** to use them effectively [49]. Moreover, **resistance to change** and the complexity of integrating new digital processes into legacy systems slow down the adoption.

Another well-known barrier is the digital divide between urban and rural areas [50]. Many rural areas, where agriculture is primarily based, still lack **access to reliable internet connectivity and digital infrastructure**. This digital divide limits the ability of farmers in these areas to adopt and benefit from digital technologies. Addressing this issue requires substantial investment in rural digital infrastructure and targeted policies to ensure equitable access to digital tools and services.

**Data privacy and security concerns** also pose a barrier to digitalisation in agriculture. Farmers may be hesitant to share their data due to fears of data breaches, misuse of information, and loss of control over their data [51]. Ensuring robust data protection measures and transparent data governance frameworks is crucial to building trust and encouraging data sharing among agricultural stakeholders. Furthermore, the **lack of interoperability and standardisation** among different digital tools and platforms can hinder their effective use [52]. Farmers may face challenges in integrating various technologies and systems, leading to inefficiencies and increased costs.

In conclusion, while digitalisation in agriculture offers significant potential to enhance productivity, sustainability and resilience, several barriers need to be addressed to achieve widespread adoption. Technological advancements, policy support and market demand are key drivers of digitalisation, but high costs, technical complexity, data privacy concerns, lack of interoperability and the digital divide pose significant challenges. Addressing these drivers and barriers through targeted CAP Strategic Plan interventions, including investments, supportive policies, and comprehensive training and education programmes, is essential to realising the full potential of digitalisation in agriculture.

[44] Nipo, D. T., Lily, J., Fabeil, N. F. and Jamil, I. A. A., *Transforming rural entrepreneurship through digital innovation: a review on opportunities, barriers and challenges*, Journal of Management and Sustainability, 2024, p. 114. https://doi.org/10.5539/jms.v14n2p114.

[45] European Commission, *Supporting Smart Village Strategies*, available at: https://agriculture.ec.europa.eu/common-agricultural-policy/rural-development/supporting-smart-village-strategies_en.

[46] EU CAP Network, *Smart Villages and rural digital transformation*, available at: https://eu-cap-network.ec.europa.eu/publications/smart-villages-and-rural-digital-transformation_en.

[47] Heidenreich, M. and Mattes, J., *Regional innovation systems and innovation clusters*, in Schulz-Schaeffer, I., Windeler, A. and Blättel-Mink, B. (eds), Handbook of Innovation, Springer, Cham, 2025. https://doi.org/10.1007/978-3-031-25143-6_44-1.

[48] Kroupová, Z. Ž., Aulová, R., Rumánková, L., Bajan, B., Čechura, L., Šimek, P., Jarolímek, J., *Drivers and barriers to precision agriculture technology and digitalisation adoption: Meta-analysis of decision choice models,* Precision Agriculture, 26(1), 2025, 17. https://doi.org/10.1007/s11119-024-10213-1.

[49] Smidt, H. J., Jokonya, O., *Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa*, Information Technology for Development, 28(3), 2022, pp. 558-584. https://doi.org/10.1080/02681102.2021.1975256.

[50] Hollman, A. K., Obermier, T. R., Burger, P. R., *Rural measures: A quantitative study of the rural digital divide*, Journal of Information Policy, 11, 2021, pp. 176-201. https://dx.doi.org/10.2139/ssrn.3757477.

[51] Kaur, J., Hazrati Fard, S. M., Amiri-Zarandi, M., Dara, R., *Protecting farmers' data privacy and confidentiality: Recommendations and considerations*, Frontiers in Sustainable Food Systems, 6, 2022, 903230. https://doi.org/10.3389/fsufs.2022.903230 and van der Burg, S., Wiseman, L., Krkeljas, J., *Trust in farm data sharing: reflections on the EU code of conduct for agricultural data sharing*, Ethics and Information Technology, 23(3), 2021, pp. 185-198. https://doi.org/10.1007/s10676-020-09543-1.

[52] Urdu, D., Berre, A. J., Sundmaeker, H., Rilling, S., Roussaki, I., Marguglio, A., Doolin, K., Zaborowski, P., Atkinson, R., Palma, R., *Aligning interoperability architectures for digital agri-food platforms*, Computers and Electronics in Agriculture, 224, 2024, 109194. https://doi.org/10.1016/j.compag.2024.109194.

## 2.2. Fostering digitalisation in agriculture and rural areas: the role of the CAP and other EU policies

Governments and international organisations are recognising the potential of digital technologies to address global challenges such as food security, climate change, and rural development [53]. Policies and initiatives aiming to promote digitalisation, must build on enablers and drivers and overcome the barriers described in the previous section. The EU is actively working to accelerate the adoption of digital tools within the agricultural sector and rural areas, primarily through the CAP and a range of complementary EU-level policies and strategies. These initiatives work in concert to create an enabling environment for farmers and other rural actors to embrace digital transformation, enhancing productivity, sustainability and resilience.

Digitalisation under the CAP is understood not merely as the adoption of individual technologies, but as a holistic, systemic transformation of agricultural practices, administrative processes and rural value chains. It leverages data, connectivity and digital tools to enhance efficiency, sustainability, resilience and knowledge flows across the agri-food sector and rural areas. This aligns with several CAP's Specific Objectives (SO) for increasing farm competitiveness through enhanced sustainable productivity and promoting a sustainable and inclusive growth of rural areas, as well as with the Cross-Cutting Objective (CCO) of fostering and sharing knowledge, innovation, and digitalisation in agriculture and rural areas.

The CAP Strategic Plans incorporate digitalisation as a means to improve farm productivity and modernise agriculture and rural areas in line with broader EU strategies, such as the EU Strategy for Data [54]and the recently published EU Vision for Agriculture and Food [55]. The CAP Strategic Plans include several types of interventions that may promote digitalisation of the agri-food sector and rural areas. They support **investments in digital infrastructure and tools** specifically for farmers and rural businesses (INVEST [56], INSTAL [57] and LEADER [58]), including through sectoral interventions [59]. These interventions may contribute to the digital infrastructure and digital business cardinal points of the EU Digital Decade. They may promote enablers such as broadband connectivity expansion and 5G network deployment in underserved rural areas, as well as rural entrepreneurship ecosystems supporting digital start-ups and innovation. They build on drivers such as the urgency of reducing the digital divide between rural and urban areas, the requirements of green transition, which demand data-intensive monitoring systems, economic diversification needs demanding new digital business models and quality of life imperatives for retaining population in rural areas. They may also help to overcome barriers such as high technology costs and infrastructure gaps via systematic rural coverage expansion, as well as limited business opportunities through digital market access and service provision.

**Eco-schemes** [60] **and environmental, climate and other commitments (ENVCLIM)** [61] may also support the adoption of digital tools that may contribute to improving the sustainable productivity of agriculture. These types of interventions may contribute to the Digital Decade's cardinal point of digital business. They may promote enablers such as precision farming technologies, reducing input waste and environmental impact, real-time environmental monitoring systems for compliance verification, and data-driven sustainability practices enabling measurable environmental outcomes. They can build on sustainability compliance demands (CSRD, Green Deal objectives) and consumer transparency expectations for sustainable production practices, as well as resource optimisation pressures from climate change and input cost volatility. They may also contribute to overcoming barriers such as the complexity of sustainability reporting through automated data collection and reporting systems, verification costs via digital monitoring that replaces manual inspection processes and knowledge gaps in sustainable practices through data-driven decision support systems.

**Sectoral types of interventions** [62] may provide support for digitalisation across the value chain. These types of interventions may contribute to the digital business cardinal point of the Digital Decade. They may promote enablers such as supply chain traceability systems enhancing food safety and quality assurance, digital marketing platforms connecting producers directly with consumers, cooperative digitalisation strengthening collective bargaining power, or quality certification systems using blockchain and IoT for authenticity verification. They build on market concentration pressures, driving the need for digital competitive advantages, consumer quality expectations requiring transparent, verifiable production processes or food safety regulations necessitating comprehensive traceability systems. They can help overcome barriers like market access limitations through digital platforms, bypassing traditional intermediaries, information asymmetries via transparent, real-time market data sharing or small-scale disadvantages through digital cooperative platforms, achieving economies of scale.

Horizontally, supporting the modernisation of agriculture and rural areas, the **Agricultural Knowledge and Innovation Systems (AKIS)** are directly involved in innovation, knowledge exchange, training, and advisory services. AKIS is crucial for capturing the needs of farmers and translating them into research specifications and for translating research findings into practical digital tools. In addition, they ensure farmers have the necessary knowledge and advice (KNOW) [63] to use these digital tools effectively. In particular, the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP) [64] actively promotes innovation, including digitalisation, and facilitates knowledge sharing through

[53] See footnote 42 for Finger, (2023).
[54] European Commission, *A European strategy for data*, Brussels, available at: https://digital-strategy.ec.europa.eu/en/policies/strategy-data.
[55] See footnote 24 for A Vision for Agriculture and Food.
[56] Article 73 of Regulation (EU) 2021/2115.
[57] Article 75 of Regulation (EU) 2021/2115.
[58] Article 77 of Regulation (EU) 2021/2115.
[59] Articles 47, 55 and 58 of Regulation (EU) 2021/2115.
[60] Article 31 of Regulation (EU) 2021/2115.
[61] Article 70 of Regulation (EU) 2021/2115.
[62] Chapter III of Title III of Regulation (EU) 2021/2115.
[63] Article 78 of Regulation (EU) 2021/2115.
[64] Article 127 of Regulation (EU) 2021/2115.

operational groups. These types of interventions may contribute to the Digital Decade's cardinal point of digital skills. They may promote enablers related to digital advisory services providing real-time, personalised farm management advice, innovation networks connecting researchers, advisors, and farmers through digital platforms and peer-to-peer learning systems facilitating knowledge sharing among farmers. They build on research and innovation transfer gaps, creating demand for better knowledge dissemination systems, generational change as younger farmers embrace digital learning modalities and community innovation potential through networked learning and collaboration. They may contribute to overcoming barriers such as geographic isolation through virtual advisory services and online learning platforms, knowledge transfer inefficiencies via direct digital connections between researchers and practitioners, resistance to change through peer demonstration and gradual adoption support systems.

Other programmes and initiatives may work together with these types of interventions. Related to the digital infrastructure cardinal point, **Connecting Europe Facility (CEF) Digital** [65] co-finances the backbone infrastructure that CAP rural investments connect to, creating seamless urban-rural digital continuity. The **Recovery and Resilience Facility** provides additional funding streams for Member States to leverage CAP infrastructure investments, particularly for climate-resilient digital infrastructure. While the broader **cohesion policy** extends beyond agriculture, its focus on regional development and investment indirectly bolsters the digital transformation of rural areas relevant to the CAP. However, the European Commission has identified several challenges in the development of advanced digital network infrastructures and discussed possible scenarios for public policy actions. A possible future **Digital Networks Act (DNA)** [66] may provide the regulatory framework and technical standards that CAP infrastructure investments should meet, ensuring interoperability and future-proofing of agricultural digital infrastructure.

On the digital business and digital skills cardinal points, the **Digital Europe** programme aims to foster the deployment of advanced digital technologies across sectors. This programme supports the establishment of European Digital Innovation Hubs (EDIHs), some of which target the agricultural and rural sectors by facilitating the uptake of AI, robotics, and digital advisory tools. Such interventions directly support CAP goals related to farm modernisation and knowledge transfer. **Horizon Europe** plays a vital role in developing digital solutions for the agricultural sector. Through thematic clusters focused on food, bioeconomy, natural resources, agriculture, and the environment, Horizon Europe supports innovation ecosystems. The interaction between Horizon Europe projects and EIP operational groups contributes to both the adaptation of research outcomes to local needs but also to informing the direction of research towards covering emerging needs. Regional **smart specialisation strategies (S3)** align digital agri-projects with regional development priorities. By tailoring investments to specific regional needs and strengths, S3 indirectly supports the effective adoption of digital tools under the CAP by fostering a conducive regional innovation ecosystem.

Again, on the digital business but also supporting digital public services, investments and operations of the **European Space Agency** (ESA) substantially contribute to the digitalisation of the agri-food sector and rural areas. ESA satellites (e.g. Copernicus Sentinel [67], SMOS [68], Envisat [69]) provide data on soil moisture, vegetation cover, crop health, and seasonal conditions, supporting farmers and agri-businesses in adapting to climate change, drought, and extreme weather. Projects like AgriCEM and CROP [70] use high-resolution satellite data and AI to optimise irrigation, fertiliser and pesticide use, reducing costs and environmental impact. New missions (CHIME, LSTM, FLEX) will further enhance monitoring of plant health and land surface temperature. ESA collaborates with commercial satellite providers (e.g. ICEYE, Pléiades Neo) to assess crop damage from storms, floods, and other natural events, supporting insurance and risk management. Initiatives such as SA4D [71]and ReSeNO [72] promote sustainable farming, carbon footprint measurement, and the reduction of chemical usage through satellite-based services. ESA supports real-time water quality forecasting and efficient water use in agriculture through projects like APPS [73]. ESA satellites are used to map forest boundaries, species, biomass and health, and to monitor logging, regeneration and land cover change. This supports sustainable forest management and helps detect illegal activities.

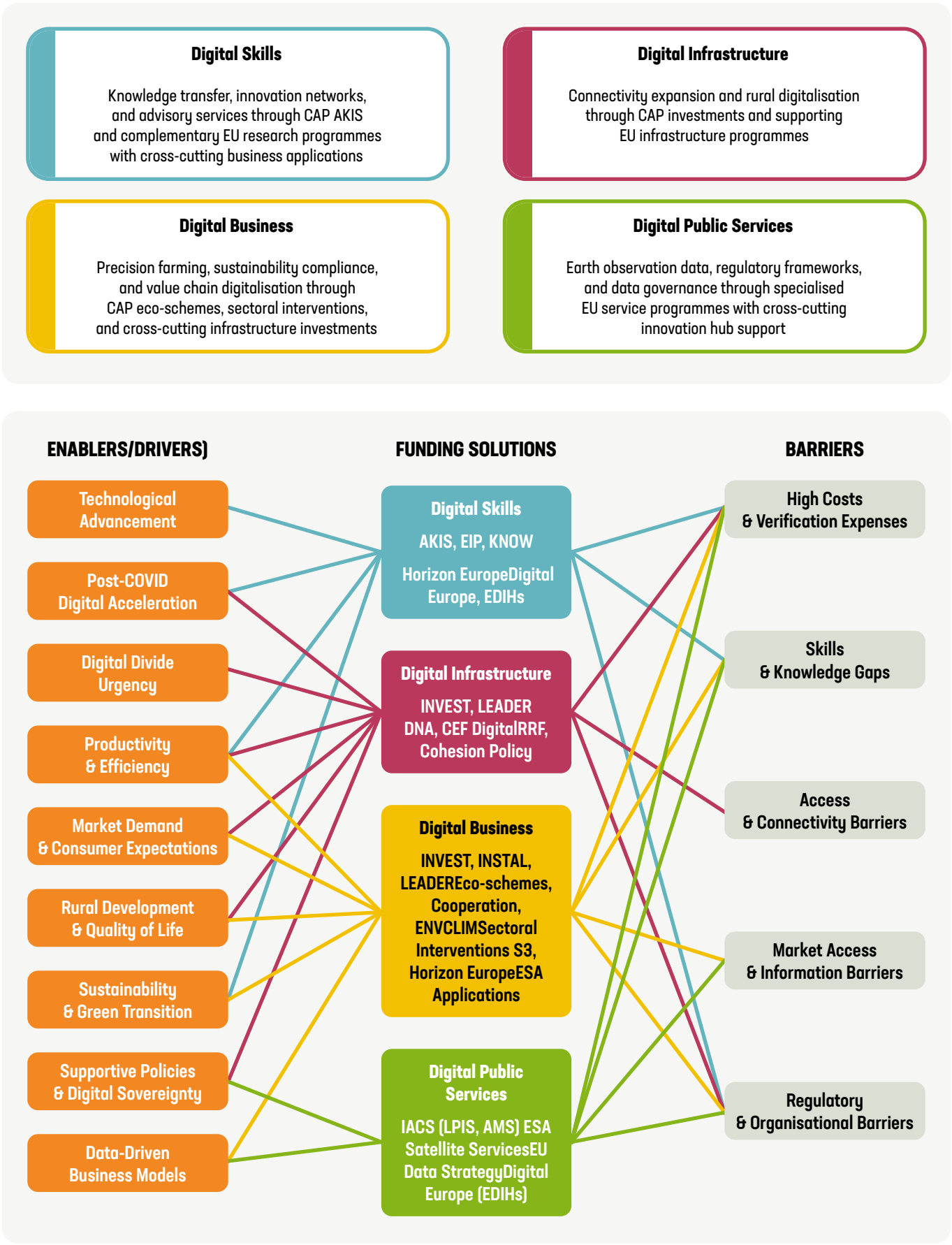
Furthermore, the European Environmental Agency (EEA) and Joint Research Centre (JRC) of the European Commission implement the **Copernicus Land Monitoring Service** (CLMS). The service provides geographical information on land cover and its changes, land use, ground motions, vegetation state, water cycle and Earth's surface energy variables to a broad range of users in Europe and across the world in the field of environmental terrestrial applications.

The ESA's services, investments and operations, and the CLMS, in concert with national earth observation data create the basis for the system for the identification of agricultural parcels (LPIS) as well as the area monitoring system (AMS), which are integral elements of the integrated administration and control system (IACS) [74]. They support the digitalisation of the administration and control of the CAP and contribute to digital public services. AMS, in particular, is designed to simplify the overall control system and potentially reduce the administrative burden for farmers.

Figure 3 provides a compact summary of the drivers, enablers and barriers for digitalisation in agriculture and how CAP Strategic Plans and other instruments can leverage drivers and contribute to overcoming barriers, while supporting the Digital Decade programme.

[65] European Commission, *Connecting Europe Facility - CEF Digital*, for more information, see: https://digital-strategy.ec.europa.eu/en/activities/cef-digital.
[66] European Commission, *White paper: How to master Europe's digital infrastructure needs*, Publications Office of the European Union, Luxembourg, 2024. https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs.
[67] For more information, see: https://sentinels.copernicus.eu.
[68] For more information, see: https://earth.esa.int/eogateway/missions/smos.
[69] For more information, see: https://earth.esa.int/eogateway/missions/envisat.
[70] For more information, see: https://business.esa.int/projects/crop.
[71] For more information, see: https://business.esa.int/projects/sa4d-0.
[72] For more information, see: https://business.esa.int/projects/reseno-service.
[73] For more information, see: https://business.esa.int/projects/apps.
[74] Article 66, Regulation (EU) 2021/2116.

**Figure 3. Relationship between digitalisation enablers/drivers, barriers, and CAP and non-CAP interventions**




Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

N.B. For explanation of abbreviations, see the text above.

# 3. Assessing digitalisation under the CAP Strategic Plans: towards a generic intervention logic

The first step towards assessing digitalisation under the CAP Strategic Plans is to set the boundaries by defining digitalisation and identify those interventions that promote its adoption and use. This will allow the development of a generic intervention logic that may set the basis for the subsequent assessment of digitalisation.

After describing the background and providing a broad introduction into digitalisation in agriculture and how this can be supported by the CAP and complementary policy instruments, it is necessary to narrow down the scope and provide a definition that can be used to both monitor and evaluate the CAP Strategic Plans contribution to digitalisation. This will be the basis for establishing and operationalising the aspects of digitalisation that must be assessed.

## 3.1. Definition and key domains of digitalisation

Building on the theoretical background set out in the previous two sections, a broad definition of digitalisation in the agri-food sector and rural areas can be established as follows:

***The systematic adoption and use of digital technologies, data and networks across all facets of the agri-food sector and rural areas, including, where necessary, the development of corresponding infrastructures, with the aim to improve sustainable farm productivity, contribute to sustainable and inclusive development of rural areas and simplify the delivery of the policy.***

Based on this definition, the assessment of digitalisation under the CAP Strategic Plans must cover, at least, the following aspects:

1. the contribution of CAP support towards fostering digitalisation, covering not only the level of adoption but also the intensity of digitalisation [75], that is how deeply the adopted tools and technologies have been integrated in operations and processes (CCO); and
2. the contribution of the CAP support for digitalisation towards the CAP SOs, and more specifically:
   - making farms more competitive and market-oriented by improving their sustainable productivity, encompassing economic, environmental and social dimensions (SO2, SO4, SO5 and SO6); and
   - improving rural service accessibility and reducing the digital urban-rural divide (SO8).

The definition of digitalisation encompasses several key domains:

1. **Infrastructure and capabilities** represent the essential layer that enables all subsequent digital agriculture activities. This domain corresponds mainly to supporting services of the Porter's value chain and addresses barriers such as the lack of infrastructure, high costs and technical complexity and the skills gap. Regarding the Digital Decade cardinal points, it may contribute to digital infrastructure and digital skills and may set the basis for digitalisation of public services. It encompasses the foundational building blocks required for successful digitalisation of the agri-food sector and rural areas, including:
   - establishing reliable internet connectivity and communication platforms,
   - deploying basic technology and equipment,
   - implementing robust data protection and security infrastructure,
   - developing digital literacy, including cybersecurity aspects, among farmers and other rural actors, and
   - creating administrative systems that enable seamless government service integration and automated compliance.
2. **Smart production**, which refers mainly to on-farm operations and reflects the cyber-physical management framework. It leverages drivers like the need for increased productivity and efficiency, market demand and sustainability considerations. Regarding the Digital Decade cardinal points, it may contribute to digital business, encompassing advanced technologies that optimise agricultural production through data analysis, automation and artificial intelligence, and includes:
   - Smart sensing and monitoring: utilising sensors and IoT devices to gather real-time data on environmental conditions, crop health, and livestock.
   - Smart analysis and planning: employing data analytics and AI to interpret data, predict outcomes and optimise farming practices.
   - Smart control: implementing automated systems and robotics to manage agricultural operations with precision and minimal human intervention to improve efficiency and reduce environmental footprint.

[75] See Section 4.1.1.5.

3. **Market integration and knowledge networks** refer mainly to upstream and downstream operations of Porter's value chain. It addresses barriers such as the resistance to change and skills gap, and leverages drivers like market demand. It also contributes to digital business and involves digital tools that connect farms and rural businesses to external resources, markets and information systems, such as:
   - Smart marketing and supply chain: encompassing e-commerce and digital marketing as well as a more transparent supply chain through traceability systems and digital quality assurance.
   - Smart knowledge and advisory services: deploying digital farm advisory platforms and e-learning systems but also platforms for peer-to-peer networking.
4. **Sustainability and rural areas integration** represent applications that contribute to the digital business cardinal point, where technology serves broader environmental and social objectives across the agri-food value chain and rural areas by:
   - Environmental and climate monitoring, resilience and certification: using digital tools to monitor the impact of agri-food production on environmental and climate parameters, improving risk management and the response to emergencies, but also complying with monitoring, reporting and verification requirements associated with nature or carbon certification and credits.
   - Integration in rural areas: improving access to services, supporting rural businesses and ensuring equal opportunities towards adopting digitalisation.
5. **Data economy and innovation ecosystems**, positioning data as a significant factor of production, complementing land, labour and physical capital. It contributes to both digital business and digital public services, supports enablers related to ethical and legal considerations and builds on data-driven business models. It includes:
   - Data sharing and integration: facilitating the exchange of data across the agricultural supply chain to ensure transparency, traceability and collaboration among stakeholders.
   - Data privacy and security: ensuring data privacy and security to foster trust and widespread adoption.
   - Data-driven business models: that leverage data to co-create value, including precision agriculture services, digital marketplaces, and data-driven advisory services.
   - Policy and governance: providing boundary conditions for fair and inclusive digitalisation.

The next step towards developing an intervention logic for the assessment of digitalisation is to effectively identify the relevant interventions of the CAP Strategic Plans.

## 3.2. Identifying interventions related to digitalisation under the CAP Strategic Plans

The analysis of the CAP Strategic Plans reveals significant diversity and heterogeneity of instruments and interventions. To facilitate the monitoring and evaluation of the policy, there is a need to more effectively identify the interventions included in CAP Strategic Plans. Two rather complementary approaches can be followed:

- the identification of interventions based on structured data, and more specifically, their linkages to specific indicators or other variables, and
- the identification of interventions based on unstructured data, namely the description of each intervention.

These two approaches can be used in combination and their strengths and limitations are described in the following paragraphs.

### 3.2.1. Identification of interventions based on result indicators

A first indication for the interventions that promote digitalisation in the CAP Strategic Plans can come from the analysis of the links between interventions and result indicators. This approach is presented in the following paragraphs, using information from the Catalogue of CAP interventions as a paradigm [76]. Although the information presented is at the EU level, it illustrates how the corresponding information at the Member State level can be used, and reveals the corresponding strengths and challenges.

EU Member States have designed a total of 2 500 interventions under the 2023-2027 CAP programming period through tailored CAP Strategic Plans. The Catalogue of CAP interventions offers a rich set of data that makes it possible to trace the intervention logic each Member State has established towards the specific and cross-cutting objectives.

Digitalisation is explicitly mentioned in SO2 and the CCO. The planned expenditures for SO2 are 7% of the total planned public funds (with a range from close to zero to 19% of planned national payments with a median of 6%). Planned expenditures for the CCO are 1% of the total planned public funds (with a range from close to zero to up to 4% of the planned national payments with a median of 1%). However, in these figures, are also included interventions that may not be directly linked to digitalisation.

Result indicator R.3 (share of farms benefitting from support for digital farming technology through CAP) is directly linked to interventions that focus on digitalisation. The most frequent types of interventions in the CAP Strategic Plans of Member States related

[76] For more information, see: https://agridata.ec.europa.eu/extensions/DashboardCapPlan/catalogue_interventions.html.

to R.3 are investments (INVEST) [77], cooperation (COOP) [78], and knowledge exchange and dissemination of information (KNOW) [79]. Interventions linked to R.3 may also be linked to other result indicators. This is not surprising, considering that digitalisation is often only one – though essential – element of the projects that can be financed under these interventions.

Typical activities, supported by interventions linked to R.3 (among other result indicators) are:

- Investments in agricultural holdings
- Cooperation of operational groups of the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI)
- Education and advisory systems
- Demonstration projects

However, R.3 has limited potential to paint the whole picture of digitalisation-related interventions under the CAP Strategic Plans. It covers, by definition, digitalisation of agriculture and does not capture all the relevant interventions. Although in the cover note on output and result indicators it is explicitly noted even if "*digital farming technologies represent a small part of a single large on-farm modernisation investment, this intervention should nevertheless be linked to R.3*" [80], Member States may not have chosen to make the linkage. These limitations can be shown, for example, if the CAP Strategic Plans interventions are filtered to select those that implemented precision agriculture [81]. The filtering reveal 43 unique interventions, including eight environmental, climate-related and other management commitments (ENVCLIM) [82], and 5 additional eco-schemes which are not linked to the R.3 indicator.

Other result indicators that may be related to digitalisation are R.39 (developing the rural economy), R.40 (number of supported smart-village strategies) and R.41 (share of rural population benefiting from improved access to services and infrastructure through CAP support). However, interventions linked to these indicators may not necessarily promote digitalisation.

One hundred ninety-six interventions have been linked to R.39, with 51 of them linked only to this indicator. Most interventions are investments, either under rural development (INVEST) or under sectoral interventions (INVRE) [83], and COOP. Four interventions explicitly mention digitalisation and are also linked to R.3. The most frequent activities of the interventions linked to R.39 include LEADER, and processing and marketing of agricultural products.

As regards R.40, 2 smart village cooperation interventions are exclusively linked to it, while 22 interventions in 17 Member States are linked to that result indicator in combination with others. Most interventions are also associated with other result indicators and all of them are of the COOP and INVEST types.

Regarding interventions linked to R.41, the situation is different. In nine Member States, there is a one-to-one relation between interventions and R.41. The types of intervention are COOP and INVEST and that are typically directed towards R.41 are:

- Investments in basic services and small-scale infrastructure in rural areas
- Creation/upgrading of basic rural infrastructure
- Improvement of basic services and infrastructure in rural areas
- Creation/modernisation of agricultural access infrastructure
- Broadband investment in rural areas

Interventions associated with R.41 in combination with other result indicators are offered in almost all Member States. Typical activities include:

- LEADER [84] projects
- Investments in basic services and small-scale infrastructure in rural areas
- Infrastructure in rural areas and implementation of the smart villages concept
- Investments in agricultural and forestry infrastructure, including rural land management

Disaggregated data on interventions [85] provides monitoring variables that report whether a condition is fulfilled. Among them is 'M200: investment in broadband'. This indicator informs of interventions aimed at improving access to broadband.

However, identifying projects under smart villages which use digital technologies or provide digital services, or digital services provided to the rural population, or rural businesses that focus on digitalisation based only on the links to the corresponding result indicator (R.40, R.41 or R.39) remains very challenging, leading to a potential over- or underestimation of the contribution of the CAP to the digitalisation of agriculture and rural areas.

It is, therefore, obvious that digital technologies are so widespread and many interventions may promote them, even if digitalisation is not explicitly addressed or mentioned in the title and description of the intervention or the links to digitalisation-related result indicators. A detailed review of the CAP Strategic Plan may offer more insights, however, such a review necessitates a comprehensive way of identifying and tracking digitalisation-related interventions, based on a clearly defined classification system that builds on the definition of digitalisation and its domains. A search for relevant keywords (such as those provided in the Annex I. A classification system for digitalisation in the agri-food sector and rural areas) in the CAP Strategic Plan document may be useful to identify interventions addressing digitalisation.

[77] Article 73 of Regulation (EU) 2021/2115.
[78] Article 77 of Regulation (EU) 2021/2115.
[79] Article 78 of Regulation (EU) 2021/2115.
[80] Cover note on output and result indicators, Version 20.0, European Commission 2024. https://agriculture.ec.europa.eu/system/files/2023-10/pmef-cover-note-indicators_en.pdf.
[81] Interventions can be filtered based on the practices implemented using the Catalogue of CAP interventions: https://agridata.ec.europa.eu/extensions/DashboardCapPlan/catalogue_interventions.html?page=FarmPractices#.
[82] Article 70 of Regulation (EU) 2021/2115.
[83] Investments in tangible and intangible assets, research and experimental and innovative production methods and other actions in the fruit and vegetables sector, the hops sector, the olive oil and table olives sector and in the other sectors (paragraph 1(a), Article 47, Regulation (EU) 2021/2115).
[84] The variable L808 (Annex VII of Regulation (EU) 2022/1475) shows the number of operations improving access to services and infrastructure, including broadband.
[85] See Annex IV of Implementing Regulation (EU) 2022/1475.

### 3.2.2. Identification of interventions using a classification system for digitalisation

#### 3.2.2.1. Principles of the classification system

The classification system is built on the recognition that digitalisation of the agri-food sector and rural areas is not a monolithic phenomenon, but rather a complex, multi-layered transformation that occurs across different scales and with varying degrees of sophistication. The system addresses the need for a systematic approach to categorise digitalisation-related interventions while maintaining both analytical rigour and practical utility for policymakers and evaluators. Indicatively:

- it can be used during the design of interventions to understand the state-of-play of digitalisation in the agri-food sector and rural areas, and assist in the assessment of needs,
- it can facilitate the establishment of a baseline for digitalisation adoption and intensity,
- it can support the development of a digitalisation-specific intervention logic and evaluation framework, and
- it can guide data collection, especially as regards surveys, interviews and focus groups.

It incorporates the following specific design:

**Hierarchical logic:** The system provides a flexible three-tier classification approach that adapts to varying levels of intervention detail. When there is sufficient information, interventions can be classified under the most granular Tier-3 level, otherwise the intervention can be labelled using Tier-2 or even Tier-1 levels. In this way, functions such as the assessment of the state-of-play of digitalisation or the establishment of a baseline can be carried out even if the level of detail is low, although with a lower analytical potential.

**Progressive complexity:** The system recognises that digital transformation follows a natural progression from basic infrastructure to sophisticated integrated applications. This progression logic helps policymakers and evaluators understand dependencies between digitalisation activities and sequence interventions appropriately. It can also help evaluators to establish a baseline and assess the relevance between objectives and needs. For example, the relevance of a set of interventions contributing to the adoption of precision agriculture can be compromised if any needs related to the lack of digital infrastructure (connectivity, basic digital skills, etc.) are not or have not yet been addressed.

**Infrastructure vs. application distinction:** A fundamental principle embedded throughout the framework distinguishes between interventions that build digital capabilities and those that utilise existing capabilities. This distinction, reinforced through specific keywords, prevents classification ambiguity and supports more targeted policy development. For example, precision agriculture may involve both the installation of sensors or the purchase of equipment and the applications that use the data generated from the sensors and allow a more targeted and efficient use of inputs. Embedding this distinction in the classification system provides a clear framework for analysing the needs, building a detailed intervention logic, and setting the basis for a better assessment of relevance and coherence of digitalisation-related interventions.

**Future-oriented flexibility:** The classification system anticipates technological evolution by organising categories around persistent functional needs rather than specific technologies. This approach ensures continued relevance as agricultural technologies evolve, avoiding the need for frequent reclassification as new technologies emerge. For example, instead of formulating Tier-3 activities around specific technologies, like IoT or blockchain, the system refers to traceability and logistics systems, which may encompass future technologies that go beyond IoT and blockchain.

**Cross-cutting integrations of simplification-related aspects of digitalisation:** Rather than treating simplification as a separate domain, the system integrates it as a cross-cutting dimension that enhances interventions across all classification domains. This approach reflects the reality that effective administrative burden reduction occurs when compliance and reporting capabilities are seamlessly integrated with operational systems, rather than requiring separate administrative processes.

#### 3.2.2.2. The three-tier classification system

The system is structured around three tiers, moving from the more general Tier-1 to the more specific Tier-3. **Tier 1** represents the highest level of abstraction, organised into five domains that reflect the natural progression of digitalisation and the key components of its definition. These domains are:

- **Domain A: Digital foundation.** This domain establishes the essential infrastructure, equipment and skills that enable all other digital activities.
- **Domain B: Smart production.** Encompasses advanced technologies that optimise agricultural production through data analysis, automation and AI.
- **Domain C: Market integration and knowledge networks.** Captures digital tools that connect farms to external resources, markets, and information systems.
- **Domain D: Sustainability and rural areas integration.** Represents applications where technology serves broader environmental and social objectives.
- **Domain E: Data economy and innovation ecosystems.** Covers digital systems and frameworks that enable the collection, sharing, analysis, and commercialisation of agricultural data to drive innovation, research and economic value creation across the agricultural ecosystem.

This domain structure reflects the infrastructure-to-application progression that characterises successful digital transformation, where foundational capabilities (Domain A) enable operational optimisation (Domain B), which facilitates market integration (Domain C), ultimately supporting comprehensive sustainability goals (Domain D) and enabling the data economy (Domain E).

**Tier 2** provides the analytical precision needed for policy development by identifying specific groups within each domain. These 19 functional groups represent distinct types of activities towards digitalisation that may require different policy approaches and implementation strategies.

**Tier 3** delivers the operational specificity required for practical intervention classification and programme design. These 36 specific activities enable precise classification of actual interventions while maintaining sufficient breadth to accommodate technological evolution and diverse implementation approaches across Member States.

The complete three-tier classification system is presented in Table 2.

### Table 2. The three-tier classification system

| Tier 1: Strategic domains | Tier 2: Functional groups | Tier 3: Specific activities |
|---|---|---|
| Domain A: Digital foundation | A1: Infrastructure and connectivity | A1.1: Rural broadband and network deployment |
| | | A1.2: Digital communication platforms |
| | A2: Basic technology and equipment | A2.1: Hardware and software systems |
| | | A2.2: Basic monitoring and sensor technologies |
| | A3: Data security and privacy | A3.1: Data protection and privacy systems |
| | | A3.2: Cybersecurity infrastructure |
| | A4: Digital skills | A4.1: Digital literacy and adoption support |
| | | A4.2: Cybersecurity training and awareness |
| | A5: Administrative infrastructure and compliance systems | A5.1: Digital government service integration |
| | | A5.2: Automated compliance and reporting systems |
| Domain B: Smart production | B1: Precision agriculture systems | B1.1: GPS-guided and variable rate technologies |
| | | B1.2: Soil and yield mapping systems |
| | B2: Automation and robotics | B2.1: Automated livestock systems |
| | | B2.2: Robotic field and harvest equipment |
| | B3: Integrated farm management | B3.1: Comprehensive farm management platforms |
| | | B3.2: Digital twin and enterprise systems |
| | B4: Analytics and automated decision-making | B4.1: Advanced analytics and automated decision-making systems |

| Tier 1: Strategic domains | Tier 2: Functional groups | Tier 3: Specific activities |
|---|---|---|
| Domain C: Market integration and knowledge networks | C1: Digital commerce and marketing | C1.1: E-commerce and digital marketplace platforms |
| | | C1.2: Digital marketing and customer engagement |
| | C2: Supply chain integration | C2.1: Traceability and logistics systems |
| | | C2.2: Digital procurement and quality assurance |
| | C3: Knowledge and advisory services | C3.1: Digital farm advisory platforms |
| | | C3.2: E-learning and educational platforms |
| | C4: Collaborative networks and platforms | C4.1: Networking and cooperation platforms |
| | | C4.2: Resource and equipment sharing systems |
| Domain D: Environmental and social sustainability integration | D1: Environmental and climate monitoring, reporting and verification | D1.1: Environmental and climate monitoring |
| | | D1.2: Environmental and climate reporting and verification |
| | D2: Emergency response and risk management | D2.1: Emergency response and risk management systems |
| | D3: Rural development | D3.1: Smart village and rural development digital initiatives |
| | | D3.2: Digital inclusion and entrepreneurship support |
| Domain E: Data economy and innovation ecosystems | E1: Data governance and standards | E1.1 Agricultural data governance frameworks |
| | | E1.2 Interoperability and data standards |
| | E2: Research and innovation infrastructure | E2.1 Digital research and innovation platforms |
| | | E2.2 Agricultural data repositories and archives |
| | E3: Data markets and commercialisation | E3.1 Agricultural data marketplace platforms |
| | | E3.2 Data analytics and insights services |

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

A more detailed presentation of the system, including specific keywords as well as examples of CAP Strategic Plans interventions associated with each Tier-3 level, is included in Annex I.

#### 3.2.2.3. Practical application of the classification system

The system provides a flexible classification approach that adapts to varying levels of intervention detail. The optimal classification level is Tier-3. It can be applied when the intervention descriptions provide specific information about technologies and implementation approaches. For example, 'GPS precision spraying equipment deployment' clearly classifies as B1.1: GPS-guided and variable rate technologies.

When interventions mention general technology categories without specific implementation details, classification can stop at the Tier-2 level. For instance, 'digital technology adoption support' can be classified as A2: Basic technology and equipment without specifying particular Tier-3 activities.

Finally, when descriptions only mention general digitalisation goals without specific technologies, the classification can identify only the relevant domain. 'Addressing poor digitalisation focus' classifies as 'Domain A: Digital foundation' and capabilities without further specification.

Figure 4 illustrates the structure of the classification system along with examples of how it can be used practically, based on the level of detail provided in the description of the corresponding interventions. Note that one intervention might be classified under more than one element. This graduated classification approach ensures comprehensive coverage while maintaining analytical honesty about classification confidence levels.

**Figure 4. Structure of the classification system and examples of classification, based on the level of detail provided in the intervention description**


Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

The simplification dimension is addressed as a structural element under 'A5: Administrative infrastructure and compliance systems'. It includes infrastructures that ensure digital government (e.g. public service digitalisation infrastructure, digital identity and unified access systems, etc) and automation of administrative tasks, compliance and reporting. However, simplification also has a horizontal aspect, which enhances interventions across all the other classification domains by integrating administrative capabilities with operational benefits. Rather than requiring separate systems for administrative tasks and regulatory compliance,

well-designed digitalisation-related interventions may automatically generate administrative outputs from day-to-day farming activities. For example, comprehensive precision agriculture systems (B1) and farm management platforms (B4) may automatically generate compliance reports. Traceability and logistics systems (C1) may simultaneously serve marketing and regulatory transparency requirements. Environmental and climate monitoring systems can automatically satisfy sustainability monitoring, reporting and verification requirements. Data governance frameworks may enable automated regulatory reporting and compliance verification through standardised data sharing protocols.

Domain E also displays horizontal behaviour, not across the other domains, but across the agri-food value chain. While domains A-D often focus on individual farms or specific production systems, Domain E activities typically serve the entire agri-food ecosystem, creating benefits that span multiple farms, sectors and value chain actors. Interventions under Domain E may enable and accelerate innovations in other domains by providing the data infrastructure and governance frameworks necessary for advanced applications. For example, the adoption of AI-powered prediction and monitoring (B3) could depend on standardised protocols for farmers to securely share anonymised data (E1), a research infrastructure platform that aggregates anonymised data from many farms across different regions, soil types and crop varieties (E2), and a commercial AI-as-a-service platform that leverages the data governance and research infrastructure activities (E3).

#### 3.2.2.4. Other applications of the classification system

Beyond the identification of digitalisation-related interventions, the system can support systematic gap analyses across multiple dimensions, which can be useful for assessing digitalisation under the CAP Strategic Plans. First, the system allows for a technology maturity assessment by analysing intervention distribution across domains. Policy makers and evaluators can identify whether, for example, a specific Member State channels the support to foundational capabilities (Domain A) or whether it progressed to advanced applications (Domains B, C, D). Heavy concentration in Domain A can be in line with basic infrastructure needs, while strong representation across domains indicates more mature digitalisation ecosystems. This is particularly useful for assessing the intensity of digitalisation, as explained in Section 4.1.1.5.

Additionally, the Tier-2 level functional groups enable precise identification of capability gaps. For example, strong representation in 'A2: Basic technology and equipment', but weak representation in 'B1: Precision agriculture systems', may indicate strong support for infrastructure, but limited support for promoting smart agriculture applications. Such observation may be further analysed using the system's progression logic to support strategic planning by identifying prerequisite capabilities. Member States cannot effectively implement 'B3.1: AI-powered prediction and monitoring' without adequate' A2.2: Basic technology and equipment' and 'A3.1: Digital skills and literacy'.

## 3.3. Other instruments that promote digitalisation outside the CAP Strategic Plans

The previous sections described the approaches that can be taken to identify CAP Strategic Plan interventions that promote digitalisation. They include the identification of interventions based on their links to specific result indicators, which, however, present several challenges that may lead to an underestimation of the CAP support towards digitalisation. To overcome these challenges, a detailed classification system is also proposed, which can help in identifying digitalisation-related interventions based on their descriptions, regardless of their links to result indicators.

However, the CAP does not operate in a void. Beyond the interventions under the CAP Strategic Plans, there are also other means that promote digitalisation, which include digital services and tools provided under the general framework of the CAP, and non-CAP actions and initiatives that support digitalisation. These must be taken into account, as external factors, when designing the intervention logic, to set the basis for the assessment of external coherence.

### 3.3.1. Digital services and tools provided under the general framework of the CAP

Information and data are resources and factors of production just like land, intermediate inputs and labour. Digital and data sharing regulations such as the Data Act Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 [86] regulate the access to and sharing of agricultural data between/among farmers, agribusinesses, retailers and processors. Other legal acts are the basis for the collection of price information and other statistics [87].

The website of the European Commission hosts many digital services that provide data and information useful to all agents of the agricultural value chain. Depending on the purpose(s), complex models integrate this information to calculate results for decision-making purposes.

The EU Agri-Food-Portal [88] is the hub of a broad range of information sources. For farmers, the most important ones are the dashboards on prices for animal and plant products [89], the outlook on markets and the information on prices of inputs [90]. Related information on production conditions is provided by the drought observatories of the Joint Research Centre: EU Science Hub [91].

[86] Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828. OJ L, 2023/2854, 22.12.2023, ELI: http://data.europa.eu/eli/reg/2023/2854/oj.

[87] Commission Implementing Regulation (EU) 2019/1746.

[88] For more information, see: https://agridata.ec.europa.eu/extensions/DataPortal/home.html#:~:text=In%20this%20dashboard%20we%20provide%20a%20selection%20of,on%20agricultural%20income%20based%20on%20the%20economic%20accounts.

[89] For more information, see: https://agridata.ec.europa.eu/extensions/DataPortal/prices.html.

[90] For more information, see: https://agridata.ec.europa.eu/extensions/DataPortal/agricultural_markets.html.

[91] For more information, see: https://joint-research-centre.ec.europa.eu/european-and-global-drought-observatories/current-drought-situation-europe_en.

The central provision of well-defined, timely and regularly updated data and making them easily accessible via application programming interfaces (APIs) is a precondition to better decision-making in all sectors. The data contributes to making the agricultural sector more competitive and resilient. As everyone can access this information and benefit from its free availability, it is difficult to identify its effects compared to a situation without the availability of this data.

### 3.3.2. Non-CAP actions and initiatives to promote digitalisation

CAP Strategic Plans are operating within a complex web of EU initiatives and programmes aimed at promoting digitalisation and increasing the adoption of digital technologies. The Digital Decade policy programme 2030 [92], establishes digital targets and objectives in the realms of digital skills, digital infrastructure, and digitalisation of business and public services. The programme creates a framework for multi-country projects that will allow Member States to join forces on digital initiatives. Reports on the progress to attain the objectives are published annually [93]. The targets of the programme may be useful for setting benchmarks or points of comparison to assess the magnitude of the effect of CAP support on digitalisation.

The following instruments provide support for digitalisation and might be relevant to be considered when assessing external coherence of digitalisation-related interventions of the CAP Strategic Plans:

- The Digital Europe programme is a central EU funding initiative, aimed at building digital capacities in supercomputing, artificial intelligence, cybersecurity and advanced digital skills, and supporting the uptake of digital technologies by businesses (especially SMEs which are in many cases service providers for agriculture) and public administrations [94].
- Digitalisation of Businesses and SMEs: Next Generation EU (NGEU) funds National Recovery and Resilience Plans (NRRPs). In some Member States, funds are allocated to support consultancy, training, and direct financial assistance for SMEs and agriculture to adopt digital technologies, enhance digital skills, and implement advanced solutions like cloud computing, AI, and big data. Furthermore, NGEU finances investments in broadband expansion, 5G deployment, and high-performance digital networks to ensure connectivity across urban and rural areas. Regional smart specialisation strategies align digital agricultural projects with regional development priorities.
- Some EU financed research projects are focusing on promoting digital solutions in agriculture (e.g. CODECS, QUANTIFARM, SmartAgriHub, ATLAS, DEMETER) [95].
- The ESA provides a wide range of services that are based on infrastructure on the ground and in space and contributes substantially to the digitalisation of the agri-food sector and rural areas. Many satellites and programmes are specifically tailored to agricultural uses.

This list is not exhaustive and similar initiatives, legislative acts and strategies have been developed by individual Member States.

## 3.4. A generic intervention logic of digitalisation under the CAP Strategic Plans

Figure 5 below shows a generic intervention logic of the CAP to promote digitalisation as a means to make farms more market-oriented and competitive, and for production to become more sustainable. It differentiates between three strategic policy approaches:

- Specific types of interventions, under the CAP Strategic Plans, that may promote digitalisation (the Catalogue of CAP Interventions [96] provides an overview of specific Member States approaches and the plans offer detailed information on relevant interventions).
- Digital services and tools provided under the general framework of the CAP (e.g. digital services on market information).
- Non-CAP instruments and strategies that are not focused on the digitalisation of the agri-food sector and rural areas specifically but benefit both (e.g. broadband networks).

The specific types of interventions under the CAP Strategic Plan are listed in **orange boxes**:

- Knowledge exchange and dissemination of information and EIP or agricultural productivity and sustainability, corresponding mostly to functional groups A4, C3 and C4 of the classification system.
- investments, setting-up of rural business start-up and LEADER, corresponding mostly to Domains A and B, and functional groups C1, C2 and D3 of the classification system.
- Eco-schemes and environmental, climate-related commitments, corresponding mostly to Domain B and functional groups D1 and D2 of the classification system.
- Sectoral interventions, corresponding predominantly to Domain C and functional groups D1 and D2.

[92] For more information, see: https://eur-lex.europa.eu/eli/dec/2022/2481/oj.
[93] For more information, see: https://digital-strategy.ec.europa.eu/en/factpages/state-digital-decade-2024-report.
[94] For more information, see: https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/digital-europe-programme_en.
[95] An overview is provided here: https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture-horizon-2020; for specific information, see: https://www.horizoncodecs.eu/, https://quantifarm.eu/, https://www.smartagrihubs.eu/; https://www.atlas-h2020.eu/; https://h2020-demeter.eu/.
[96] For more information, see: https://agridata.ec.europa.eu/extensions/DashboardCapPlan/catalogue_interventions.html.

General CAP measures and instruments (in **light blue box**) are categorised in services of the European Commission (e.g. market information dashboards) and administrative tools offered by national authorities (e.g. digital portal of a Paying Agency for the submission of applications for support and payment claims), mostly corresponding to functional group A5, and Activity E.2.2.).

Non-CAP funding instruments are shown in the **dark blue box** and may correspond to all domains of the classification system. For example, the Digital Europe programme may correspond both to Domain A and Domain B while non-CAP support under shared management, such as cohesion policy, smart specialisation strategies and NGEU may correspond to Domains from A to D depending on their specific interventions.

The main hypothesis is that the more digital tools and technologies are employed on a farm and in rural areas, and the better the farmers' and other rural actors' skills are at making use of them, the better the outcomes will be, through:

- better decision making,
- higher productivity in crop, livestock and/or service production,
- higher value products,
- lower administrative, procurement and/or sales costs,
- a smaller environmental footprint when chemical substances (plant protection substances, mineral fertilisers) can be saved and applied more precisely, and
- improved rural service accessibility and quality, reduced digital urban-rural divide, and reduced social asymmetries in accessing resources and information in rural areas.

Rolandi et al. [97] provides a comprehensive taxonomy of impacts of digitalisation of agriculture and rural areas. This taxonomy is structured around economic, environmental, governance and social impacts. CAP support mostly affects the economic, environmental and social aspects.

At farm level, a major intended impact of increased adoption and more intense use of digitalisation is to make farms more competitive, combined with a lower environmental and climate footprint. Digitalisation plays a dual role in relation to this impact, contributing to the **simultaneous improvement of both the economic and environmental performance of the farms**. Changes in sustainable farm productivity (see Section 4.1.2) can capture this dual role. For example, the adoption of a variable rate application technology by a farm not only decreases the environmental and climate footprint but also reduces the costs of the inputs per unit of output, thus increasing sustainable productivity. On the other hand, digitalisation uses electricity, and many digital technologies are resource-intensive and create waste, which may offset on-farm environmental gains [98] and reduce sustainable productivity. In this context, taking a holistic view of the effects of digitalisation on the agricultural sector through assessing its effects on sustainable farm productivity is very helpful in assessing the concurrent contribution of digitalisation to SO2, SO4, SO5 and SO6.

At the territorial level, the major impact is to achieve a more sustainable and inclusive growth in rural areas. The taxonomy of impacts referenced above identifies five areas of impact, namely:

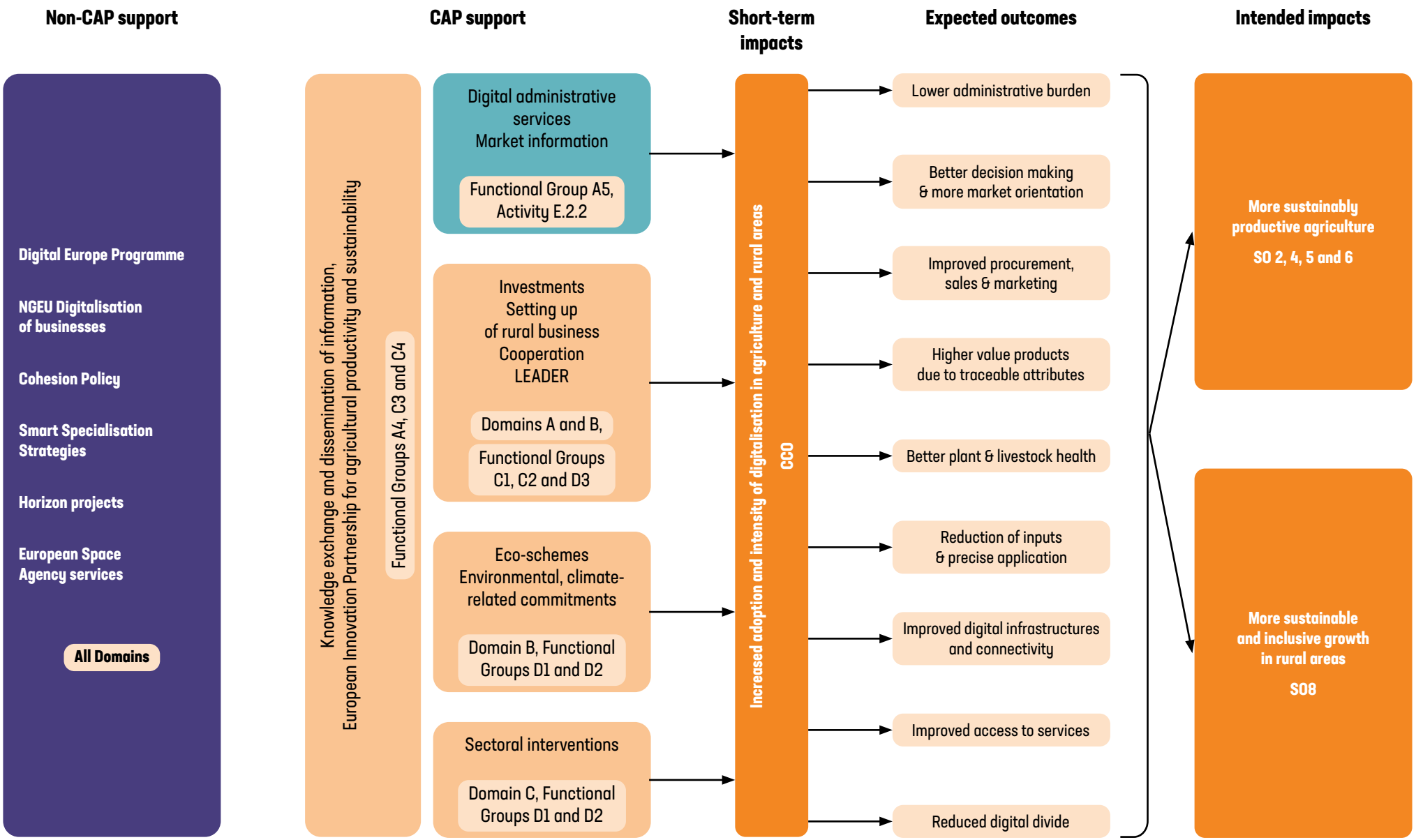
- Individual, aspects and characteristics that refer to a single person.
- Access, the chance and conditions to enlarge social interactions.
- Rights, effects on the related issue of fundamental rules.
- Social capital, the key resources, e.g., information and social contacts and related issues.
- Control, the issue of data security, utilisation and the pervasiveness of digital change.

CAP support mostly affects individual (health, learning, skills), which refers to improved access and adoption of digital services; access (information and communication technology (ICT), resources), which can be mapped to improved digital infrastructure and connectivity and digital skills; rights (equity, gender gap), which can be captured by changes in the digital urban-rural divide but also in the traditional gaps inside the rural areas (e.g. the gender gap); and social capital, which is mostly promoted by LEADER interventions.

Furthermore, there may be unintended, but welcome effects, such as requiring less mental effort or improved well-being for those utilising digital tools, as well as negative effects (mostly related to the control area of impacts) related to problems with privacy, data ownership and their use.

[97] Rolandi S, Brunori G, Bacco M, Scotti I, *The Digitalization of Agriculture and Rural Areas: Towards a Taxonomy of the Impacts*, Sustainability, 2021; 13(9):5172. https://doi.org/10.3390/su13095172.
[98] Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F., *Towards a green and digital future*, Publications Office of the European Union, Luxembourg, 2022, JRC129319, https://data.europa.eu/doi/10.2760/977331.

## Figure 5. Generic CAP intervention logic fostering digitalisation and the intended impacts




EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

NB. See thev text above for an explanation of the different colours

# 4. Assessing digitalisation under the CAP Strategic Plans: key considerations for structuring and implementing evaluations

Digitalisation or other variants thereof (i.e. digital technologies) are mentioned 21 times in Regulation (EU) 2021/2115. Compared to other topics present in the CAP Strategic Plan regulation, this is a relatively less frequent term (e.g. young farmers are referenced 53 times), but digitalisation is viewed as a conduit to boost technological progress, and thus contribute to the Specific Objectives of the CAP.

Digitalisation is explicitly put into the context of market orientation and competitiveness in SO2, in combination with a focus on research [99]. Digitalisation is deemed as important, not only for enhancing farm performance, but also for improving the sustainable management [100].

Digitalisation requires not only digital infrastructures, tools and technologies, it also requires complementary digital skills. As per the CCO [101], farmers should be encouraged to adopt digital technologies through improved access to research, innovation, knowledge exchange and training.

Furthermore, reducing administrative burden is an important objective of the CAP [102], where Member States, "*...shall take appropriate measures to reduce the administrative burden and ensure simplification in the implementation of the CAP*" [103]. The wider use of digital technologies in Member State administration(s) is a means to reduce both transaction and administrative costs, and a more frequent use thereof is expected:

- to reduce the administrative burden of interventions that are similar to those of previous periods when digital tools were not used;
- to facilitate innovative interventions that would not be manageable without digital tools.

Digital technologies can have many more effects that go beyond productivity and environmental improvements. For example, operators of tractors with automated steering systems can focus their attention on other things than keeping the tractor on track. The digitally enhanced technology reduces cognitive effort and contributes to the overall well-being of those working in agriculture. Such an outcome is positive, even if it is not an explicit target of the CAP Strategic Plan.

However, promoting digitalisation is not an end in itself; it serves specific purposes. Beneficiaries of CAP Strategic Plan interventions who adopt digital technologies are expected to:

- be more productive while reducing their environmental and climate footprint, and/or
- contribute to the sustainable and inclusive growth of rural areas.

A difficulty arises because digitalisation, innovation and research are intertwined and are not easy to disentangle. Furthermore, many investments in physical assets are associated with features of digitalisation that cannot be separated. Therefore, it may turn out to be very hard to identify causal effects between expected outcomes and interventions that address digitalisation indirectly or not explicitly.

## 4.1. Key considerations for assessing digitalisation under the CAP Strategic Plans

The Commission Implementing Regulation (EU) 2022/1475 defines 'key elements to assess' and 'recommended factors of success' for the interventions addressing the specific and cross-cutting objectives. As shown in Section 3.2, interventions focusing on digitalisation are few among all the interventions addressing these objectives.

This overview defines the evaluation framework for exploring the effects of CAP Strategic Plan interventions, regardless of whether the underlying interventions focus on digitalisation or not. In order to better capture the effects of CAP support on digitalisation, evaluators may want to define additional evaluation questions and corresponding factors of success. In this direction, the assessment of digitalisation must take into account at least the effect of:

- CAP support in fostering digitalisation for the modernisation of agriculture and rural areas;
- CAP support for digitalisation on sustainable farm productivity; and
- CAP support for digitalisation on sustainable and inclusive growth of rural areas.

An example of a more detailed evaluation framework for assessing digitalisation is presented in Annex II, while its main underlying considerations are presented in the following paragraphs.

[99] See Article 6 (b) of Regulation (EU) 2021/2115 "to enhance market orientation and increase farm competitiveness both in the short and long term, including greater focus on research, technology and digitalisation".
[100] See recital 50 of Regulation (EU) 2021/2115.
[101] Article 6 (2) of Regulation (EU) 2021/2115.
[102] See e.g. recitals 1, 19, 54 of Regulation (EU) 2021/2115.
[103] Article 6 (3) of Regulation (EU) 2021/2115.

### 4.1.1. The effect of CAP support in fostering digitalisation for the modernisation of agriculture and rural areas

The 'EU level CAP evaluation framework' [104] suggests separating the assessment of AKIS and digitalisation strategies when structuring evaluations. Although the recommended factor of success in Annex I of the Regulation (EU) 2022/1475 mentions only farmers, the EU CAP Network publication suggests looking also at rural areas supported for introducing digital technologies through CAP Strategic Plans.

The Digital Decade Programme [105] provides a solid basis regarding the dimensions that must be considered when assessing the effect of CAP support in fostering digitalisation for the modernisation of agriculture and rural areas. Figure 6 presents a schematic outline of the overall approach, which is then discussed in the following paragraphs.

**Figure 6. Outline of the approach for assessing the effects of CAP support on fostering digitalisation**

#### Digital Infrastructure & Connectivity

Rural broadband coverage, speed, and quality improvements

**Target: 100% Gigabit coverage by 2030**

**Group A1** **M200 Variable** **Domain A**

**Effectiveness**
Calculate percentage point coverage improvement towards Digital Decade target

**Efficiency**
Compare cost effectiveness with other funding instruments for similar connectivity quality

**Coherence**
Internal: Analyse relationships with digital security and skills interventions under Domain A
External: Analyse relationships with non-CAP funding sources

**Relevance**
Assess territorial prioritisation and 'leave no one behind' implementation

#### Digital Skills & Capacity Building

Development of digital competencies in rural populations

**Target: 80% adults with basic digital skills by 2030**

**Group A4** **IFS 2026** **ICT Surveys**

**Effectiveness**
Measure CAP contribution as percentage point improvement in rural adult digital skills

**Efficiency**
Compare cost effectiveness of CAP vs other digital skills funding instruments

**Coherence**
Internal: Examine relationships across all domains, especially smart production and market integration

**Relevance**
Analyze participation rates, equity issues, and gender balance in rural areas

#### Digital Transformation in Enterprises

Adoption intensity in farms and rural businesses

**Target: 75% enterprises using cloud, AI, analytics by 2030***

**Group A2** **Domains B-E** **Result R.3**

**Effectiveness**
Limited benchmark applicability – focus on before/after percentage changes for agri-food sector

**Efficiency**
Cost comparison with other enterprise digitalisation support programs

**Coherence**
Internal: Analyse interdependencies between smart production, infrastructure, and skills development

**Relevance**
Consider enterprise size differences and agricultural sector specificities

#### Digital Public Services

Enhancement of digital services for rural populations

**Approach: National targets & comparative analysis**

**Group D3** **Domain E** **Group A5**

**Effectiveness**
Use national-level targets and before/after implementation comparative analysis

**Efficiency**
Compare delivery costs and user adoption rates with alternative service models

**Coherence**
Internal: Analyse interdependencies with infrastructure, and skills development
External: Analyse relationships with non-CAP funding sources

**Relevance**
Evaluate service accessibility and usability for diverse rural user needs

**Digitalisation Intensity Assessment**
Horizontal dimension: Beyond adoption to integrated utilisation
**Basic Adoption → Operational Integration → Long-term Transformation**

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

[104] For more information, see: https://eu-cap-network.ec.europa.eu/support/evaluation/evaluation-framework_en#paragraph-43493.
[105] See https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en.

#### 4.1.1.1. Digital infrastructure and connectivity enhancement

Evaluators may examine the extent to which rural populations have gained access to improved broadband coverage, enhanced speed and higher quality connectivity as a direct result of CAP support. CAP Strategic Plan interventions falling under the functional group 'A1: Infrastructure and connectivity' of the classification system must be considered. These interventions can also be identified using the variable M200 (investment in broadband) of the disaggregated data on interventions [106].

For effectiveness, the Digital Decade target, which aims to achieve 100% coverage of populated areas with gigabit networks by 2030, can be used as a benchmark for estimating the magnitude of the effect of CAP support. The effectiveness of CAP interventions can be quantified by calculating the percentage point of coverage improvement due to CAP support towards achieving the Digital Decade target.

For efficiency, evaluators may compare the cost-effectiveness of CAP support to that of other funding instruments that support (or have supported) digital infrastructure and connectivity. Specific attention must be paid to the type of infrastructure deployed by each funding source in order to compare cases with a similar quality of connectivity.

For coherence, evaluators may look at the existence of relationships between digital infrastructure interventions and other interventions, especially under Domain A of the classification system. For example, how digital infrastructure interventions work together with interventions that promote digital security and the acquisition of digital skills. In cases where the infrastructure is funded by instruments outside the CAP, the complementarities between the funding sources can be analysed, as can the complementarities of non-CAP-supported infrastructure with other interventions of the CAP Strategic Plan, especially under Domain A of the classification system.

For relevance, evaluators may want to look at how the contextual characteristics of the different territories, where digital infrastructure has been deployed, played a role in prioritising their coverage, and how the commitment to 'leave no one behind' has been implemented.

#### 4.1.1.2. Digital skills development and capacity-building

The evaluation may assess the extent to which rural inhabitants have developed their digital skills due to CAP support. The CAP Strategic Plans interventions and beneficiaries falling under the functional group 'A4: Digital skills and literacy' of the classification system must be considered.

For effectiveness, this assessment can be benchmarked against the Digital Decade target of ensuring that 80% of adults possess at least basic digital skills by 2030. Evaluators may measure the CAP's contribution as a percentage point improvement towards achieving this target, specifically within rural adult populations. National data derived from annual surveys examining ICT use by households and individuals can be used for the total number of adults in rural areas with basic digital skills. In addition, according to Annex II of the Commission Implementing Regulation (EU) 2024/2914 of 25 November 2024 [107], the Integrated Farm Statistics (IFS) 2026 will include a specific variable measuring farmers who received advice or training in digital tools/skills.

For efficiency, evaluators may compare the cost-effectiveness of CAP support to that of other funding instruments that support (or have supported) the development of digital skills.

For coherence, evaluators may examine the existence of relationships between digital skills interventions and other interventions, under all domains of the classification system. For example, how digital skills interventions work together with interventions that promote smart production and market integration.

For relevance, evaluation may focus on how contextual characteristics of different territories where the interventions have been implemented affected the participation rate of the rural actors as well as on equity issues and the gender balance in acquiring digital skills.

Detailed data about the participants of capacity building interventions and, preferably, follow-up information about the adoption and intensity of digitalisation are critical for the assessment of this dimension. The collection of these data may require carrying out dedicated surveys (see Section 4.2.2).

#### 4.1.1.3. Digital transformation in farms and rural enterprises

Evaluators may assess the intensity or extent to which farms and rural enterprises have adopted digital technologies with CAP support.

As a benchmark for effectiveness, the digital decade target of having 75% of EU enterprises utilise cloud computing, data analytics and AI by 2030 can be used. However, this benchmark has several limitations. First of all, it covers only a subset of digital transformation, focusing on the use of cloud computing, data analytics and AI. Second, available national data from annual surveys on ICT usage in enterprises do not include agriculture and cover only enterprises with ≥ 10 persons employed. As a result, the benchmark can only be used for rural businesses, other than farms, that have ≥ 10 persons employed and benefit from interventions under the activity D3.2 of the classification system. For the whole agri-food sector and rural areas, the assessment can focus on the direction of the effect by looking at the change in the percentage of farms and other rural businesses before and after the implementation of the CAP Strategic Plan. Interventions and beneficiaries falling under the functional group A2, as well as under domains B, C, D and E of the classification system, can be taken into account. In addition, result indicator R.3 and other result indicators as explained in Section 3.2.1, are key for the assessment of this dimension.

For coherence, evaluators may examine the existence of relationships between digital business interventions and other interventions, especially under lower domains of the classification system. For example, how the adoption of interventions that promote smart production and market integration was based on the development of digital infrastructure and/or skills, or how the adoption of environmental and climate monitoring (D1) was affected by the adoption of smart production and management (Domain B).

[106] Annex IV of Regulation (EU) 2022/1475.

[107] Commission Implementing Regulation (EU) 2024/2914 of 25 November 2024 on the data to be provided for the reference year 2026 pursuant to Regulation (EU) 2018/1091 of the European Parliament and of the Council on integrated farm statistics as regards the list of variables and their description. OJ L, 2024/2914, 26.11.2024, ELI: http://data.europa.eu/eli/reg_impl/2024/2914/oj.

#### 4.1.1.4. Enhancement of digital public services

Evaluators may assess the extent to which a rural population benefits from improved digital services as a result of CAP support. CAP Strategic Plan interventions and beneficiaries falling under the functional group D3 and Domain E may be considered. In addition, digital services falling under the functional group A5, such as the IACS, should also be considered.

For effectiveness, the Digital Decade target of making all key public services available online by 2030 may not be directly applicable as a benchmark for assessing the effectiveness of CAP interventions. This target typically encompasses administrative steps for major life events such as moving, transport procedures, legal processes, family matters, career development, education and health services, which generally fall outside the scope of CAP support. Consequently, evaluators are advised to identify alternative relevant targets established at national levels or to conduct comparative analyses examining the situation before and after policy implementation.

Finally, beyond adoption, **the change in the intensity of digitalisation** should also be assessed. This assessment focuses on beneficiaries of CAP Strategic Plan interventions who receive support for adopting more sophisticated digital tools and services. For this, evaluators must define and use measures of digitalisation intensity. Section 4.1.1.5 offers some insights towards this direction.

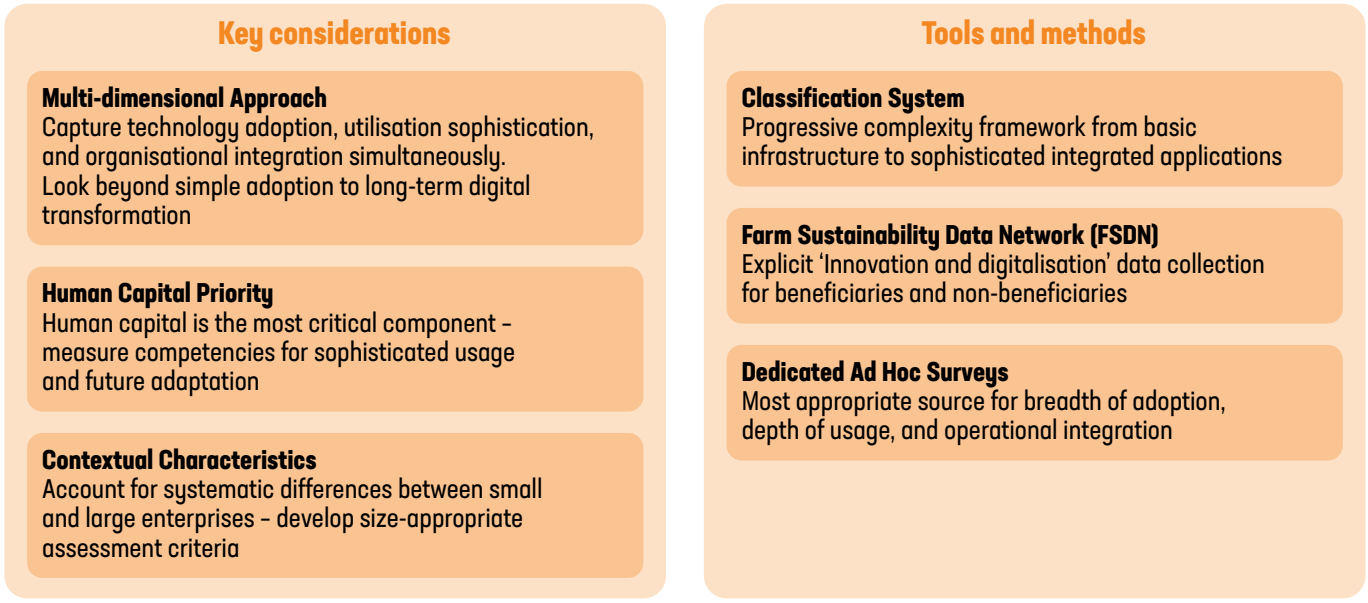
#### 4.1.1.5. Digitalisation intensity on farms and in rural areas

A key concept in assessing the effects of CAP support on fostering digitalisation is the digitalisation intensity. Beneficiaries of CAP Strategic Plans interventions are not homogeneous. Among them are corporations with hundreds of employees and part-time farms that earn most of their income from non-agricultural sources. However, all of these entities rely on digital technologies to improve their businesses' livelihoods. Many interventions aim to improve competitiveness and market orientation of farms, either via supporting investments, cooperation, training and innovation, while others support infrastructure and basic services that benefit the entire population of rural regions. The level of professionalism among agents in rural regions is very heterogeneous. A well organised large farm may have specialised IT staff handling digital tools, whereas a typical small farmer needs to integrate digital tools, relying only on his or her own knowledge or support from a service provider.

These differences, along with the differences in foundational infrastructures, may be responsible for disparities in the adoption and use of digital technologies on farms and in rural areas, which can be measured by the **digitalisation intensity**. Digitalisation intensity can be understood as a comprehensive metric that measures the extent to which farmers and rural areas have adopted, integrated and utilised digital technologies across their operations and business processes. While adoption typically measures whether specific digital technologies have been implemented or the percentage of farm and rural areas that have acquired particular digital tools, digitalisation intensity provides a comprehensive assessment of how deeply and effectively these technologies are integrated across operations and processes. Adoption answers 'what technologies and tools are being used', whereas intensity addresses 'how well and how extensively they are being utilised'.

Figure 7 summarises the key considerations for assessing digitalisation intensity as well as some tools and methods, all of which are discussed in the following paragraphs.

**Figure 7. Key considerations, tools and methods for assessing digitalisation intensity**




Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

**The Organisation for Economic Co-operation and Development (OECD)** proposed a taxonomy of sectors according to the extent to which they have gone digital [108]. The taxonomy accounts for some of the key facets of the digital transformation and recognises that sectors differ in their development and adoption of the most advanced 'digital' technologies, in the human capital needed to embed them in production and in the extent to which digital tools are used to deal with clients and suppliers. The indicators used to classify 36 International Standard of Industrial Classification (ISIC) revision 4 sectors over the period 2001-15 are: share of ICT tangible and intangible (i.e. software) investment; share of purchases of intermediate ICT goods and services; stock of robots per hundreds of employees; share of ICT specialists in total employment; and the share of turnover from online sales.

**Eurostat** also has a specific metric for digitalisation intensity, called the **Digital Intensity Index (DII)**. The Index is a composite indicator, derived from the EU survey on ICT usage and e-commerce in enterprises [109]. The indicator is calculated based on 12 variables [110], with each of the variables having a score of one point. The exact composition varies between survey years, depending on included questions. Nevertheless, for the last four years (2021-2024), they can be grouped under nine categories:

1. Use of internet
2. Use of high speed connectivity
3. Use of e-commerce
4. Use of cloud computing/remote access
5. Fostering ICT security
6. Developing or employing digital skills
7. Use of social media
8. Use of management information systems
9. Use of advanced technologies (AI, IoT, robots)

The DII distinguishes four levels of digital intensity for each enterprise:

- 0-3 points: very low
- 4-6 points: low
- 7-9 points: high
- 10-12 points: very high

The indicator measures the use of different technologies by enterprise and is useful to describe the extent to which EU enterprises are digitalised.

The JRC has developed a **Digital Maturity Assessment (DMA) Framework** [111] for EDIHs to measure and track digital transformation progress. The DMA Framework views digitalisation holistically across six dimensions:

- Digital business strategy – strategic planning and investment
- Digital readiness – technology adoption and infrastructure
- Human-centric digitalisation – skills, training, and staff engagement
- Data management – data storage, security, and analytics
- Automation and intelligence – AI and automated processes
- Green digitalisation – environmental sustainability through digital technologies

A recent publication by Saskia Hohagen and Uta Wilkens [112] developed a **model for measuring digital maturity in farms**, based on the state-of-the-art in methodological standards for maturity model development. Digital maturity refers to the process of digital transformation within an organisation and provides an indication of how far an organisation has integrated digital technologies. The developed model is designed as a diagnostic tool for strategic farm management and comprises nine dimensions:

- Human issues: farmer competencies, exploration mindset and exploitation mindset.
- Technology: establish a better relationship with consumer/customer, improve production and processes, network with other actors and ensure security in decision-making.
- Organisation: coping and dealing with other external and societal factors, changes in the market, and internal factors.

The publication also includes the detailed structure of the questionnaire used to survey farmers about their digital maturity.

The main characteristics of the different approaches are presented in the following table. It must be noted that this list of approaches is not exhaustive, but includes examples of quantitative and qualitative approaches with their strengths and limitations, to provide Managing Authorities and evaluators with a starting point for understanding digitalisation intensity.

[108] Calvino, F. et al., *A taxonomy of digital intensive sectors*, OECD Science, Technology and Industry Working Papers, No 2018/14, OECD Publishing, Paris, 2018, https://doi.org/10.1787/f404736a-en.
[109] See more at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:EU_survey_on_ICT_usage_and_e-commerce_in_enterprises.
[110] See more at: https://circabc.europa.eu/ui/group/89577311-0f9b-4fc0-b8c2-2aaa7d3ccb91/library/84b390d2-6a83-4dae-8aba-37c18557eb5b/details.
[111] Kalpaka, A., *Digital Maturity Assessment (DMA) Framework and Questionnaires for SMEs/PSOs: A guidance document for EDIHs*, European Commission, JRC133234, 2023, https://european-digital-innovation-hubs.ec.europa.eu/knowledge-hub/guidance-documents/overview-digital-maturity-assessment-tool-dmat.
[112] Hohagen, S. & Wilkens, U., *How to measure digital maturity in agriculture? Conceptual outline, instrument development and measurement results from German farms*, International Food and Agribusiness Management Review, 2025, https://doi.org/10.22434/ifamr.1027.

**Table 3. Comparison of different approaches to measuring digitalisation intensity**

| OECD taxonomy | EUROSTAT digital intensity index | JRC digital maturity assessment framework | Hohagen and Wilkens digital maturity model |
|---|---|---|---|
| › Quantitative measurement framework to assess and rank digital transformation intensity across economic sectors using standardised indicators.<br>› Recognises digitalisation as a universal economic phenomenon requiring comparable measurement methodologies across all industries.<br>› Covers all major economic sectors using consistent metrics to enable relative positioning and competitive analysis between industries and countries.<br>› Designed to support academic analysis, policy benchmarking and evidence-based understanding of digital transformation patterns across the economy. | › Quantitative, statistical measurement tool to benchmark general business digitalisation across sectors.<br>› Assumes standardised digitalisation patterns across all economic sectors.<br>› Focuses on individual business/enterprise digital capabilities. Agriculture is excluded from the scope of the underlying survey.<br>› Designed for comparative statistical analysis. | › Qualitative framework that uses structured questionnaires to assess digital maturity across two modules: customer data and digital maturity assessment.<br>› The framework takes a sector-agnostic approach rather than focusing specifically on agriculture or rural areas. 'Agriculture and food' appears as one of 22 sectors organisations can select from, without a special emphasis.<br>› Covers SMEs, mid-caps and public sector organisations at all digital maturity levels, with universal application across all sectors.<br>› Designed to monitor EDIH effectiveness, track progress toward 2030 Digital Decade targets (75% of companies using cloud/AI/big data, 90% of SMEs reaching basic digital intensity), and enable benchmarking by allowing organisations to compare performance with sector and regional peers. | › Qualitative, organisational diagnostic framework to assess and benchmark individual farm digital maturity across socio-technical dimensions.<br>› Recognises agriculture's unique organisational challenges where human factors, technological adoption and organisational adaptation must develop in parallel.<br>› Covers human competencies and mindsets, technological applications and organisational coping mechanisms across internal and external challenges.<br>› Designed as a diagnostic tool for individual farm self-assessment, peer benchmarking and transformation planning with prescriptive development pathways. |

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Three key lessons can be extracted from these approaches.

1. All the approaches presented above demonstrate that digitalisation intensity is inherently multi-dimensional. Evaluators should avoid relying on simple proxies like 'number of technologies adopted' or intervention counts and, instead, focus on capturing technology adoption, utilisation sophistication and organisational integration simultaneously. They should also look beyond technology deployment to measure whether supported farms and rural areas are developing strategic capabilities for long-term digital transformation rather than just tactical improvements. In this context, infrastructure development should be treated as an enabler by measuring how infrastructure translates into productive digitalisation rather than just achieving coverage.
2. In all approaches, human capital is the most critical component. Evaluators should measure not only technology provisions, but also whether beneficiaries have acquired competencies for sophisticated usage and future adaptation.
3. Contextual characteristics must be taken into account when assessing digitalisation intensity. The OECD and Eurostat frameworks show systematic differences between small and large enterprises in digitalisation patterns. Eurostat excludes enterprises with <10 employees, while agricultural contexts involve many smaller operations. Evaluators must develop size-appropriate assessment criteria and avoid measurement bias that favours large-scale technology deployment over effective small-scale integration.

**The classification system**, presented in Section 3.2.2, can be used as a basis to categorise beneficiaries, and, where possible, non-beneficiaries according to the adoption and use of different digitalisation technologies and tools. The progressive complexity, which is at the core of its design, recognises that digital transformation follows a natural progression from basic infrastructure to sophisticated integrated applications and maps well with the dimensions used in the approaches presented above. However, its connection to empirical research on the digital transformation of agriculture and rural areas is limited. Nevertheless, in combination with well-designed, dedicated surveys, it can create a practical tool for assessing digitalisation intensity.

The **Farm Sustainability Data Network (FSDN)** explicitly adds 'Innovation and digitalisation' (Table DI) to the list of topics to be collected at farm level for both beneficiaries and non-beneficiaries [113]. Once the corresponding variables for farm management, precision farming, and machinery for livestock management start being collected and reported, evaluators may be able to construct a digitalisation uptake index, based on the number of digital technologies and/or services a specific farm has adopted. FSDN also has certain limitations related to its scope and sampling methodology. It can be used to measure digitalisation intensity on farms, but not in other rural actors or rural areas in general. Even for farms, efforts to increase digitalisation intensity of smaller farms may not be captured, since smaller farms are excluded from the sample.

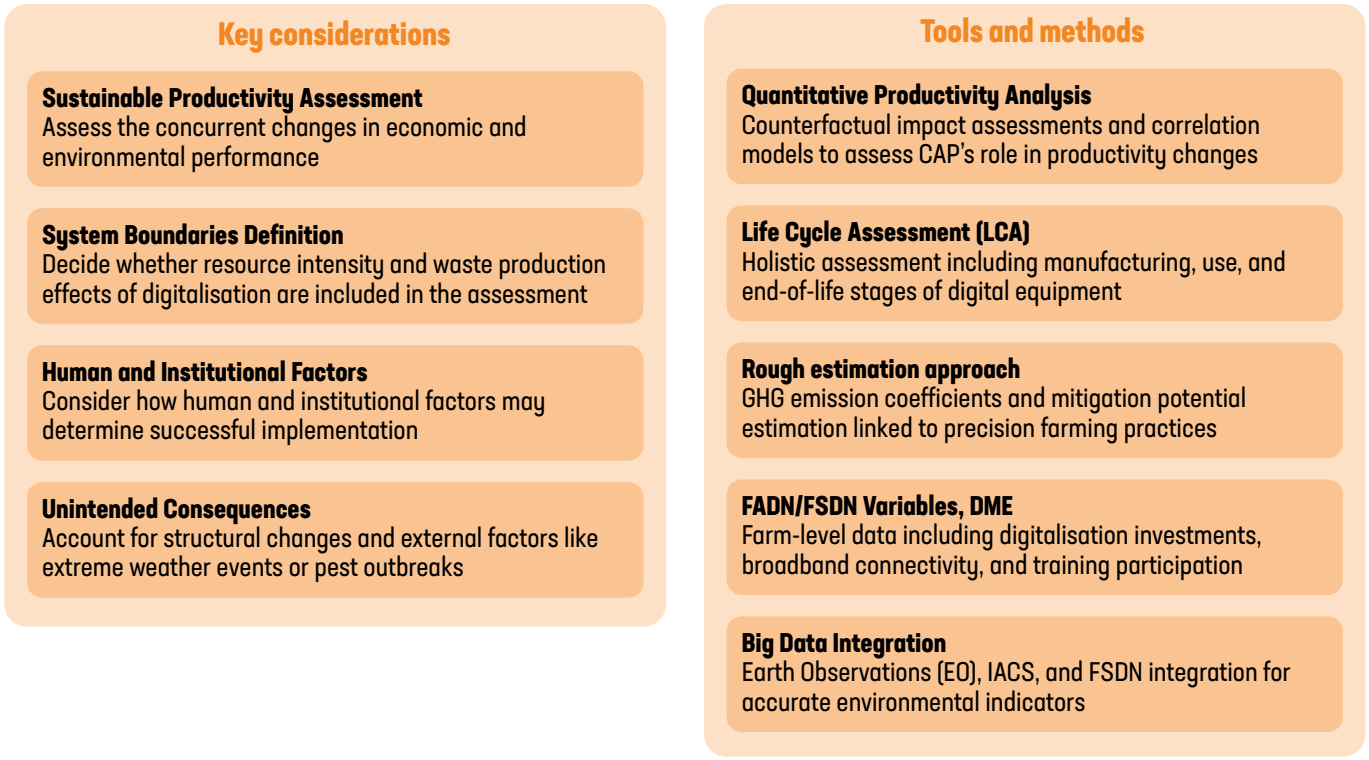
**Standardised dedicated surveys**, addressed to both non-beneficiaries and beneficiaries of the CAP Strategic Plan interventions, are the most appropriate source for information related to the breadth of adoption, depth of usage and operational integration of digitalisation in farms and rural areas. More details about designing such surveys are presented in Section 4.2.2.

### 4.1.2. The effect of CAP support to digitalisation on sustainable farm productivity

The combined effect of CAP support on digitalisation on both economic and environmental performance of farms can be approached through a sustainable productivity analysis. Figure 8 summarises the key considerations, tools and methods which are further discussed in the following paragraphs.

[113] The uptake of digitalisation and benefits from funding opportunities will be tracked in the FSDN from 2025 onwards; see Regulation (EU) 2023/2674, amending Council Regulation (EC) No 1217/2009, with further details set by Commission Implementing Regulation (EU) 2024/2746 and Delegated Regulation (EU) 2024/1417.

**Figure 8. Key considerations, tools and methods for assessing the effect of CAP support to digitalisation on sustainable farm productivity**




Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

A quantitative productivity analysis builds on the assessment of the extent to which CAP support fostered digitalisation (described in Section 4.1.1) and moves deeper to evaluate the extent to which differences in the intensity of digitalisation between farms have an impact on farm standard or sustainable productivity. Measuring the changes in sustainable productivity can be useful for assessing effectiveness, but also efficiency, when combined with information about the corresponding costs.

A publication of the European CAP Network supported by the European Evaluation Helpdesk for the CAP [114] offers a detailed description of methods to evaluate both standard productivity (without special attention to environmental and social aspects) and sustainable productivity in the context of any interventions of CAP Strategic Plans. It demonstrates how to address the triple economic, environmental and social challenges facing the agricultural sector today. The guidelines are designed to enhance technical expertise and promote the adoption of robust methodologies by Member States/evaluators seeking to evaluate the CAP's impact on sustainable productivity.

The document, along with its annexes, describes various approaches, emphasising quantitative methods. It offers practical advice on data sources for evaluating sustainable productivity and includes methods, such as counterfactual impact assessments and correlation models, to assess the CAP's role in observed productivity changes. Such quantitative empirical assessments offer a solid ground for obtaining well-founded evidence on the effects of digitalisation on productivity.

The concurrent increase in the adoption and intensity of digitalisation, along with improvements in environmental and climate performance, constitutes what is often called the twin transition. The publication of Myshko et al. [115] presents a comprehensive framework for understanding the twin transition in the agri-food sector, where digitalisation and sustainability initiatives converge to address global challenges, including climate change and food security. Their comprehensive review of academic literature and policy documents identified a process-driven approach that follows the integration of digital technologies from their initial adoption to the achievement of measurable benefits in environmental, economic and social sustainability. However, this research also uncovered structural imbalances in the current state of digital agriculture applications. The analysis demonstrates an uneven representation of digital technologies with a pronounced bias toward farming applications and farmers as the primary beneficiaries, rather than a more holistic view of the entire agri-food supply chain.

[114] European Commission, Directorate-General for Agriculture and Rural Development – Unit A.3, *Assessment of CAP contribution to sustainable productivity*, EU CAP Network, Brussels, 2025, available at: https://eu-cap-network.ec.europa.eu/publications/assessment-cap-contributions-sustainable-productivity_en.

[115] Myshko, A., Checchinato, F., Colapinto, C., Finotto, V., Mauracher, C., *Towards the twin transition in the agri-food sector? Framing the current debate on sustainability and digitalisation*, Journal of Cleaner Production, 452, 2024, 142063. https://doi.org/10.1016/j.jclepro.2024.142063.

The emergence of big data has introduced a transformative dimension to the evaluation of environmental impacts within the framework of the CAP. Weersink et al. [116] examined the broader context of big data applications in agricultural and environmental analysis. Their analysis identified that the primary obstacle to realising the potential of big data lies in the inability to aggregate and interpret data effectively to create useful decision support tools for farmers, combined with the need for capacity building for farmers to utilise these tools.

In the same context, the outcome of the Good Practice Workshop organised by the EU CAP Network supported by the European Evaluation Helpdesk for the CAP [117] showed that the integration of diverse data sources such as Earth observations (EO), IACS, and the evolving FSDN can result in more accurate and timely estimations of environmental indicators like soil erosion, biodiversity, and carbon sequestration. However, access to and integration of such data remain significantly challenging. The need for improved data accessibility and interoperability across datasets, as well as the need for capacity building and awareness, are necessary to fully exploit existing data and assess the effect of digitalisation on sustainable farm productivity.

For a holistic assessment of the twin transition, which looks beyond local environmental effects, evaluators may also follow a more sophisticated approach based on life cycle assessment (LCA). Huck et al. [118] conducted the first review of LCA applications in the digitalisation of agriculture. Their analysis of 69 studies, with 36 specifically employing LCA frameworks, revealed that most digital technologies addressed crop production systems, particularly supporting activities such as fertilisation and irrigation. Significantly, around one-third of the digital technologies analysed were robotic or automated systems, underscoring the central role of mechanisation in ongoing digitalisation initiatives. This review highlights major methodological challenges for future evaluations, including defining functional units, setting scenarios, and establishing system boundaries. Key issues involve gathering data across all stages of digitalisation (including manufacturing and end-of-life stages of digital equipment) and assessing their impact on agricultural systems. Limited data and the multifunctional nature of these technologies further complicate LCA processes.

Changes in farm productivity may also have (unintended) consequences on farm structures. As shown by the work of Vik et al, [119] "Structural developments in milk production in Norway are neither politically nor economically driven but are mainly an unintended consequence of farmers' aggregated investments in automated milking systems".

The findings of these publications have significant implications for evaluation design as they suggest that comprehensive assessments of the effects of digitalisation on sustainable farm productivity must build on a concrete intervention logic that:

- captures environmental and climate impacts across all nodes of the food system rather than focusing exclusively on on-farm applications,
- puts significant importance on the boundaries of the system under assessment, depending on which it should be decided whether the adverse effects of digitalisation in terms of resource intensity and waste production will be taken into account,
- considers not only the technical aspects of digital technologies but also the human and institutional factors that determine their successful implementation and environmental-climate impact, and
- considers unintended consequences of farm digitalisation but also, where relevant, external factors such as extreme weather events or pest outbreaks that may affect agricultural output.

On the methodological side, the systematic literature review of Koutsos et al. [120] shows that studies that meet the criteria for a policy evaluation and those examining farm productivity and environmental effects simultaneously are very rare. One study that explores the effects of digitisation on productivity was conducted by Borowiecki et al [121]. This research was not focused on enterprises in agriculture but on firms from other sectors. However, similar variables exist in the Farm Accountancy Data Network (FADN) dataset and will be improved by the transition to FSDN. Moreover, if combined with information about the adoption of digitisation coming from the data for monitoring and evaluation (DME), they could set the basis for estimating the effects of digitisation on standard or sustainable productivity. Annex 1 of the mentioned guidelines document [122] offers a detailed list of variables that can be used to assess sustainable farm productivity. Table 4 provides some additional variables that can be used to focus the analysis on the effects of digitisation.

[116] Weersink, A., Fraser, E., Pannell, D., Duncan, E., Rotz, S., *Opportunities and Challenges for Big Data in Agricultural and Environmental Analysis*, Annual Review of Resource Economics, 10(1), 2018, pp. 19-37. https://doi.org/10.1146/annurev-resource-100516-053654.

[117] European Commission, Directorate-General for Agriculture and Rural Development - Unit A.3, *Assessment of environmental impacts of the CAP, EU CAP Network*, Event Report, Brussels, 2025, https://eu-cap-network.ec.europa.eu/publications/assessment-environmental-impacts-cap_en.

[118] Huck, C., Gobrecht, A., Salou, T., Bellon-Maurel, V., Loiseau, E., *Environmental assessment of digitalisation in agriculture: A systematic review*, Journal of Cleaner Production, 472, 2024, 143369. https://doi.org/10.1016/j.jclepro.2024.143369.

[119] Vik, J., Stræte, E. P., Hansen, B. G., Nærland, T., *The political robot - The structural consequences of automated milking systems (AMS) in Norway*, NJAS: Wageningen Journal of Life Sciences, 90-91(1), 2019, pp. 1-9. https://doi.org/10.1016/j.njas.2019.100305.

[120] Koutsos, T. M., Menexes, G. C. & Dordas, C. A., *An efficient framework for conducting systematic literature reviews in agricultural sciences, Science of the Total Environment*, vol. 682, 2019, pp. 106-117. https://doi.org/10.1016/j.scitotenv.2019.04.354.

[121] Borowiecki, M. *et al.*, *The impact of digitalisation on productivity: Firm-level evidence from the Netherlands*, OECD Economics Department Working Papers, No 1680, OECD Publishing, Paris, 2021. https://doi.org/10.1787/e800ee1d-en.

[122] See footnote 114.

**Table 4. Examples of variables that can be used to estimate the effects of digitalisation on farm productivity**

| Farm-level variable | Source |
|---|---|
| Share of investments for digitalisation of total assets. | DIB variable R003 and corresponding total amount of investment in digitalisation.<br><br>Data from beneficiaries of interventions labelled according to A2, B1, B2, B3, B4, C1, C2, C4, D1, D2. |
| Dummy variable on broadband connection ('1' if farm has ≥30 Mbit/s fixed line or reliable 4G/5G in field, 0 otherwise). | Information from broadband coverage, FSDN-Table SE. |
| Dummy variable on digitalisation training ('1' if farm manager or employees attended formal training, received advice or participated in EIP Operational Group related to digitalisation in the last 12 months). | Information from training programmes, farm advisory services and EIP Operational Groups, FSDN – Table TR, beneficiaries of interventions labelled according to A4. |

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

In a similar way, an efficiency analysis that looked at the effects of digitalisation for a sample of pig farms was carried out by Kügler and Sinabell [123]. In this study, expenditures for digitalisation were used to evaluate their effects on farm profitability and efficiency. The data were obtained from a sample of FADN farms.

For an assessment of the isolated effects of digitalisation on the environment and climate, the publication of the EU CAP Network supported by the European Evaluation Helpdesk for the CAP about the 'Use of factors of success in evaluation' [124], describes the factors of success that can be used for the assessment of environmental and climate objectives of the CAP Strategic Plans as well as key considerations about data and methods. Additional factors of success may look at how digitalisation-related interventions, as well as digitalisation intensity, have affected the intensity of the use of inputs, e.g. the input of chemicals (mineral fertilisers, herbicides, fungicides, etc.) per unit of output.

Another publication by the same organisation about the 'Rough estimate of the climate change mitigation potential of the CAP Strategic Plans (EU-27) over the 2023-2027 period' [125] establishes, for the first time, a link between CAP Strategic Plans instruments, such as good agricultural and environmental conditions (GAECs) and CAP interventions and their mitigation potential, across the 27 Member States. The methodology relies on programming data extracted from the CAP Strategic Plans, rough estimates of expected uptake levels, and on average emission and removal coefficients for farming practices, greenhouse gas (GHG) emissions, enhancing carbon removals and conserving existing carbon stocks. Since certain practices (like, for example, precision farming) can be related to digitalisation, this methodology may be useful in estimating the effects of digitalisation on climate change.

### 4.1.3. The effect of CAP support to digitalisation on sustainable and inclusive growth in rural areas

Digitalisation plays a pivotal role in advancing social sustainability, particularly in rural regions. By improving access to digital services, education, and e-health, digitalisation helps bridge the urban-rural divide, empowering rural communities to participate in economic, social and civic life on more equal terms. Enhanced connectivity and equality in digital skills training foster social inclusion, reduce isolation and open pathways for youth engagement, innovation, and local entrepreneurship. Digital tools also bolster vital public services, such as remote healthcare, digital public administration and online education, making rural living more viable and attractive for all generations.

Evaluations of the effect of CAP support for digitalisation on sustainable and inclusive growth in rural areas must, at least, capture the contribution to:

- reducing the digital urban-rural divide, but also divides inside rural areas,
- improving access to services, and
- fostering rural growth and employment.

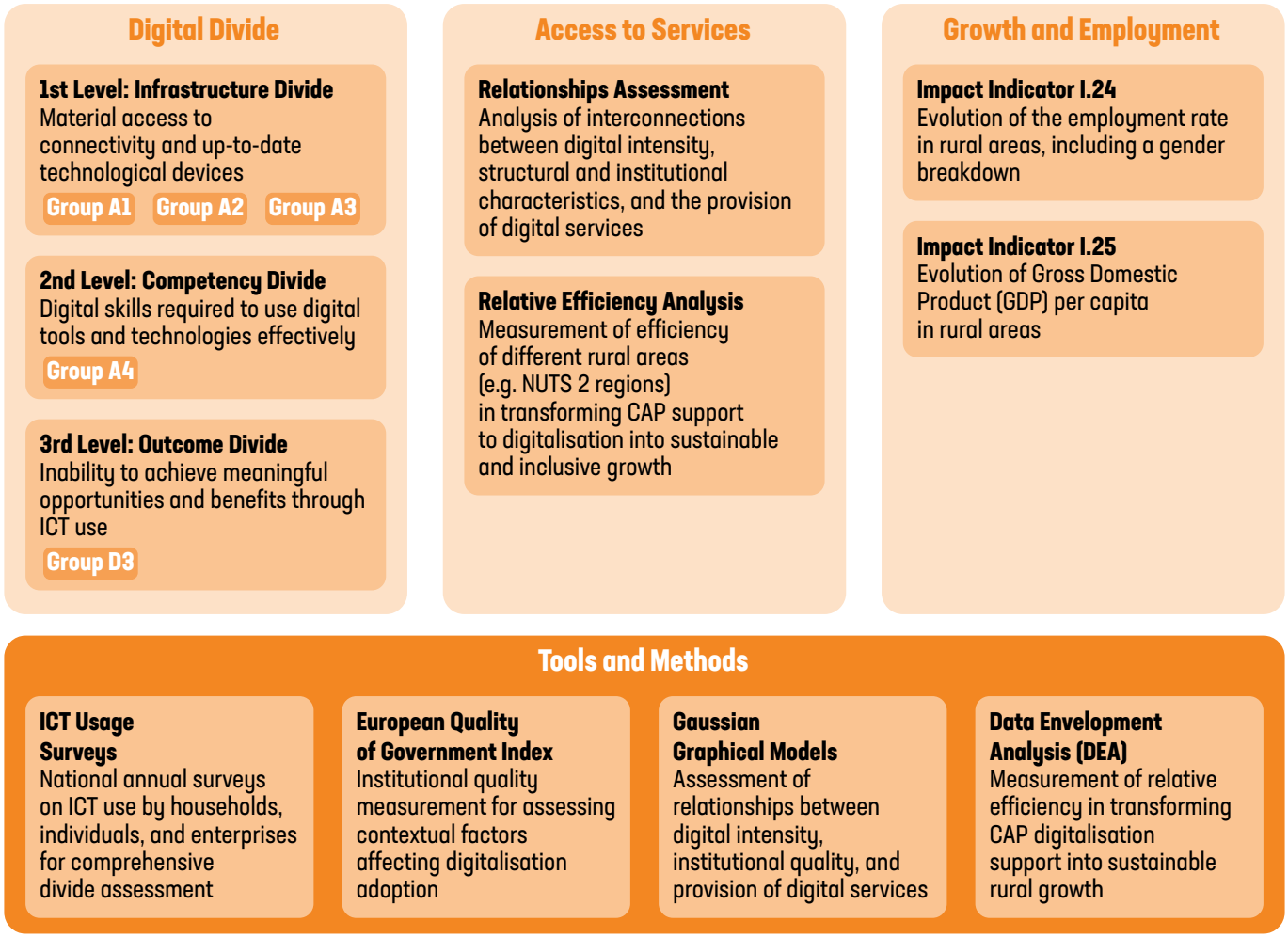
Figure 9 presents an outline of the approach, which is discussed in the following paragraphs.

[123] Kügler, A. and Sinabell, F., *Economic benefits of digitisation – the case of pork production in Austria*. In: Eder, M., Garaus, Ch., Grüneis, H., Hambrusch, J., Kantelhardt, J., Kirchweger, St., Leonhardt, H., Mitter, H., Niedermayr, A., Huber, J., Sinabell, F. and Zeilinger, J. (eds), Tagungsband 2024 der 34. Jahrestagung der Österreichischen Gesellschaft für Agrarökonomie, Selbstverlag, Wien, pp. 49–50, 2024.

[124] European Commission, Directorate-General for Agriculture and Rural Development – Unit A.3, *Use of factors of success in evaluation*, EU CAP Network, Brussels, 2024, available at: https://eu-cap-network.ec.europa.eu/publications/use-factors-success-evaluation_en.

[125] European Commission, Directorate-General for Agriculture and Rural Development – Unit A.3, *Rough estimate of the climate change mitigation potential of the CAP Strategic Plans (EU-27) over the 2023-2027 period*, EU CAP Network, Brussels, 2025, https://eu-cap-network.ec.europa.eu/publications/rough-estimates-climate-change-mitigation-potential-cap-strategic-plans-eu-27-over_en.

**Figure 9. Outline of the approach for assessing the effects of CAP support to digitalisation on sustainable and inclusive growth in rural areas**




Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

Rural digitalisation requires disaggregated, territorially sensitive evaluation approaches. A study by Morte-Nadal and Esteban-Navarro [126] demonstrates that "barriers such as limited digital skills, access to technology, and inadequate service design disproportionately affect the elderly, low-income populations, and those with minimal education", revealing how digital divides manifest differently across demographic and geographic contexts. Effective evaluation must therefore disaggregate effects at minimum by degree of urbanisation or, ideally, local administrative units classifications and vulnerability strata. It should also move beyond simple availability measures to assess equity effects across affordability, skills, and interface accessibility dimensions. The three-level digital divide framework provides the analytical foundation:

- First level: infrastructure divide, corresponding to the availability of material access to infrastructure, such as internet connectivity and up-to-date technological devices (functional groups A1, A2 and A3 of the classification system),
- Second level: competency divide, concerning the possession of the digital skills required to use the digital tools and technologies (functional group A4 of the classification system), and
- Third level: outcome divide, stemming from the inability to achieve meaningful opportunities, outcomes and benefits through the use of ICTs, such as improving education, health or socioeconomic situation (functional group D3).

[126] Morte-Nadal, T. & Esteban-Navarro, M. Á., *Recommendations for digital inclusion in the use of European digital public services*, Humanities and Social Sciences Communications, Vol. 12, 273, 2025, https://doi.org/10.1057/s41599-025-04576-7.

This framework requires systematic linkage from infrastructure availability through service quality and uptake to outcome achievement. The classification system presented in Section 3.2.2 with its progression from infrastructure to applications, along with the considerations for assessing digitalisation intensity presented in Section 4.1.1.5 can be useful in getting a holistic picture of the three-level divide. National data from annual surveys examining ICT use by households and individuals, as well as surveys on ICT usage and e-commerce in enterprises, or other data available at the national level can be used to assess the level of the divide. Fang et al. [127] provide a comprehensive approach which uses indices to assess the divide, compiled by a combination of indicators about adoption and use with indicators about gaps between urban and rural areas.

For the assessment of improved access to services, the publication by Lobonț et al. [128] uses various methods, including:

- gaussian graphical models to assess the relationships between digital intensity, institutional quality, and e-government, highlighting the interconnections between variables, and
- data envelopment analysis to measure the relative efficiency of public service delivery.

Their aim was to assess the digital performance of public services in the EU. Evaluators may adapt these methods to assess the relationship between digitalisation intensity, structural or institutional characteristics and the provision of digital services, as well as the relative efficiency of different rural areas (e.g. NUTS 2 regions) in transforming CAP digitalisation support into sustainable and inclusive growth.

Gaussian graphical models are useful for assessing relevance and especially how the contextual characteristics of rural areas in terms of institutional quality may affect the adoption of e-government and digital services. In addition, they can be used for assessing effectiveness by looking at how increased digitalisation intensity as a result of CAP support has affected the change in the adoption of digital services. This method requires data about digitalisation adoption and intensity, institutional quality indicators and data about the adoption rates of digital services. The European Quality of Government Index, developed by the University of Gothenburg [129], can be used to measure institutional quality. The European Central Bank (ECB) Working Paper No 3045 includes a practical approach to using these data [130].

Data envelopment analysis (DEA) can be used to measure the efficiency of digitalisation efforts in improving access to services in rural areas. By comparing the efficiency scores, evaluators can identify which regions or initiatives are performing well and which need improvement, providing insights into how digitalisation can be optimised for better service access. This method requires data about inputs, such as the resources allocated for digitalisation or the level of digital literacy in a specific rural region, as well as information about outputs, such as the adoption of digital services.

For assessing the effects of digitalisation on growth and employment, the publication of the EU CAP Network supported by the European Evaluation Helpdesk for the CAP about the 'Use of factors of success in evaluation', describes the factors of success that can be used for assessing growth and employment rates in rural areas, as well as key considerations about data and methods.

## 4.2. Sources of information

Unfortunately, there is no one-stop shop for the data necessary to carry out quantitative or qualitative evaluations for digitalisation. However, depending on the context of the analysis and the analytical needs, several public data sources are available. For a sounder analysis, these can be complemented by dedicated surveys.

### 4.2.1. Available data sources

The following table presents available data sources with relevance to digitalisation, along with a brief description of their use.

[127] Fang, C., Chen, Z., Liao, X. et al., *Urban-rural digitalisation evolves from divide to inclusion: empirical evidence from China*, npj Urban Sustainability, Vol. 4, 51, 2024, https://doi.org/10.1038/s42949-024-00187-4.

[128] Lobonț, O. R., Criste, C., Vintilă, A. I., Crăciun, A. F. & Moldovan, N. C., *Assessing digital performance of public services in the EU: e-governance and technology integration*, *Systems*, Vol. 13, No 6, 425, 2025, https://doi.org/10.3390/systems13060425.

[129] Charron, N., Lapuente, V. and Bauhr, M., *The geography of quality of government in Europe. Subnational variations in the 2024 European Quality of Government Index and comparisons with previous rounds*, QoG Working Paper Series 2024:2, Department of Political Science, University of Gothenburg, 2024. ISSN 1653-8919. https://www.gu.se/en/quality-government/qog-data/data-downloads/european-quality-of-government-index.

[130] Filip, M.-D. & Setzer, R., *The impact of regional institutional quality on economic growth and resilience in the EU*, ECB Working Paper Series No 3045, 31 March 2025. https://www.ecb.europa.eu/press/research-publications/working-papers/html/index.en.html.

**Table 5. Data sources related to digitalisation of the agri-food sector and rural areas**

| Data sources | Availability |
|---|---|
| **Aggregate data** | |
| CAP indicators and data explorer | https://agridata.ec.europa.eu/extensions/DataPortal/pmef_indicators.html |
| CAP Strategic Plans | Member State specific websites |
| Rural Observatory | https://observatory.rural-vision.europa.eu/?lng=en&ctx=ROBS<br><br>Offers relevant statistics, indicators and analyses based on data from multiple sources and at the most appropriate territorial granularity, covering the economic, social and environmental dimensions. It also provides information on digital infrastructure and connectivity. |
| Agrifood data portal | Data about context and impact indicators of the CAP: https://agridata.ec.europa.eu/extensions/DataPortal/context_indicators.html<br><br>Data about pesticides that can be used to assess the intensity of the use of inputs in agriculture: https://agridata.ec.europa.eu/extensions/IndicatorsEnvironmental/Pesticides.html; https://agridata.ec.europa.eu/extensions/compass/pesticides-infopage.html |
| EUROSTAT | Integrated Farm Statistics (IFS)<br><br>The IFS 2023 includes several variables related to the digital equipment (robotics, variable rate techniques, precision monitoring, automatic regulation of barn climate, etc.)<br><br>The IFS 2026 will include variables about the use of digital tools for irrigation, production of renewable energy or specific for small farms as well as about training in digital tools.<br><br>Digital Intensity Index: https://ec.europa.eu/eurostat/cache/metadata/en/isoc_e_dii_esmsip2.htm<br><br>Consumption of inorganic fertilisers that can be used to assess the intensity of the use of inputs in agriculture: https://ec.europa.eu/eurostat/databrowser/view/aei_fm_usefert/default/table?lang=en<br><br>Pesticide sales that can be used to assess the intensity of the use of inputs in agriculture: https://ec.europa.eu/eurostat/databrowser/view/aei_fm_salpest09/default/table?lang=en |
| DESI dashboard for the Digital Decade | https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/indicators<br><br>Various indicators to assess the progress towards the Digital Decade targets. Can be useful for setting benchmarks to assess the effectiveness of CAP support for digitalisation. Limited specificity for rural areas. |
| Broadband coverage in Europe 2024 | Mapping progress towards the coverage objectives of the digital decade : final report [131]<br><br>https://data.europa.eu/doi/10.2759/9441597<br><br>Indicators of coverage of rural areas per technology and Member State. |
| eGovernment Benchmark reports | Data on the progress towards e-government: https://digital-strategy.ec.europa.eu/en/library/digital-decade-2025-egovernment-benchmark-2025 |
| European Severe Weather Database | Data on severe weather events that can be used for contextual information when assessing the effects of digitalisation on sustainable farm productivity.<br><br>https://www.essl.org/cms/european-severe-weather-database/ |

[131] European Commission: Directorate-General for Communications Networks, Content and Technology, OMDIA and Point Topic, *Broadband coverage in Europe 2024 – Mapping progress towards the coverage objectives of the digital decade – Final report*, Publications Office of the European Union, 2025, https://data.europa.eu/doi/10.2759/9441597.

| Data sources | Availability |
|---|---|
| **Sources of microdata** | |
| FADN/FSDN | https://agridata.ec.europa.eu/extensions/FarmEconomyFocus/FADNDatabase.html<br><br>Individual farm-level data. The new FSDN dataset will include specific variables for Innovation and Digitalisation (Table DI), which can be used both for establishing a baseline and assessing the intensity of digitalisation but also for assessing the effects of digitalisation on sustainable farm productivity. |
| Disaggregated data on interventions and beneficiaries | Paying Agencies (see Annex IV of Implementing Regulation (EU) 2022/1475) |
| National data | National Statistics. Include data from the annual surveys on:<br>› ICT use by households and individuals<br>› ICT usage in enterprises<br>Useful for adapting Digital Decade targets to agriculture and rural areas. |

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

### 4.2.2. Dedicated surveys

Surveys that explore the intensity of digital technologies typically can follow the classification system described in Section 3.2.2 and collect information about:

- Digital foundations e.g. basic equipment, data security, digital skills;
- Smart production e.g. precision agriculture, automation and robotics, analytics and decision making, integrated farm management;
- Market integration e.g. digital commerce, supply chain integration;
- Sustainability e.g. environment and climate monitoring systems, emergency response and risk management, sustainability certification and verification.

Furthermore, such surveys should identify:

- obstacles (e.g. lack of broadband signals, dysfunctional digital platforms and data interfaces, lacking data protection), and
- favourable conditions (e.g. access to infrastructure, administrative simplification training, specialised services).

There is a number of studies in several countries where such surveys have already been carried out [132]. These sources are helpful to identify strategies to obtain information on the intensity of digitalisation in representative surveys.

The key recommendations from these studies are presented in Table 6.

[132] Such as: e.g. Michels, M., Fecke, W., Feil, J.-H., Mußhoff, O., Pigisch, J., Krone, S., *An empirical analysis of internet usage intensity in German agriculture,* German Journal of Agricultural Economics, 2019. https://doi.org/10.22004/ag.econ.319804; Gabriel, A., *Gandorfer, M., Landwirte-Befragung 2020. Digitale Landwirtschaft Bayern*, Bayerische Landesanstalt für Landwirtschaft, 2020, available at: https://www.lfl.bayern.de/mam/cms07/ilt/dateien/ilt6_praesentation_by_2390_27082020.pdf; Groher, T., Heitkämper, K., Umstätter, C., *Nutzung digitaler Technologien in der Schweizer Landwirtschaft,* Agrarforschung Schweiz, 11, 2020, pp. 59-67. https://doi.org/10.34776/AFS11-59; Westermann, J., *Analyse und Klassifizierung von Digitalisierungsinitiativen in der Landwirtschaft*, Hochschule Hannover, 2022. https://doi.org/10.25968/opus-2328; Ammann, J., Walter, A., El Benni, N., *Adoption and perception of farm management information systems by future Swiss farm managers – An online study*, Journal of Rural Studies, 89, 2022, pp. 298-305. .https://doi.org/10.1016/j.jrurstud.2021.12.008; and Sinabell, F., *Digitalisation in Austrian agriculture. An overview on current evidence and challenges,* WIFO Reports on Austria, 11/2025, 2025. https://www.wifo.ac.at/publication/pid/60776165.

**Table 6. Key recommendations for developing standardised surveys to measure farm digitalisation intensity**

| Recommendation | Related resources |
|---|---|
| **1.** Use established administrative or advisory platforms for survey distribution and stratify the sample to mirror the farm population. | The Bavarian online survey, distributed via the iBALIS application portal during the single-payment-scheme filing period, secured a large, demographically balanced sample with a median completion time of 18 minutes, thus demonstrating the value of trusted, sector-specific channels. |
| **2.** Establish a baseline | If possible, conduct the survey both before and after the implementation of the relevant interventions of the CAP Strategic Plan. This will allow establishing a baseline of digitalisation intensity. Otherwise, try to establish a baseline using information from the DESI dashboard, the Rural Observatory, variables related to the use of digital equipment available in IFS 2023 [133], annual surveys examining ICT use by households and individuals, the annual surveys on ICT usage and e-commerce in enterprises, or other data available at the national level [134]. |
| **3.** Build the questionnaire around distinct thematic blocks:<br>› farm/rural business and farmer/rural actor characteristics,<br>› motivation and perceived benefits,<br>› actual technology use,<br>› information channels,<br>› data governance, and<br>› support instruments. | The Bavarian 'Landwirte-Befragung 2020' [135] achieved high data quality by organising its 2 390 responses into exactly these six blocks, which enabled systematic, comparable analyses across topics. |
| **4.** Capture digitalisation intensity with a multi-dimensional technology inventory:<br>Use the classification system developed under Section 3.2.2 and ask about both adoption (yes/no) and usage frequency/coverage. | The classification system described in Section 3.2.2 can be used to understand the state-of-play of digitalisation of the agri-food sector and rural areas.<br>The Swiss study by Groher et al., [136] distinguishes plant-production tools (e.g. guidance systems) from livestock tools (e.g. activity sensors), and records not only whether, but to what extent they are used. |
| **5.** Record structural and managerial covariates essential for explaining intensity. Include:<br>› farm size (economic, physical) or business size (turnover, persons employed),<br>› specialisation,<br>› region,<br>› full-/part-time status, and<br>› manager age, education and attitudes. | Regression analyses in Groher et al. [137], show that these variables explain pronounced adoption gaps between farms and technologies, underscoring their importance for representative modelling. |

[133] European Commission. Integrated Farm Statistics Manual | 2023 edition. https://wikis.ec.europa.eu/spaces/IFS/pages/83690092/Integrated+Farm+Statistics+Manual+2023+edition.
[134] For a list of data sources relevant to digitalisation see Section 4.2.
[135] Ibid.
[136] See footnote 132 for Groher et al. (2020).
[137] Ibid.

| Recommendation | Related resources |
|---|---|
| **6.** Systematically ask about barriers, especially costs, economic returns and data-security concerns.<br><br>Consider including specific questions about annual expenditures for digital services (e.g. annual subscription for using a farm management system provided as an online service) and annual depreciation of digital equipment or software. | In Bavaria, high investment and operating costs as well as uncertainty over data ownership were the most frequently cited obstacles to further uptake; addressing them is crucial for interpreting observed intensity levels. |
| **7.** Include questions about the rate by which the adoption of digitalisation affected production decisions, changed production processes or the delivery of services to the rural population. | This is not related to digitalisation intensity but is necessary to better understand the effect of CAP Strategic Plan interventions on farm productivity, environmental-climate performance or sustainable and inclusive growth in rural areas. |
| **8.** Include questions on the use of digital administrative tools in the context of agricultural policy implementation. | This is also not related to digitalisation intensity, but is necessary to better understand the simplification potential of adopting digitalisation for administrative purposes. |

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

Based on such surveys, the sample can be clustered into groups using metrics that are derived from the responses, as shown in Table 7.

### Table 7. Categories of the intensity of digitalisation based on empirical research

| Type of variable | Indicator | Levels |
|---|---|---|
| Index of intensity | A composite index of the number of digital technologies and tools employed on farm and digital skills of staff | Only Domain A: Low<br><br>Domain A + B1, B2 : Medium<br><br>Domains A + B, C, D, or E: High |
| Intermediates | Annual variable expenditures for digital services as a percentage of economic size or turnover | < 1%: Low<br><br>≥ 1% and <2%: Medium<br><br>> 2%: High |
| Capital | Annual depreciation of software or physical investment with digital features as a percentage of economic size or turnover | < 1%: Low<br><br>≥ 1% and <2%: Medium<br><br>> 2%: High |

Source: EU CAP Network supported by the European Evaluation Helpdesk for the CAP (2025)

NB. Depending on the underlying ordinal clusters (low, medium and high) may be substituted by interval or ratio scales.

zTo explain the direction and magnitude of the digitalisation effect, inform decision-makers about potential improvements, barriers to their adoption or use and options to expand the scope of current approaches, it is crucial to explore farmers' views on various aspects of digitalisation. Several such studies were carried out [138] and a summary of empirical databases and analytical strategies employed to elicit farmers' views on digitalisation in these studies is presented in Annex III.

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# Annex I. A classification system for digitalisation in the agri-food sector and rural areas

## Introduction and framework overview

The five-domain classification system for digitalisation in agri-food sector and rural areas provides a comprehensive framework for categorising and analysing digital agriculture interventions across the complete transformation spectrum.

The framework is structured around:

- **Five strategic domains** (Tier 1): broad areas of digital transformation.
- **Nineteen functional groups** (Tier 2): specific technological and operational categories.
- **Thirty-size specific activities** (Tier 3): precise intervention types with detailed keywords.

The key design principles include:

- **Progressive complexity**: domains reflect natural progression from basic infrastructure to sophisticated applications.
- **Infrastructure vs application distinction**: clear separation between building capabilities and using them.
- **Administrative simplification integration**: cross-cutting dimension reduces bureaucratic burden.
- **Future-oriented flexibility**: categories based on persistent functions rather than specific technologies.

The framework's core analytical distinction separates interventions that **build digital capabilities** (infrastructure) from those that **utilise existing capabilities** (applications). This logic is embedded throughout the classification system and creates the foundation for understanding integrated management pathways.

Infrastructure keywords include:

- **Development, establishment, deployment, setup, installation, creation**
- Focus on building foundational capabilities
- Example: 'broadband deployment', 'platform infrastructure development'

Application keywords include:

- **Participation, adoption, implementation, usage, operation, engagement**
- Focus on utilising existing capabilities
- Example: 'marketplace participation' and 'platform usage'

The framework encompasses a management integration logic which constitute of the following elements:

- **Infrastructure enablement**: Domain A infrastructure enables management applications across all other domains.
- **Operational integration**: Domain B production management generates data that feeds into Domain C market systems and Domain D sustainability tracking.
- **Value creation**: Domain E data economy capabilities enable advanced management insights that improve operations across all domains.

# Domain A: Digital foundation and capabilities

Establishes essential infrastructure, equipment, skills and systems that enable all subsequent digital agriculture activities and integrated management approaches.

## A1: Infrastructure and connectivity

### A1.1: Rural broadband and network deployment

**Purpose**: establishing high-speed internet infrastructure in rural areas.

**Keywords**: broadband infrastructure deployment, fibre network installation, wireless connectivity establishment, telecommunications infrastructure setup, internet access infrastructure rollout, connectivity infrastructure development.

### A1.2: Digital communication platforms

**Purpose**: creating information sharing and collaboration infrastructure for the agri-food sector and rural areas.

**Keywords**: communication platform infrastructure setup, messaging system deployment, information sharing infrastructure installation, collaboration platform establishment, digital communication network creation.

## A2: Basic technology and equipment

### A2.1: Hardware and software systems

**Purpose**: deploying computing infrastructure and software applications.

**Keywords**: computing hardware procurement, software system installation, digital equipment acquisition, foundational computing system deployment.

### A2.2: Basic monitoring and sensor technologies

**Purpose**: installing monitoring equipment and sensor networks.

**Keywords**: sensor network installation, monitoring equipment deployment, measurement infrastructure setup, weather monitoring station installation, environmental sensing equipment deployment, agricultural monitoring infrastructure establishment.

## A3: Data security and privacy

### A3.1: Data protection and privacy systems

**Purpose**: establishing systems to protect data and ensure privacy compliance.

**Keywords**: data backup infrastructure deployment, security system installation, access control system setup, privacy protection framework establishment, data governance infrastructure creation, information security system deployment.

### A3.2: Cybersecurity infrastructure

**Purpose**: deploying technical security measures to protect digital systems.

**Keywords**: security software deployment, network protection infrastructure installation, intrusion detection system setup, cyber defence system establishment, security monitoring infrastructure deployment.

## A4: Digital skills

### A4.1: Digital literacy and adoption support

**Purpose**: building essential digital competencies among users.

**Keywords**: digital skills training programme delivery, technology adoption support implementation, digital competence development initiatives, user education programme execution, technology literacy training provision.

### A4.2: Cybersecurity training and awareness

**Purpose**: developing security awareness and safe computing practices.

**Keywords**: cybersecurity training delivery, Digital safety education programmes, privacy protection training implementation, security awareness programme execution, Safe computing practice instruction.

## A5: Administrative infrastructure and compliance systems

### A5.1: Automated compliance and reporting systems

**Purpose**: creating systems that automatically generate information and reports from operational data for administrative purposes.

**Keywords**: compliance automation infrastructure setup, regulatory reporting system deployment, administrative process automation implementation, paperwork reduction system installation, automated verification infrastructure establishment.

### A5.2: Digital government service integration

**Purpose**: establishing unified access systems for agricultural government services.

**Keywords**: digital identity infrastructure deployment, unified government service access setup, public service integration platform installation, administrative and control service digitalisation infrastructure, electronic government service infrastructure establishment.

# Domain B: Smart production

**Core purpose**: advanced technologies that use data and automation to optimise agricultural production through intelligent analysis and autonomous execution, building on Domain A infrastructure.

## B1: Precision agriculture systems

### B1.1: GPS-guided and variable rate technologies

**Purpose**: implementing positioning systems that enable precise, location-specific agricultural applications.

**Keywords**: GPS guidance system deployment, precision positioning equipment installation, variable rate application technology setup, site-specific management system implementation, precision agriculture equipment installation, guided machinery system deployment.

### B1.2: Soil and yield mapping systems

**Purpose**: creating spatial data layers for comprehensive field management including soil, productivity, plant health, and water management.

**Keywords**: field mapping system installation, soil analysis technology deployment, yield monitoring equipment setup, spatial analysis system implementation, geographic information system deployment, productivity mapping technology implementation.

## B2: Automation and robotics

### B2.1: Automated livestock system

Deploying robotic and automated systems for livestock management and care.

**Keywords**: automated milking system installation, livestock monitoring technology deployment, automated feeding system setup, animal health monitoring equipment installation, livestock identification system deployment, dairy automation technology implementation.

### B2.2: Robotic field and harvest equipment

**Purpose**: implementing autonomous machinery for field operations and harvesting activities.

**Keywords**: agricultural robot deployment, autonomous field equipment installation, robotic harvesting system setup, unmanned agricultural vehicle implementation, automated field operation equipment deployment.

## B3: Integrated farm management

### B3.1: Comprehensive farm management platforms

**Purpose**: implementing integrated systems that coordinate diverse farm operations and data sources while serving as the integration point for cross-domain management.

**Keywords**: integrated farm management system deployment, operational coordination platform setup, enterprise resource planning system deployment, integrated business management system installation, holistic agricultural management system implementation, multi-system integration platform installation.

### B3.2: Digital twin and enterprise systems

**Purpose**: deploying virtual modelling and enterprise resource planning systems for agricultural operations.

**Keywords**: digital farm modelling system implementation, virtual farming simulation setup, digital farm representation technology implementation.

## B4: Analytics and automated decision-making

### B4.1: advanced analytics and automated decision-making systems

**Purpose**: implementing analytics systems and automated decision-making technologies for agricultural prediction, monitoring, and optimisation, including both AI-powered and conventional analytical approaches.

**Keywords**: data analytics system implementation, automated decision-making system installation, predictive analytics technology deployment, intelligent crop monitoring setup, statistical analysis system deployment, business intelligence platform implementation, AI system implementation, machine learning technology implementation, computer vision system deployment, rule-based decision support setup, agricultural intelligence system installation, decision support system access or utilisation.

# Domain C: Market integration and knowledge networks

**Core purpose**: digital connections that link farms to external resources, markets, information sources, and peer communities, building on production data from Domain B.

## C1: Digital commerce and marketing

### C1.1: e-commerce and digital marketplace platforms

**Purpose**: participating in online selling platforms and digital marketplaces.

**Keywords**: online marketplace participation, digital commerce platform adoption, e-commerce system operation, online sales channel implementation, digital marketplace engagement, electronic commerce participation.

### C1.2: Digital marketing and customer engagement

**Purpose**: implementing digital marketing strategies and customer engagement activities.

**Keywords**: digital marketing campaign implementation, online marketing activities execution, social media marketing engagement, online customer engagement implementation, digital brand development activities, customer relationship management system utilisation.

## C2: Supply chain integration

### C2.1: Traceability and logistics systems

**Purpose**: implementing systems for product tracking and supply chain transparency.

**Keywords**: product traceability system utilisation, supply chain tracking implementation, logistics optimisation system usage, distributed ledger application deployment, chain transparency system operation, commercial quality verification system engagement.

### C2.2: Digital procurement and quality assurance

**Purpose**: participating in digital procurement platforms and quality verification systems.

**Keywords**: digital procurement platform participation, online purchasing system implementation, supplier platform engagement, business-to-business platform participation, quality control system operation, certification process digitalisation.

## C3: Knowledge and advisory services

### C3.1: Digital farm advisory platforms

**Purpose**: Accessing digital advisory services and extension platform capabilities.

**Keywords**: digital agricultural extension service participation, digital farm advisory platform usage, technical assistance platform utilisation, agricultural guidance service access.

### C3.2: e-learning and educational platforms

**Purpose**: participating in online educational platforms and training services.

**Keywords**: online education platform participation, e-learning course engagement, educational system usage, training platform utilisation, knowledge management platform engagement, agricultural education service access.

## C4: Collaborative networks and platforms

### C4.1: Networking and cooperation platforms

**Purpose**: participating in digital networking and cooperation platforms with other farmers or rural actors.

**Keywords**: digital networking platform participation, peer-to-peer digital network utilisation, community digital platform activities, collaborative system participation, farmer group coordination platform usage.

### C4.2: Resource and equipment sharing systems

**Purpose**: engaging in resource sharing and cooperation initiatives.

**Keywords**: equipment sharing coordination, machinery sharing system participation, physical resource sharing activities, cooperative equipment management, shared service utilisation, agricultural resource pooling system operation.

# Domain D: Environmental and social sustainability integration

**Core purpose**: digital applications that serve broader environmental and/or social goals beyond individual farm optimisation, building on operational data from Domain B.

## D1: Environmental and climate monitoring, reporting and verification systems

### D1.1: Environmental and climate monitoring

**Purpose**: implementing integrated systems for measuring environmental and climate effects of agricultural production.

**Keywords**: environmental performance tracking implementation, natural resources impact monitoring activities, biodiversity impact monitoring activities, carbon footprint monitoring activities, sustainability indicator measurement, resource efficiency evaluation, ecosystem services performance monitoring activities.

### D1.2: Environmental and climate reporting and verification

**Purpose**: implementing integrated systems for environmental and climate performance assessment and reporting using production data as well as data about the environmental and climate effects of production.

**Keywords**: nature credits reporting and verification platform utilisation, carbon credits reporting and verification platform utilisation, sustainability certification system operation, verification platform utilisation, compliance verification activities, standards certification system usage.

## D2: Emergency response and risk management

### D2.1: Emergency response and risk management systems

**Purpose**: implementing systems for emergency coordination and disaster preparedness.

**Keywords**: emergency response coordination, disaster management planning activities, crisis management system operation, early warning system utilisation, emergency preparedness programme implementation, agricultural risk management system operation.

## D3: Rural development

### D3.1: smart village and rural development digital initiatives

**Purpose**: implementing digital technologies and solutions within broader smart village and rural development strategies for social and economic benefit.

**Keywords**: digital community platform deployment, smart village technology integration, digital governance system implementation, electronic public service deployment, digital civic engagement platform setup, digital social innovation tool deployment, rural digital hub establishment, community information system implementation.

### D3.2: Digital inclusion and entrepreneurship support

**Purpose**: implementing actions that ensure equitable access to digital technologies and support rural entrepreneurship.

**Keywords**: digital inclusion programme implementation, rural entrepreneurship support activities, agricultural business development coordination, innovation hub operation, rural economic development platform utilisation.

# Domain E: Data economy and innovation ecosystems

**Core purpose**: systems and frameworks that enable strategic use of agricultural data for research, innovation, and economic value creation, building on data generated across all other domains.

## E1: Data governance and standards

### E1.1: Agricultural data governance frameworks

**Purpose**: establishing policies and frameworks for agricultural data ownership, sharing, and usage rights that enable integrated management while protecting farmer interests.

**Keywords**: agricultural data governance framework development, data ownership policy establishment, data privacy protection standards implementation, data rights framework deployment, agricultural data policy creation.

### E1.2: Interoperability and data standards

**Purpose**: creating technical standards that enable seamless data exchange between agricultural systems across all domains.

**Keywords**: data interoperability standards creation, agricultural data sharing protocol development, system integration standards implementation, data exchange infrastructure deployment, compatibility framework establishment.

## E2: Research and innovation infrastructure

### E2.1: Digital research and innovation platforms

**Purpose**: developing collaborative platforms for agricultural research and innovation that leverage data from integrated management systems.

**Keywords**: collaborative research platform development, agricultural innovation ecosystem establishment, research network infrastructure creation, digital innovation hub deployment, knowledge generation platform development.

### E2.2: Agricultural data repositories and archives

**Purpose**: establishing repositories for agricultural research data and scientific datasets that preserve knowledge from integrated management systems.

**Keywords**: agricultural data repository establishment, research data archive creation, scientific dataset infrastructure deployment, agricultural knowledge base development, research data preservation system implementation.

## E3: Data markets and commercialisation

### E3.1: agricultural data marketplace platforms

**Purpose**: developing platforms for trading and licencing agricultural data generated by integrated management systems.

**Keywords**: agricultural data marketplace development, data trading platform creation, data licensing system establishment, agricultural data commerce platform deployment, data exchange marketplace setup.

### E3.2: Data analytics and insights services

**Purpose**: providing commercial data analysis and insights services to agricultural stakeholders using aggregated data from integrated management systems.

**Keywords**: commercial agricultural analytics service development, data insights service platform creation, agricultural intelligence service establishment, decision support service platform development, data-driven advisory service deployment.

# Annex II. An example of an evaluation framework for the assessment of digitalisation under the CAP Strategic Plans

| Evaluation question | Factor of success | Assessment metrics/ methods | Benchmarks/comparison points |
|---|---|---|---|
| EQ1: To what extent have CAP Strategic Plans effectively promoted the digitalisation of agriculture and rural areas? | Digital infrastructure and connectivity are improving due to CAP support. | Rural population with broadband coverage, speed and quality due to CAP support. | Digital Decade target: 100% coverage of populated areas with gigabit networks by 2030.<br><br>Benchmark: Measure CAP contribution as a percentage point improvement towards the connectivity target.<br><br>Relevant data: broadband coverage in Europe 2024 [139]. |
| | Digital skills are being developed due to CAP support. | Rural population participating in digital skills development supported by the CAP. | Digital Decade target: 80% of adults should have at least basic digital skills by 2030.<br><br>Benchmark: Measure CAP contribution as a percentage point improvement towards having 80% of the rural adult population with at least basic digital skills by 2030.<br><br>Relevant data: DESI Dashboard [140]. |
| | Digital business transformation is being facilitated due to CAP support. | Number of farms and rural enterprises adopting digital business technologies supported by the CAP.<br><br>Use the classification system for digital business technologies. | Digital Decade target: 75% of EU enterprises should use cloud computing, data analytics, and AI by 2030.<br><br>Benchmark: Measure CAP contribution as A percentage point improvement towards having 75% of rural enterprises (with ≥ 10 persons employed) to use cloud computing, data analytics, and AI by 2030. The target and the underlying data collection exclude agriculture. Therefore, the target can only be used for rural enterprises other than farms. Ad hoc surveys addressed to farmers may be necessary.<br><br>Relevant data: Towards Digital Decade targets for Europe [141]. National data from the annual survey on ICT usage in enterprises may be necessary for specific data for rural areas. |
| | Digital public services are being enhanced due to CAP support. | Rural population benefitting from digital services supported by the CAP. | Digital Decade target: All key public services available online by 2030.<br><br>Benchmark: The Digital Decade Target refers to the share of administrative steps that can be done fully online for major life events of citizens or businesses. These services, which refer to events such as moving, transport, starting a small claims procedure, family, career, studying AND health, are usually out of the scope of CAP support. Therefore, the use of this Digital Decade target may not be applicable. Evaluators should check for other relevant targets set at national level or compare the situation before and after the implementation of the policy. |

[139] See footnote 131.
[140] See more at: https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts.
[141] See more at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Towards_Digital_Decade_targets_for_Europe.

| Evaluation question | Factor of success | Assessment metrics/ methods | Benchmarks/comparison points |
|---|---|---|---|
| EQ1: To what extent have CAP Strategic Plans effectively promoted the digitalisation of agriculture and rural areas? | Digitalisation intensity in the agri-food sector and rural areas is increasing due to CAP support. | See Section 4.1.1.5.<br><br>Beneficiaries of CAP Strategic Plan interventions are supported in adopting more sophisticated digital tools and services (Domains B, C, D or E).<br><br>In addition, technology adoption surveys measuring penetration rates and diversity of digital tools (e.g. precision agriculture equipment, farm management software, IoT sensors, automated systems, etc.) among CAP beneficiaries and, if possible, non-beneficiaries. | |
| EQ2.1: To what extent has the support provided through digitalisation-related CAP Strategic plan interventions affected sustainable farm productivity? | Factors of success in the guidelines 'Assessment of CAP contributions to sustainable productivity', focusing on digitalisation-related interventions.<br><br>Factors of success in Annex II of the guidelines 'Use of factors of success in evaluation', adapted to focus on digitalisation related interventions.<br><br>Additional factors of success may look at how digitalisation-related interventions as well as digitalisation intensity have affected the intensity of the use of inputs, e.g. the input of chemicals (mineral fertilisers, herbicides, fungicides, etc.) per unit of output. | See guidelines for the assessment of CAP contributions to sustainable productivity.<br><br>See Annex II of the guidelines for the 'Use of factors of success in evaluation'.<br><br>In addition, the methodology developed for the rough estimation of the climate change mitigation potential of the CAP Strategic Plans (EU-27) over the 2023-2027 period may provide valuable insights on using the farm practice labelling, available in the Catalogue of CAP interventions, and the coefficients developed by the JRC under the iMAP project, for assessing the contribution of digitalisation-supported farm practices not only to climate change mitigation but also to soil or water quality.<br><br>Furthermore, see methods implementing a life cycle analysis approach [142].<br><br>Contextual information about extreme weather events or pest outbreaks should be taken into account when assessing the net effects of digitalisation on sustainable farm productivity. | |

[142] See footnote 118 for Huck et al. (2024).

| Evaluation question | Factor of success | Assessment metrics/ methods | Benchmarks/comparison points |
|---|---|---|---|
| EQ2.2: To what extent have the support provided through digitalisation-related CAP Strategic plan interventions contributed to sustainable and inclusive growth in rural areas? | Factors of success in Annex III of the guidelines 'Use of factors of success in evaluation', adapted to focus on digitalisation related interventions. More specifically:<br>› Rural areas' economy is growing or, at least, is stable and the urban-rural digital divide is decreasing.<br>› Employment rate in rural areas is improving.<br>› Local services and infrastructures are improving.<br>› Women's employment is improving.<br>› Rural poverty is decreasing. | See Annex III of the guidelines for the 'Use of factors of success in evaluation'.<br>Furthermore, see methods for assessing the relationship between digitalisation intensity, structural or institutional characteristics and the provision of digital services as well as the relative efficiency of different rural areas (e.g. NUTS 2 regions) in transforming CAP support into digitalisation for sustainable and inclusive growth [143]. | |
| EQ3.1: To what extent has CAP support enhanced administrative digitalisation and simplification for agricultural stakeholders? | Administrative process efficiency is improved.<br>Stakeholder satisfaction with digital administrative services is increased. | Processing times, error rates, completion rates and cost-effectiveness of digital vs. traditional CAP administrative processes using administrative records from Paying Agencies and Managing Authorities.<br>Survey agricultural stakeholders (farmers, advisors, agricultural businesses) on accessibility, usage frequency, user satisfaction and perceived effectiveness of CAP digital administrative services using structured stakeholder satisfaction surveys. | |

Source: EU CAP Network supported by the Evaluation Helpdesk for the CAP (2025)

[143] Lobonț, O. R., Criste, C., Vintilă, A. I., Crăciun, A. F. & Moldovan, N. C., Assessing digital performance of public services in the EU: e-governance and technology integration, Systems, Vol. 13, No 6, 425, 2025, https://doi.org/10.3390/systems13060425.

# Annex III. Summary of empirical databases and analytical strategies employed to elicit farmers' views on digitalisation

| Ref. | Empirical material | Key variables/constructs | Analytical procedure | Main distinctive feature |
|---|---|---|---|---|
| Block et al. (2023) | Online questionnaire, 160 German farmers (2020): Questionnaire embeds a trans-theoretical model of perceived usefulness (TTMU) with five ordered stages. | Stage of perceived usefulness (ordinal), personal traits (age, education), farm characteristics (size, full-time/part-time), technology environment (mobile use, importance of digital tools). | Ordered logit regression to explain transitions between TTMU stages; model fit diagnostics reported. | First agricultural application of the TTM paradigm to digital risk-management tools; captures *gradual* – rather than binary attitudes. |
| Vik et al. (2019) | *Multi-source qualitative case study* of Norwegian dairy: 28 semi-structured farmer interviews complemented by policy documents, sector statistics (2000-2018) and secondary literature. | Perceived labour flexibility, quality-of-life gains and structural change narratives linked to automated milking systems (AMS). | Thematic content analysis triangulated with descriptive sector statistics. | Connects farmers' subjective motives to national structural change, arguing AMS diffusion is an unintended political outcome. |
| Tey & Brindal (2012) | Systematic literature review: Scopus search; ten ex-post empirical adoption studies (25 econometric models) retained after screening >50 papers. | Thirty-four adoption determinants grouped into socioeconomic, agro-ecological, institutional, informational, perception, behavioural and technological factors. | Structured review grid (author, country, technology, method, sample, variables, significance) + qualitative synthesis of significant predictors. | Provides the earliest consolidated evidence base for policy on farmer adoption of precision technologies; no primary data collection. |
| Abdulai et al. (2024) | Professionally administered online survey, 1 000 Canadian farmers (852 complete cases) across all provinces (quota sampling, July-Aug 2021). | Five perceived 'relative advantages' of digitalisation (quality of work, productivity, profitability, return on investment, reliability) on a 5-point Likert scale; 11 socioeconomic covariates and technology-experience indicators. | Ordered-probit and marginal-effects analysis of positive vs. neutral/negative perceptions; robustness checks for sample representativeness. | Large national sample with balanced regional quotas; focuses on comparative advantage perceptions rather than adoption intentions. |

Source: EU CAP Network supported by the Evaluation Helpdesk for the CAP (2025)

**Comparative observations on methodology**

Regarding data types, three studies rely on newly collected cross-sectional survey data, while Vik et al. use qualitative interviews, and Tey & Brindal synthesise secondary econometric data.

From a methodological point of view, Block et al. operationalise process stages (TTMU), Abdulai et al. employ Likert-type agreement levels, Vik et al. derive attitudes inductively from narratives, while Tey & Brindal report determinants identified in earlier work. Quantitative papers apply ordered discrete-choice models; the qualitative study employs thematic coding; the review utilises structured comparative tables rather than meta-analysis.

In terms of scope, Abdulai et al. achieve the broadest geographic coverage, Block et al. target a specific digital tool class, Vik et al. deliver depth on one transformative technology and Tey & Brindal provide cross-country factor generalisation.

Collectively, these publications illustrate how farmer perceptions of digitalisation can be captured through stage-based readiness frameworks, stated relative advantages, narrative inquiry into technology-life interactions and synthesis of adoption determinants – with each approach serving different research and policy objectives.

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