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The state of digitalisation in EU agriculture

Insights from farm surveys

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Contents

Abstract

The digitalisation of the EU agricultural sector is an essential part of the broader EU Digital Agenda and the Common Agricultural Policy (CAP) aiming to promote competitiveness, sustainability, and resilience in agriculture through digital transformation. This report analyses the current state of digitalisation in EU agriculture, covering the adoption of general IT and software tools and farm-specific technologies, key drivers and barriers, perceived sustainability aspects, and farm-level practices in data collection, management and sharing. The analysis is based on farm survey data from 1 444 respondents in nine EU Member States – Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland – collected between June and October 2024. The results show that while general IT and software tools are widely used, more expensive technologies specific to crop or livestock production have been less widely adopted. Adoption rates are higher among larger farms, those with better internet connectivity and those with specialised training. Key drivers of adoption include efficiency gains, cost savings, regulatory pressures and improved quality of life, while high costs and limited skills remain notable barriers. Farmers expect digital technologies to have positive economic, environmental and social impacts. Farm-level data collection is still largely manual or based on basic digital tools, which increases the administrative burden on farmers. Farmers appear to take a selective approach to data sharing, mainly due to concerns about privacy, security and data control. Promoting transparent data policies, ensuring farmers benefit from sharing and adopting a targeted policy approach for advanced technologies can help build trust and support wider digital adoption.

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Visualization of results

More details on the report's results are available in the interactive dashboards on the JRC agro-economic portal (DataM):
https://datam.jrc.ec.europa.eu/datam/mashup/DIGITALISATION_IN_EU_AGRICULTURE/

Executive summary

The digitalisation of the EU agricultural sector is an essential component of both the broader EU Digital Agenda and the Common Agricultural Policy (CAP), aimed at enhancing the competitiveness, sustainability and resilience of agriculture and rural areas through digital transformation. The EU recognises digital technology as a catalyst for modernising farming practices and addressing current challenges, such as competitiveness, climate change, biodiversity loss and food security. As part of this effort, the European Commission has developed policy frameworks and initiatives that target the integration of digital technologies in agriculture to drive efficiency, innovation and sustainability (European Commission, 2021, 2022, 2023, 2025a, 2025b; Ciucci et al., 2025).

This report gathers farm survey data related to digitalisation in EU agriculture in order to establish a baseline for assessing the current state of play. This information is relevant for measuring progress towards achieving the digital transformation outlined in the EU's broader Digital Agenda and the Common Agricultural Policy.

The report provides an overview of the current state of digitalisation in EU agriculture, focusing on the adoption of general IT tools and farm-specific technologies for crop and livestock production. It also examines the perceived sustainability of these technologies and the main drivers of and barriers to their adoption. In addition, it examines farm-level practices related to data collection, management and sharing.

The analysis is based on stratified farm survey data from 1 444 respondents in nine EU Member States: Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland. Data were collected between June and October 2024 through a combination of face-to-face interviews and telephone or online interviews. To provide a comprehensive analysis of digitalisation in EU agriculture, the report combines descriptive statistics with econometric estimations.

The results of the farm survey data on digitalisation in EU agriculture suggest the following main findings.

Digitalisation in agriculture

Most of the farms surveyed (85 %) report adequate overall internet coverage (both at the farm and in the fields), while 15 % still face poor connectivity. Ownership of digital devices is widespread, especially smartphones. Farmers frequently engage in practical online activities, such as communication and information gathering, while more advanced uses such as e-commerce or online professional networking are less common.

The survey reveals a varied and uneven pattern of adoption of digital technologies among EU farms. General IT and software tools are widely used, with 93 % of farms using at least one such tool and 68 % using three or more. In contrast, the adoption of most specialised crop- and livestock-specific digital technologies is lower and more heterogeneous, ranging from 3 % to 23 %. Some 79 % of farms have adopted at least one crop-specific technology, but only 29 % have adopted three or more. For livestock-specific tools, 83 % of farms have adopted at least one, but only 17 % have adopted three or more. Adoption increased significantly between 2008 and 2020 but has slowed down since 2020, probably due to increased economic uncertainty. Looking ahead, farmers indicate only modest intentions to adopt new technologies over the next five years.

Digital technologies for livestock production are generally considered the most expensive by the farmers surveyed, followed by crop-specific technologies. At least half of all the livestock- and crop-related technologies discussed are deemed expensive. However, several crop technologies are considered more affordable, and general IT and software solutions for farm management are widely viewed as affordable. In general, digital technology adoption decreases as more farmers perceive the technology to be expensive.

The adoption of digital technologies is mainly facilitated by farmers' own initiative, with moderate facilitation by supply-chain stakeholders that are closely linked to farmers, such as consumers, suppliers and competitors. Public authorities, cooperatives and other organisations play a rather minor facilitating role, suggesting the potential for greater involvement.

The econometric estimates show that a larger farm size, better internet connectivity, engaging in direct sales, a full-time farming status and specialised digital and agricultural training are strongly associated with higher adoption rates, especially for crop- and livestock-specific technologies. Specifically, depending on the technology category, larger farms adopt 10–84 % more digital technologies, a poor or insufficient internet connection reduces adoption by 4–30 %, farmers involved in direct sales adopt digital technologies 14–36 % more often, part-time farmers adopt them 10–33 % less often and specialised digital and agricultural training increases adoption by 14–71 %.

Age has a limited influence, with a small negative effect on the adoption of IT and software. Farmers who plan to retire later adopt more crop-specific technologies. Higher levels of education correlate with higher adoption levels of general IT and software technologies, but the effect is weaker for crop- and livestock-specific technologies. Regional and production specialisation differences show that southern Member States and farms specialising in crop and livestock production adopt more technologies. Interestingly, partial land ownership or renting is associated with higher adoption rates of livestock technologies, possibly indicating a trade-off between digital investment and land ownership.

In contrast, variables such as gender, legal ownership and engagement in organic production are for the most part not significantly associated with the adoption of digital technologies.

The econometric estimates also show that farmers' perceived drivers are more strongly associated with digital technology adoption than their perceived barriers are. Drivers such as efficiency gains and cost reduction, quality of life and welfare enhancement, management and operational improvement, growth opportunities and market pressure are associated with high adoption rates across categories of digital technologies. Farmers affected by these drivers adopt 8–38 % more technologies, with stronger adoption rates observed for crop- and livestock-specific technologies.

Among the barriers identified in the economic estimations, only the lack of knowledge and skills, low interest in and low perceived benefits of technologies, and perceived susceptibility to errors show some relationship with digital technology adoption. Although financial constraints (e.g. the high cost of digital technology) and the lack of knowledge and skills are often reported as barriers by the farmers surveyed, the estimated correlation of these barriers with technology adoption is significantly weaker than that of the drivers. This discrepancy suggests that the perceived importance of barriers may be partially captured by other factors included in the econometric estimations.

Most farmers surveyed expect digital technologies to make a positive contribution to sustainability, particularly in the economic (76 %), environmental (72 %) and social (67 %) dimensions. In addition, 68 % of farmers perceive that digital technologies can increase their resilience to disruption, at least to some extent.

Data practices in agriculture

Data collection and sharing are critical components of the digital transformation of agriculture, enabling more informed decision-making, greater operational efficiency and improved resource use. The survey results show that farmers collect a wide range of data – spanning from financial and soil data to livestock, input and market data – but the frequency of collection varies considerably. Most data are collected on a monthly basis (by between 10 % and 35 % of farms for most data types), followed by annual (10–30 %), weekly (14–25 %) and daily (10–15 %) intervals.

Data collection and management on the farms surveyed are still largely manual or supported by basic digital tools, such as scanned paper records or spreadsheets. Only a minority of farms use specialised software or fully automated systems, while some rely on external services for data collection and management.

The results suggest that farmers are cautious and selective in their approach to electronic data sharing. Many do not share at all, and those who do tend to share with trusted parties, such as advisors, fellow farmers or cooperatives. Sharing with more distant stakeholders – such as financial institutions, researchers, agri-tech companies or public administrations – is much less common. Data-sharing practices vary considerably among Member States, with some showing a higher level of engagement than others. Farmers on larger farms and younger farmers are generally more open to sharing, while farmers on smaller farms and older farmers tend to be more reluctant. The farmers surveyed report that indirect benefits are the main driver for data sharing, while privacy, security and control over data use and ownership are the main barriers.

Discussion and policy implications

Despite the widely discussed benefits of digital agriculture, adoption remains rather low and uneven across the EU. While general IT and software tools are commonly used, more specialised and often costlier crop- and livestock-specific technologies are less widely adopted. This gap between the expected and actual uptake of these technologies is likely due to affordability concerns, unclear benefits, limited tailoring to farm-specific needs and some solutions not being ready for commercial use. As a result, farmers tend to adopt only those digital tools that both are affordable and offer tangible benefits.

The data reveal high variability in adoption, even within a given technology category, highlighting the need for targeted, rather than one-size-fits-all, policy approaches. Financial pressures, including recent crises, have further constrained adoption, despite digital tools' potential to enhance resilience.

While some farmers view digital technologies as enhancing resilience, this is not a major driver for adoption. Key motivators include efficiency gains, cost savings, regulatory compliance and improved quality of life and welfare. Barriers such as high costs, limited IT skills and lack of support are less important when analysed alongside other factors. Nevertheless, the findings highlight the importance of specialised, targeted digital training and education to support wider adoption.

Structural factors, such as farm size and farmer age, have a significant impact on the adoption of digital technologies. Smaller farms and older farmers are less likely to adopt digital tools, highlighting the need for tailored engagement strategies. The report also suggests that organisations such as extension services, technology providers and research centres currently have a limited impact on adoption, indicating room for greater involvement in supporting technology diffusion within EU agriculture.

Current farm-level data collection remains mostly manual or semi-digital, contributing to the administrative burden for farmers. The adoption of advanced digital tools could reduce this burden and support broader digital transformation. Furthermore, ensuring data interoperability between digital platforms and across diverse systems could improve operational efficiency, reduce data duplication and encourage wider adoption of digital technologies, thereby lowering administrative burdens. However, farmers remain reluctant to share data, citing concerns about privacy, security and data control. Promoting clear and transparent data-sharing policies and business practices that give farmers security and control over their data can help build trust. In addition, offering clear benefits, such as knowledge sharing and tailored services, is also key to encouraging farmer participation in data sharing and digitalisation.

The growing interest in artificial intelligence (AI) in agriculture underlines the relevance of this report's findings for understanding potential pathways and barriers to AI adoption. As with other digital technologies, uptake will depend on affordability, perceived benefits and suitability for different farm types and regional contexts. Given AI's reliance on large-scale data use, concerns around data security, ownership and control – key issues highlighted by farmers – need to be addressed. Ensuring clear benefits, including access to tailored services, will also be critical to supporting AI adoption among farmers.

1. Introduction

Digitalisation of agriculture refers to the adoption and integration of digital technologies into farming systems and practices. This process involves the deployment of tools – such as data analytics, mobile applications (apps), sensors, the Global Positioning System (GPS), farm management software, drones and data analytics – to transform agricultural operations. Digitalisation enhances the capacity to collect and analyse data on various aspects of farming, such as crop and animal health, soil conditions, weather patterns and market trends. This data-driven approach enables more precise decision-making, resource optimisation and improved management of agricultural processes. Ultimately, the objective of agricultural digitalisation is to enhance the efficiency, productivity and environmental and social sustainability of agricultural systems (Basso and Antle, 2020; Kenney et al., 2020; Shang et al., 2021; MacPherson et al., 2022; Abiri et al., 2023; Finger, 2023).

Digitalisation is an integral part of the cross-cutting objective of modernisation of agriculture and rural areas, which is embedded in all the objectives of the Common Agricultural Policy (CAP) for 2023–2027. It also aligns with the broader transformation of the EU economy and society as outlined in the EU's Digital Agenda (European Commission, 2021, 2022, 2023; European Parliament, 2024). Further deployment of digitalisation technologies has the potential to strengthen the competitiveness and improve the environmental and socioeconomic performance of agriculture and rural communities in the EU. In this context, Member States have developed digitalisation strategies for agriculture and rural areas as part of the CAP Strategic Plans, aiming to support the sustainable digital transformation of these sectors (European Commission, 2023, 2025a) ([1]). The Commission's Vision for Agriculture and Food highlights the importance of digital technologies as key enablers of economic performance, innovation, resilience and sustainability at the farm level. In line with the vision, the Commission will work on the building blocks towards a digital-ready and AI-empowered agri-food sector (European Commission, 2025b).

However, there is currently no established baseline for the degree of digitalisation of the agricultural sector, and therefore no way to measure the progress of digitalisation at the EU level. The fact that there are no available reference data with which to draw a baseline for the CAP is also because there is no dedicated context or impact indicator for digitalisation in agriculture. The absence of a baseline makes it difficult to determine whether digitalisation efforts are achieving their intended goals or making a meaningful impact. This gap is particularly significant given that digitalisation is widely recognised as a key enabler for achieving sustainability goals across environmental, economic and social dimensions (Mondejar et al., 2021; Barabanova and Krzysztofowicz, 2023; Finger, 2023). Without a clear reference baseline, it becomes challenging to track progress, identify gaps and steer policy interventions effectively to harness the full potential of digital technologies in supporting a more sustainable and resilient EU agricultural sector.

Hence, gathering farm survey data related to digitalisation is necessary to understand the current state of digitalisation in agriculture in the EU. This information can then be used to measure progress towards achieving the digital transformation outlined in the EU's broader Digital Agenda and the CAP.

([1]) For some examples of digitalisation initiatives in agriculture and the food sector in Member States, see Federal Ministry of Agriculture, Food and Regional Identity (2020); Ministry of Agriculture, Fisheries and Food (2024); 4Growth (2024); and Digital Innovation Observatories (2025).

The present report provides a comprehensive overview of the main findings on the state of digitalisation in EU agriculture. This research's primary objective was to assess the current landscape of digital technology adoption on EU farms, covering IT and software technologies common to all farms as well as farm-specific digital technologies tailored to crop and livestock production. The report also provides insights into the drivers of and barriers to digital technology adoption and the sustainability aspects of these technologies. Given the importance of farm-level data collection, management and sharing for the digital transformation of agriculture, the report also examines data availability, collection methods and sharing practices among farmers, including their main drivers and barriers.

The analyses in this report are based on a farm survey of 1 444 respondents conducted between June and October 2024. The survey was conducted through a combination of face-to-face interviews (61 %) and telephone or online interviews (39 %). It covered nine Member States selected for their diverse agricultural landscapes and varying levels of technological advancement: Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland.

The methodology employed involved a stratified sampling approach, ensuring that the survey captured a representative cross section of the agricultural population in the Member States surveyed. The survey itself was developed through a rigorous process of cognitive testing, translation and pilot testing, resulting in a robust and reliable tool for data collection.

The questionnaire included questions on (1) the respondents' current level of adoption of digitalisation, including financial support received (e.g. investments, credits) and the cost of adoption, (2) drivers of and barriers to digital technology adoption, (3) sustainability aspects of the digital technologies and (4) aspects related to the collection and sharing practices of data at the farm level.

To provide a comprehensive analysis of digitalisation in EU agriculture, the report combines descriptive statistics with econometric estimations. The descriptive statistics summarise key patterns from the survey data, while the econometric analysis explores the relationship (correlation) between the number of digital technologies adopted and various factors that may influence adoption.

The report is structured as follows. Section 2 outlines the questionnaire and the sampling methodology, while Section 3 provides an overview of the sample's characteristics. Section 4 presents the main findings on the adoption of digital technologies, including related aspects such as their drivers and barriers, their costs and their contribution to sustainability. Section 5 focuses on farm-level data practices in agriculture, examining data availability, management and sharing. Finally, Section 6 presents the study's conclusions.

2. Methodology

2.1. Questionnaire

A comprehensive questionnaire was designed to collect farm-level data to assess the state of play of digitalisation in EU agriculture. The aim was to capture current levels of digital adoption and future intentions to adopt, while also exploring drivers of and barriers to adoption, enabling factors, potential contributions to sustainability and resilience, and data availability at the farm level.

The initial screening questions were designed to be used during first contact over the phone to establish farmer eligibility and ensure that the stratified sampling quota was met. The screening included questions on the farm's size (in hectares or livestock units (LSUs)), the farm's location within a NUTS (nomenclature of territorial units for statistics) level 2 region and the main activities contributing to farm income, thus determining the farm's specialisation.

The main questionnaire included a total of 40 questions, divided into six sections: (1) structural characteristics of the farm, (2) farmers' online activities, (3) adoption of digital technologies, (4) drivers of and barriers to adoption of digital technologies, (5) expected net benefits of digital technologies for sustainability and (6) aspects related to data collection, data ownership and data-sharing practices (Annex 1).

The first section of the questionnaire included structural questions about the farm manager, covering aspects such as legal status, ownership, full-time or part-time involvement, gender, age, education, whether the farmer had any plans to leave the farm and whether they had a successor in mind. It also collected details about the farm, such as the proportion of organic production, proportion of direct sales, size, labour force, income and farm activities.

The second section focused on understanding farmers' online activities. It collected data on the devices they use for work on the farm (e.g. computers, tablets, smartphones); internet coverage on the farm; and online and social media engagement related to farming, including, for example, e-commerce, communications and e-advice services. In addition, it enquired about any digital technology training the farmer had received in the past five years and whether such training had been offered to them.

The questions in the third section were designed to assess both the current level of adoption of digital technologies and future intentions to adopt in the next five years. Information was also collected on the year of adoption, funding methods and farmers' perceptions of the cost and affordability of digital technologies. More specifically, the questions covered the following three types of digital technologies:

- **IT and software technologies common to all farms**, which include enabling technologies such as (1) accounting platforms, (2) forecast apps (e.g. for the weather), (3) trading platforms (e.g. e-commerce, mobile banking, commodity prices platforms), (4) mobile apps (e.g. to monitor the weather or pests) and (5) communication platforms (e.g. WhatsApp, Facebook Messenger, Viber);
- **crop-specific technologies**, which include (1) drones for spraying, (2) tractors with global navigation satellite systems (GNSS) (e.g. GPS), (3) fully automatic field robotics (hoeing units, weeders, etc.), (4) augmented-reality technologies (headsets, eyeglasses, goggles), (5) drones for monitoring, (6) automatic steering systems, (7) light bar guidance systems, (8) variable-rate application technology (e.g. for irrigation, seeding, fertilising, weed control), (9)

soil sensors (for temperature, humidity, nutrients, etc.), (10) yield mapping, (11) farm management software (crop management, livestock management, financial and accounting software), (12) connected weather stations, (13) field cameras, (14) georeferenced soil sampling, (15) telemetry, (16) connected insect traps, (17) maps from satellite data, (18) digital field records and (19) section controls (for sprayers, spreaders, planters);

- **livestock-specific technologies**, which include (1) automatic milking systems, (2) robotic feed pushers, (3) robotic slat clearers, (4) barn cameras, (5) behaviour monitoring sensors, (6) collars, (7) farm management software (crop management, livestock management, financial and accounting software) and (8) digital livestock records.

The fourth section addressed the drivers and barriers influencing the adoption of digital technologies, which were selected based on the literature and expert consultation. Farmers were asked to select up to five key drivers and barriers. The options for drivers included regulatory requirements, market pressures (e.g. consumer demand, competitive pressures), growth opportunities, efficiency and cost reduction, management and operational improvement, enhanced quality of life and animal welfare, personal motivation and an open-ended option for other drivers not listed in the survey. The options for barriers included financial constraints, a lack of policy support, concerns about data privacy and ownership, the susceptibility of digital technologies to errors and an open-ended option for other barriers not listed in the survey. In addition, this section identified the main stakeholders facilitating technology adoption.

The fifth section collected information on the expected net benefits of the digital technologies in terms of economic, social and environmental aspects and on these technologies' contribution to unforeseen disruptions (e.g. price shocks, cost increases, labour safety and health crises, droughts, plant/animal diseases) occurring on the market or in the environment.

The final section focused on data availability at the farm level. It aimed to capture the types of data collected at the farm level, the frequency and format of data collection (e.g. paper, digital, specialised apps, automated) and data ownership. It also asked about data-sharing practices and the benefits and challenges associated with data sharing.

The questionnaire was refined through two distinct phases of the study: a pre-test using cognitive tests ([2]) and a pilot survey. In each phase, the questions and answer options were reviewed to address any content issues.

Initially developed in English, the questionnaire was then translated into the national languages of the Member States covered. Translation efforts prioritised conveying equivalent meanings across languages rather than word-for-word translations. Technology-related terminologies were assessed on a case-by-case basis to determine whether and how they should be translated. For instance, 'GPS' remained untranslated across languages, while 'drones' was intentionally left untranslated in Greek. These decisions were part of the cognitive test phase assessments. The pilot phase highlighted critical aspects of survey functionality, including participant comprehension and the effectiveness of the translated materials. The feedback obtained during this phase led to further adjustments, ensuring that the final version of the questionnaire was both effective and engaging.

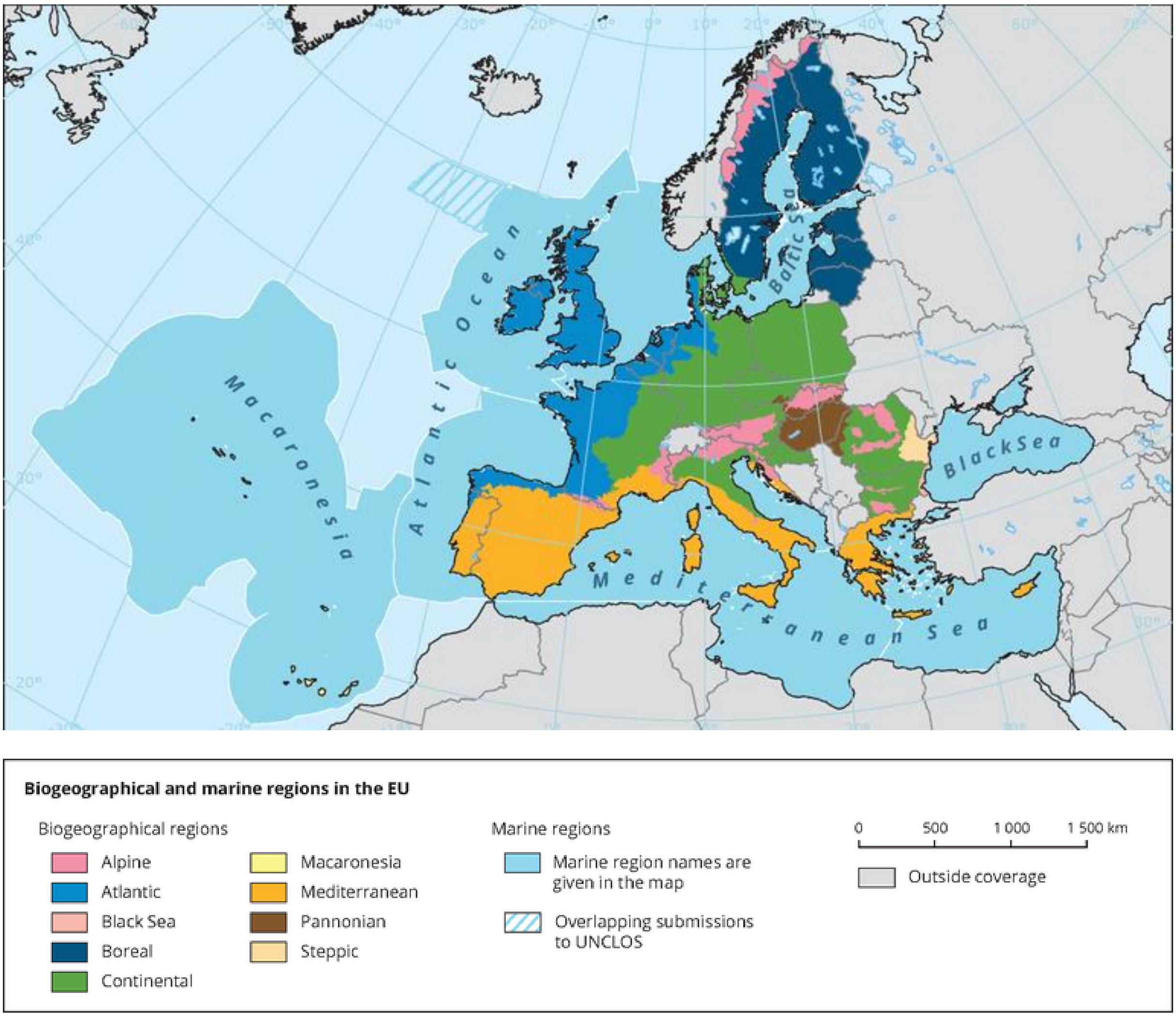
([2]) The aim of the cognitive test was to involve respondents from the Member States covered who could provide effective feedback on the questionnaire, particularly with regard to its presentation, content, flow of questions and comprehensibility. The goal was to incorporate the suggested changes to improve clarity and understanding, thereby making the survey easier for respondents to follow and complete.

The target population of the survey was farmers in the Member States covered. The survey used a mixture of face-to-face interviews and telephone and online interviews.

2.2. Selection of Member States

The study included data collection in nine Member States – Germany, Ireland, Greece, Spain, France, Italy, Lithuania ([3]), Hungary and Poland – with the aim of achieving a representative sample of the EU agricultural population. Together, these Member States collectively provide a balanced representation of the different biogeographical and geographical regions in the EU, based on the European Environment Agency's biogeographical and marine regions classifications ([4]) (Figure 1) and the United Nations' classification and definition of regions ([5]).

Figure 1. Biogeographical and marine regions in the EU



Source: Retrieved from European Environment Agency, (2020), reference data are from Esri.

([3]) Lithuania was included in the study due to low response rates in Ireland and Hungary during data collection. It was selected because it contributes to greater overall diversity in terms of EU regional coverage.

([4]) https://www.eea.europa.eu/data-and-maps/figures/biogeographical-and-marine-regions-in.

([5]) https://unstats.un.org/unsd/methodology/m49/

A comprehensive list of the different biogeographical and geographical regions that correspond to the Member States covered is presented in Table 1. It is worth mentioning that the Member States selected cover all the biogeographical and geographical regions found in the EU and correspond to 54 % of the total number of farms in the EU (27 Member States from 2020) according to the 2020 EU farm specialisation statistics (6).

Table 1. Classification of the Member States covered by biogeographical and geographical region

Country	Biogeographical region	Geographical region
Germany	Atlantic, alpine, continental	Western Europe
Ireland	Atlantic	Northern Europe
Greece	Mediterranean	Southern Europe
Spain	Atlantic, alpine, Mediterranean	Southern Europe
France	Atlantic, alpine, continental, Mediterranean	Western Europe
Italy	Alpine, continental, Mediterranean	Southern Europe
Lithuania	Boreal	Northern Europe
Hungary	Pannonian	Eastern Europe
Poland	Alpine, continental	Eastern Europe

Source: Authors' compilation based on the classifications of the United Nations and the European Environment Agency.

2.3. Sampling strategy

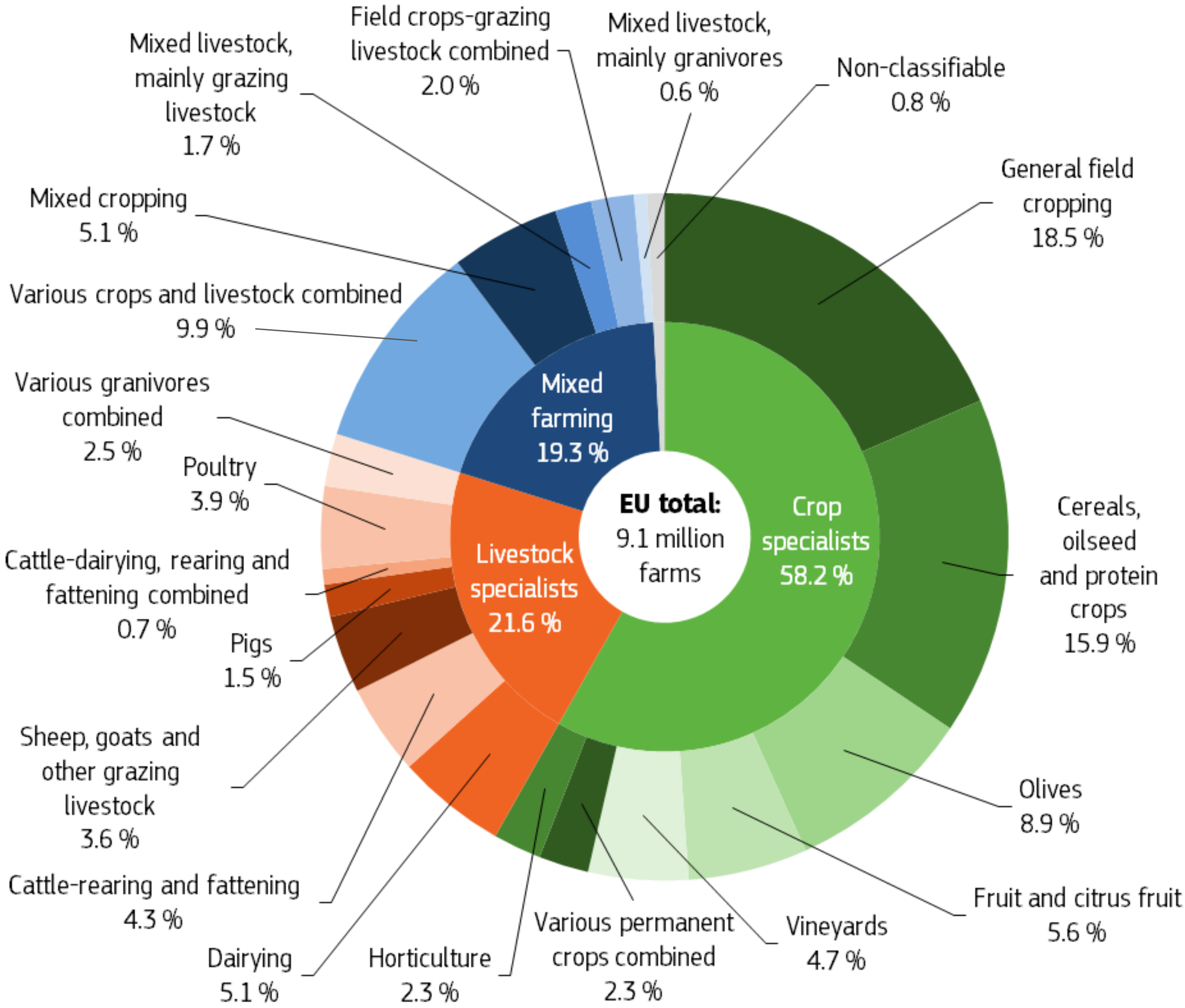
For the purposes of this survey, stratified sampling was used. This sampling method involved the identification of interest of groups from the population based on shared characteristics and the random selection of participants within the groups formed. It involved dividing the target population elements into homogeneous, mutually exclusive segments. From each segment, simple random sampling was performed. The selected samples from the different segments were then combined to form a single sample, as described by Iliyau and Etikan (2021).

Farm specialisation and farm size were the main characteristics used to develop this survey's stratified random sampling strategy. The size and specialisation of farms are key characteristics that define the structure of the farming sector, making them particularly relevant when analysing the adoption of crop- and livestock-specific digital technologies. Specifically, the 2020 EU farm specialisation statistics were utilised to select potential respondents based on farm specialisation. There were three main farm specialisations used in the survey, namely, crop specialists, livestock specialists and mixed-farming specialists. Crop specialists referred to farmers for whom at least two thirds of their agricultural business was based on crop production. Similarly, livestock specialists referred to farmers for whom at least two thirds of their agricultural business was based on livestock production, while mixed-farming specialists were farmers for whom neither crop nor livestock production dominated (7) (Figure 2).

(6) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_specialisation#Data_sources.

(7) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Farm_typology.

Figure 2. Farm specialisations among all EU farms in 2020 (%)



Source: Eurostat (dataset ef_lus_main).

Regarding farm size, three different classes (small, medium and large) were used in the survey. Farm size was categorised in terms of utilised agricultural area in hectares for crop specialisations and in LSU for livestock specialisations. Specifically, for the livestock specialisations, the respondents were asked about the number of animals that they had, and this number was converted to LSUs using the Eurostat conversion table ([8]) (Table 2). For mixed-farming specialisations, size was classified using the scale for the more dominant specialisation (crops or livestock) ([9]). Table 2 shows the farm size classification by specialisation used in the study.

([8]) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU).

([9]) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agriculture_statistics_at_regional_level.

Table 2. Farm size classification by specialisation for the questionnaire

Farm specialisation	Class	Range
Crop specialisation	Small	< 5 ha
	Medium	5–50 ha
	Large	≥ 50 ha
Livestock specialisation (except beehives, rabbits, deer, fur animals and other animals not classified)	Small	< 50 LSU
	Medium	50–200 LSU
	Large	≥ 200 LSU
Mixed-farming specialisation	Small	Measured using the scale for the more dominant specialisation (crops or livestock)
	Medium	
	Large	

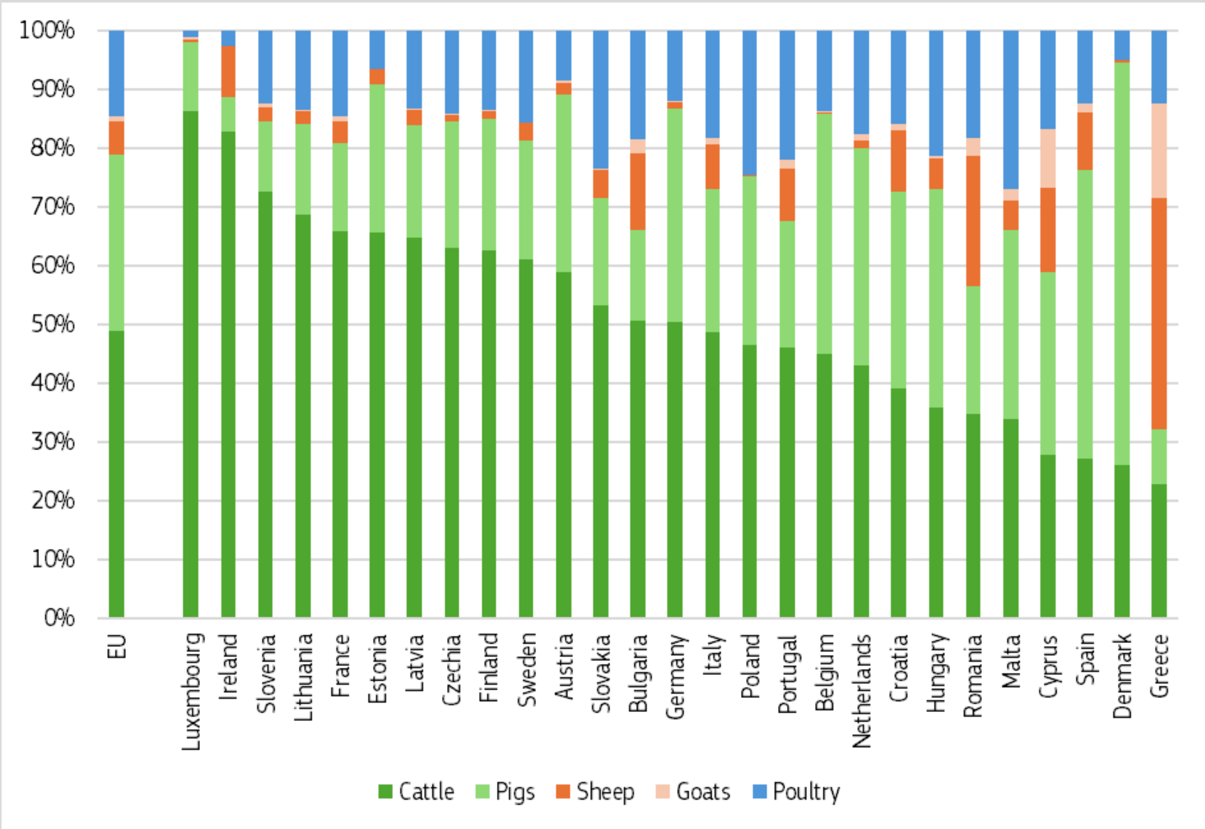
Source: Authors' own compilation.

To ensure a balanced selection of respondents within each Member State, some additional variables such as livestock density at the national level ([10]), the economic size of farms and farm specialisation at the NUTS 2 level ([11]) were also taken into account (Figure 3, Figure 36 in Annex 2).

([10]) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_livestock_patterns#Livestock_density_at_EU_level_in_2020.

([11]) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agriculture_statistics_at_regional_level; https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_specialisation#Data_sources.

Figure 3. Livestock population composition in LSU, Member States (%)



Source: Eurostat, 2023.

Table 3 shows an indicative list of the regions selected for the survey, together with the percentages of farm specialisations within each region. The regions were chosen based on their production importance and their representation of different farm typologies, which were used as criteria for sample stratification. The selection shown in Table 3 ensures strong coverage of the criteria across the Member States included in the survey. This initial regional analysis served as a starting point for prioritising the recruitment activities. However, it became clear early on that recruitment efforts had to be expanded in all regions in order to facilitate the fieldwork, due to low response rates. The low response rates were often a consequence of holiday periods or peak seasons in some farm activities conflicting with fieldwork or outbreaks of severe animal diseases limiting in-farm visits.

Table 3. Indicative list of regions selected for the survey and their farm specialisations

Region code	Region name	Farm specialisation (%)			Country
		Crop	Livestock	Mixed farming	
DE11	Stuttgart	55.5	31.2	13.2	Germany
DE21	Oberbayern	39.8	55.0	5.1	Germany
DE26	Unterfranken	69.6	18.4	12.0	Germany
DE40	Brandenburg	51.2	33.5	15.3	Germany
DE94	Weser-Ems	25.9	63.0	10.9	Germany
IE04	Northern and Western	6.0	93.5	0.5	Ireland
IE05	Southern	11.9	85.9	2.2	Ireland
IE06	Eastern and Midland	15.1	81.8	3.0	Ireland
EL43	Kriti	84.1	8.2	7.5	Greece
EL53	Dytiki Makedonia	69.2	17.2	12.5	Greece
EL54	Ipeiros	62.7	24.1	11.3	Greece
EL61	Thessalia	76.2	13.0	9.4	Greece
EL65	Peloponnisos	90.8	3.8	4.9	Greece
ES11	Galicia	47.0	38.3	14.5	Spain
ES21	País Vasco	37.8	46.7	15.4	Spain
ES42	Castilla-La Mancha	83.3	6.3	9.1	Spain
ES52	Comunitat Valenciana	94.7	2.4	2.7	Spain
ES61	Andalucía	90.2	4.7	4.8	Spain
FRH0	Bretagne	28.6	59.3	12.0	France
FRF3	Lorraine	38.9	43.5	17.6	France
FRI1	Aquitaine	60.8	26.3	12.6	France
FRJ1	Languedoc-Roussillon	81.6	13.7	4.4	France
FRL0	Provence-Alpes-Côte d'Azur	79.1	13.9	6.9	France
ITC2	Valle d'Aosta/Vallée d'Aoste	40.4	44.4	14.8	Italy
ITF4	Puglia	90.6	1.5	6.2	Italy
ITF6	Calabria	85.7	3.7	9.8	Italy
ITG2	Sardegna	45.7	41.3	12.3	Italy
ITI1	Toscana	75.5	6.1	16.3	Italy
ITF1	Abruzzo	72.4	6.2	20.3	Italy
ITI4	Lazio	74.4	10.8	13.8	Italy
LT01	Sostinės regionas	48.2	7.6	44.2	Lithuania
LT02	Vidurio ir vakarų Lietuvos regionas	46.3	16.7	36.9	Lithuania
HU22	Nyugat-Dunántúl	63.7	17.1	18.6	Hungary
HU23	Dél-Dunántúl	59.9	21.9	17.3	Hungary
HU31	Észak-Magyarország	63.2	19.1	15.8	Hungary
HU32	Észak-Alföld	60.3	22.2	16.8	Hungary
HU33	Dél-Alföld	61.0	20.9	16.7	Hungary
PL21	Małopolskie	56.9	12.3	30.4	Poland
PL41	Wielkopolskie	61.6	16.7	21.5	Poland
PL61	Kujawsko-pomorskie	62.2	15.5	22.1	Poland
PL71	Łódzkie	68.9	12.0	18.4	Poland
PL81	Lubelskie	74.2	5.6	19.7	Poland

Source: Eurostat.

2.4. Data collection

2.4.1. Contact procedure

The contact procedure for this study aimed to ensure both the representativeness and the quality of the respondents as well as achieving the required number of respondents across multiple Member States. Potential participants for both face-to-face and online interviews in the countries covered were identified using a variety of strategies: contacting cooperatives and agricultural associations, engaging with agricultural universities, promoting through social media, advertising on work platforms, contacting chambers of commerce, purchasing business leads, using existing databases and collaborating with specialised market research companies.

Once identified, the respondents were contacted by telephone to check their willingness to participate. Screening questions were then used to confirm their eligibility. If they were eligible and willing to participate, an appointment was made for an interview either face to face or by phone/video call. Of the total number of farmers contacted in the recruitment phase, on average 10 % accepted and completed the interview.

2.4.2. Fieldwork

The main fieldwork phase involved extensive data collection in the nine Member States covered (Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland), with a focus on obtaining a representative sample of the farm population. The survey used a mixture of face-to-face interviews and other methods, such as telephone or online calls.

The main fieldwork took place between June and October 2024. Interviews lasted between 40 and 50 minutes, with an average duration of 42 minutes.

The total number of interviews was 1 444. Of these, 61 % were face-to-face interviews using a computer-assisted personal interviewing (CAPI) methodology, while 39 % were telephone or web interviews using a computer-assisted telephone interviewing (CATI) methodology (Gourlay et al., 2021; Kevala, 2023).

2.5. Weighting

To ensure consistency and alignment with the distribution of the real farming population in Europe with regard to specific characteristics, a weighting ([12]) system was developed and applied at two levels: first, by farm specialisations within each Member State (within-country), and second, by the number of farms in all nine Member States covered (across-country). The within-country weights were designed to ensure that the distribution of surveyed farms across farm specialisations reflected the actual distribution of the farm population in that Member State. At the country level, the weights were intended to reflect the distribution of the farm population across the Member States covered, assigning greater weight to Member States with larger farm populations. The results presented in this report are based on the weighted sample. When reporting results at the Member State level, the survey data are weighted using the within-country weights to ensure representativeness within each country. When reporting results for the overall sample, the data are

([12]) The process of weighting involves emphasising the contribution of some observations (giving them more weight in the analysis) over others so that the weighted sample matches the real population.

weighted using both within- and across-country weights, ensuring representativeness for the EU agricultural population surveyed (i.e. the Member States surveyed).

2.6. Econometric estimation

Multivariate regression was used to analyse the relationship (correlation) between the number of adopted digital technologies and various explanatory variables that may influence the adoption of digital technologies. Regression analysis enables the influence of several explanatory variables on the adoption of digital technologies to be jointly estimated. The dependent variable is the number of digital technologies adopted by each of the farmers surveyed, indicating the degree of the farmer's digitalisation.

In the econometric estimations, ordinary least squares (OLS) and Poisson regressions are used. Both regressions are used in order to check the robustness of the results. The Poisson regression (see Wooldridge, 2010) is also used because the dependent variable is count data showing the number of technologies adopted by the farmer, ranging between 0 and the number of technologies available to the farmer. The OLS results, if significant, are to be interpreted as the correlation of a given explanatory variable with an increase (if positive) or a decrease (if negative) in the number of technologies adopted by farmers. The results of the Poisson regression are reported in terms of the incidence rate ratios (IRR) for each explanatory variable, which represent the multiplicative change in the incidence rate per unit increase in a predictor, controlling for the remaining predictors. If significant, an incidence rate ratio value less than one indicates a negative relationship (decrease) between the explanatory variable and the number of technologies adopted, while a value greater than one indicates a positive relationship (increase).

Three groups of econometric specifications are estimated to distinguish between the types of technologies adopted: the first one to account for the number of IT and software technologies common to all types of farmers and the other two groups to account for specific technologies used in either crop or livestock production. The explanatory variables include information on farm size and specialisation, farmer gender, age, legal ownership status, land ownership status, full-time or part-time work dedication to farming, education, specific agricultural training, retirement plans, digitalisation training, farm organic production, direct sales, internet connection availability and region where the farm is located. The estimations also added two extensions of the specifications to account for the drivers of and barriers to technology adoption ([13]).

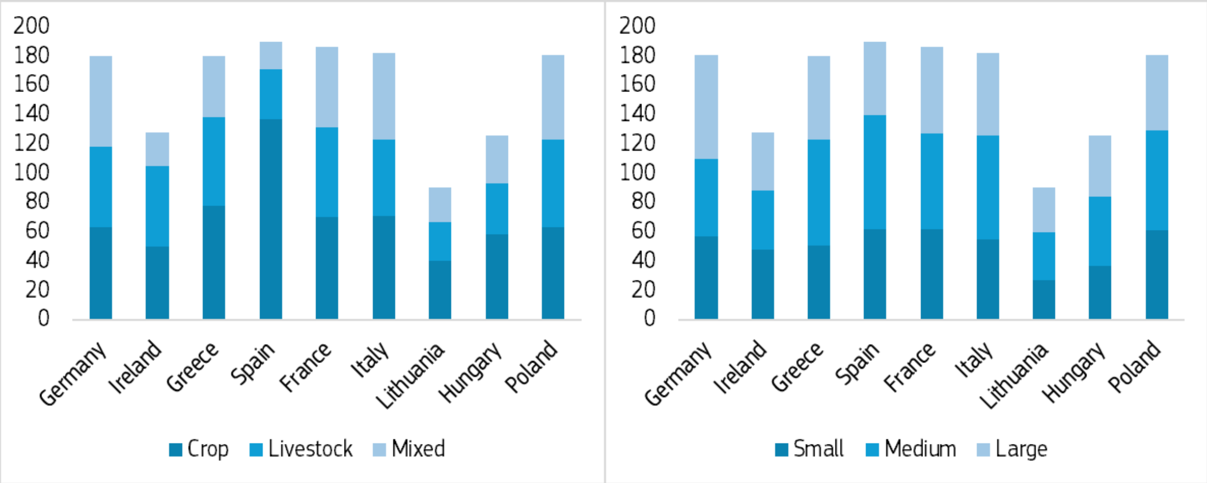
([13]) The drivers and barriers were grouped into more general categories in the econometric estimation. See Annex 4 for more details.

3. Sample description

3.1. Coverage of the study

The study collected 1 444 responses in the nine Member States covered: Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland. The number of respondents per country ranges from 180 to 190 except in the cases of Ireland, Lithuania and Hungary, where it ranges from 90 to 128. With regard to farm size, the number of respondents is fairly balanced between the categories (small, medium, large). With regard to farm specialisation, crop farms represent a significant proportion of the sample (44 %), particularly among the small- and medium-sized farms, while livestock farms represent 30 % and mixed farms 26 % of the respondents. Overall, the sample is representative of the different farm specialisations and sizes in the different Member States considered.

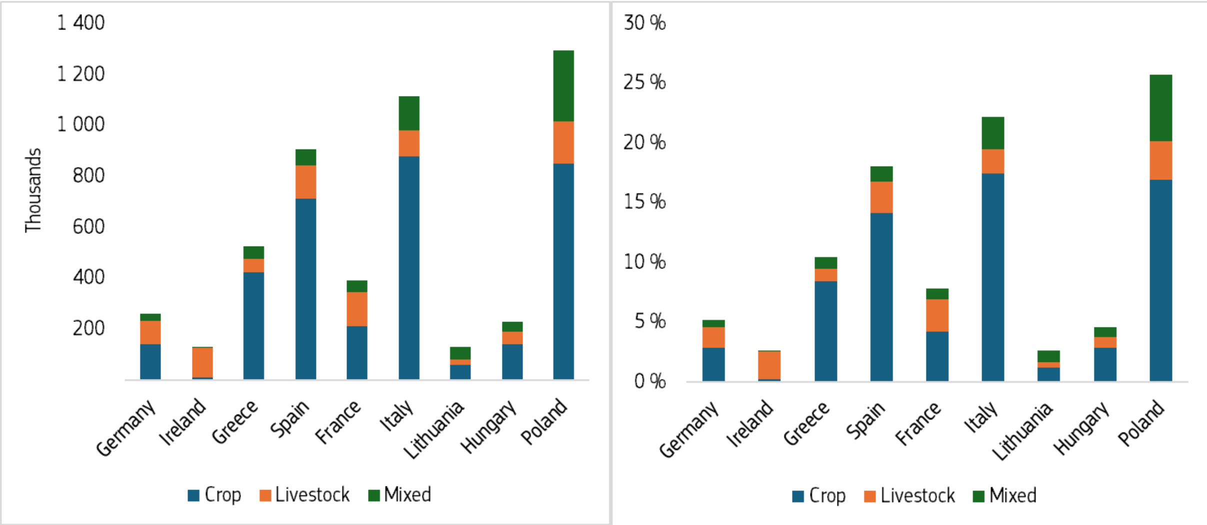
Figure 4. Number of respondents in the sample by farm specialisation, size and Member State



Source: Authors' own compilation based on the survey data.

The data obtained were weighted to reflect the characteristics of the population of farmers by country and by specialisation. Figure 5 shows that the distribution of the number of farms and the share of farm specialisations by country in the general population is well reflected in the distribution of the weighted sample. This means that the weighted sample is broadly representative of the farming population of the Member States covered along these dimensions, which increases the reliability of the analysis and the generalisability of the results.

Figure 5. Number of farms and share of farm specialisations by Member State in the general population (left) and in the weighted sample (right)

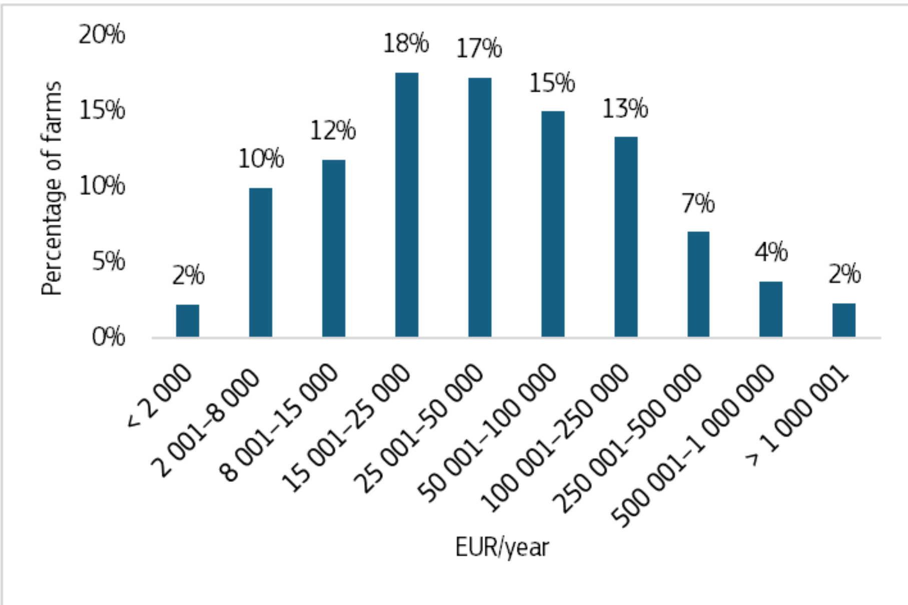


Sources: Eurostat (left) and authors' own compilation based on the survey data (right).

3.2. Farm characteristics

The average farm size in the sample was 42.4 ha (median 30 ha). The average farm size is larger than the average farm in the Member States covered (29.3 ha) (Eurostat, 2025). Most of the farms surveyed have an annual turnover of between EUR 15 000 and EUR 100 000 (Figure 6). Of the farms surveyed, 42 % reported receiving CAP subsidies, which accounted on average for 21 % of the total turnover. In addition, 41 % of the farms surveyed sell part of their production directly to consumers, accounting on average for 50 % of their income. Around 42 % of the farms surveyed also have at least part of their production certified as organic.

Figure 6. Distribution of the number of surveyed farms by turnover category (%)

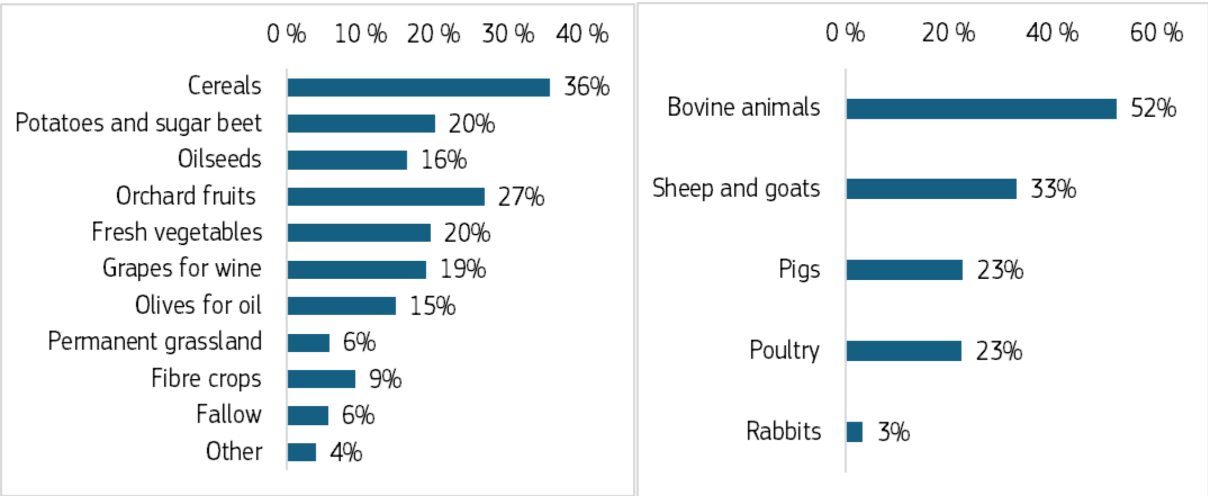


Source: Authors' own compilation based on the survey data.

3.3. Crop and animal production

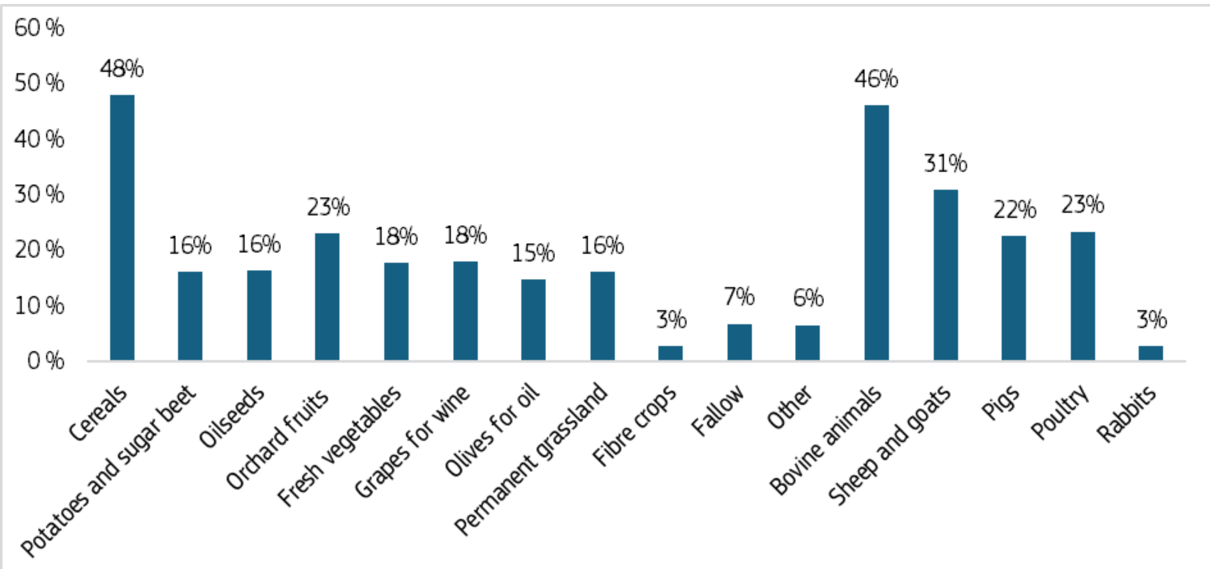
The study included three types of farms according to the defined specializations: crop farms, livestock farms and mixed-farming farms. Within each specialisation, there is a variety of crops grown and animal categories reared by the farmers surveyed. Figure 7 and Figure 8 show the percentage of surveyed farms growing specific crops or rearing specific kinds of animal. For crops, the most common were cereals, orchard fruits, potatoes and sugar beet, and fresh vegetables. For livestock farms, the most common animals reared were bovines, pigs, and sheep and goats (Figure 7). Mixed farms were mainly engaged in growing cereals and rearing bovines and sheep and goats (Figure 8).

Figure 7. Distribution of surveyed crop and livestock farms by crops grown (left) and animals reared (right), respectively (%)



Source: Authors' own compilation based on the survey data.

Figure 8. Distribution of surveyed mixed farms by crops grown and animals reared



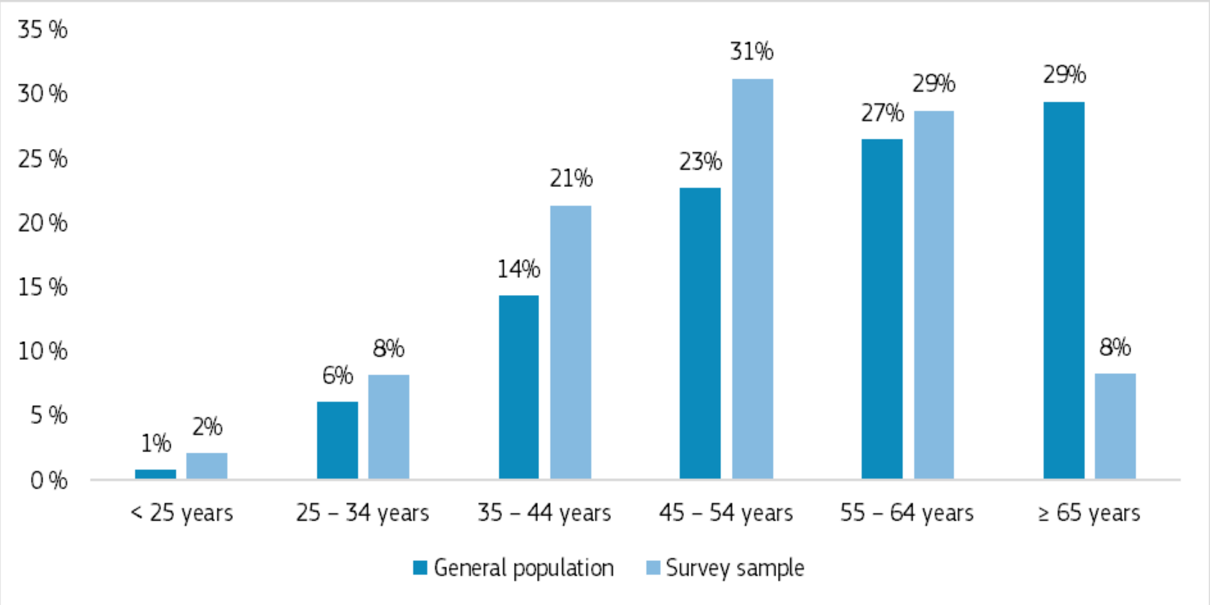
Source: Authors' own compilation based on the survey data.

3.4. Farmers' profiles

The vast majority of the farmers surveyed were male (84 %). This is broadly consistent with the gender distribution in the overall farming population in the EU, where male farmers represent slightly more than two thirds (68.4 %) of farm managers (Eurostat, 2025). The mean average age of the farmers surveyed was 50 years, with an average of 23 years of experience. Figure 9 shows the distribution of farm managers by age, both in the general population of the Member States covered and in the survey sample. The sample under-represents older farmers: while farmers over 65 years of age represent 33 % of the population, they represent only 8 % of the survey sample. Conversely, younger age groups are over-represented compared with the general farming population. This is mainly because the sample was not stratified by the farmers' ages, which led to disproportionate representation across the age categories.

The majority of farmers (89 % of the respondents) reported working full time on their farm. In terms of education, 45 % of the surveyed farmers had completed high school, 17 % had completed elementary or lower secondary education and 1 % had no education. In addition, 39 % of the farmers surveyed reported having professional training or university education in agriculture.

Figure 9. Age distribution of farm managers in the population of the Member States covered and in the survey sample (%)



Source: Eurostat (dark blue) and authors' own compilation based on the survey data (light blue).

4. Digitalisation in agriculture

4.1. Internet coverage and availability of digital devices

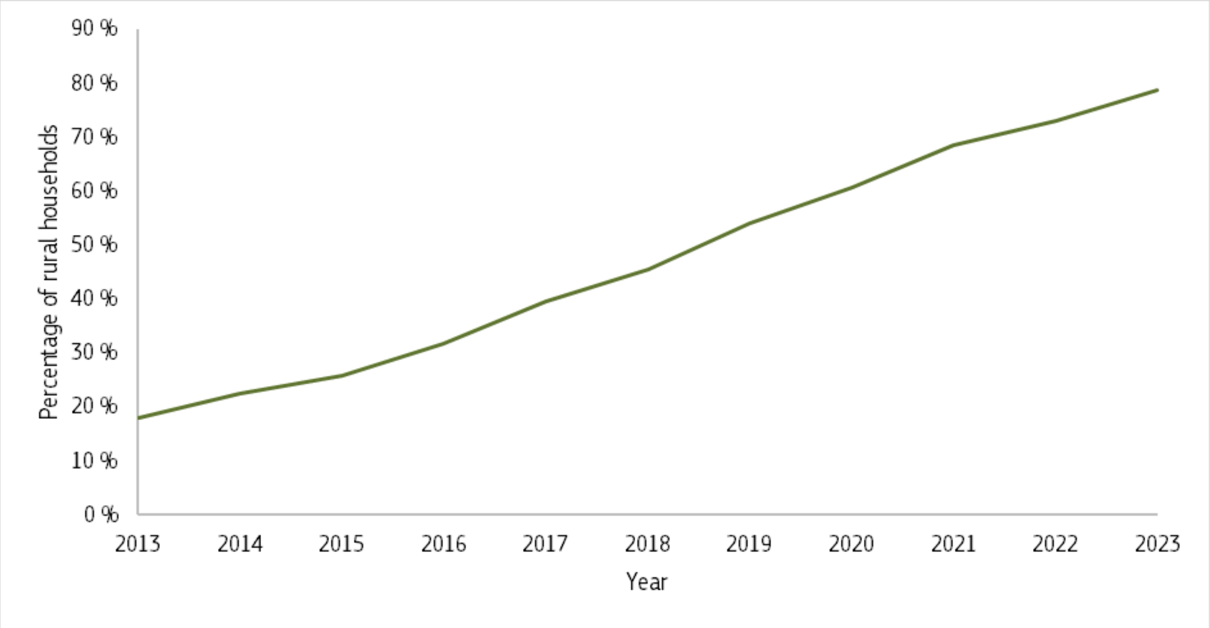
Internet access in rural areas supports the transition to sustainable food systems by facilitating access to digital services and information, thus promoting sustainable practices and technologies and supporting rural development and innovation. Connectivity also aims to bridge the digital divide and ensure equal opportunities for rural communities. Connectivity in rural areas presents a significant challenge due to the historically low profitability of infrastructure investment in these low-population-density regions. According to the *Broadband Coverage in Europe 2023* report ([14]), there has been notable progress in technology deployment, with fixed wireless access and satellite technology increasingly offering viable alternatives to conventional broadband. Satellite now provides almost universal coverage, even in the most remote areas, and there has been growing deployment of 5G technologies. These developments collectively suggest a growing focus on and investment in improving rural connectivity, aiming to address disparities with urban areas and achieve broader digital access goals. According to the Rural Next Generation Access (NGA) indicator ([15]), broadband internet coverage in rural areas of the EU has significantly increased since 2013, reaching 78.9 % coverage of EU's rural households in 2023 (Figure 10). The internet coverage of the farms surveyed seems to be in line with this trend. A significant majority of the farms surveyed (86 %) reported having internet coverage at the farm (including in the fields) that is either sufficient to meet basic usability needs or good. The most common response was sufficient internet coverage (46 %), closely followed by good coverage (40 %). In contrast, 12 % of farms reported having deficient internet coverage, indicating potential challenges in accessing reliable digital connectivity. Meanwhile, poor coverage was the least common scenario, affecting 3 % of surveyed farms, suggesting that only a relatively small proportion of farms face significant limitations in internet access.

Similarly, the farms surveyed reported widespread ownership of a range of digital devices. A large majority, 94 %, own a smartphone, indicating widespread adoption of this technology. Computers or laptops are also common, with 73 % of surveyed farms owning one. Tablets are less prevalent, with 43 % of surveyed farms reporting ownership. This distribution suggests that smartphones are the most accessible and commonly used device on farms, while computers/laptops and tablets, although less common, are still used significantly for farm-related activities.

([14]) For further details, see https://digital-strategy.ec.europa.eu/en/library/digital-decade-2024-broadband-coverage-europe-2023.

([15]) NGA connectivity provides a comprehensive framework for assessing internet quality and accessibility, making it crucial for planning and digital inclusivity efforts. It includes a variety of advanced technologies designed to meet current and future internet demands, such as fibre to the premises (FTTP), fibre to the cabinet (FTTC), very high-speed digital subscriber line (VDSL) and very high-speed digital subscriber line 2 (VDSL2), Data Over Cable Service Interface Specification (DOCSIS) 3.0/3.1, Long-Term Evolution (LTE) and 5G.

Figure 10. Share of rural households with a fixed broadband internet connection (%)

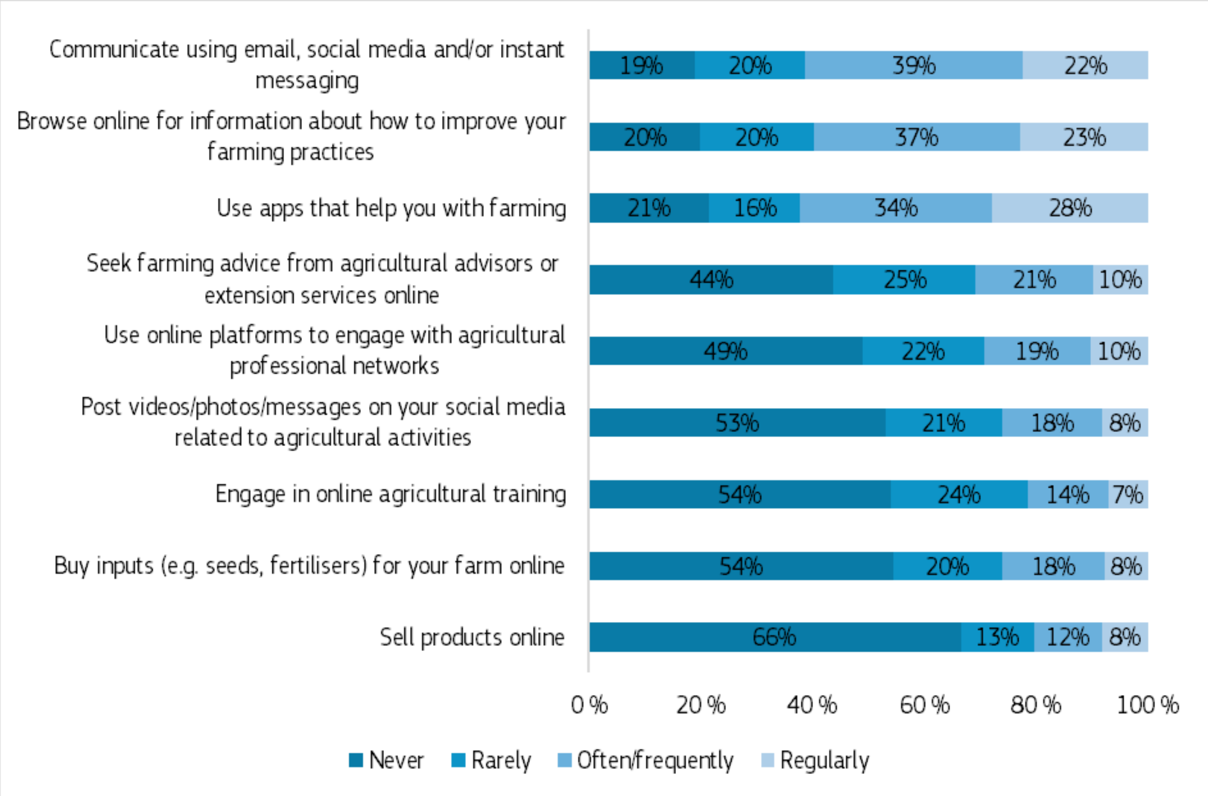


Source: Eurostat (2023), 'Rural next generation access broadband coverage' indicator.

4.2. Farmers' online activity

Figure 11 provides an insight into the types of online activities the farmers surveyed engage in for agricultural purposes and how frequently. The most common activities are communicating online (61 % of respondents often or regularly engage in this online activity), using apps to help with farming (62 %) and browsing online for information on how to improve farming practices (60 %). About half of the farmers surveyed seek online advice from agricultural advisors or extension services and use online platforms to engage with professional agricultural networks at least rarely, while half of the farmers do not. Selling products online is the least common activity, with 66 % of the farmers reporting that they never do so. Similarly, buying farm inputs online, participating in online agricultural training and posting on social media about agricultural activities (e.g. sharing videos and photos, sending messages) are not common for a large majority of the farmers, with percentages ranging from 53 % to 54 % reporting that they never engage in these activities.

Figure 11. Distribution of farmers' online activities related to agriculture (%)

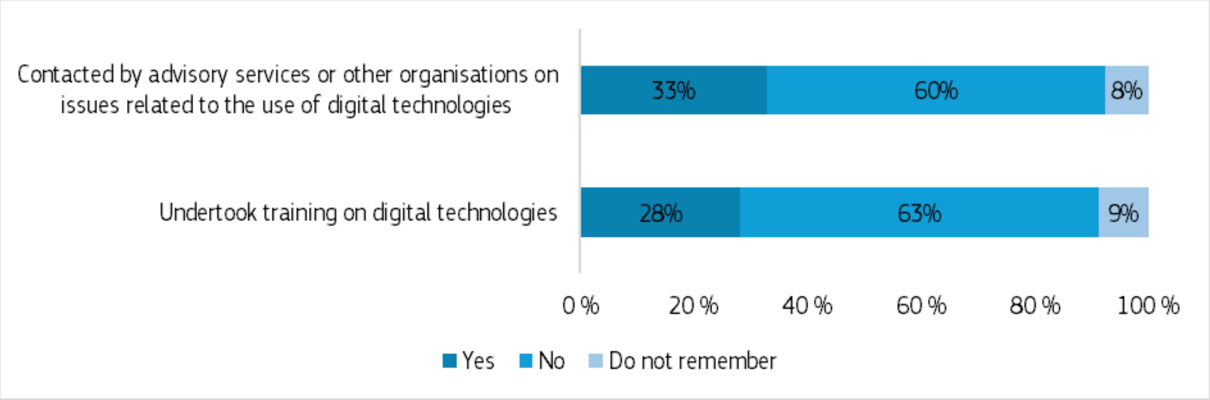


Source: Authors' own compilation based on the survey data.

While seeking online advice from extension services and using online platforms to engage with professional agricultural networks shows mixed adoption among the farmers surveyed, a significant proportion of respondents (63 %) have also not undertaken training in digital technologies, with only 28 % having done so (Figure 12). Similarly, 60 % reported not being reached out to by advisory services or other organisations regarding digital technology issues, while 33 % did receive such outreach.

These results suggest that while more advanced or interactive online activities (e.g. e-commerce, training or professional networking) are used relatively infrequently, online activities that are perceived as directly useful and easy to integrate into day-to-day farming operations (e.g. digital tools for communication, information gathering and operational support) are used more frequently and regularly. Therefore, increased outreach and training efforts could potentially improve engagement with various online agricultural activities, highlighting potential areas for policy support and digital capacity building in the agricultural sector.

Figure 12. Distribution of surveyed farmers who undertook digital training or were contacted by organisations on the use of digital technologies in agriculture (%)



Source: Authors' own compilation based on the survey data.

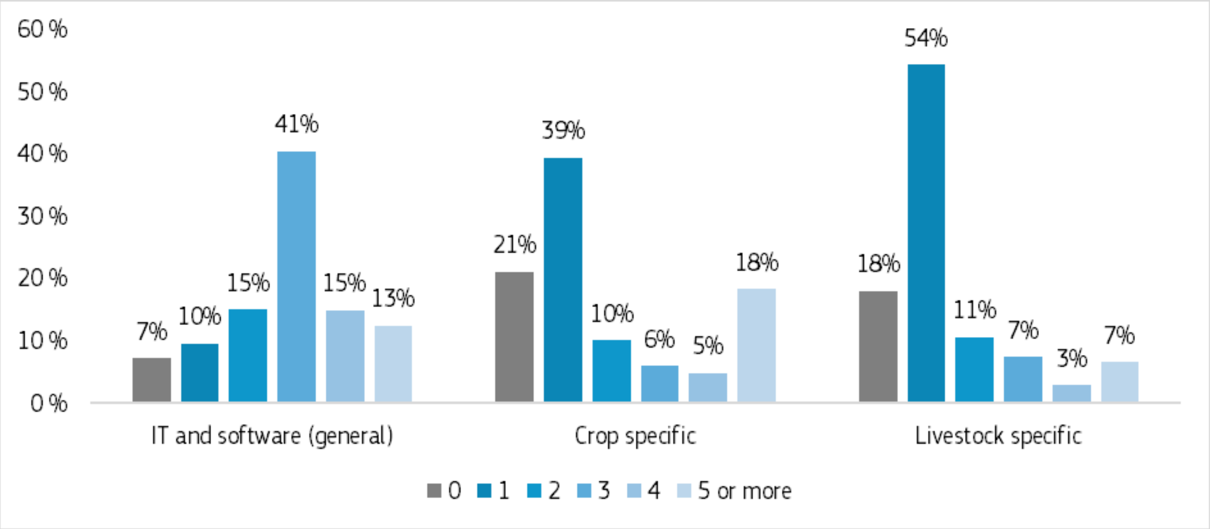
4.3. Digital technology adoption at the farm level

4.3.1. Adoption of technologies

As discussed in the methodology section, we distinguish between five general IT and software technologies common to all farms and farm-specific digital technologies tailored to crop and livestock production (19 and 8 technologies, respectively). We analyse the number of technologies adopted out of each of these three groups and the adoption rates of specific technologies across all three groups.

Figure 13 shows the number of digital technologies adopted by the farmers surveyed. The adoption of IT and software technologies is relatively common, with 93 % of respondents using at least one, and only 7 % reporting no adoption. About 10 % have adopted only one IT and software technology, 15 % have adopted two, 41 % have adopted three and 27 % have adopted four or more. The majority of farmers (68 %) have adopted at least three IT and software technologies.

Figure 13. Number of digital technologies adopted by the farmers surveyed (%)

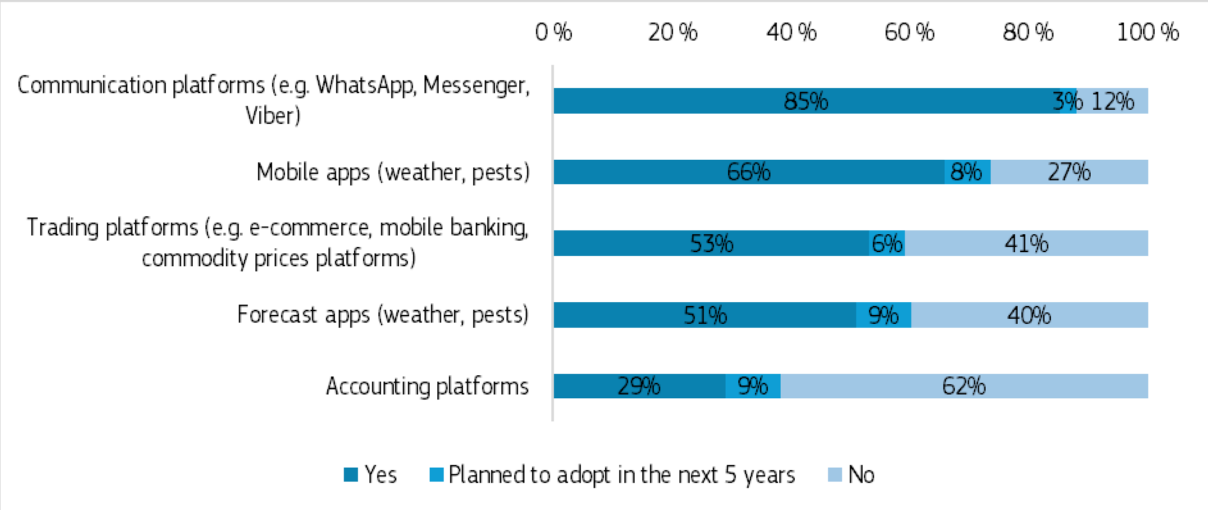


Source: Authors' own compilation based on the survey data.

The adoption rates of specific IT and software technologies by the farmers surveyed are shown in Figure 14. These rates show the relatively high level of integration of IT and software technologies into farm activities. The most widely used technologies are communication platforms (85 % of respondents) and mobile apps (66 %). The use of trading platforms (53 %) and forecast apps (51 %) is also fairly common. In contrast, accounting platforms seem to be the least used, with only 29 % of surveyed farmers reporting their use.

The adoption plans for the next five years reported by the farmers surveyed predict a modest increase in the use of IT and software technologies. Across the different technologies examined, 3–9 % of respondents intend to increase their use. Planned adoption tends to be inversely related to the current adoption rates of different technologies.

Figure 14. Adoption rates of general IT and software technologies among surveyed farmers (%)



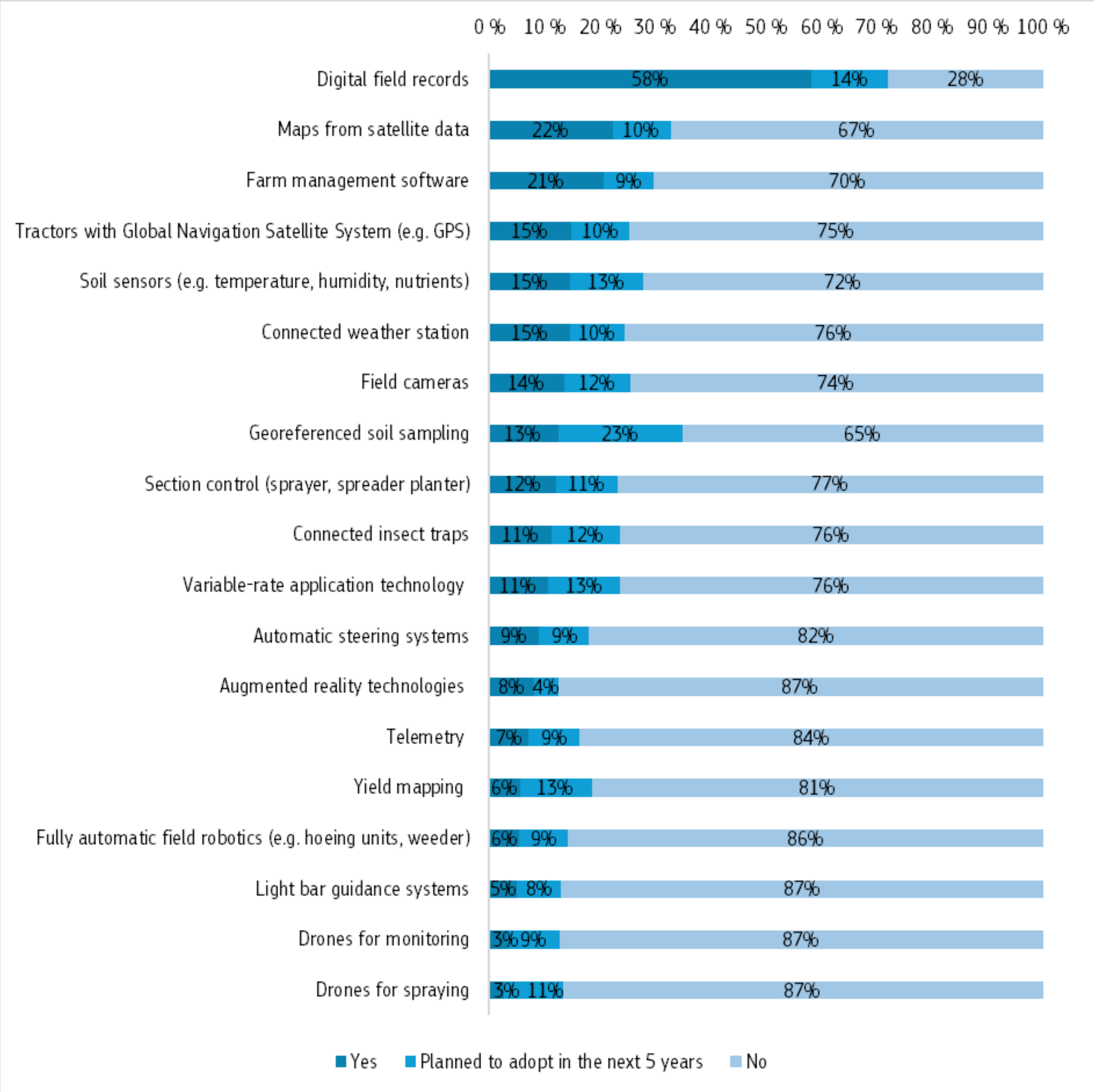
Source: Authors' own compilation based on the survey data.

The adoption rates for crop-specific digital technologies are lower than those for IT and software technologies, with 79 % of respondents using at least one and 21 % of respondents using none. Around 39 % of respondents have adopted only one crop-related technology, while 10 % have adopted two and 6 % have adopted three. Only 23 % of respondents have adopted four or more crop-related technologies (Figure 13).

The adoption rates of specific digital technologies used in crop production are shown in Figure 15. There is significant heterogeneity between the different technologies, with most of them being used by less than 25 % of the farms surveyed. The exception is digital field records, which is the most widely used technology, adopted by 58 % of respondents. This is followed by maps from satellite data (22 %) and farm management software (21 %). Drones for both monitoring and spraying are the least adopted technologies, with only 3 % of respondents using them. Automatic steering systems, telemetry, yield mapping, fully automatic field robotics and light bar guidance systems also have relatively low adoption rates (between 5 % and 9 % of respondents). For the rest of the crop-specific digital technologies considered, the adoption rate varies between 11 % and 15 %.

Farmers' plans to adopt crop-specific digital technologies in the next five years suggest a trend towards increased digital integration in farming practices, with the adoption of most technologies expected to increase by between 9 % and 15 %. Georeferenced soil sampling stands out for having a relatively low current usage rate at 13 % but the highest planned adoption rate at 23 %, indicating a growing interest in accurate soil analysis techniques.

Figure 15. Adoption rates of specific digital crop-production technologies among surveyed farmers (%)



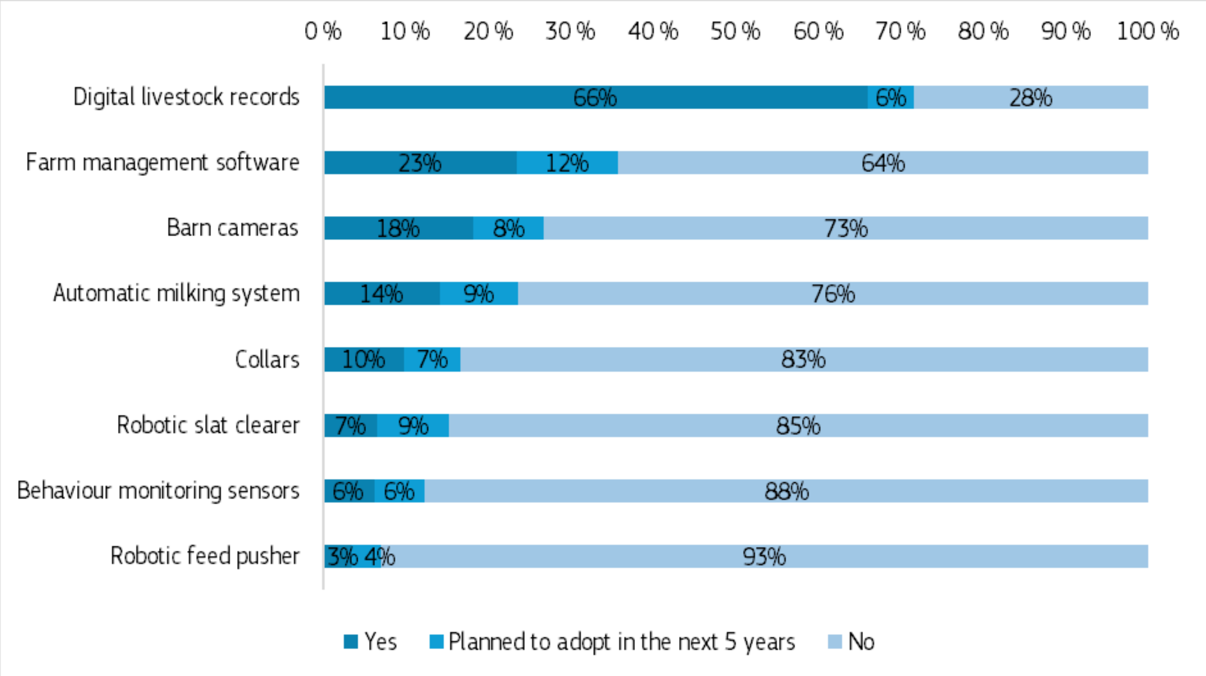
Source: Authors' own compilation based on the survey data.

The adoption rates of livestock-specific digital technologies are slightly lower than those of crop-specific digital technologies. Around 82 % of respondents use at least one livestock-specific digital technology, while 18 % report no adoption. The majority of livestock farmers (54 %) have adopted only one livestock-related technology, while 11 % have adopted two. Only 17 % of respondents have adopted three or more (Figure 13).

In terms of specific livestock technologies (Figure 16), digital livestock records are the most commonly adopted by respondents (66 %). The remaining technologies have adoption rates below 25 %. Farm management software (23 %), barn cameras (18 %) and automatic milking systems (14 %) show moderate adoption rates. The lowest adoption rates are found for robotic feed pushers

(3 %) and behavioural monitoring systems (6 %). Rates of planned adoption in the next five years range from 4 % to 12 %, suggest increases in the use of these technologies by the farmers surveyed. Farm management software is the technology most likely to be adopted in the next five years (12 %), followed by automatic milking systems (9 %) and robotic slat clearers (9 %). The least currently adopted livestock technology – the robotic feed pusher – also has the lowest planned adoption rate (4 %).

Figure 16. Adoption rates of specific digital livestock-production technologies among surveyed farmers (%)



Source: Authors' own compilation based on the survey data.

The above analyses suggest that basic digital technologies are widely adopted and well integrated into farm operations. Online communication platforms and mobile apps are commonly used across farms, reflecting a high level of familiarity and comfort with general IT and software tools. However, there is a clear gap between the use of these general easy-to-use digital tools and the adoption of farm-specific technologies. While IT and software solutions are widespread, with few exceptions, digital tools tailored to crop and livestock production are much less commonly adopted, revealing a two-speed digitalisation trend within the sector. Moreover, there is considerable variation in the level of adoption within each group of farm-specific technologies, with a few tools being more widely used, while most others have very limited uptake or remain niche. These patterns highlight the need for a more targeted approach to digitalisation in agriculture. A one-size-fits-all strategy is unlikely to be effective; instead, policies and extension services should be tailored to the different adoption dynamics of different types of technologies. It should also be noted that not all technologies are necessarily suitable for all farms, as their applicability depends, among other factors, on the scale of operation, the production structure and the farm specialisation (e.g. an automatic milking system would not be relevant for livestock farms focusing on activities other than milk production). In addition, many agri-tech solutions on the market may not be adequately tailored to the needs, scale or context of different farming systems (e.g. Rose et al., 2016; Klerkx and Rose, 2020; Gabriel and Gandorfer, 2023). Accordingly, expectations of digital adoption should be based on the practical relevance and availability of each technology, rather than expecting 100 % uniform adoption across all farm types.

Further analyses of technology adoption rates reveal additional differences by Member State, farm size and farmer age, which are discussed in next sections.

4.3.1.1. Adoption of technologies by Member State

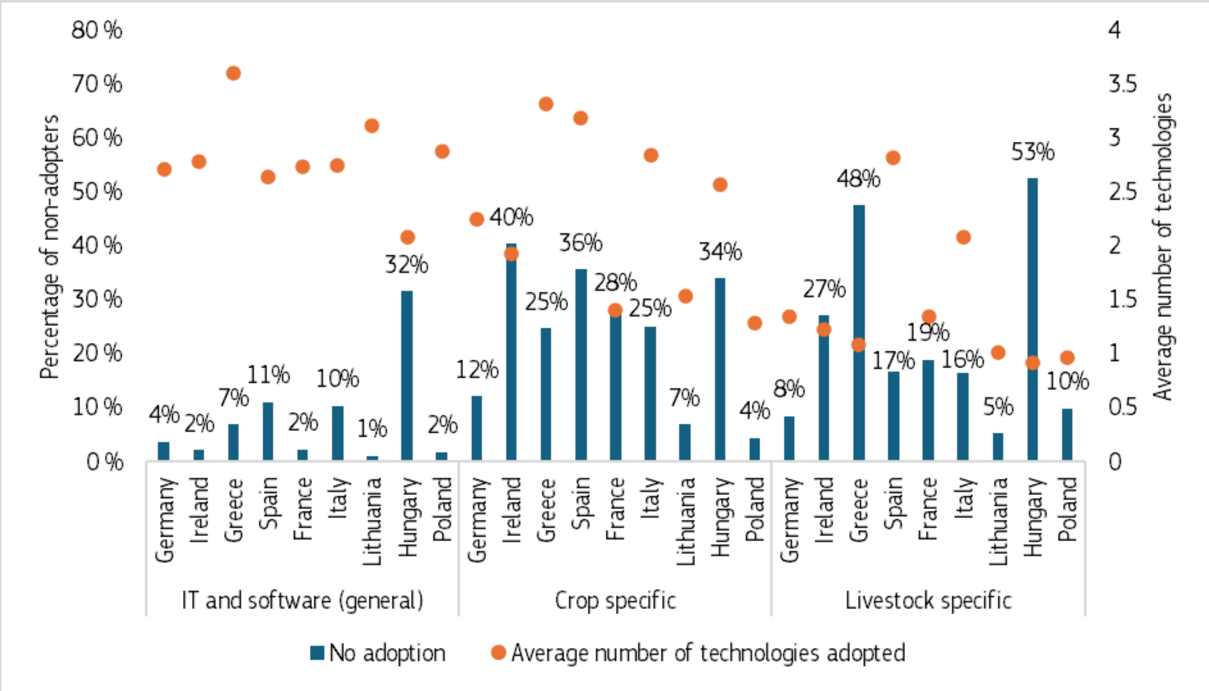
Further analysis suggests that national factors may influence the use of digital tools in farming. National differences in the adoption of agricultural technologies are observed, possibly influenced by a variety of factors including economic conditions, agricultural practices, government policies and cultural perceptions of technology (Gabriel and Gandorfer, 2023; Kroupová et al., 2025). Figure 17 shows the differences between the Member States covered with regard to the percentage of non-adopters and the average number of digital technologies adopted. For general software and IT technologies, Hungary has the highest non-adoption rate (at 32 %) and the lowest average number of technologies adopted (at 2.1), whereas Greece stands out with a relatively high average number of technologies adopted (3.6) and a moderate proportion of non-adopters (7 %). In the rest of the Member States covered, the share of non-adopters ranges between 1 % and 11 % and the average number of technologies adopted between 2.6 and 3.1.

For crop-specific technologies, Ireland has the highest non-adoption rate at 40 % and a moderate average number of technologies adopted at 1.9; conversely, Poland has the lowest proportion of non-adopters (4 %) and also the lowest average number of technologies adopted (1.3). In the remaining Member States, the proportion of non-adopters ranges from 7 % to 36 % and the average number of technologies from 1.4 to 3.3 (Figure 17).

For livestock technologies, Hungary and Greece exhibit the highest non-adoption rates (53 % and 48 %, respectively) and a below-average number of adopted technologies (0.9 and 1.1, respectively). Lithuania has the lowest proportion of non-adopters (5 %) and one of the lowest average numbers of adopted technologies (1.0). In the other Member States covered, the proportion of non-adopters ranges between 8 % and 27 % and the average number of technologies adopted between 1.0 and 2.8 (Figure 17).

Overall, the survey data indicate a mixed picture of the proportion of non-adopters and the average number of technologies adopted across countries. However, Greece and Hungary tend to have higher non-adoption rates across all technology categories, while Germany, France and Poland generally have lower non-adoption rates. The picture is less clear with respect to the average number of technologies adopted. Spain and Italy tend to have on average a larger number of technologies adopted, whereas Lithuania and Poland appear to, on average, have a lower number of technologies adopted.

Figure 17. Percentage of non-adopters and average number of digital technologies adopted by Member State



Source: Authors' own compilation based on the survey data.

Regional differences also appear in the adoption of specific technologies. Northern Europe, exemplified by Member States such as Germany and Ireland, shows high usage of forecast apps and digital field records. This pattern may reflect an emphasis on climate prediction and data management, possibly influenced by variable weather conditions that require precise forecasting for effective crop and livestock management. The preference for decision-making technologies in these Member States may also be linked to factors such as well-developed infrastructure and access to advanced data analytics (Figure 37, Annex 2).

Southern European Member States, like Spain and Italy, demonstrate significant use of trading platforms and pest management technologies. This may reflect the importance of market connectivity and pest control in regions with diverse agricultural production and a high specialisation in the production of less-processed consumer products (e.g. fruits and vegetables). Climatic conditions and the need to monitor and manage pest impacts more intensively may be driving these technological preferences (Figure 37, Annex 2).

In eastern Europe, including Member States such as Lithuania and Poland, there is high adoption of communication platforms, indicating the need to connect with professional farm networks and other supply chain stakeholders. However, there is less engagement with more complex technologies, which may be attributed to economic constraints or limited access to advanced agricultural tools. In this region, more accessible and easier-to-use digital communication tools appear to be an essential means of supporting farm operations, especially where more advanced solutions may be out of reach (Figure 37, Annex 2).

Western European Member States, such as France, show moderate use of a variety of technologies. The diversity of agriculture in this region may require a more balanced approach, with moderate investment in both basic and more advanced digital tools (Figure 37, Annex 2).

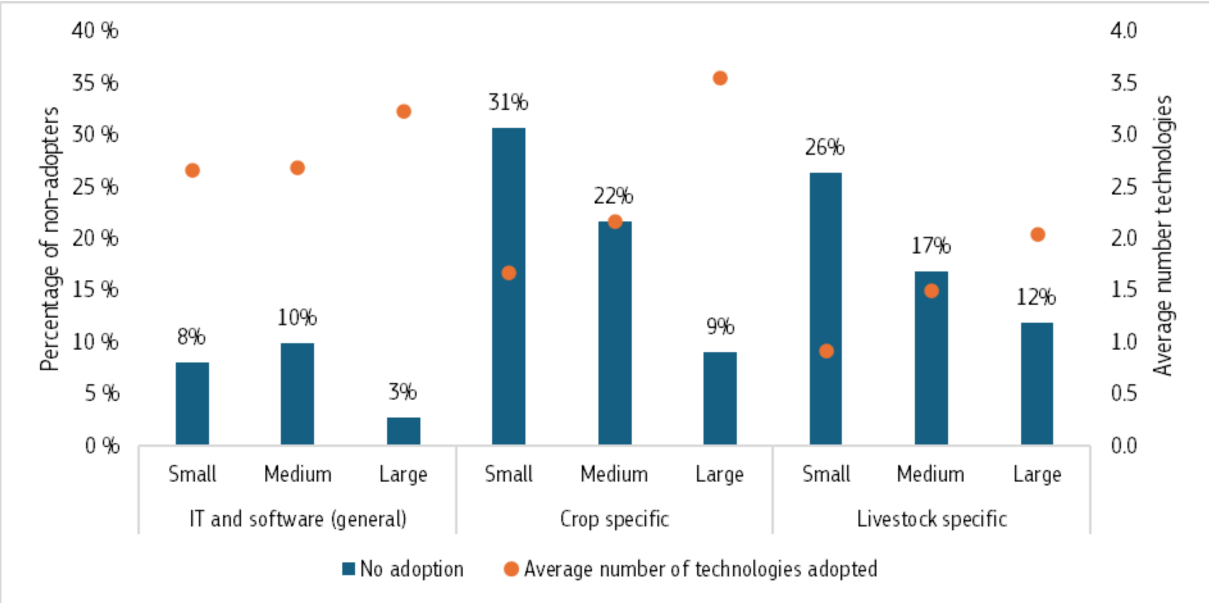
Southern and eastern Europe also display a moderate use of certain digital tools like georeferenced soil sampling and accounting platforms. This indicates a recognition of the importance of detailed data in improving yield and efficiency but highlights a slower transition to automation, possibly due to cost issues or a focus on technologies that provide a more immediate return on investment (Figure 37, Annex 2).

Overall, national and regional differences in the adoption of digital technologies across the EU are shaped by a combination of factors, including the specific structure of the agricultural sector, economic conditions, access to capital and financial support, the quality of infrastructure and the availability of technology. Cultural familiarity with digital tools and varying levels of digital literacy may also contribute to the diversity of technology adoption across regions (Rotz et al., 2019; Kroupová et al., 2025).

4.3.1.2. Adoption of technologies by farm size

The survey data suggest that smaller farms are generally less likely to adopt digital technologies, although there is considerable heterogeneity across technologies. Figure 18 shows the proportion of non-adopters and the average number of adopted digital technologies by farm size. The share of non-adopters decreases the larger the farm size, indicating that smaller farms have lower adoption rates than larger farms. This is particularly the case for crop-specific and livestock-specific technologies. For the average number of technologies adopted, the figure shows a positive relationship: the number increases with farm size.

Figure 18. Percentage of non-adopters and average number of digital technologies adopted by farm size



Source: Authors' own compilation based on the survey data.

The adoption of specific technologies also appears to be related to farm size, with some heterogeneity across technologies. For small operations, there is a notable reliance on general technologies like forecast apps (57 %) and communication platforms (83 %). However, smaller farms show lower adoption rates of more advanced technologies such as automatic steering systems (1 %), drones for monitoring (1 %), robotic feed pushers (2 %) and yield mapping (1.8 %). This may be due to financial constraints, low perceived benefits or the limited suitability of such tools for small-scale production (Figure 38, Annex 2).

Medium-sized farms show a higher adoption rate than large farms for several technologies, in particular digital livestock records (98 %), digital field records (96 %), farm management software (33 %), maps from satellite data (29 %), automatic milking systems (25 %) and georeferenced soil sampling (22 %). In contrast, they show a lower adoption rate than small and large farms for telemetry (6 %), accounting platforms (25 %), forecast apps (45 %) and communication platforms (82 %). Their adoption rates tend to be generally lower than those of larger farms, although the difference is not as pronounced as that between small and large farms (Figure 38, Annex 2).

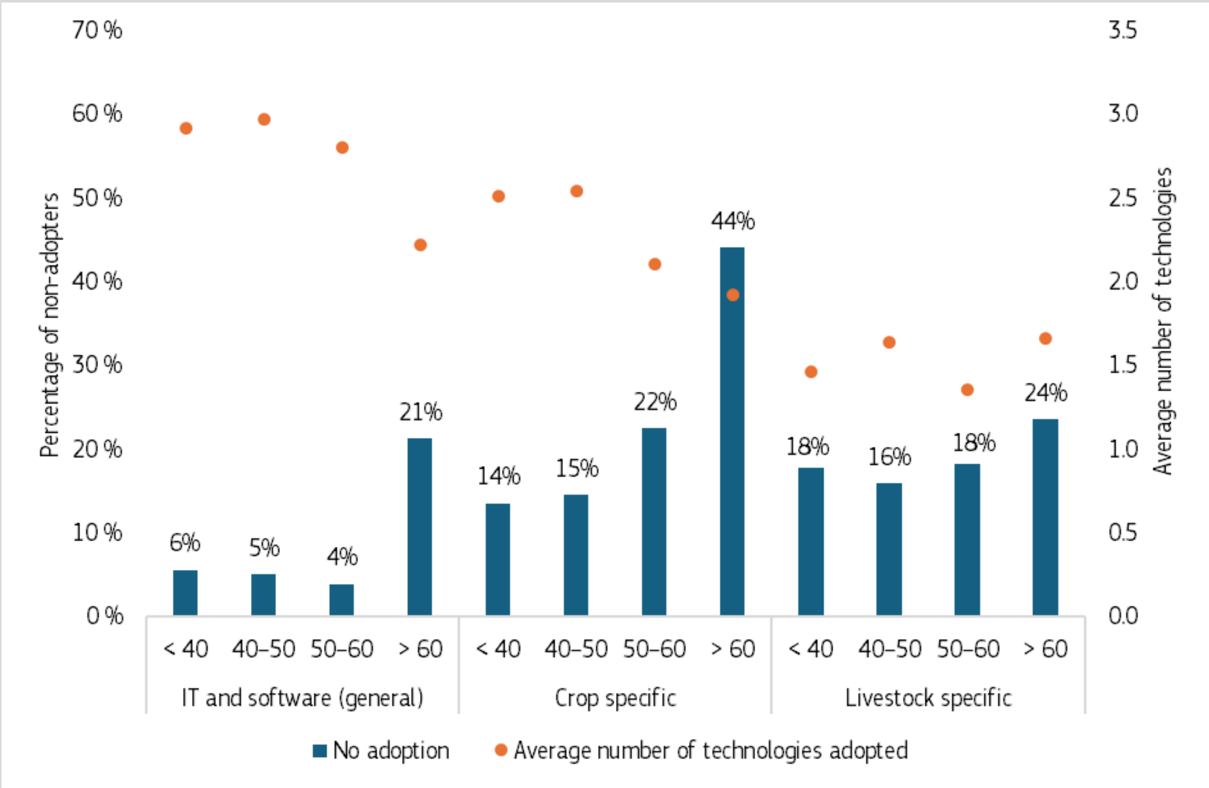
Large farms generally show the highest adoption rates across most digital technologies, suggesting both the willingness and capacity to invest in tools that enhance productivity and precision. However, there are a few exceptions: large farms report lower adoption rates than both small and medium-sized farms for field cameras and augmented reality technology and lower adoption rates than small farms for forecast apps. As noted above, the adoption gap between large and medium-sized farms is less pronounced than that between large and small farms, and in some cases large farms actually perform worse than medium farms. The largest adoption gaps between large and small/medium farms are observed for mobile apps, trading platforms, accounting platforms, tractors with GNSS, robotic slat clearers and telemetry, with adoption rates for larger farms of 77% (mobile apps), 65% (trading platforms), 38% (accounting platforms), 19% (tractors with GNSS), 13% (robotic slat clearers) and 13% (telemetry) (Figure 38, Annex 2).

Overall, farm size significantly influences the adoption of digital technologies. Larger farms tend to integrate a broader range of advanced digital tools into their operations. Medium-sized farms show substantial, though less comprehensive, adoption patterns compared with large farms. In contrast, small farms rely more heavily on easy-to-use digital tools, with limited uptake of more advanced technologies. These patterns suggest that operational scale plays a crucial role in shaping the adoption strategy of digital tools in EU agriculture. The findings are consistent with the broader literature, which also reports a positive relationship between farm size and adoption rates – probably due to greater access to capital, economies of scale that enhance cost-efficiency and higher levels of skills and organisational capacity (Pierpaoli et al., 2013; Tamirat et al., 2017; Kernecker et al., 2020; Shang et al., 2021).

4.3.1.3. Adoption of technologies by the age of the farm manager

Age also appears to be related to the adoption of digital technologies in EU agriculture. Younger farmers tend to adopt digital technologies more often. Indeed, Figure 19 shows that the proportion of non-adopters and the average number of technologies adopted seem to be related to the age of the farm manager. A higher percentage of non-adopters and a lower average number of technologies adopted are especially observed in the older groups of farmers. However, this pattern is weaker and more heterogeneous than the relationship between digital technology adoption and farm size. In particular, age seems to play a smaller role in the adoption of livestock-related technologies: while older farmers are more likely to be non-adopters, there is no clear relationship between age and the average number of technologies adopted.

Figure 19. Percentage of non-adopters and average number of digital technologies adopted by farmer age group



Source: Authors' own compilation based on the survey data.

When looking at specific technologies, there are also differences between age groups, with variations depending on the type of technology. For general IT and software, the key difference in the adoption rates is between farmers under 60 and those over 60 years old: the younger group shows higher adoption rates for mobile apps, communication platforms and trading platforms, while the older group shows higher adoption rates for forecast apps and accounting platforms (Figure 39, Annex 2).

For crop-specific digital technologies, adoption rates generally tend to decrease with the age of the farmer. Technologies for which younger farmers show significantly higher adoption rates than older farmers include digital field records, georeferenced soil sampling, fully automated field robotics, drones for spraying, section controls, variable-rate application technology and augmented reality technology. However, for several crop technologies – such as automatic steering systems, maps for satellite data and connected weather stations – there are no clear age-related adoption patterns (Figure 39, Annex 2).

For livestock-specific digital technologies, adoption rates generally appear to be the least correlated with farmer age. In fact, for several technologies – such as farm management software, automatic milking systems and robotic slat clearers – older farmers show higher adoption rates than younger farmers. Younger farmers show a higher adoption rate for digital livestock records. For the remaining technologies – such as barn cameras, behavioural monitoring sensors, collars and robotic feed pushers – no clear age-related adoption patterns are observed (Figure 39, Annex 2).

Overall, adoption and use rates tend to be lower for older age groups for most digital technologies, suggesting a potential age-related digital divide in the adoption of modern agricultural technologies.

Young farmers' higher adoption rates of digital technologies despite having lower initial investment capacity may be explained by the potential of these technologies to introduce innovative practices and business opportunities. Meanwhile, older farmers – who typically have greater financial capacity and resources for investment – may invest less due to their individual choices regarding risk, retirement and uncertain succession. This divide is particularly evident for general and crop-specific technologies, for which younger farmers consistently exhibit higher adoption rates. For livestock-related technologies, however, the relationship with age is weaker and more heterogeneous, with some tools even showing higher adoption rates among older farmers. The literature generally finds that younger farmers are more likely to adopt digital technologies than older farmers, although the relationship can vary by technology type, context (e.g. digital literacy) and region (Rose et al., 2016; Barnes et al., 2019a; Shang et al., 2021; Kroupová et al., 2025).

4.3.2. Trends in adoption

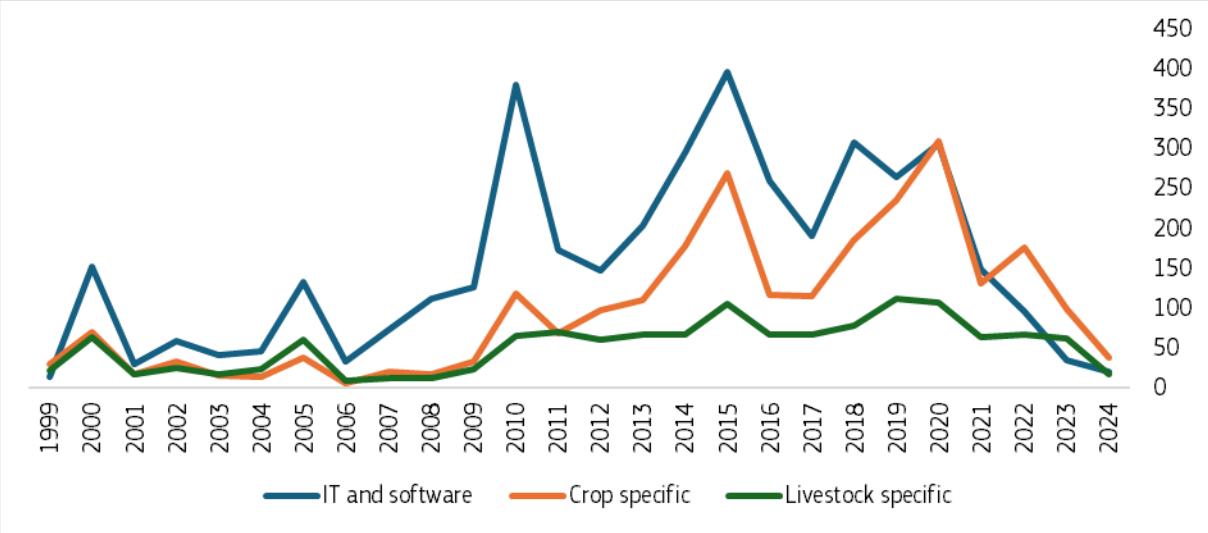
To analyse the temporal dynamics of digital technology adoption among the farms surveyed, Figure 20 presents the total number of technologies adopted over time, based on the farmers' reported adoptions each year for the three categories considered: IT and software technologies, crop-specific technologies and livestock-specific technologies. The figure covers 1999 to 2024. These trends reflect the evolving patterns of technology integration among the farms surveyed, highlighting periods of rapid uptake and periods of stabilisation within each category. It is important to note that the trends shown in Figure 20 are specific to the sample surveyed and do not represent the entire agricultural sectors of the Member States covered during the period considered.

Figure 20 shows that the total number of technologies adopted by the surveyed farms stagnated between 1999 and 2008, followed by an increase from 2008 to 2020 and a decrease from 2020 to 2024. In the second period (2008–2020), a particularly strong increase is observed for IT and software and crop technologies. This suggests an increasing acceptance and implementation of digitalisation technologies in agriculture by the respondents, likely driven by efficiency gains and the expanding availability of these technologies. In addition, this trend may be influenced by the spread of internet access in rural areas, as indicated in Figure 10. The adoption peaks could also be related to innovation cycles, market conditions or the impact of support programmes ([16]). In contrast, the trend for livestock technologies shows moderate stability, with relatively steady adoption rates in general and less pronounced fluctuations compared with the other two categories. This suggests that technology adoption in the livestock sector may be slower due to the technology lifecycle in this sector, with innovation occurring more gradually and steadily.

For all three technology categories considered, there is an apparent decline in their adoption by the farms surveyed between 2020 and 2024, indicating a reversal of the adoption trend from the previous years. This could be due to a general reluctance to invest due to economic uncertainty and recent crises (e.g. COVID-19 and the Russian invasion of Ukraine), which appear to have reduced the adoption of digital technologies. This decline is likely to be due to increased financial uncertainty for farmers, such as higher energy costs and greater market volatility.

([16]) For example, the European Innovation Partnership for Agricultural Productivity and Sustainability, rural development programmes under the CAP, Horizon 2020 and the Leader programme / the community-led local development approach.

Figure 20. Number of digital technologies adopted by the farms surveyed, by year

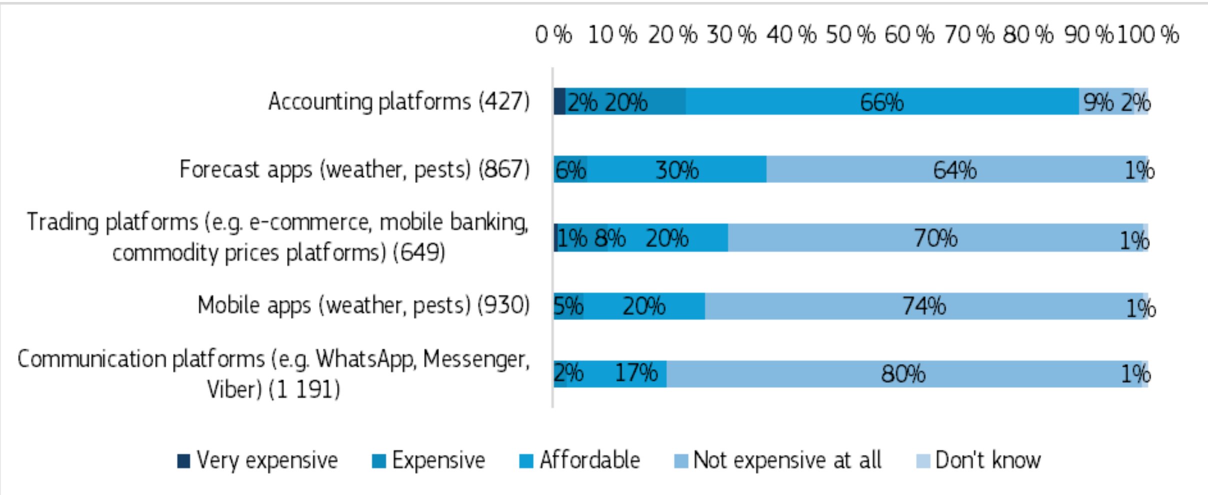


Source: Authors' own compilation based on the survey data.

4.3.3. Cost of adoption

Figure 21, Figure 22 and Figure 23 show the perceived costs of adopting digital technologies as reported by the farmers surveyed. The costs of adopting IT and software technologies appear to be largely perceived as inexpensive by the farmers surveyed (between 75 % and 97 % of respondents), with the exception of accounting platforms, which are perceived as more expensive compared with the other categories but still largely affordable for most users (75 %). A smaller percentage of respondents (22 %) consider the accounting platforms to be expensive or very expensive. The remaining IT and software technologies are perceived as expensive by less than 10 % of respondents (Figure 21).

Figure 21. Perceived costs of adopting IT and software technologies as reported by the farmers surveyed (%)



NB: The number of observations for each technology is given in brackets.
Source: Authors' own compilation based on the survey data.

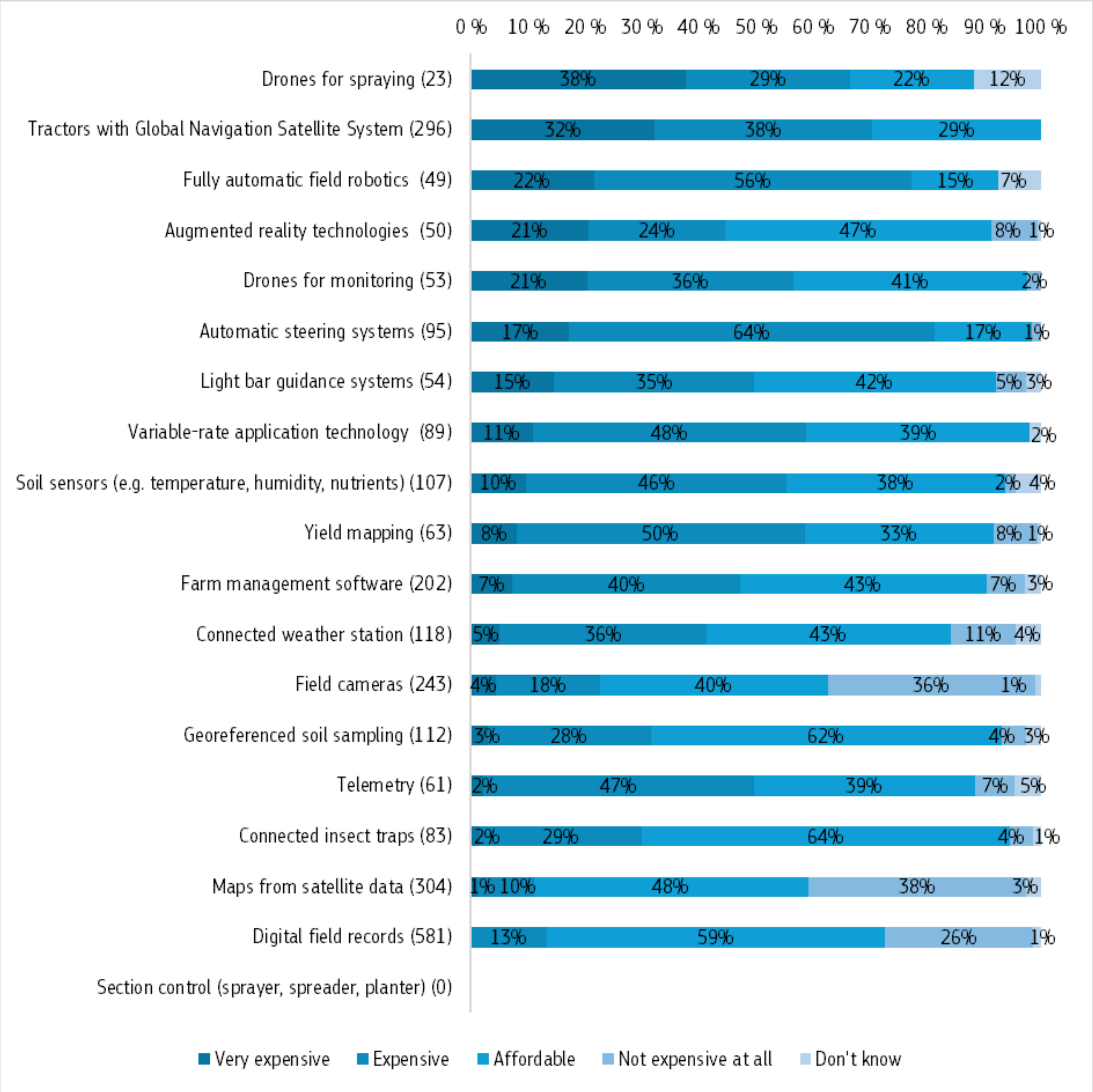
The farmers surveyed perceive crop-specific digital technologies as more expensive than IT and software technologies. A significant majority of respondents perceive GNSSs (70 %), fully automatic field robotics (77 %) and automatic steering systems (81 %) as expensive or very expensive, indicating a perception of high cost associated with these technologies. Drones for spraying also fall into this category, with most respondents (67 %) considering them expensive (Figure 22).

Variable-rate application technology, drones for monitoring, soil sensors and yield mapping are perceived as more affordable, but a majority of respondents still consider them very expensive or expensive (59 %, 57 %, 56 % and 58 %, respectively) (Figure 22).

Light bar guidance systems, farm management software and telemetry are more balanced in perception, with around half of respondents considering them affordable (50 %).

The ones considered more affordable are connected insect traps, field cameras and georeferenced soil sampling. Notably, maps derived from satellite data and digital field records stand out as technologies that many respondents view as not expensive at all (Figure 22).

Figure 22. Perceived costs of adopting crop-specific digital technologies as reported by the farmers surveyed (%)



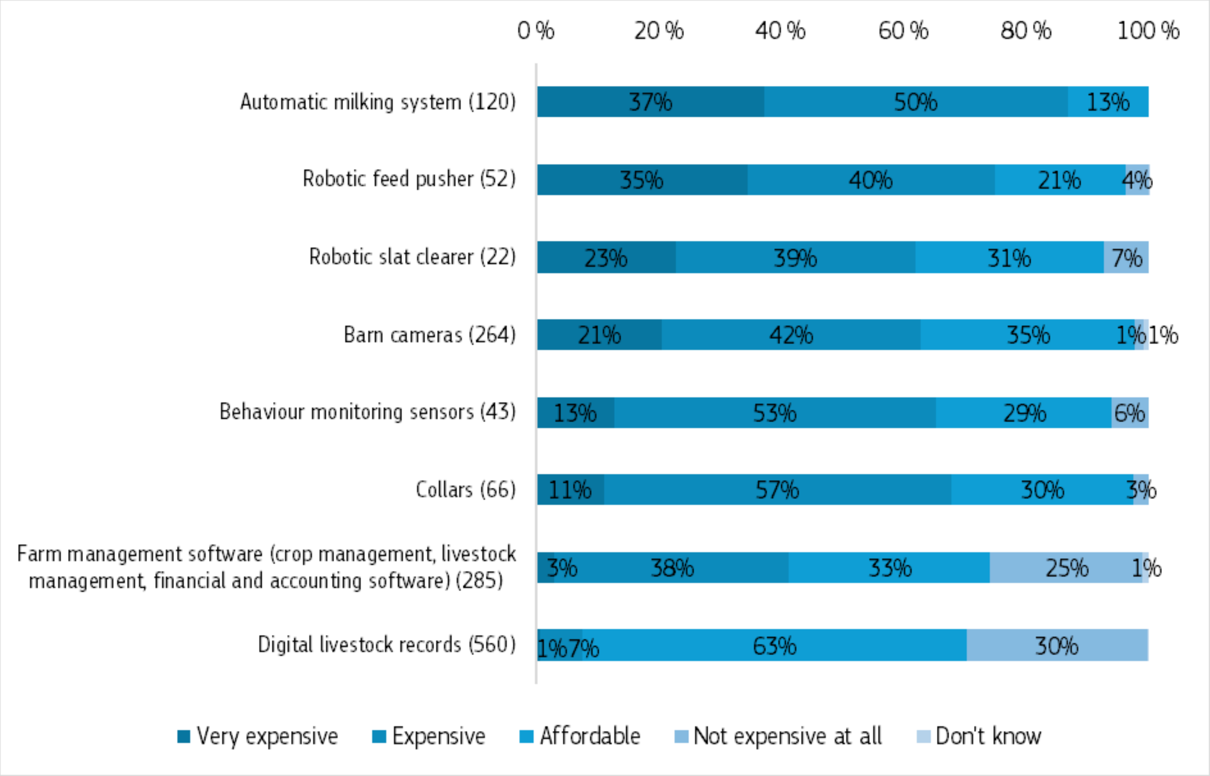
NB: The number of observations for each technology is given in brackets. There are no observations for section control technology.

Source: Authors' own compilation based on the survey data.

The farmers surveyed perceive livestock-specific digital technologies as more expensive than both IT and software technologies and crop technologies. Automatic milking systems and robotic feed pushers are commonly perceived as either very expensive or expensive (by 87 % and 75 % of respondents, respectively), with the majority of respondents indicating a significant cost barrier associated with these advanced technologies. Robotic slat clearers, barn cameras, behaviour monitoring sensors and collars for livestock also fall into this category, with the majority of respondents perceiving them as either very expensive or expensive (between 62 % and 68 %), although a significant proportion of respondents consider them affordable or not expensive (between 32 % and 38 %) (Figure 23).

Farm management software is perceived by the majority of respondents (58 %) as affordable or not expensive at all, although 41 % of respondents find it very expensive or expensive. Digital livestock records stand out, with 93 % of respondents seeing them as affordable or not expensive at all (Figure 23).

Figure 23. Perceived costs of adopting livestock-specific digital technologies as reported by the farmers surveyed (%)

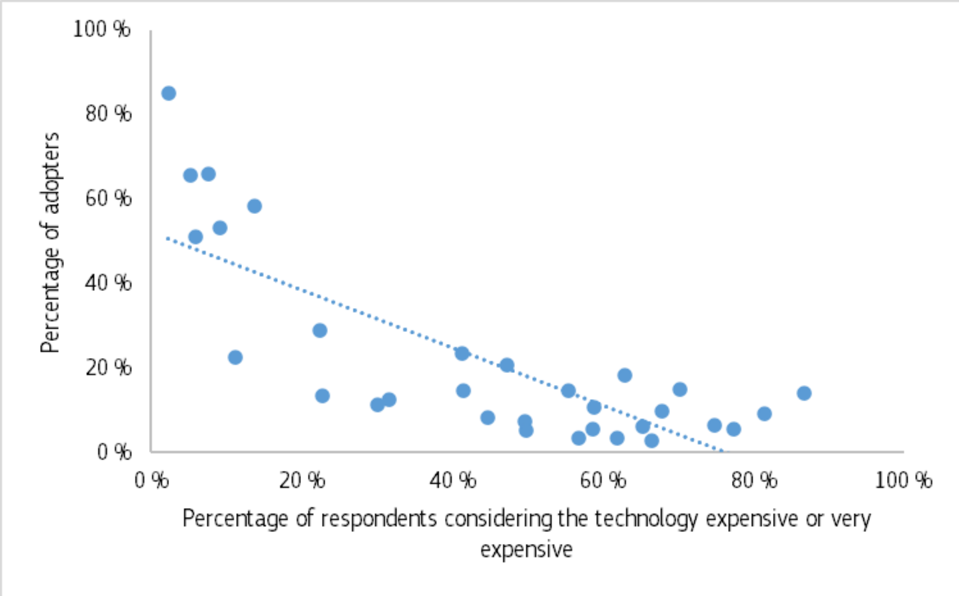


NB: The number of observations for each technology is given in brackets.

Source: Authors' own compilation based on the survey data.

Figure 24 shows the relationship between the adoption of digital technologies and their perceived cost. Adoption is negatively correlated with perceived cost: the higher the proportion of farmers who consider a technology to be expensive or very expensive, the lower the proportion of farmers who adopt it.

Figure 24. Relationship between the adoption rate of digital technologies and the cost of adoption as perceived by the farmers surveyed (all technology types) (%)



Source: Authors' own compilation based on the survey data.

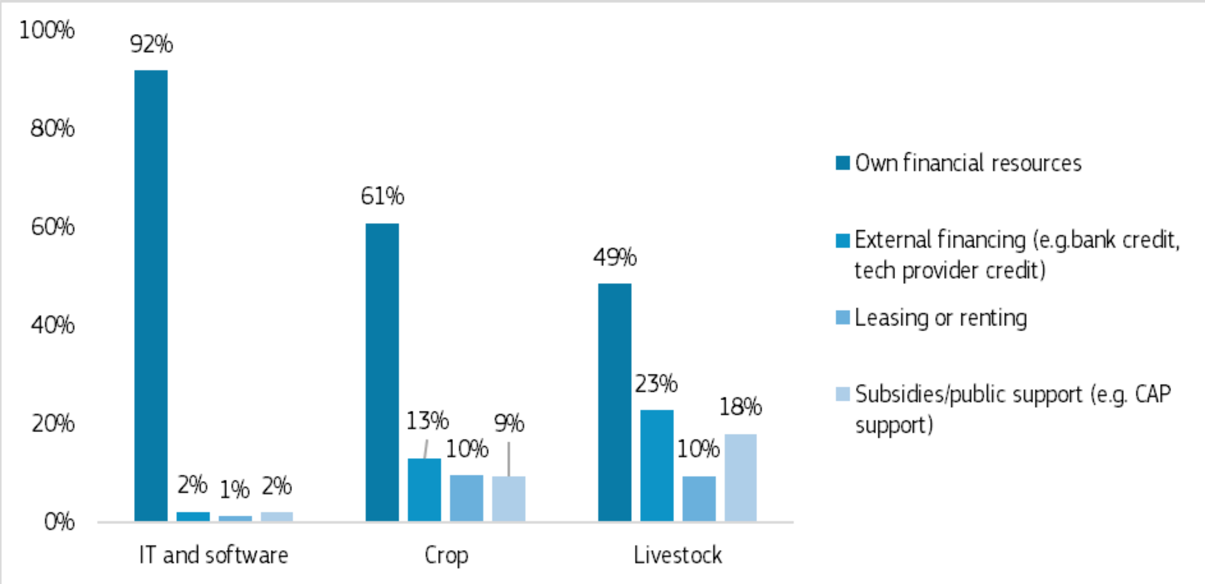
Overall, digital technologies used in livestock production are perceived as the most expensive. Automatic milking systems and robotic feed pushers are the livestock technologies most commonly considered expensive by respondents. In contrast, only a few livestock-related tools – farm management software and, in particular, digital livestock records – are considered affordable by most of the farmers surveyed. Digital crop technologies follow, with at least half being perceived as expensive, especially tractors equipped with GNSSs, fully automatic field robotics and automatic steering systems. However, several crop technologies are considered more affordable, including connected insect traps, digital field records, satellite data maps, field cameras and georeferenced soil sampling. IT and software solutions used to support the farm management are generally perceived as affordable and not expensive by most farmers surveyed. In general, digital technology adoption decreases as more farmers perceive the technology to be expensive.

These findings raise the question of how many different types of digital technologies farmers can realistically afford. For technologies that remain expensive – or are perceived as such – widespread adoption of a wide range of tools, from robots and drones to sensors, is unlikely. Farmers are therefore likely to prioritise and adopt only those digital technologies that they perceive to be both affordable and capable of delivering tangible benefits. This underlines the importance of targeted financial support or incentives, particularly for advanced livestock and crop production systems that are perceived to be very costly, rather than an undifferentiated, one-size-fits-all approach (e.g. Barnes et al., 2019a; Klerkx and Rose, 2020).

4.3.4. Sources of finance for digital technology adoption

According to the majority of respondents, technology adoption is primarily financed by the farmers' own financial resources (Figure 25). The importance of one's own resources is especially relevant for IT and software applications, where 92 % of adoption is self-financed. One's own financial resources are less important for crop technologies (61 % self-financed) and even less important for livestock technologies (49 % self-financed), but it is still the main source of financing. External financing and renting and leasing are particularly important for crop technologies (23 %) and livestock technologies (33 %), probably due to the higher costs of these technologies, as discussed in in the previous section. Subsidies and public support are the least common sources of finance for technology adoption, accounting for just 2 % of IT and software adoption, 9 % of crop technology adoption and 18 % of livestock technology adoption.

Figure 25. Overview of sources of financing for the adoption of digital technologies among the farms surveyed, by technology category (%)



Source: Authors' own compilation based on the survey data.

The main sources of finance used by respondents for adopting crop technologies are shown in Table 4. According to the majority of respondents, self-financing is the predominant form of financing most crop technologies. Digital field records are the technology most commonly self-financed at 88 %, closely followed by connected insect traps, maps from satellite data and georeferenced soil sampling, all of which were self-financed for over 80 % of respondents. For most of the other of crop technologies adopted, self-financing is the main source of funding too, with 49 % to 72 % of respondents using this method. The exceptions are drones for spraying, tractors with GNSSs and fully automatic field robotics, for which self-funding accounts for less than 40 % of the adoptions among the farmers surveyed.

Although less common than self-funding, external financing plays a significant role in the case of field cameras, where it accounts for 39 % of adoptions by the farmers surveyed, and in those of tractors with GNSSs, light bar guidance systems and fully automatic field robotics, where it finances between 24 % and 27 % of adoptions (Table 4).

The use of leasing or renting is relatively common for fully automatic field robotics and drones for spraying, with 27 % and 46 %, respectively, of adoptions by the farmers surveyed being financed in this way. Tractors equipped with GNSSs and drones for monitoring are also frequently leased or rented (20 % and 21 %, respectively) (Table 4).

The use of subsidies and public support as a source of finance for adoption is low for most crop technologies. This form of financing is used to a significant extent for automatic steering systems, tractors with GNSSs, augmented reality technologies and soil sensors at 19 %, 18 %, 19 % and 17 %, respectively (Table 4).

Table 4. Sources of financing for the adoption of digital technology in crop production among the farms surveyed (%)

	Number observations	Own financial resources	External financing (e.g. bank credit, tech provider credit)	Leasing or renting	Subsidies / public support (e.g. CAP support)	Other
Digital field records	610	88%	2%	1%	5%	4%
Connected insect traps	85	83%	6%	3%	4%	5%
Maps from satellite data	327	83%	3%	3%	5%	7%
Georeferenced soil sampling	118	80%	2%	4%	5%	9%
Yield mapping	72	72%	9%	3%	11%	6%
Light bar guidance systems	62	71%	24%	2%	3%	0%
Farm management software (crop management, livestock management, financial and accounting software)	231	67%	4%	6%	14%	10%
Augmented reality technologies (headsets, eyeglasses, goggles)	55	67%	5%	10%	19%	0%
Connected weather station	140	63%	3%	5%	10%	19%
Soil sensors (e.g. temperature, humidity, nutrients)	124	62%	11%	3%	17%	7%
Variable rate application technology (e.g. Irrigation, seeding, fertilizers, weed control)	105	59%	21%	3%	13%	4%
Automatic steering systems	115	56%	16%	8%	19%	0%
Field cameras	250	53%	39%	3%	5%	0%
Telemetry	76	51%	15%	7%	11%	17%
Drones for monitoring	58	49%	12%	21%	3%	15%
Fully automatic field robotics (e.g. hoeing units, weeder)	54	39%	24%	27%	9%	0%
Tractors with RNSS	326	33%	27%	20%	18%	2%
Drones for spraying	28	22%	13%	46%	0%	19%
Section control (e.g. sprayer, spreader, planter)	0	NA	NA	NA	NA	NA

NB: There are no observations for section control technology.

Source: Authors' own compilation based on the survey data.

The funding patterns of the farmers surveyed for livestock-related technologies show a varying reliance on different sources of finance (Table 5). Self-funding remains significant, especially for digital livestock records (financing 69 % of adoptions according to the respondents) and collars (66 %). Other technologies, such as farm management software and behaviour monitoring sensors, are also usually self-funded, at 48 % and 50 %, respectively.

External financing is quite important for high-cost technologies, notably automatic milking systems (35 %), robotic feed pushers (33 %) and robotic slat clearers (30 %). These figures indicate a reliance on bank loans or loans from technology providers for investments in automation technologies. For other livestock technologies, external finance is used as the main source of finance for between 11 % and 21 % of adoptions (Table 5).

Leasing or renting is not widely used to finance the adoption of livestock technologies, accounting for between 3 % and 9 % of adoptions. The exceptions are barn cameras and farm management software, where this form of financing is somewhat more common, accounting for 23 % and 16 % of adoptions, respectively (Table 5).

Subsidies and public support appear to be more commonly used to finance technology adoption in animal production than in crop production. They are notably important for automatic milking systems (25 %) and behaviour monitoring sensors (25 %). Subsidies also play a role in other categories, such as robotic feed pushers, barn cameras and farm management software (20 %, 19 % and 17 %, respectively). For the remaining livestock technologies – collars and digital livestock records – subsidies and public support are used as a source of finance for 14 % and 11 % of adoptions, respectively (Table 5).

Table 5. Sources of financing for the adoption of digital technology in livestock production among the farms surveyed (%)

	Number of observations	Own financial resources	External financing (e.g. bank credit, tech provider credit)	Leasing or renting	Subsidies / public support (e.g. CAP support)	Other
Digital livestock records	573	69%	11%	7%	11%	1%
Collars	73	66%	17%	3%	14%	0%
Behaviour monitoring sensors	52	50%	21%	3%	25%	0%
Farm management software (crop management, livestock management, financial and accounting software)	300	48%	19%	16%	17%	1%
Robotic slat clearer	24	46%	30%	7%	12%	4%
Barn cameras	271	41%	17%	23%	19%	0%
Robotic feed pusher	70	39%	33%	8%	20%	0%
Automatic milking system	149	29%	35%	9%	25%	1%

Source: Authors' own compilation based on the survey data.

Overall, the results suggest that the importance of self-financing for the adoption of digital technologies decreases as the technology becomes more expensive, while external financing and public support become more important in such cases. Specifically, for IT and software applications, the majority of adoption is self-financed. However, for more expensive crop and livestock technologies, farmers increasingly rely on external sources, such as loans, leasing and subsidies. Implications for farmers include the need to make strategic financial decisions about which technologies to adopt based on the resources available. While self-financing remains important, many farmers may be constrained by the high up-front costs of advanced technologies, potentially limiting their ability to adopt a wider range of digital tools. With regard to policy, the findings suggest that targeted financial support, such as subsidies or low-interest loans for credit-constrained farmers, could be essential to encourage the adoption of costly technologies and reduce the technological divide, particularly in livestock production (e.g. Shang et al., 2021; Kroupová et al., 2025).

4.4. Drivers of and barriers to digital technology adoption

Understanding what drives and hinders the adoption of digital technologies is essential for grasping the patterns of digitalisation in agriculture. The following analysis examines the main motivations for and barriers to adoption as reported by the farmers surveyed.

Regulatory compliance emerges as the main driver for technology adoption, reported as an important driver by 40 % of respondents (Figure 26). This illustrates the strong influence of policies and regulatory requirements on technological change. Economic considerations are also important in driving digital technology adoption, with 36 % of respondents adopting these technologies to reduce operational costs. In addition, 29 % of respondents were motivated by the need to improve the efficiency of input use and reduce their environmental footprint, reflecting the growing emphasis on sustainability in the agricultural sector.

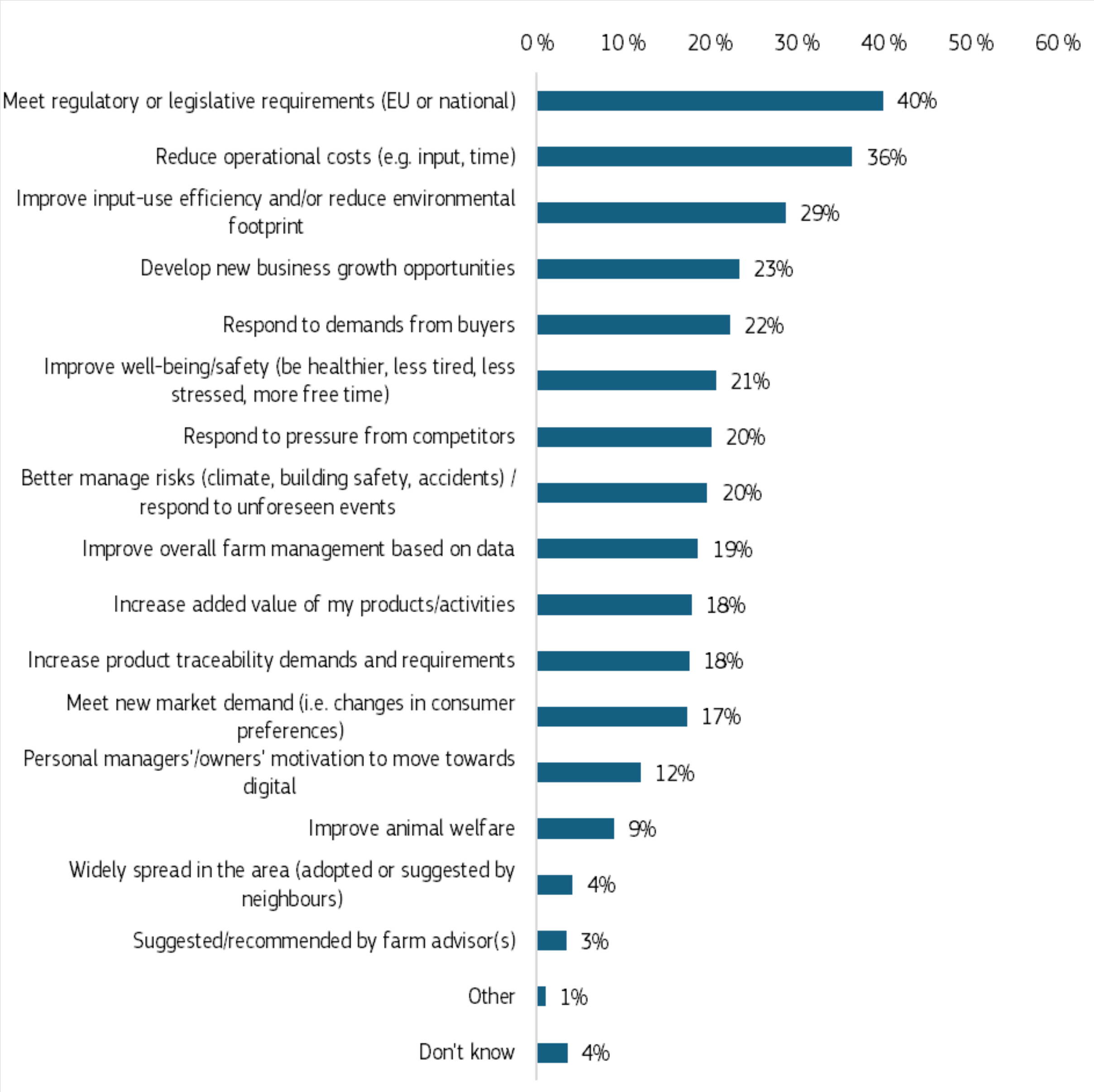
The pursuit of business growth and market responsiveness is another critical dimension, with the development of new business opportunities and responding to buyer demands motivating the adoption of digital tools for around 23 % and 22 % of respondents, respectively. Improving personal well-being and safety and maintaining competitive parity also play significant roles in driving adoption (for 21 % and 20 % of respondents, respectively) (Figure 26).

The potential to enhance farm resilience by improving risk management and responding to unforeseen circumstances and to improve overall farm management through data-driven approaches were reported by 20 % and 19 % of respondents, respectively, as driving the adoption of digital technologies. Consumer-focused changes, such as increasing product value and meeting traceability standards, reflect changing market demands and are motivators for digitalisation for 18 % of respondents in each case. Similarly, 17 % of respondents have adopted digital technologies to address new markets such as changing consumer preferences (Figure 26).

Minor drivers for digitalisation among the farmers surveyed include personal motivation towards digitalisation, animal welfare considerations and community influences from neighbouring farms, accounting for between 4 % and 12 % of respondents. Recommendations from farm advisors are also reported, but their influence on farmers' decisions is minimal (3 %) (Figure 26).

Overall, the adoption of digital technology is driven primarily by a mix of regulatory and economic drivers, especially efficiency, cost reduction and growth opportunities. Other important factors include market pressures, quality of life and welfare, and managerial and operational improvements. These findings are in line with the broader literature, which consistently highlights regulatory compliance, environmental concerns, economic efficiency and market and consumer demands as key drivers of digital adoption. In contrast, the survey results suggest a comparatively weaker influence of advisory services, which are more strongly emphasised as relevant enablers in the existing literature (e.g. Tey and Brindal, 2012; Barnes et al., 2019b; Shang et al., 2021).

Figure 26. Main drivers for the adoption of digital technologies as reported by the farmers surveyed (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

Figure 27 shows the main barriers to the adoption of digital technologies reported by the farmers surveyed. These barriers are mainly economic, followed by issues related to a lack of knowledge about the available digital technologies or a lack of skills. The high cost of the digital technologies is the most important barrier to technology adoption, reported by 53 % of respondents. This is in line with the results above on the perceived costs of adoption, where at least half of the crop-specific technologies and the majority of livestock-specific technologies are perceived as expensive or very expensive by the farmers surveyed. A lack of knowledge about the digital technologies available is the second most important barrier, reported by 37 % of respondents, highlighting the need for better information dissemination and training.

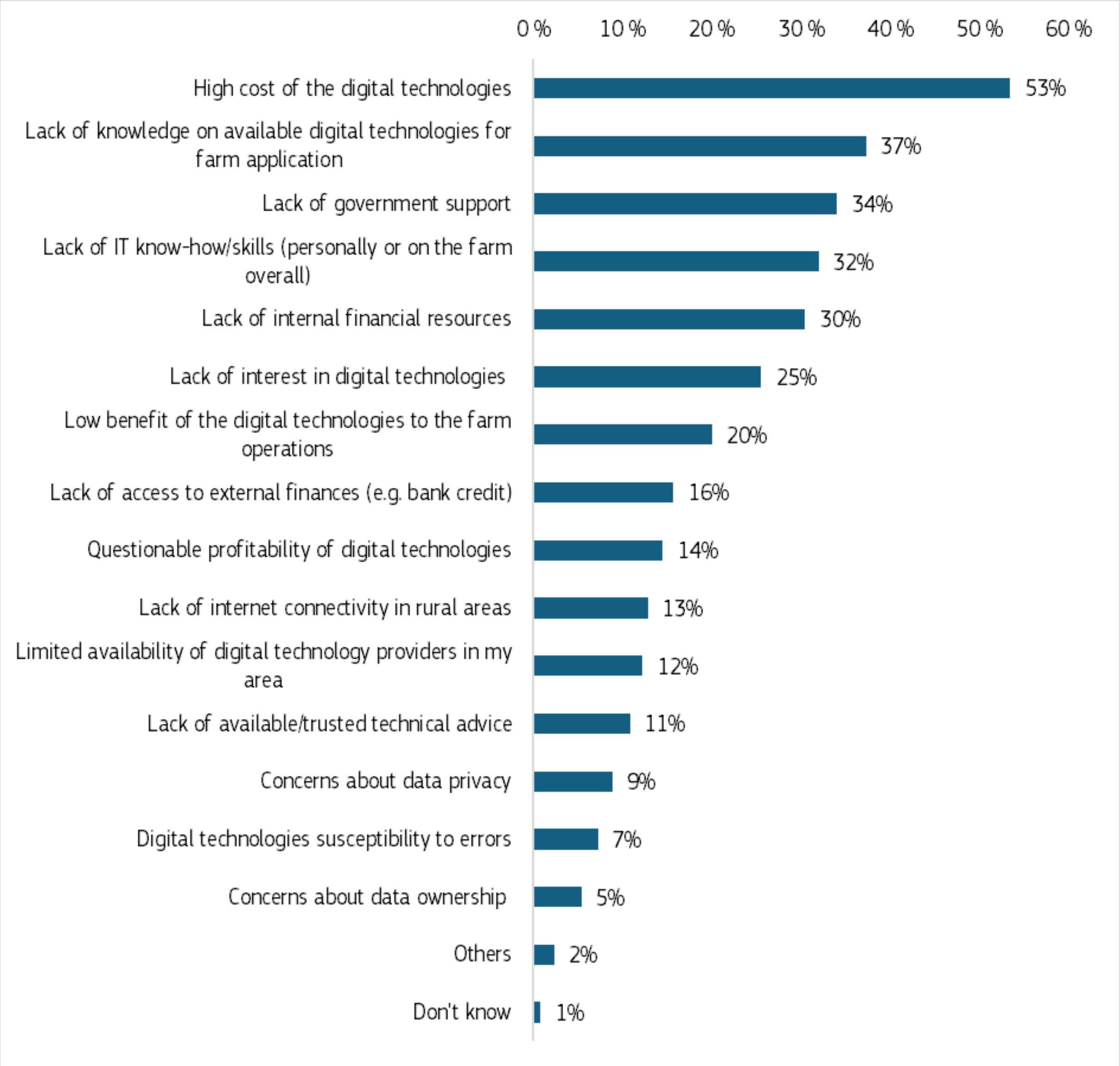
The lack of government support is also a commonly reported barrier to digitalisation adoption by the farmers surveyed, affecting 34 % of respondents. Similarly, a lack of IT skills on farms, reported by 32 % of respondents, points to a skills gap that is limiting technology uptake (Figure 27).

As shown above, self-financing is the main source used by the farmers surveyed to finance the adoption of digital technologies. However, internal financial constraints are reported as an important barrier by 30 % of respondents, limiting farmers' ability to further advance digitalisation. In addition, the perceived low benefits and questionable profitability of digital technologies, at 20 % and 14 %, respectively, suggest scepticism about the return on investment. Moreover, constraints on external financing, which according to the above results is often used to adopt more expensive technologies, are seen as a barrier by 16 % of farmers surveyed. These reasons, together with the perceived high cost of the digital technologies, highlight the importance of economic aspects as barriers to the adoption of digital technologies (Figure 27).

A lack of interest in digital solutions is also perceived as an important barrier by 25 % of respondents. The remaining barriers are considered by respondents to be less important in influencing their digitalisation decisions. These include poor internet connectivity in rural areas (13 %), limited availability of local technology providers (12 %), the lack of trusted technical advice (11 %), concerns about data privacy (9 %), technical susceptibility to errors (7 %) and concerns about data ownership (5 %) (Figure 27).

Overall, the adoption of digital technologies is largely hampered by farmers' financial constraints. The lack of knowledge and skills is the second most important barrier, followed by the lack of policy support, the lack of interest and the low perceived benefits of digital technologies. The literature generally supports the idea that the adoption of digital technologies in agriculture is significantly constrained by these interrelated barriers (e.g. Cisternas et al., 2020; Bulut and Wu, 2024; Degieter et al., 2024; Kroupová et al. 2025).

Figure 27. Main barriers to the adoption of digital technologies as reported by the farmers surveyed (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

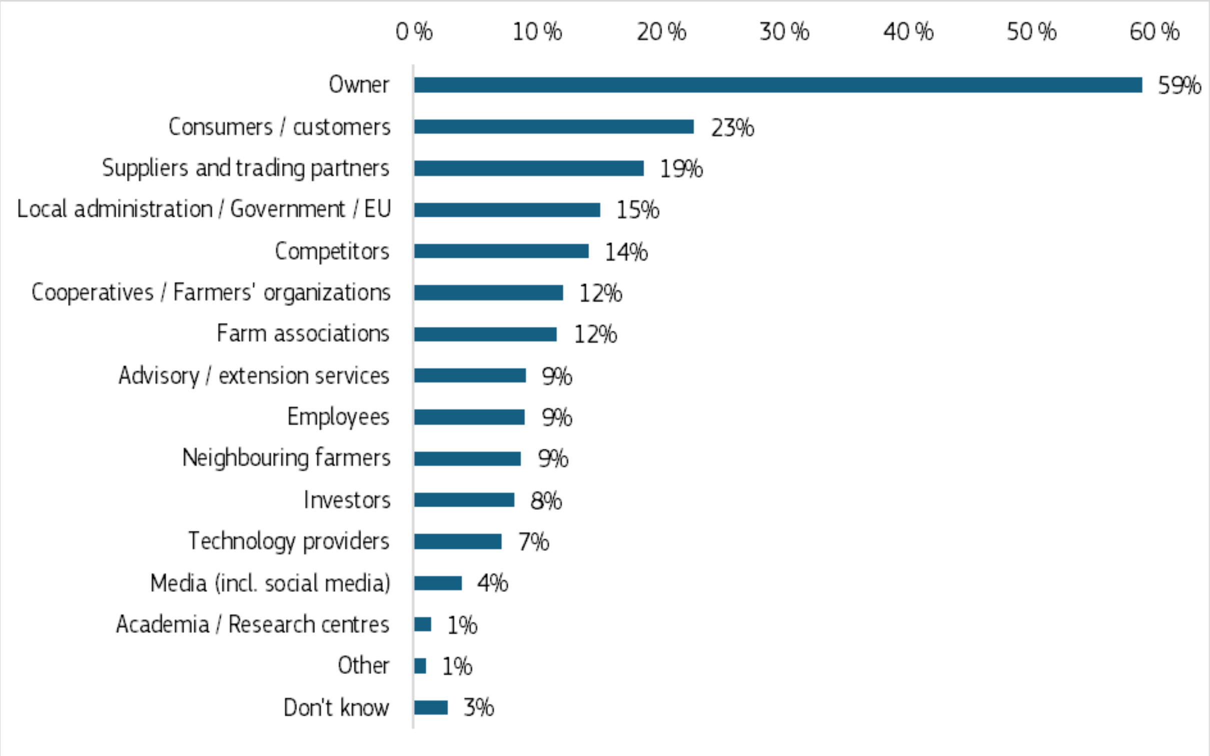
Facilitators are important for the adoption of digital technologies in agriculture because they can help farmers overcome the barriers they face when adopting digital technologies. According to the survey, farm owners are the main facilitators, with 59 % of the respondents identifying them as central to the adoption process (Figure 28), probably due to their control over strategic and investment decisions. Consumers or customers are the next most frequently reported facilitators (23 %), as their preferences and demands can strongly influence technology choices. Suppliers and trading partners (19 %) also play a considerable role by integrating new digital solutions into the supply chain and thus stimulating technological innovation in other parts of the chain, including among farmers.

Local administrations, governments and bodies such as the EU are also mentioned as facilitators by 15 % of the respondents and are likely to facilitate adoption through regulatory frameworks, incentives and policy initiatives. Competitors are reported as facilitators by 14 % of respondents. Cooperatives and farm associations are both reported as facilitators by 12 % of the respondents.

Extension services, employees and neighbouring farmers are considered to facilitate technology adoption to some extent (9 % each), probably by sharing knowledge, expertise and peer influence, which are essential to overcome barriers to technology adoption. Investors and technology providers are perceived as facilitators by 8 % and 7 % of respondents, respectively. The media, including social media, have a limited direct facilitation power over the adoption of digital technologies among the farmers surveyed (4 %). The same is true for academia and research centres, which are seen as having the least influence on adoption among the farmers surveyed (1 %).

Overall, the farm owners' own initiative plays the dominant role in facilitating the adoption of digital technologies as reported by those surveyed. Other stakeholder groups are ranked much less important. Stakeholders more closely linked to farmers in the supply chain, such as consumers, suppliers and competitors, are perceived to facilitate adoption to a moderate extent. While public administration, cooperatives and farmers' associations are also reported as relevant, their relatively low recognition suggests room for greater involvement. This is particularly the case for organisations more directly involved in technology development and diffusion – such as extension services, technology providers, universities and research centres – which are perceived as having minimal influence on adoption.

Figure 28. Key stakeholder groups reported by the farmers surveyed as facilitators of digital technology adoption (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

4.5. Determinants of adoption of digital technologies

This section brings together the various factors discussed in the descriptive sections above and analyses whether they remain relevant (i.e. statistically significant) determinants of digital technology adoption when considered jointly. As described in the methodology section, OLS and

Poisson estimations were carried out, with the dependent variable being the number of technologies adopted by the farmers surveyed. We ran the estimations separately for the three categories of digital technologies adopted: IT and software, crop-specific technologies and livestock-specific technologies. For each category, we ran one specification excluding the drivers and barriers to technology adoption (Annex 3) and another including them. The results of the OLS, if significant, should be interpreted as the correlation of each of the explanatory variables with an increase (if positive) or a decrease (if negative) in the number of technologies adopted by farmers. The results of the Poisson regression are reported in terms of incidence rate ratio for each explanatory variable. A significant value greater than 1 indicates a positive correlation with the explanatory variable, and a significant value less than 1 indicates a negative correlation. The estimated results of the Poisson regression are shown in Table 6. These results are consistent with those of the OLS estimations; therefore, we focus our analysis on the Poisson regression results. The results of the OLS estimations are presented in Table 7 in Annex 5.

The econometric results confirm the above descriptive statistics and suggest that the number of digital technologies adopted by farmers is positively correlated with farm size. This relationship is stronger for crop and livestock technologies than for IT and software technologies. When comparing small with medium-sized farms, statistically significant differences are found for crop and livestock digital technologies, suggesting that medium-sized farms adopt 12–15 % more crop technologies and 17–20 % more livestock technologies than small farms. When comparing small farms with large farms, the differences are significantly more pronounced in all three technology categories. In the case of IT and software technologies, the results suggest that large farms adopt 10–13 % more of these enabling technologies than small farms. Greater differences are found for crop technologies, where the results suggest that large farms adopt 74–84 % more digital technologies than small ones. Similarly, in the case of livestock technologies, large farms adopt 34–47 % more technologies than small farms (Table 6).

The age of the farmer is not an important determinant of the number of digital technologies adopted in all three categories. The coefficients for crop and livestock farmers are not found to be significant. The only exception is found for IT and software technologies common to most farmers, where a negative correlation is found, suggesting that older farmers may rely less (by 0.4 %) on these general digital technologies to support the farming activities (Table 6).

These results partly confirm the above descriptive statistics: the relationship between age and the use of digital technologies was more pronounced for crop-specific and IT and software technologies and less pronounced for livestock-related technologies.

The specialisation of farms also shows a significant correlation with the adoption of crop and livestock digital technologies. Mixed farms adopt 17–20 % fewer technologies specific to livestock or crop production than farms specialised in crop and livestock production. This could be explained by the fact that mixed farms may benefit less from specialised technologies, as their production structure tends to be less specialised. Indeed, in the case of general IT and software, which are not specific to a particular production system, the relationship between farm specialisation and the number of technologies adopted is not statistically significant (Table 6).

Several variables capture the effect of specialised training and general education on the adoption of digital technologies. Farmers' level of education appears to have an impact on the adoption of digital technologies, particularly enabling technologies such as IT and software applications common to most farms, for which higher levels of education correlate with more technologies adopted and no education correlates with fewer technologies adopted. The effects on crop- and livestock-specific technologies are weaker and less clear. A higher level of education (post-secondary, master's degree or PhD) is associated with higher levels of adoption of crop-specific technologies, while secondary education is associated with lower levels adoption of livestock-specific technologies compared with primary education. Other levels of education are not statistically significant or robust with regard to crop or livestock technology adoption (Table 6).

Agricultural training is associated with the adoption of 15–20 % more crop-specific technologies and 21–24 % more livestock-specific technologies. Specific digital training shows an even stronger relationship across all three categories of digital technologies: it is associated with the adoption of 14–17 % more IT and software technologies, 60–71 % more crop-specific technologies and 17–20 % more livestock-specific technologies. These results suggest that either participation in specialised agricultural training, particularly digital training, promotes the adoption of digital technologies or, alternatively, that farmers who are more interested in technology are also more likely to participate in such training. In either case, the results suggest that the availability of specific training in digital technologies for agriculture seems to enable the adoption of more digital technologies (Table 6).

Part-time farmers are also found to adopt significantly fewer digital technologies than full-time farmers. These farmers adopt 10–13 % fewer IT and software technologies, 22–23 % fewer crop-specific technologies and 28–30 % fewer livestock specific technologies (Table 6).

Conversely, the farmers involved in direct sales adopt significantly more digital technologies in all three categories than farmers not involved in direct sales. Farmers engaged in direct sales adopt 14 % more IT and software technologies, 24–25 % more crop-specific technologies and 34–36 % more livestock-specific technologies (Table 6).

The availability of a good internet connection also seems to be an important determinant of the adoption of digital technologies. According to the estimated results, farmers who consider their internet connection to be poor, deficient or just sufficient are less likely to adopt digital technologies than those who consider their connection to be good. Compared with farmers with good internet connectivity, those with poor, deficient or only sufficient connectivity adopt 4–22 % fewer IT and software technologies, 13–24 % fewer crop-specific technologies and 5–35 % fewer livestock-specific technologies. Furthermore, the adoption of digital technologies decreases consistently with the quality of internet connectivity: farmers with sufficient connectivity adopt 4–10 % fewer digital technologies, those with deficient connectivity adopt 13–20 % fewer and those with poor connectivity adopt 17–35 % fewer than those with good connectivity (Table 6).

The econometric estimation also suggests regional differences in the adoption of digital technologies (Table 6). Compared with the southern Member States, the eastern Member States covered appear to adopt 19–25 % fewer digital technologies related to IT and software applications. There are also significant regional differences in the adoption of technologies related to crop and livestock production. Compared with the southern Member States covered, the northern Member States adopt 15–19 % fewer crop-specific technologies, the eastern ones adopt 10 % fewer and the western ones adopt 33–37 % fewer. These differences may be related to the use of specific tools, such as georeferenced soil sampling and accounting platforms, which are particularly important in the southern and eastern regions. In the case of livestock-specific technologies, the western Member States covered adopt 18–24 % fewer and the eastern ones about 13 % fewer than the southern Member States covered. These results for livestock-specific technologies could be explained by the high average number of technologies adopted in Spain and Italy, as discussed in the descriptive statistics (see Figure 17). Note that the estimates for the eastern regional variable in relation to crop- and livestock-specific technologies in Table 4 are not robust as they are only significant in the specification that excludes drivers of and barriers to technology adoption.

The variable capturing farmers' plans to retire shows a statistically significant relationship with the adoption of crop-specific technologies. Farmers who plan to retire in more than 10 years adopt 15–22 % more crop-specific technologies than those who do not plan to retire. This suggests that farmers who plan to stay in farming for more than 10 years may adopt long-term strategies and adopt more crop-specific technologies. Two other coefficients are also statistically significant: one for IT and software technologies among farmers planning to retire in more than 10 years and one for crop-specific technologies among those planning to retire within 10 years. However, these results are not robust across the estimated models (Table 6).

Land ownership is also found to have a statistically significant correlation with the adoption of livestock-specific technologies. Farms with partially, mainly or fully leased land adopt 21–32 % more livestock-specific technologies than those that fully own the land. This result appears counterintuitive, as farmers who own their land are typically expected to be more inclined to invest.

These results may indirectly indicate the existence of substitution effects between investments in digital technologies and other forms of capital, such as land (Table 6). Variables such as gender, legal ownership and engagement in organic production are either not significantly correlated with the number of digital technologies adopted or produce estimates that are not robust (Table 6).

Based on the estimates for drivers of and barriers to technology adoption reported in Figure 26 and Figure 27 ([17]), drivers appear to be more strongly associated with digital technology adoption than barriers. All drivers considered in the regression are statistically significant for at least two technology categories, except for personal motivation and influence, which are insignificant for all three technology categories. Farmers who identify these as drivers of digitalisation in the farming sector seem to adopt more technologies. In terms of the magnitude of the estimated coefficients, the strongest statistically significant relationship is found for efficiency and cost reduction (farmers affected by this driver adopt 16–38 % more technologies), followed by regulatory pressure (10–30 %), quality of life and welfare (16–31 %), management and operational improvement (14–20 %), growth opportunities (9–17 %) and market pressure (8–14 %) (Table 6). For the three categories of digital technologies, farmers affected by statistically significant drivers adopt 8–20 % more IT and software technologies, 9–38 % more crop-specific technologies and 14–31 % more livestock-specific technologies (Table 6).

These estimates are broadly in line with the descriptive statistics above. The differences are mainly due to the fact that in the econometric estimations, efficiency and cost reduction appear to be slightly stronger drivers than regulatory pressure, whereas the opposite is true in the descriptive statistics. Similarly, quality of life and welfare and management and operational improvement appear to be slightly stronger drivers in the econometric estimations than in the descriptive statistics.

Among the barriers, only the lack of knowledge and skills, the lack of interest and low perceived value, and the digital technologies' susceptibility to errors show significant negative correlations with the adoption of digital technologies. Farmers who identify a lack of knowledge and skills as a barrier are associated with 8 % less adoption of general IT and software, while farmers who

([17]) The various drivers and barriers considered in Figure 26 and Figure 27 were grouped into categories containing similar elements (see Annex 3) to avoid potential problems in the regression analysis, such as multicollinearity, overfitting and loss of degrees of freedom.

identify a lack of interest and low perceived value as a barrier are associated with 12 % less adoption of crop-specific technologies. Farmers who identify the digital technologies' susceptibility to errors as a barrier are associated with 14 % more adoption of IT and software technologies and 32 % more adoption of crop-specific technologies. These estimates are contrary to expectations, as one would typically expect a negative relationship. This may be because farmers still adopt digital technologies that are perceived as error-prone, possibly because some of the errors could be related to the way the technologies are used rather than to the technology itself. The remaining barriers do not have statistically significant relationships with the adoption of digital technologies (Table 6).

Surprisingly, these estimates indicate a rather low relevance of the barriers, in contrast to the relatively high frequency with which they are reported to be relevant by the farmers surveyed, as discussed in the descriptive statistics above. The descriptive statistics suggest that the adoption of digital technologies is constrained most often by farmers' financial contexts, followed by a lack of knowledge and skills. In the econometric estimations, only the lack of knowledge and skills has some relevance, while the barrier of farmers' financial constraints is statistically not significant. This discrepancy may be due to other explanatory variables in the regression capturing similar effects to the barriers, thereby rendering the barrier variables statistically insignificant.

The econometric analysis largely confirms the descriptive findings and identifies several key factors associated with the adoption of digital technologies in farming. Farm size, internet connectivity, direct sales, full-time farming and specific training – particularly digital training – are strongly and consistently associated with higher adoption rates, especially for crop- and livestock-specific technologies. Age has a limited influence, except for a slight negative association with IT and software adoption. Farmers planning to retire later adopt more crop-specific technologies than those with no retirement plans. Higher levels of general education are associated with greater adoption of general IT and software technologies, while the effects on crop- and livestock-specific technologies are weaker and less consistent. Regional and farm-specialisation differences are also observed, with southern Member States and farms specialising in crop and livestock production generally adopting more technologies. Partial ownership or renting land is unexpectedly associated with higher adoption of livestock technologies, possibly indicating a substitution between digital investments and land ownership. In contrast, variables such as gender, legal ownership and engagement in organic production are largely not significantly associated with the adoption of digital technologies. Drivers of adoption – particularly efficiency and cost reduction, regulatory pressure and improved quality of life – have stronger explanatory power than barriers. Among the barriers, only the lack of knowledge and skills, low interest and perceived susceptibility to errors are statistically significant, although the last is, contrary to expectations, positively correlated with adoption. Overall, barriers appear to play a weaker role in the econometric results than suggested by the descriptive statistics, probably because their effects are captured by other correlated explanatory variables in the regression models (e.g. the effect of a lack of knowledge and skills may be captured by the specific digital training variable).

Table 6. Poisson regression results explaining respondents' adoption of IT and software technologies, crop-specific technologies and livestock-specific technologies

		IT and software				Crop specific				Livestock specific			
		Poisson		Poisson D & B		Poisson		Poisson D & B		Poisson		Poisson D & B	
Size	Small (reference)												
	Medium	1.03		1.02		1.15	**	1.12	**	1.24	***	1.17	**
	Large	1.13	***	1.10	**	1.84	***	1.74	***	1.47	***	1.34	***
Specialisation	Crop (reference)												
	Livestock	0.98		0.99									
	Mixed	1.00		1.02		0.81	***	0.83	***	0.8	***	0.82	***
Gender	Male (reference)												
	Female	0.99		0.98		1.00		0.93		1		1.02	
Age	Age of respondent	1.00	***	1.00	**	1.00		1.00		1		1.00	
Legal ownership	Shared ownership (reference)												
	Individual/family farm (sole holder)	0.95		0.97		0.88	***	0.94		0.88	**	0.91	
Land ownership	Fully owned (reference)												
	Mainly owned	0.99		0.99		0.99		1.01		1.3	***	1.32	***
	Mainly leased	1.01		1.01		1.04		1.06		1.21	**	1.21	**
	Fully leased	0.92		0.90		0.93		0.90		1.29	**	1.24	*
Work status	Full-time farmer (reference)												
	Part-time farmer	0.90	*	0.87	**	0.78	***	0.77	***	0.67	***	0.72	**
Education	Primary education (reference)												
	Secondary or vocational	1.17	***	1.16	***	1.03		1.00		0.86	*	0.86	*
	Post-secondary	1.17	**	1.10		1.20	**	1.11		1.05		0.99	
	University	1.20	***	1.15	**	1.07		1.00		0.85		0.86	
	Master's or PhD	1.22	**	1.14		1.39	***	1.29	***	1.08		1.06	
	No education	0.48	***	0.53	**	0.67		0.84		0.91		0.92	
Agricultural training	No specific agricultural training (reference)												
	Professional training related to agriculture	1.01		1.00		1.20	***	1.15	***	1.24	***	1.21	***
Retirement plans	No plans to retire (reference)												
	Retiring within the next 10 years	0.98		0.95		1.12	*	1.08		1.01		0.98	
	Retiring in more than 10 years	1.14	**	1.09		1.22	***	1.15	**	1.07		1.06	
Organic production	No organic production (reference)												
	Organic production	1.00		1.01		1.04		1.06		1.12	*	1.08	
Direct sales	No direct sales (reference)												
	Direct sales	1.14	***	1.14	***	1.25	***	1.24	***	1.36	***	1.34	***
Internet connection	Internet good (reference)												
	Internet sufficient	0.94	*	0.96		0.81	***	0.82	***	0.9	*	0.95	
	Internet deficient	0.81	***	0.87	**	0.80	***	0.87	*	0.8	**	0.86	
	Internet poor	0.78	**	0.83	*	0.76	**	0.81		0.65	**	0.72	*
Specific digitalisation training	No training (reference)												
	Undertook digitalisation training	1.17	***	1.14	***	1.71	***	1.60	***	1.2	***	1.17	**
Region	South (reference)												
	North	0.93		0.95		0.81	***	0.85	**	0.89		0.92	
	East	0.75	***	0.81	***	0.90	*	0.99		0.87	*	0.90	
	West	0.97		0.98		0.63	***	0.67	***	0.76	***	0.82	**
Drivers	Regulatory pressure			1.10	***			1.30	***			1.16	**
	Market pressure			1.08	**			1.06				1.14	**
	Growth opportunities			1.00				1.09	**			1.17	***
	Efficiency and cost reduction			1.16	***			1.38	***			1.22	***
	Management and operational improvement			1.20	***			1.14	***			1.02	
	Quality of life and animal welfare			1.05				1.16	***			1.31	***

		IT and software		Crop specific		Livestock specific	
		Poisson	Poisson D & B	Poisson	Poisson D & B	Poisson	Poisson D & B
	Personal motivation and influence		1.02		1.02		1.05
Barriers	Knowledge and skills		0.92 **		1.00		1.05
	Interest and perceived value		1.03		0.88 ***		0.91
	Access and infrastructure		1.01		1.04		0.97
	Financial constraints		0.96		0.93		0.98
	Support and policy		1.01		1.05		1.07
	Data privacy and ownership		1.07		1.04		0.94
	Susceptibility to errors		1.14 **		1.32 ***		0.99
Intercept		3.52 ***	2.49 ***	3.68 ***	1.31 *	2.35 ***	1.01
Number of observations		1 444	1 444	1 004	1 004	814	814

NB: * significant at the 10 % level; ** significant at the 5 % level; *** significant at the 1 % level; D & B: drivers and barriers.

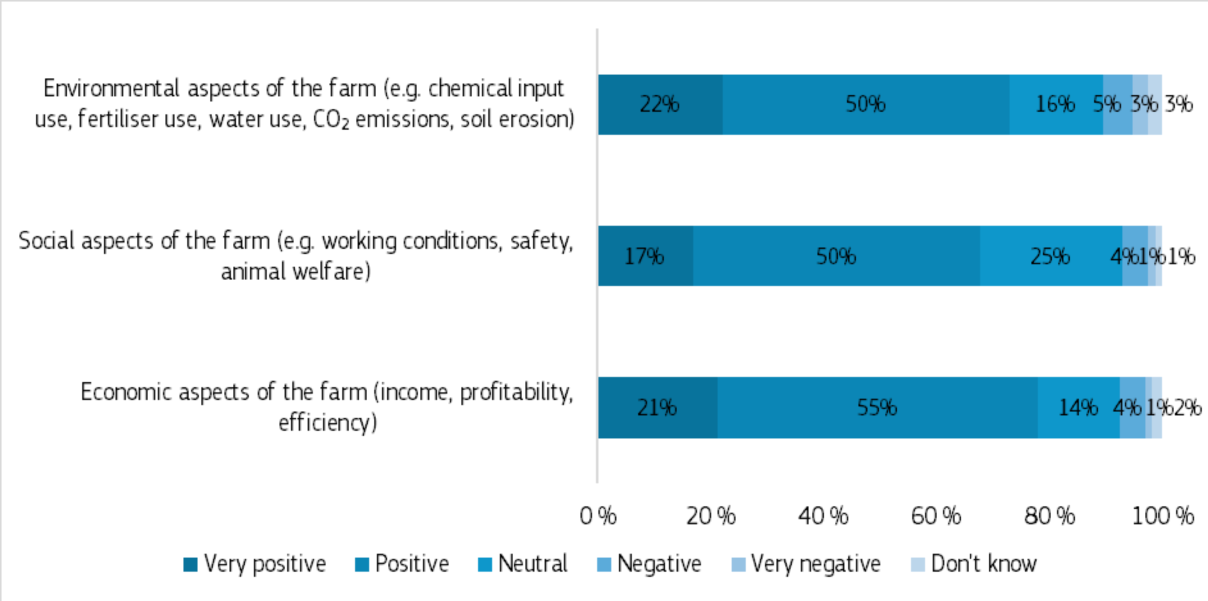
Source: Authors' own compilation based on the survey data.

4.6. Sustainability aspects of digital technologies

Figure 29 shows the net contribution to sustainability that farmers expect the digital technologies they adopt to have in the short-to-medium term (five years) across the three sustainability dimensions (economic, environmental and social). In line with the descriptive and econometric analyses above, farmers primarily perceive digital technologies as having a positive net impact on the economic aspects of their farm operations, with 76 % reporting either positive or very positive net impacts on economic aspects, such as income, profitability and efficiency. This is followed by a 72 % net positive perception of environmental impacts. Social impacts are also viewed positively by 67 % of farmers. Between 14 % and 25 % of respondents expect a neutral contribution of the digital technologies across the three sustainability dimensions. Negative and very negative net contributions to sustainability are only expected by a small percentage of respondents (between 8 % and 12 % ([18])), indicating an overall common perception that digital technologies positively impact sustainability dimensions.

([18]) Negative effects on different dimensions of sustainability may arise because farmers do not necessarily adopt technologies taking into consideration all aspects of sustainability. For example, a technology may be adopted primarily for its cost-reducing benefits, despite this resulting in adverse environmental impacts due to increased production intensity on the farm. As shown in the previous section, adoption may also be driven by regulatory pressures. In this case, farmers may incur higher investment costs on the farm while achieving environmental improvements, reflecting the trade-offs between economic and environmental outcomes.

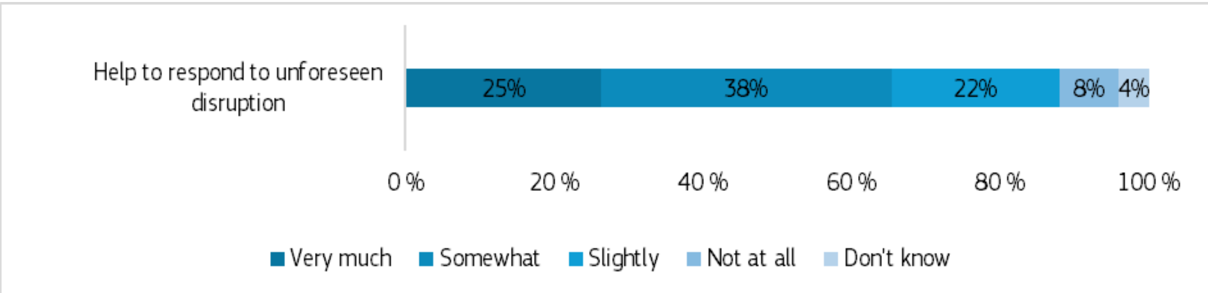
Figure 29. Surveyed farmers' expected net benefits of digital technologies adopted or planned to be adopted in terms of costs and risks in the short-to-medium term (five years) in each sustainability dimension (%)



Source: Authors' own compilation based on the survey data.

The majority of respondents also view digital technologies as contributing to farmers' resilience by helping them to respond or adapt to various unforeseen market and environmental disruptions (e.g. price shocks, cost increases, labour safety and health crises, droughts and plant and animal diseases). According to the survey results, 63 % of the farmers surveyed expect digital technologies to play a significant role in helping them respond and adapt to such disruptions, 22 % perceive a slight benefit and 12 % see no advantage in this regard (Figure 30).

Figure 30. Surveyed farmers' expectations regarding the contribution of adopted or planned digital technologies to responding or adapting to unforeseen market and environmental disruptions (%)



Source: Authors' own compilation based on the survey data.

Overall, the survey results suggest that digital technologies are viewed positively by farmers for their economic, environmental and social impacts and potential to enhance farmers' capacity to cope with unforeseen challenges. These findings highlight that, while farmers primarily associate digital technologies with generating net positive economic impacts (as shown in Figure 29) and mainly identify economic factors as key drivers of and barriers to their adoption (as discussed in the descriptive and econometric analyses above), they also recognise technology's potential environmental and social benefits and, to some extent, potential contribution to resilience.

5. Data practices in agriculture

Data collection and sharing are critical components of the digital transformation of agriculture, enabling more informed decision-making, greater operational efficiency and improved resource use. The literature highlights that effective data sharing can add value across the sector by fostering innovation, improving efficiency and sustainability and supporting better farm management and policy implementation. However, significant challenges remain – in particular, whether data are actually collected, managed and processed in digital formats or in traditional nondigital ways. In addition, stakeholders have concerns about data ownership, privacy and a general lack of trust, which may hinder more effective data sharing and use (e.g. Reichardt and Jürgens, 2009; Clapp and Ruder, 2020; Kenney et al., 2020; Linsner et al., 2021; Yang et al., 2021; Barabanova and Krzysztofowicz, 2023; Bulut and Wu, 2024). This section explores these issues as reported by the farmers surveyed, focusing on data availability and frequency, collection methods and data-sharing practices, including their main drivers and barriers.

5.1. Data availability and frequency

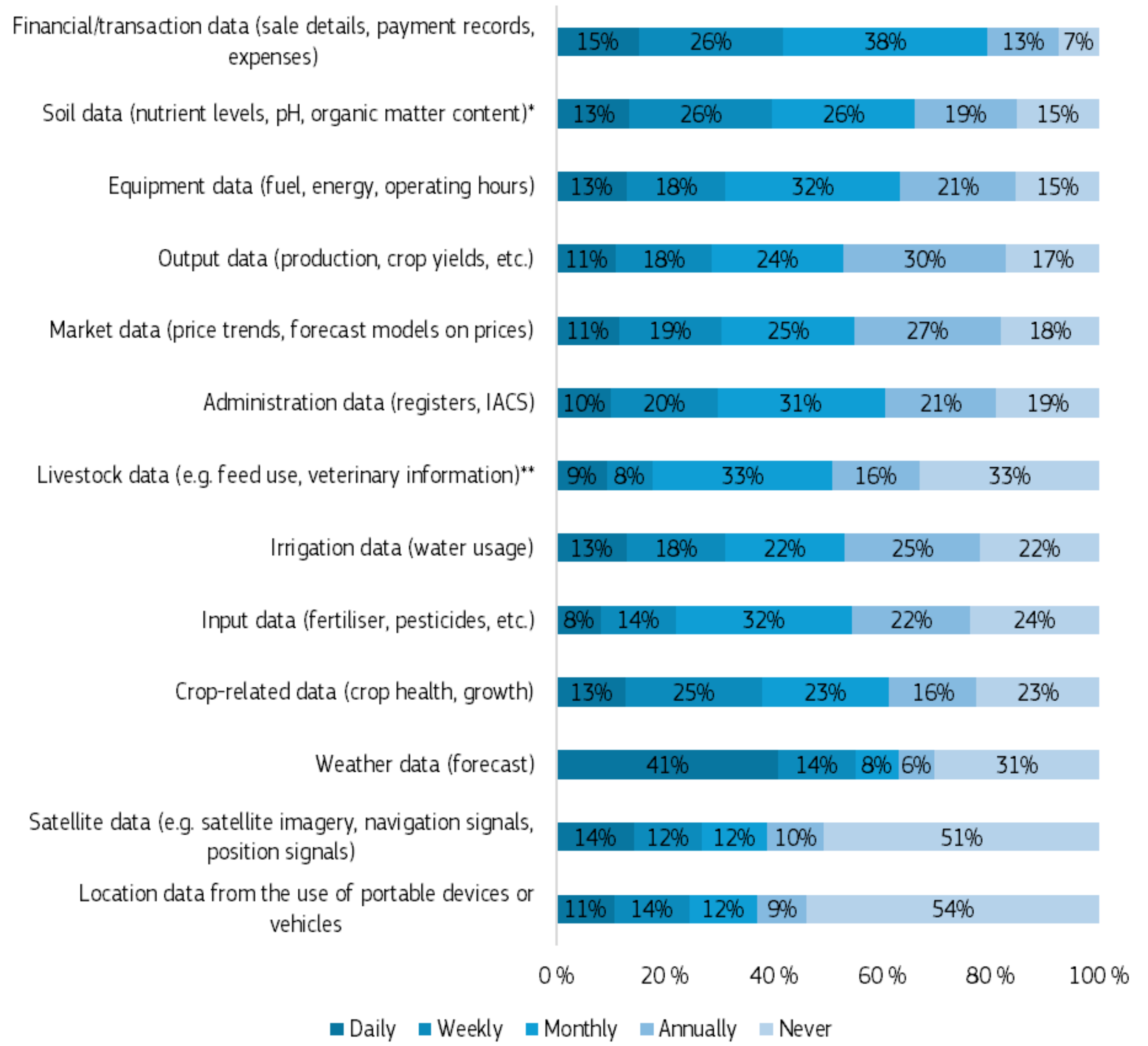
Figure 31 shows the data available at the farm level and the frequency of their collection by the farms surveyed. Weather data stands out as being the most frequently updated on a daily basis by the farms surveyed, with 41 % of users collecting these data every day and 2 % collecting them weekly or monthly. Financial and transactional data, although not as frequently collected, are the data least likely to be indicated as never collected (7 % of respondents), indicating their critical ongoing need. On the other hand, location and satellite data are among the least collected, with more than half of users (5 % and 51 %, respectively) indicating they never collect these data.

The types of data that are also collected quite frequently (daily, weekly or monthly) by the farms surveyed include soil data (66 % of users collecting them daily, weekly or monthly), equipment data (63 %), livestock data (51 %), administrative data (61 %), market data (55 %), crop-related data (61 %), input data (54 %), output data (53 %) and irrigation data (61 %). However, a significant proportion of farmers collect certain types of data annually, such as output data (30 %), market data (27 %), irrigation data (16 %), input data (22 %), equipment data (21 %) and administrative data (21 %). For the remaining types of data, annual collection ranges from 6 % to 19 % of the farms surveyed (Figure 31).

Analysing the availability of data among the farms surveyed by frequency of collection shows that most types of data are collected monthly (by between 10 % and 35 % of respondents for most data types), followed by annually (10–30 %), weekly (14–25 %) and daily (10–15 %) (Figure 31).

Overall, financial and weather data are the types most frequently collected by the farms surveyed, with many updating them on a daily or weekly basis. Other commonly collected data types include soil, equipment, livestock and administrative data, often collected on a daily to monthly basis. In contrast, location and satellite data are among the least collected. Several types of data, such as output, market and irrigation data, are collected annually by a significant proportion of farmers. Most data are collected on a monthly basis, followed by annual, weekly and daily.

Figure 31. Frequency of farm-level data collection among farms surveyed, by data type (%)



(*) Soil data refer only to crop farmers.

(**) Livestock data refer only to livestock farmers.

NB: IACS, Integrated Administration and Control System.

Source: Authors' own compilation based on the survey data.

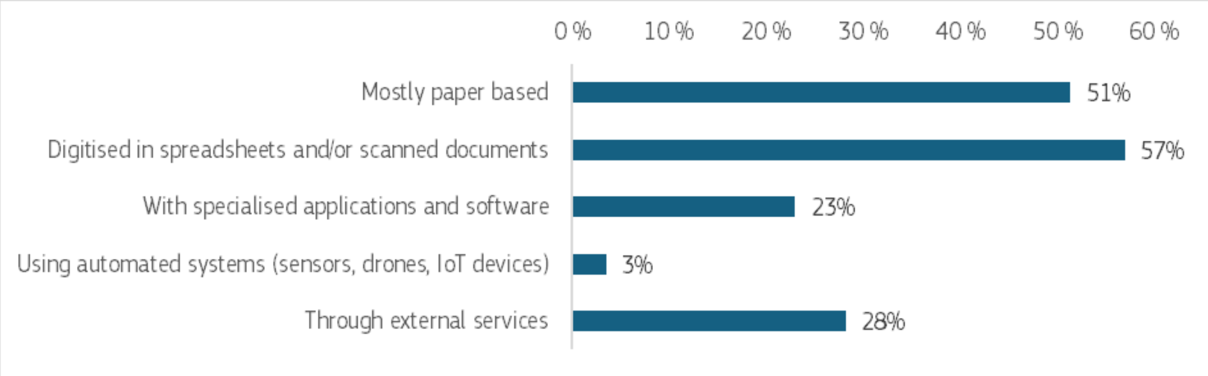
5.2. Data collection and management method

Figure 32 shows the most common data collection and management methods used by the farms surveyed. More than half of the farmers surveyed (51 %) still rely on paper-based data collection and management methods, while 57 % reported digitising data using spreadsheets and/or scanned documents. This highlights the continued prevalence of manual or semi-manual data management processes among the farms surveyed.

In contrast, only a relatively small proportion of the farms surveyed, 23 %, use specialised applications and software for some data collection and management, and an even smaller proportion, 3 %, employ fully automated systems, such as sensors, drones or internet of things devices. This suggests that the uptake of advanced technological solutions for data collection and management is limited. In addition, 28 % of respondents have their data collected and managed by external services, reflecting some reliance on outsourcing for data management needs (Figure 32).

Overall, despite technological advances, traditional methods of data collection and management, like paper or basic digital tools, prevail among the farms surveyed. The relatively low use of automation and specialised software highlights the limited emergence of digitised data systems.

Figure 32. Data collection and management methods at the farm level among farms surveyed (%)



NB: Multiple responses were allowed. IoT, internet of things.

Source: Authors' own compilation based on the survey data.

5.3. Sharing data

5.3.1. Data-sharing practices

Respondents were asked whether they share data electronically[19] (e.g. through websites or apps, telemetry, real-time sensors or tracking) with external parties (Figure 33). A significant proportion of respondents (39 %) declared that they do not share their data at all. Of those who do share data, consultants and advisors are the most common recipients, with 25 % of respondents indicating they share information with them. This is closely followed by 22 % of respondents who share with other farmers. Associations and cooperatives receive data from 20 % of respondents, while some respondents also share data with other stakeholders in the supply chain (15 %). Only 13 % of the farmers surveyed share data with public administrations.

The proportions of farmers surveyed sharing data electronically with agri-tech companies and researchers are rather low (12 % and 11 % of respondents, respectively), indicating limited sharing practices or collaboration with stakeholders involved in the development of digital tools. Financial institutions are the least likely to receive data from the farmers surveyed, with only 7 % sharing with them, possibly due to less frequent collaboration (Figure 33).

Further analysis of the farmers' data-sharing practices suggests differences by farmer age, farm size and Member State (Figure 40, Annex 4). Looking at the Member State results, the proportion of famers not sharing data ranges from 8 % to 73 %, with the highest proportions of farmers not

[19] In this report, the terms electronically and digitally are used interchangeably, since they largely refer to the same concept: the transfer of data from one system to another using electronic signals. Both terms refer to the sharing of digital data, usually via computer networks or the internet.

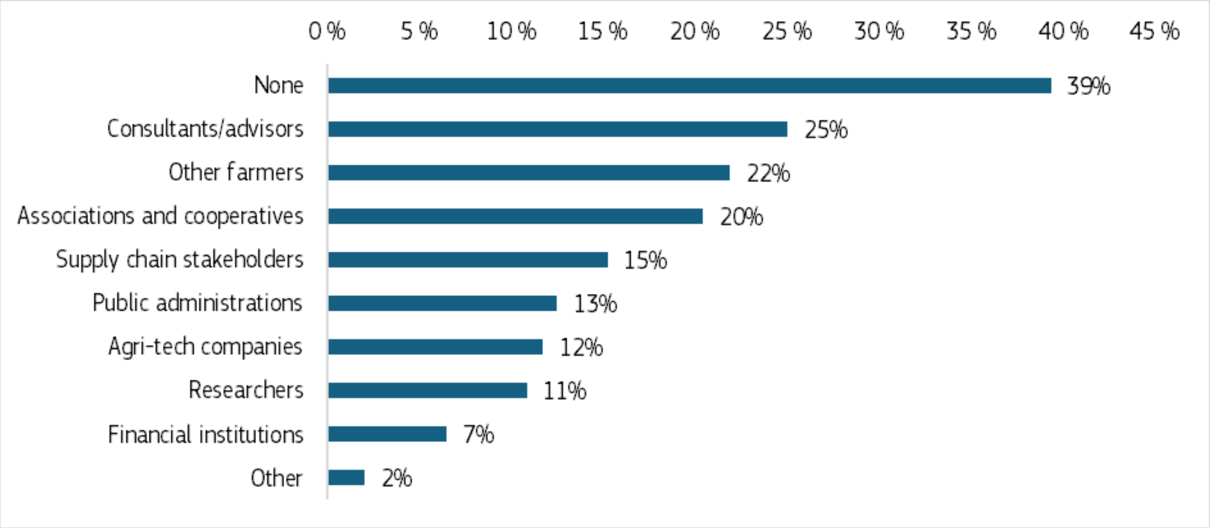
sharing data in Spain (71 %) and Hungary (73 %). The lowest proportions are observed in Poland (15 %) and Lithuania (8 %), indicating more active involvement in data-sharing practices.

There is considerable heterogeneity across the Member States covered in terms of the external parties with whom farmers share data electronically. Surveyed farmers in Lithuania and Poland share data quite often (more than 20 % of respondents each) with several external parties, such as other farmers, consultants and advisors, supply chain stakeholders, agri-tech companies, associations and cooperatives, researchers and public administrations. In Germany, more than 20 % of the farmers surveyed share data mainly with other farmers, consultants and advisors. In France, more than 20 % of the farmers surveyed share data mainly with other farmers, supply chain stakeholders, associations and cooperatives. In Italy, more than 20 % of respondents mainly share data with consultants, advisors, associations and cooperatives. In Ireland, more than 20 % of respondents share data mainly with other farmers and supply chain stakeholders. In Greece, more than 20 % of the farmers surveyed share data mainly with consultants and advisors. In Spain, surveyed farmers' rate of data sharing with external parties is rather low, with some data sharing (by less than 20 % of respondents) occurring with other farmers, associations and cooperatives. Similarly, in Hungary, some data are shared with consultants and advisors (by less than 20 % of respondents) (Figure 40, Annex 4).

There is a positive correlation between farm size and electronic data sharing. Larger farms tend to share data electronically more often than smaller farms. Specifically, 47 % of smaller farms reported that they do not share any data, compared with only 31 % of large farms. More than 20 % of respondents from large farms tend to share data mainly with consultants and advisors and associations and cooperatives; medium-sized farms mainly with consultants and advisors; and small farms mainly with other farmers (Figure 40, Annex 4).

In terms of age, there is a negative correlation between the age of the farmers surveyed and electronic data sharing. More older farmers (59 % of those aged over 60) reported that they do not share data than those in younger age groups (below 60), where the proportion of non-sharers ranges from 31 % to 37 %. Younger farmers share data mainly with other farmers, consultants and advisors, and associations and cooperatives (more than 20 % of young farmers surveyed), while older farmers share data mainly with consultants and advisors (Figure 40, Annex 4).

Figure 33. Proportions of the farmers surveyed sharing data electronically with external parties (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

Among the farmers surveyed who share their data electronically, the large majority declared they do so on their own (65 %), while 20 % do so through associations or cooperatives and the remaining 14 % through external providers.

Overall, these results suggest that the farmers surveyed adopt a selective approach to sharing electronic data with external parties, which probably reflects their established business and personal relationships to a large extent. While a significant proportion do not share data at all, those who do tend to do so with trusted or closely related groups, such as consultants and advisors, fellow farmers and associations and cooperatives. In contrast, data sharing with more distant or institutional stakeholders, such as financial institutions, agri-tech companies, researchers and public administrations, remains limited. Data-sharing practices vary considerably between the Member States covered, with higher levels observed in Lithuania and Poland and lower engagement in Spain and Hungary. Farm size and farmer age also play a role: larger farms and younger farmers are more likely to share data electronically, while smaller farms and older farmers are more reluctant. Most farmers who share data do so independently.

5.3.2. Drivers of data sharing

Figure 34 shows the main reasons for sharing data electronically with external parties among the farmers surveyed who do share their data. The primary reason for sharing data with external parties is to share knowledge, accounting for 44 % of respondents. This shows a strong tendency to exchange information for mutual benefit and learning. In addition, 29 % of respondents share data to receive services from technology providers, such as personalised recommendations and performance assessments, demonstrating the value placed on tailored insights and expertise.

Risk management and access to new digital technologies are equally important motivations, both reported by 24 % of respondents, indicating that data sharing is seen as a way to improve operational resilience and embrace innovation. Informed decision-making is a driver for 20 % of respondents, highlighting the role of shared data in guiding effective strategies (Figure 34).

Financial compensation drives 18 % of respondents to share data, reflecting a tangible benefit for some data owners. Regulatory compliance drives data sharing for 17 % of respondents, highlighting the need to comply with regulations. Supply management, including concerns like traceability and transparency, motivates 14 % to share data, indicating an interest in maintaining product integrity and market trust (Figure 34).

Contributing to research is a less common reason for sharing data, reported by 9 % of respondents, while only 3 % share data to support policymaking, suggesting limited direct engagement with governmental or academic initiatives (Figure 34).

Overall, indirect benefits such as improving knowledge, receiving services and managing risk are more common reasons for sharing data electronically with external parties than financial compensation. This may indicate a preference for traditional practices or indirect benefits from data sharing, a lack of established channels for monetising data or a combination of both. Regulatory compliance is also not among the most common reasons for sharing data, suggesting that most farmers who share data do so voluntarily rather than because of formal obligations.

Figure 34. Main reasons for sharing data electronically with external parties among the farmers surveyed who do share their data (%)

NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

5.3.3. Barriers to data sharing

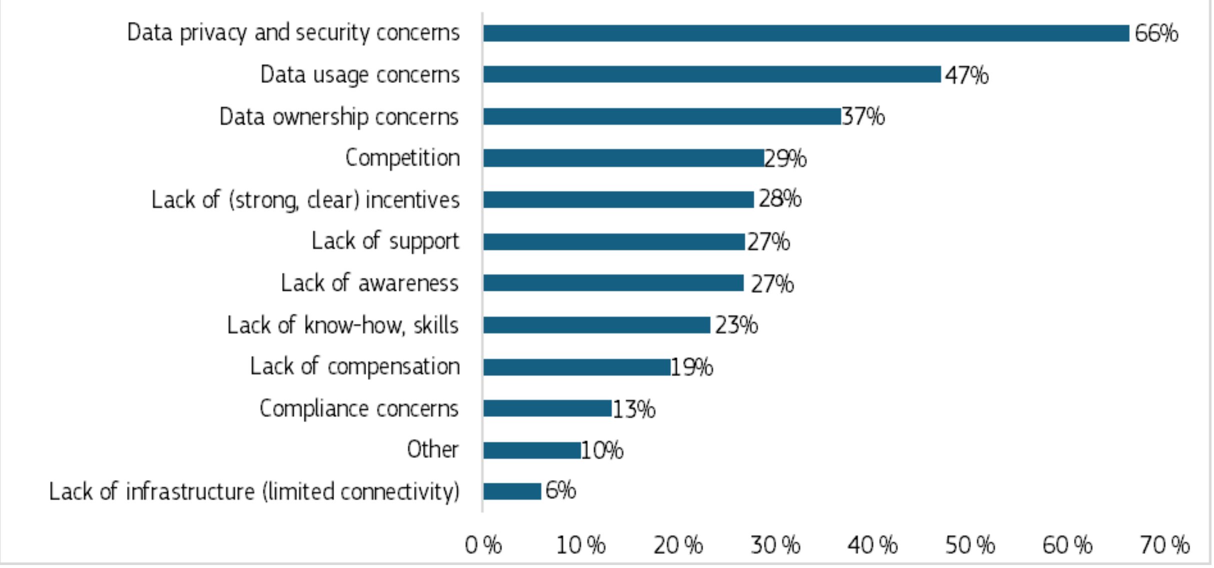
Figure 35 shows the main concerns reported by the farmers surveyed regarding electronic data sharing with external parties. The most important concern about sharing data electronically with external parties is data privacy and security, reported by 66 % of respondents. This is followed by concerns about how the data will be used (47 %) and data ownership issues (37 %). Concerns about competition also play a role, reported by 29 % of participants. This suggests that farmers have concerns about how shared data might be accessed, used or interpreted by external parties, potentially leading to unintended consequences, such as loss of control, competitive disadvantages or breaches of confidentiality.

Other notable issues include a lack of strong or clear incentives to share data, reported by 28 % of respondents, and a lack of support and lack of awareness, both reported by 27 % of respondents, suggesting gaps in guidance and understanding of data-sharing processes. A lack of know-how or skills is reported by 23 % of respondents, suggesting that technical challenges or the complexity of digitalisation may be preventing a significant proportion of farmers from sharing data electronically (Figure 35).

Smaller proportions of respondents expressed concern about the lack of financial or non-financial compensation (19 %) and compliance concerns (13 %) (Figure 35). Lack of infrastructure (limited connectivity) is the least concerning issue with regard to sharing data electronically.

Overall, privacy, security and control over the use and ownership of data appear to be the primary barriers to data sharing for the farmers surveyed. In addition to these dominant barriers, other concerns also play an important role – namely, the lack of clear incentives or support, the lack of awareness and knowledge, and concerns about competitive disadvantages. While these findings suggest that privacy, security and data ownership are important concerns when it comes to data sharing, the descriptive statistics above have shown that these issues were not commonly reported by the farmers surveyed (Figure 27) or economically estimated as the main barriers to adopting digital technologies in general (Table 6). This discrepancy may be due to the fact that data sharing and digital technology adoption are perceived as separate processes with different perceived risks, or that concerns about data use only become more salient once digital tools are already in use.

Figure 35. Main issues with sharing data electronically with external parties among the farmers surveyed who do share their data (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

6. Conclusions

This report provides a comprehensive overview of the state of digitalisation in EU agriculture, examining the adoption of both general IT and software tools and crop- and livestock-specific digital technologies. In addition to mapping adoption patterns, the report examines the main drivers and barriers to the uptake of digital technologies and considers their potential sustainability aspects. Given the importance of farm-level data for digital transformation, the report also analyses how farmers collect, manage and share data. The analyses in this report are based on a farm survey of 1 444 respondents conducted between June and October 2024 in nine Member States (Germany, Ireland, Greece, Spain, France, Italy, Lithuania, Hungary and Poland). The report combines descriptive statistics to summarise key survey patterns with econometric estimations to explore the relationship between the number of digital technologies adopted and the factors influencing adoption.

This report also aims to establish a baseline level of digitalisation in the EU agricultural sector, which can serve as a reference point for assessing future progress. Farm-level data related to digitalisation in this respect include the quality of farmers' internet coverage, their online activities, the adoption rates and costs of different digital technologies, the sustainability aspects of these technologies, the availability and management of data at the farm level, and data-sharing practices. In addition, understanding the main drivers and barriers for the adoption of digital technologies and data sharing is essential to interpret the current state of digitalisation.

6.1. Digitalisation in agriculture

The results show that most of the farms surveyed (85 %) reported having at least sufficient internet coverage to meet basic needs. However, around 15 % still face insufficient or poor internet connectivity, highlighting the ongoing challenges of digital connectivity for a sizable proportion of EU farms. Ownership of digital devices is widespread among the farms surveyed, with smartphones being the most common (94 %), followed by computers/laptops (73 %) and tablets (43 %).

The online activities of the farmers surveyed show a mixed picture. While more advanced or interactive online activities (e.g. e-commerce, training or professional networking) are used relatively infrequently, online activities that are perceived as directly useful and easy to integrate into day-to-day farming operations (e.g. digital tools for communication, information gathering and farm support) are used more frequently and regularly.

The survey results show a heterogeneous pattern of digital technology adoption across EU farms, based on the analysis of 5 general IT and software technologies, 19 crop-specific digital technologies and 8 livestock-specific digital technologies. Online communication platforms and mobile apps are commonly used across farms, reflecting a high level of familiarity and comfort with general IT and software tools. While the adoption rate of general IT and software tools is high, that of farm-specific digital technologies is much lower. Moreover, there is considerable variation in the levels of adoption within each category of farm-specific technologies, with a few tools being more widely used and most others having very limited uptake or remaining niche.

- **General IT and software technologies.** 93 % of farmers use at least one, and 68 % use three or more. Most of these technologies are used by more than 50 % of farms. Communication platforms (85 %) and mobile apps (66 %) are the most widely used, while accounting software is the least used (29 %).

- **Crop-specific digital technologies.** 79 % of farms have adopted at least one, and only 29 % have adopted three or more. Digital field records are the most widely used (58 %), while the adoption of other crop-specific technologies ranges from 3 % to 22 %.

- **Livestock-specific technologies.** 83 % of farmers have adopted at least one, while only 17 % have adopted three or more. Digital livestock records (66 %) are the most widely used, while the adoption of other technologies ranges from 3 % to 23 %.

Adoption of digital technologies by the farms surveyed increased significantly between 2008 and 2020, especially for IT and crop-specific tools, but declined between 2020 and 2024 – probably due to economic uncertainty. Livestock technologies show more stable, gradual adoption rates over time. Across all three technology categories, farmers expressed modest plans for increased adoption over the next five years, with an additional 3 % to 15 % of farms expected to adopt, depending on the technology.

Digital technologies in livestock production are generally seen as the most expensive, with automatic milking systems and robotic feed pushers being the most commonly perceived as costly. However, farm management software and digital livestock records are considered affordable by most farmers. Crop-specific digital technologies follow, with at least half of the technologies considered being perceived as expensive, especially GNSS-equipped tractors, fully automatic field robotics and automatic steering systems. However, other tools such as connected insect traps, digital field records, satellite data maps, field cameras and georeferenced soil sampling are perceived as more affordable. IT and software solutions for farm management are generally considered affordable by the majority of surveyed farmers. In general, digital technology adoption decreases as more farmers perceive the technology to be expensive.

The adoption of digital technologies is mainly facilitated by farmers' own initiative, with moderate facilitation from supply chain stakeholders more closely linked to farmers, such as consumers, suppliers and competitors. Public authorities, cooperatives and farmers' associations, extension services, technology providers and research institutions play a rather minor facilitating role, suggesting the opportunity for greater engagement.

The econometric estimations show that the adoption of digital technologies in agriculture is influenced by several key factors. Larger farm size, better internet connectivity, direct sales, full-time farming status and specialised digital and agricultural training are strongly associated with higher adoption rates, particularly for crop- and livestock-specific technologies. Specifically, depending on the technology category, the estimation results show the following.

- Large farms adopt between 10 % and 84 % more digital technologies than small farms, and medium-sized farms adopt between 12 % and 24 % more than small farms.

- Farmers with poor or insufficient internet connection adopt between 4 % and 35 % fewer digital technologies than those with good internet connection.

- Farmers involved in direct sales adopt between 14 % and 36 % more digital technologies than those not involved in direct sales.

- Part-time farmers adopt between 10 % and 33 % fewer digital technologies than full-time farmers.

- Farmers who have received specialised digital training adopt between 14 % and 71 % more digital technologies than those without such training. Similarly, farmers who have received agricultural training adopt between 15 % and 24 % more digital technologies than those without such training.

Age has a limited influence, except for a slight negative association with the adoption of IT and software. Farmers planning to retire later adopt more crop-specific technologies than those with no retirement plans. Higher levels of general education are associated with greater rates of adoption of general IT and software technologies, while the effects on crop- and livestock-specific technologies are weaker and less consistent. Differences by region and farm specialisation are also observed, with southern Member States and farms specialising in crop and livestock production generally adopting more technologies. Partial ownership or rental of land is unexpectedly associated with higher rates of adoption of livestock technologies, possibly indicating a substitution between digital investments and land ownership.

In contrast, variables such as gender, legal ownership and engagement in organic production are largely not significantly associated with the adoption of digital technologies.

Furthermore, the econometric estimations show that drivers are more strongly associated with digital technology adoption than barriers. Key drivers such as efficiency and cost reduction (farmers affected by this driver adopt 16–38 % more technologies), regulatory pressure (10–30 %), quality of life and welfare (16–31 %), management and operational improvement (14–20 %), growth opportunities (9–17 %) and market pressure (8–14 %) are associated with higher adoption rates across the different digital technology categories. Farmers affected by these drivers adopt 8–20 % more IT and software technologies, 9–38 % more crop-specific technologies and 14–31 % more livestock-specific technologies than those not considering these drivers relevant.

Among the barriers identified in the economic estimations, only a lack of knowledge and skills, low interest in and perceived benefits of technologies and perceived susceptibility to errors show some relationship with digital technology adoption, although the last is, contrary to expectations, positively correlated with adoption. This contrasts with the results of the descriptive statistics on the proportion of farmers reporting different barriers to digital technology adoption. The descriptive statistics analyses suggest that the adoption of digital technologies is largely hampered by farmers' financial constraints (e.g. high cost of digital technology), followed by lack of knowledge and skills as the second most important constraint, as these were most frequently reported by the farmers surveyed. This discrepancy suggests that the perceived importance of barriers may be partially captured by other factors included in the econometric estimations.

Most farmers surveyed expect digital technologies to make a positive contribution to sustainability, particularly in the economic (76 %) and environmental (72 %) dimensions, with 67 % also expecting social benefits and only 8–12 % expecting negative impacts. In addition, most farmers (68 %) perceive that digital technologies can potentially enhance their resilience to disruption, at least to some extent.

6.2. Data practices in agriculture

Data collection and sharing are critical components of the digital transformation of agriculture, enabling more informed decision-making, greater operational efficiency and improved resource use. The survey results show that farmers collect a wide range of data, but the frequency with which they do so varies considerably. Most farmers (more than 70 %) collect financial data, soil data, equipment data, output data, market data, administrative data, livestock data, irrigation data and input data. In contrast, location and satellite data are among the least collected (by less than 50 %

of respondents). Most data are collected monthly (by between 10 % and 35 % of respondents for most data types); followed by annually (10–30 %), weekly (14–25 %) and daily (10–15 %).

Data collection and management on the farms surveyed remains largely manual or done with basic digital tools, with 51 % using paper and 57 % relying on spreadsheets and/or scanned documents. Only 23 % use specialised software, and only 3 % use fully automated systems, while 28 % rely on external services for some data collection and management.

The results show that farmers adopt a selective approach to electronic data sharing with external parties, probably reflecting their established business and personal relationships to a large extent. While a significant proportion of farmers do not share data at all (39 % of respondents), those who do tend to do so with trusted or closely related groups, such as consultants and advisors (25 %), fellow farmers (22 %) and farm associations and cooperatives (20 %). Data sharing with more distant stakeholders, such as financial institutions (7 %), researchers (11 %), agri-tech companies (12 %) and public administrations (13 %), remains limited. Data-sharing practices vary considerably between the Member States covered , with higher levels observed in Lithuania and Poland and lower engagement in Spain and Hungary. Larger farms and younger farmers are more likely to share data electronically, while smaller and older farms are more reluctant. The majority of farmers who share data do so independently (65 %).

The farmers surveyed report that indirect benefits are the main driver for data sharing, while privacy, security and control over data use and ownership are the main barriers to data sharing. More specifically, obtaining indirect benefits, such as improving knowledge (44 % of respondents), receiving services from technology providers (29 %), managing risk (24 %) and gaining access to new technologies (24 %), are more common reasons for electronically sharing data with external parties than financial compensation (18 %). Regulatory compliance is also not among the most common reasons for sharing data (17 %), suggesting that most farmers who share data do so voluntarily rather than because of formal obligations.

Concerns about data privacy and security (66 % of respondents), data use (47 %) and data ownership (37 %) are the main barriers to data sharing for the farmers surveyed. In addition to these dominant barriers, other concerns also play an important role: competition concerns (29 %), the lack of clear incentives (28 %), the lack of support (27 %), the lack of awareness (27 %) and the lack of skills (23 %). While these findings suggest that privacy, security and ownership of data are important concerns when it comes to data sharing, the econometric estimates show that these issues are not the main barriers to adopting digital technologies. This discrepancy may be due to the fact that data sharing and the adoption of digital technologies are perceived as separate processes with different perceived risks or that concerns about data use become more salient once digital tools are already in use.

6.3. Discussion and limitations of the study

The results show that while the adoption of general IT and software technologies is relatively common among farmers, the adoption of more expensive specific technologies for crop or livestock production is less common. The report suggests that despite widespread discussion about the benefits of such technologies (Mondejar et al., 2021; Finger, 2023; Sermuksnyte-Alesiuniene and Melnikiene, 2024), there is a gap between the expected diffusion of and the actual adoption rates of many digital technologies by farmers in the Member States covered. This discrepancy may stem from the benefits not being fully understood or effectively communicated to farmers or insufficient to offset the costs of the technology. Indeed, although economic drivers (e.g. efficiency and cost reduction) are among the main factors influencing adoption, a significant proportion of farmers perceive many digital technologies – especially more specialised ones – as costly and financially inaccessible. In addition, many agri-tech solutions on the market may not be adequately tailored to the needs, scale or context of different farming systems. Furthermore, some digital technologies remain at a pre-commercial or development stage, which limits their availability or reliability for wider adoption in practical farm settings (Rose et al., 2016; Klerkx and Rose, 2020; Abiri et al., 2023; Abdulai et al., 2024).

Given the combination of low adoption rates for many digital technologies and farmers' perceptions that they are expensive, an important question arises: how many different types of digital tools can farmers realistically afford? For technologies that remain expensive – or are perceived as such – widespread adoption of a wide range of tools, from robots and drones to sensors, seems unlikely. Farmers are therefore likely to prioritise and adopt only those technologies that they perceive to be both affordable and capable of delivering tangible benefits. This highlights the importance of a targeted policy approach, particularly for advanced crop and livestock technologies that are perceived to be prohibitively expensive, rather than relying on an undifferentiated, one-size-fits-all policy approach (Barnes et al., 2019a; Klerkx and Rose, 2020).

The report results also show considerable variation in the levels of adoption within each category of farm-specific technologies – with only a few tools being widely used and many others remaining marginal or niche. This heterogeneity further highlights the limitations of one-size-fits-all digitalisation strategies in agriculture and points to the need for a more targeted approach. A one-size-fits-all strategy is unlikely to be effective; instead, policies and extension services should be adapted to reflect the different adoption dynamics, practical needs and relevance of different technologies in a given context.

Recent global crises, including the COVID-19 pandemic and geopolitical tensions, have exacerbated financial and market volatility for farmers (e.g. Helfenstein et al., 2022; Vo and Tran, 2024). The findings suggest that the emergence of this adverse context is likely to have hampered farmers' ability to adopt new technologies, challenging the notion that digital tools would be widely adopted as a coping mechanism, despite their perceived contribution to increasing the agricultural sector's resilience (Mondejar et al., 2021; Finger, 2023). Instead, the evolution of technological adoption seems to be slowing, suggesting that the adverse effects of these crises have hindered technology adoption.

While some farmers see digital technologies as potentially improving farm resilience and risk management, this is not a primary driver of adoption. Instead, the main drivers of adoption are efficiency and cost reduction, regulatory pressure, and quality of life and welfare improvements. Barriers appear to have a weaker impact on the adoption of digital technologies when different determinants are analysed together. Nevertheless, a significant proportion of farmers indicated that the main barriers to adoption include the farmers' financial constraints (e.g. the high cost of technology), the lack of knowledge and skills and the lack of policy support. In addition, the study highlights the importance of capacity-building programmes offering specialised training, especially in digital skills, for promoting digital technology adoption, which points to the importance of educational initiatives are important to equip farmers with the necessary skills to effectively adopt digital technologies.

Structural factors also play a crucial role in influencing the adoption of digital technologies. Smaller farms, constrained by limited resources, are less likely to adopt digital technologies than larger farms are. In addition, although less conclusive, age has an effect in the agricultural sector, with older farmers showing lower adoption rates. These findings indicate the need for tailored engagement strategies for different sizes of farms and age groups of farmers.

The report's findings suggest that there is scope for greater involvement in facilitating technology diffusion, particularly by organisations directly involved in technology development and diffusion – such as extension services, technology providers, universities and research centres – which farmers currently perceive as having minimal influence on adoption. Strengthening the role of these organisations could support the wider adoption of digital technologies in EU agriculture.

The continued reliance on paper-based and semi-manual methods of data management indicates a significant administrative burden on farmers, both for personal business management purposes and for policy compliance. A move to more advanced digital tools could help alleviate this burden by reducing the administrative workload associated with data collection and management. The digitalisation of data is critical for the successful digital transformation of agriculture. Furthermore, ensuring data interoperability between different digital platforms and across diverse systems can enhance usability and operational efficiency. This could enable smoother data exchange and reduce the duplication of efforts. This may, in turn, contribute to higher adoption rates of digital technologies and lower administrative burdens (Bahlo et al., 2019; Poppe et al., 2021).

However, to facilitate the digitalisation of farm data, it is crucial to establish clear policies, regulatory frameworks and business practices to address the privacy, security and data ownership concerns that have been identified as the main barriers to data sharing among farmers. Promoting policies, regulations and business practices that ensure transparency in data use and ownership, provide a secure framework for data sharing and give farmers more control over their data could help alleviate these concerns and foster greater trust in data sharing and digitslisation. In addition, creating more opportunities to amplify both the direct and indirect benefits of data sharing, such as enhanced knowledge exchange and access to tailored advisory services, is essential to incentivise farmers to actively engage in data-sharing practices.

By focusing on the areas highlighted above, policymakers and stakeholders can foster an environment that supports the adoption of digital technologies in agriculture. This will enable farmers to capture the benefits of technological advancements, enhancing their competitiveness, resilience and capacity to navigate future challenges.

The growing interest in AI and its application in agriculture (European Parliament et al., 2023; Javaid et al., 2023) underlines the relevance of this report's findings for understanding the potential pathways and barriers to AI adoption. The findings highlight both opportunities and challenges. As the findings suggest, adoption of AI technologies will not be straightforward – it will largely depend on their affordability and the extent to which they deliver tangible benefits to farmers. Adoption is also likely to be uneven across regions and farm types. As AI relies on processing large amounts of data using advanced algorithms to identify patterns and support decision-making, issues around data security, control and ownership will be critical. Farmers in this study identified these concerns as key barriers to data sharing. In addition, the prospect of both direct and indirect benefits – such as improved efficiency or access to tailored services – was found to be an important motivator for data sharing. Addressing these issues will be critical to facilitating the adoption of AI-based technologies in agriculture.

When drawing conclusions from this report, it is important to keep in mind the methodological assumptions and data limitations. First, the interview-based information on which the analysis is based was collected through farm surveys in nine Member States and is not representative of the EU as a whole. Second, the survey relied on self-reported data, particularly regarding farmers' perceptions of and intentions regarding digital technologies, which may be subject to personal judgement. A third caveat of the analysis is that the stratified random sampling strategy focused primarily on farm specialisation and size, which may lead to under- or over-representation of farms based on other criteria not considered in the sampling (e.g. age). Fourth, the survey data are primarily qualitative, which limits the ability to quantify certain aspects of digital technology adoption, such as adoption costs or their net contribution to sustainability. Fifth, challenges faced during the data collection phase, such as low response rates in certain regions, seasonal constraints and disruptions such as severe animal diseases in some Member States studied, may have affected the representativeness of the sample and the accuracy of the findings. Finally, the econometric estimations used in the report to analyse the determinants of digital technology adoption should not be interpreted as causal effects but rather as associations or correlations between the variables considered.

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List of abbreviations

Abbreviations	Definitions
AI	artificial intelligence
CAP	common agricultural policy
FTTC	fibre to the cabinet
FTTP	fibre to the premises
GNSS	global navigation satellite system
GPS	Global Positioning System
LSU	livestock units
NGA	next-generation access
NUTS	nomenclature of territorial units for statistics
OLS	ordinary least squares

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Annexes

Annex 1. Questionnaire on digitalisation

Digitalisation in EU agriculture	
Digitalisation in EU agriculture survey	
Please find **here** the privacy statement – info about personal data protection.	
Date of the interview:	
What time did you start the interview?	
Please do not forget to start the audio recording of the interview now.	
Please do not use the camera during the video recording.	
Screening question	
Screening introduction	
Good morning/afternoon, my name is … from … We are conducting a study on behalf of the European Commission to better understand the current state of digitalisation in EU agriculture. Your answers throughout this survey will be kept confidential. The European Commission will not receive any information that would allow you to be identified. Your responses will be grouped together with the responses provided by all participants and will be used strictly for research purposes and may be used to inform policy.	
Would you be interested in participating?	[Yes] [No]
S0. Are you a farmer?	[Yes] [No]
S1. Are you the person in charge of the farm? **Explanation: Person with decision-making power.**	[Yes] [No]
S2. Which of the following contributes most to the overall income of your farm?	[1. Crops, if your income from field crops is > 66 %] [2. Livestock, if income from livestock is > 66 %] [3. Mixed – mixture of crops and livestock: please consider mixed when crops are > 33 % of income and livestock is > 33 % of income]
S3. What is your farm size (hectares)?	[1. Less than 5 ha] [2. From 5 ha to 50 ha] [3. More than 50 ha]
S4. What is your livestock size (number of LSU except beehives, rabbits, deer, fur animals and other livestock)?	[1. < 50 LSU] [2. 50–200 LSU] [3. > 200 LSU]
S5. Where is your farm located?	

Questionnaire

Introduction

Questionnaire to European farmers about digital technologies adoption in agriculture.

The European Commission's Joint Research Centre has launched this study, in collaboration with [organisation name], to contribute to a better understanding of the current state of digitalisation in EU agriculture. This information will contribute to set targets and measure progress towards achieving EU objectives in line with the European Green Deal and a Europe fit for the digital age.

This survey is addressed to farmers, who are invited to reply to a set of questions and share their opinion in respect to the adoption of digital technologies on their farms. The results of the survey will contribute to the assessment of the state of play of digital technology in EU agriculture. The survey covers digital technologies such as precision farming, real-time applications, terrestrial and aerial drones, tools on prices, sensors, artificial intelligence, blockchain, satellite imagery, big data and analytics, agricultural decision support systems, etc.

The questionnaire takes about 45 minutes to complete. We thank you in advance for your valuable contributions.

Please note that all individual responses will be treated confidentially and will only be used to produce an analytical summary of the aggregated responses that may be made public by the European Commission services.

The survey will be conducted in compliance with the Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation).

General aspects about the farm manager

1. Please select the legal status that better describes the farm:	[Individual/family farm (sole holder)] [Family farm (shared ownership)] [Limited company (legal holding)] [Holding group] [Other (please specify)]
1a. Please specify	
2. What is your status on the farm:	[Owner] [Tenant farmer] [Business partner] [Hired manager] [Other]
3. What is the ownership of the land where the farm is located?	[Fully owned] [Mainly owned (more than 50 %)] [Mainly leased (more than 50 %)] [Fully leased]
4. Are you a:	[Full-time farmer] [Part-time farmer]
4a. Please specify:	
5. Please indicate your gender:	[Male] [Female] [Non-binary] [Prefer not to say]
The next question is not mandatory. If the farmer does not want to share the information, please skip the question.	
6. What is your age?	
7. What is the highest level of education you have achieved?	[Elementary or lower secondary school] [High school or vocational school] [Post-secondary non-tertiary education (Vocational training)] [University degree (bachelor's)] [Master's/PhD] [None]
8. Did you receive any professional or university education in agriculture? (Training, seminars not included)	[Yes] [No]

9. When did you start working on the farm (year)?	
10. When do you intend to stop farming?	[In 1 to 5 years] [In 6 to 10 years] [In more than 10 years] [I have no plan to stop] [Don't know yet]
11. Do you expect to have a successor for the management of your farm? **Note for interviewer:** do not read out loud the option 'Not applicable'; please select it if no other option is suitable.	[Yes, to a family member] [Yes, it will be sold or rented out] [Yes, other] [No, I will close down] [Don't know] [Not applicable]

About farm activities

In the next question (Q12) please only enter numbers, without a % sign.

12. What percentage of your turnover, of your total production, is made with organic certification? (Record %, if none, please insert 0)	[Yes] [No]

In the next question (Q13) please only enter numbers, without a % sign.

13. What is the percentage of sales made directly to consumers? (Record % sold directly to consumers)	
14. What is the total size of the farm (ha)? (Only utilised agricultural area)	

The next question is not mandatory. If the farmer does not want to share the information, please skip the question.

15. How many people, including you, work on the farm on average? (Please provide a number.) Please remember that all your answers are anonymous.

	Full-time	Part-time
Employees (hired labour) (other than family members)		
Family members with remuneration		
Family members without remuneration		
Seasonal workers		

The next question is not mandatory. If the farmer does not want to share the information, please skip the question.

17. What category describes better the total turnover (total value of market sale of goods and services excluding subsidies) of the farm in the last year (2023)?	[< 2 000 EUR/year] [2 001–8 000 EUR/year] [8 001–15 000 EUR/year] [15 001–25 000 EUR/year] [25 001–50 000 EUR/year] [50 001–100 000 EUR/year] [100 001–250 000 EUR/year] [250 001–500 000 EUR/year] [500 001–1 000 000 EUR/year] [> 1 000 001 EUR/year] *{Version in Hungary}* [< 800 000 HUF/year] [800 001–3 200 000 HUF/year] [3 200 001–6 000 000 HUF/year] [6 000 001–10 000 000 HUF/year] [10 000 001–20 000 000 HUF/year] [20 000 001–40 000 000 HUF/year] [40 000 001–100 000 000 HUF/year] [100 000 001–200 000 000 HUF/year] [200 000 001–400 000 000 HUF/year] [> 400 000 001 HUF/year] *{Version in Poland}* [< 8 700 PLN/year] [8 700–34 699 PLN/year] [34 700–65 099 PLN/year] [65 100–108 499 PLN/year] [108 500–216 999 PLN/year] [217 000–439 999 PLN/year] [434 000–1 084 999 PLN/year] [1 085 000–2 169 999 PLN/year] [2 170 000–4 339 999 PLN/year] [> 4 340 000 PLN/year]

The next question is not mandatory. If the farmer does not want to share the information, please skip the question.

In the next question (Q18) please only enter numbers, without a % sign.	
18. What is the share of CAP (common agricultural policy) subsidies in the total turnover? (Please estimate a percentage). Remember that all your answers are anonymous.	
In the next question (Q19) please only enter numbers, without a % sign.	

19. Thinking about the arable crops that you usually grow on your farm, what was the distribution of crops in number of hectares over the last year (2023)?

What was the approximate % of total turnover that you obtained per crop over the last year (2023)?

Crop	Area grown (ha)	% of total turnover
Cereals		
Potatoes and sugar beet		
Oilseeds (rapeseed and turnip rapeseed, sunflower, soya)		
Fruit orchards: pome fruits (apples and pears), stone fruits (such as peaches, apricots, plums and cherries), nuts fruits (such as almonds, hazelnuts, walnuts, pistachios), subtropical and tropical fruits (kiwi, figs, bananas, etc.), berries excluding strawberries (blueberries, redcurrants, gooseberries, raspberries, etc.), olives for consumption, grapes for consumption		
Fresh vegetables (including melons) and strawberries: brassicas (cauliflowers, broccolis, cabbages), leafy and stalked vegetables (such as lettuces, spinach, chicory, endives, asparagus, artichoke), root and bulb species (carrots, radishes, onions, shallots and garlic), fresh pulses (peas, beans) and all the herbaceous crops cultivated for their fruits (such as tomatoes, peppers, aubergines, courgettes, cucumbers and gherkins)		
Grapes for wine		
Olives for oil		
Permanent grassland		
Fibre crops (fibre flax, hemp, cotton fibre)		
Fallow		
Other (specify)		

Note: The sum of the % of total turnover of all crops should not necessarily add up to 100 %. However, the sum of the % of total turnover of all crops and animal categories should add up to 100 %.

Sum of crops turnover:	
Please specify what it was:	
In the next question (Q20) please only enter numbers, without a % sign.	

20. Thinking about the animals that you usually have on your farm, what was the average number of animals that you had over last year (2023)?

What was the % of the average turnover that you obtained per group over the last 4 campaigns (2019–2023)?

	Number of animals	% of total turnover
Bovine animals – under 1 year old		
Bovine animals – more than 1 but less than 2 years old		
Bovine animals – male and dairy cows, buffaloes, 2 years old and over		
Bovine – other cows and heifers, 2 years old and over		
Sheep and goats		
Piglets having a live weight of under 20 kg		
Pigs – breeding sows weighing 50 kg and over		
Other pigs		
Broilers		
Laying hens		
Turkeys		
Ducks		

Geese		
Ostriches		
Other poultry fowls not elsewhere classified		
Rabbits		

Sum of livestock turnover	

Note: The sum of the % of total turnover of all livestock categories should not necessarily add up to 100 %. However, the sum of the % of total turnover of all crops and animal categories should add up to 100 %.

In the next questions (Q19–20 cont.) please only enter numbers, without a % sign.

19–20 cont. Thinking about the arable crops that you usually grow on your farm, what was the distribution of crops in number of hectares over the last year (2023)?
What was the approximate % of total turnover that you obtained per crop over the last year (2023)?
Thinking about the animals that you usually have on your farm, what was the average number of animals that you had over last year (2023)?
What was the % of the average turnover that you obtained per group over the last 4 campaigns (2019–2023)?

	Area grown (ha) / number of animals	% of total turnover
Cereals		
Potatoes and sugar beet		
Oilseeds (rapeseed and turnip rapeseed, sunflower, soya)		
Fruit orchards: pome fruits (apples and pears), stone fruits (such as peaches, apricots, plums, cherries), nuts fruits (such as almonds, hazelnuts, walnuts, pistachios), subtropical and tropical fruits (kiwi, figs, bananas, etc.), berries excluding strawberries (blueberries, redcurrants, gooseberries, raspberries, etc.), olives for consumption, grapes for consumption		
Fresh vegetables (including melons) and strawberries: brassica (cauliflowers, broccoli, cabbages), leafy and stalked vegetables (such as lettuce, spinach, chicory, endives, asparagus, artichoke), root and bulb species (carrots, radish, onion, shallots and garlic), fresh pulses (peas, beans) and all the herbaceous crops cultivated for their fruits (such as tomatoes, peppers, aubergines, courgettes, cucumbers and gherkins)		
Grapes for wine		
Olives for oil		
Permanent grassland		
Fibre crops (fibre flax, hemp, cotton fibre)		
Fallow		
Other (crops)		
Bovine animals – under 1 year old		
Bovine animals – more than 1 but less than 2 years old		
Male and dairy cows, buffaloes, 2 years old and over		
Other cows and heifers, 2 years old and over		
Sheep and goats		
Piglets having a live weight of under 20 kg		
Breeding sows weighing 50 kg and over		
Other pigs		
Broilers		
Laying hens		
Turkeys		
Ducks		
Geese		
Ostriches		
Other poultry fowls not elsewhere classified		
Rabbits		

Sum of mixed turnover:	
Please confirm you provided all data here:	[Yes] [No]

About online activity of the farmer

21. Which kind of devices does your farm own? Please consider only the devices you use for work. [More than one response allowed]	[Computer/laptop] [Tablet] [Smartphone]
22. How would you classify the internet coverage at the farm, including in the fields?	[Good] [Sufficient] [Deficient] [Very poor]

23. Regarding the use of online and social media activity (e-commerce, e-advisory and other) related to farming …

	Never	Rarely	Often/frequently	Regularly
a) Do you regularly communicate with suppliers/buyers/customers using email, social media and/or instant messaging (e.g. WhatsApp, Viber, Facebook)? [Info: this does not include calling through phone]				
b) Do you sell products online?				
c) Do you buy inputs (seeds, fertilisers) for your farm online?				
d) Do you post videos/photos/messages on your social media related to your agricultural activity?				
e) Do you engage in online agricultural trainings?				
f) Do you use online platforms (e.g. LinkedIn, Facebook groups) to engage with agricultural professional networks?				
g) Do you browse online for information about how to improve your farming practices?				
h) Do you seek farming advice from agricultural advisors or extension services online? [**Note for interviewer:** extension services refer to private (companies) or public (e.g. research institutes) organisations that facilitate the knowledge transfer on new technologies and practices to farmers]				
i) Do you use apps that help you with farming? [**Note for interviewer:** e.g. weather forecast, pest and disease prediction and/or detection, farm accounting, geographical information systems, crop or animal monitoring apps through sensors]				
j) Other uses of online services in support of the farm business				

23j. Please specify:

24. Have you followed training on digital technologies related to agriculture in last 5 years?	[Yes] [No] [Do not remember]
25. Have you reached out to the advisory services or other organisations on issues related to the use of digital technologies related to agriculture in the last 5 years?	[Yes] [No] [Do not remember]

About digital technology adoption at farm level

26. Which type of digital technologies have been adopted, or do you plan to adopt in the next 5 years, in the farm you represent? Please, select all the digital technologies you adopted or you plan to adopt).

26.1. Forecast applications (weather, pests)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]

26.2. Mobile apps (weather, pests)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.3. Communication platforms (e.g. WhatsApp, Messenger, Viber)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.4. Trading platforms (e.g. e-commerce, mobile banking, commodity prices platforms)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.5. Accounting platforms	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
Crop farming	
26.6. Digital field records	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.7. Automatic steering systems [**Note for interviewer:** systems that allow the steering of farm machinery (e.g. tractor or combine harvester) without human intervention]	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.8. Farm management software (crop management, livestock management, financial and accounting software)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.9. Maps from satellite data	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.10. Yield mapping [**Note for interviewer:** yield sensors are utilised to create maps that show how crop yields vary across different areas of a field. These maps provide information about various crop yield factors such as grain yield and protein content]	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.11. Georeferenced soil sampling	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.12. Soil sensors (temperature, humidity, nutrients)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.13. Fully automatic field robotics (hoeing units, weeder)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.14. Drones for monitoring	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.15. Drones for spraying	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.16. Telemetry [**Note for interviewer:** remote data acquisition from various sensors (e.g. weather, crop, animal)]	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.17. Connected weather station	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.18. Tractors with global navigation satellite system (e.g. GPS)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.19. Section control (sprayer, spreader, planter) [**Note for interviewer:** adjusting	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]

the application sections of farm machinery to vary input rates based on the specific needs of different areas within a field]	
26.20. Light bar guidance systems [**Note for interviewer:** a system which indicates to the farm machinery driver where to drive to avoid overlaps of crop inputs applications]	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.21. Variable-rate application technology (e.g. irrigation, seeding, fertilisers, weed control)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.22. Connected insect traps	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.23. Field cameras	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.24. Augmented reality technologies (headsets, eyeglasses, goggles)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
Livestock farming	
26.25. Barn cameras	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.26. Farm management software (crop management, livestock management, financial and accounting software)	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.27. Digital livestock records	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.28. Behaviour monitoring sensors	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.29. Collars	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.30. Automatic milking system	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.31. Robotic slat clearer	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.32. Robotic feed pusher	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.33. Others	[Yes, adopted] [Yes, plan to adopt within the next 5 years] [No, the technology is not and will not be adopted within the next 5 years]
26.33a. Please specify:	
26.a. Which is the year of adoption?	
26.b. How did you finance it?	[Own financial resources] [External financing (e.g. bank credit, tech provider credit)] [Leasing or renting] [Subsidies / public support (e.g. CAP support)] [Other (e.g. contractors, collaborative scheme)]
26.c. How expensive is it?	[Not expensive at all] [Affordable] [Expensive] [Very expensive] [Do not know]
26.d. How do you plan to finance it?	[Own financial resources] [External financing (e.g. bank credit, tech provider credit)] [Leasing or renting] [Subsidies / public support (e.g. CAP support)] [Other (e.g. contractors, collaborative scheme)]

26.e. How expensive do you think it will be?	[Not expensive at all] [Affordable] [Expensive] [Very expensive] [Do not know]

About drivers and barriers for digital technologies adoption

28. Which are the main barriers that the farm you represent has faced in adopting digital technologies? Select maximum 5.	[Lack of knowledge on available digital technologies for farm application] [Lack of IT know-how/skills (personally or on the farm overall)] [Lack of interest in digital technologies] [Lack of availability of digital technology providers in my area] [High cost of the digital technologies] [Low benefits of the digital technologies for the farm operations] [Lack of internal financial resources] [Lack of access to external finances (e.g. bank credit)] [Lack of government support] [Questionable profitability of digital technologies] [Lack of internet connectivity in rural areas] [Lack of available/trusted technical advice] [Concerns on data privacy] [Concerns on data ownership] [Technical susceptibility to errors of the digital technologies] [Others] [Don't know]
No of selected items:	
Please specify:	
29. Which are the main drivers/reasons for the adoption of digital technologies? Select maximum 5.	[Meet regulatory or legislative changes requirements (EU or national)] [Meet new market demand (i.e. changes in consumer preferences) [**Note for interviewer:** for example, fruits of bigger diameter, higher sugar content and different colour, need for organic production]] [Respond to pressure from competitors] [Respond to demands from buyers] [Develop new business growth opportunities] [Improve input use efficiency and/or reduce environmental footprint] [Personal managers'/owners' motivation to move towards digital] [Increase product traceability demands and requirements] [Reduce operational costs (input, time)] [Increase added value of my products/activities] [Improve well-being/safety (be healthier, less tired, less stressed, more free time)] [Better manage risks (climate, building safety, accident) / respond to unforeseen events] [Improve overall farm management based on data [**Note for interviewer:** moving away from relying solely on instincts, tradition or calendars, and instead using data-driven, fact-based approaches that are more efficient and profitable]] [Improve animal welfare] [Widely spread in the area (adopted or suggested by neighbours)] [Suggested/recommended by farm advisor(s)] [Other] [Don't know]
No of main adoption drivers/reasons:	
Please specify:	
30. In your opinion, which stakeholder groups are the main facilitators on the adoption of digital technologies in the farm you represent? Select maximum 3.	[Owner] [Consumers/costumers] [Suppliers and trading partners] [Competitors] [Investors] [Neighbour farmers] [Employees] [Local administration/government/EU] [Media (incl. social media)] [Advisory/extension services] [Cooperatives / farmer organisation] [Farm associations] [Technology providers] [Academia / research centre] [Other] [Don't know]
Please specify:	
No of main stakeholder groups selected:	

About sustainability aspects of the digital technologies

33. Considering the technologies that you adopted or plan to adopt, what do you think are or could be the effects of these technologies, in terms of benefits and costs/risks, in the short-to-medium term (5 years) with respect to the following 3 dimensions of sustainability?

	Very negative	Negative	Neutral (none)	Positive	Very positive	Don't know
Economic aspects of the farm (income, profitability, efficiency)						
Social aspects of the farm (e.g. working conditions, safety, animal welfare)						
Environmental aspects of the farm (e.g. chemical input use, fertiliser use, water use, CO_2 emissions, soil erosion)						

34. Do you expect that the digital technology(ies) you have adopted or plan to adopt will help you respond/adapt to different	[Not at all] [Slightly] [Somewhat] [Very much] [Don't know]

unforeseen disruptions (e.g. price shocks, cost increase, labour safety and health crises, droughts, plant/animal disease) occurring on the market or the environment?	

About data originated from digital technologies

This section refers to the use and analysis of data generated with digital technologies to extract patterns, trends and insights for better decision-making with the aim of improving performance (e.g. increase production, reduce costs). Data may be extracted from your own enterprise's data source or from external sources (e.g. suppliers, customers, government).

35a. What type of data and with which frequency does your farm collect and/or use from the following sources in digital form? Please select all data your farm collects or uses.

a) Financial/transaction data (sale details, payment records, expenses)	[Daily] [Weekly] [Monthly] [Annually] [Never]
b) Administration data (registers, Integrated Administration and Control System)	[Daily] [Weekly] [Monthly] [Annually] [Never]
c) Output data (production, crop yields, etc.)	[Daily] [Weekly] [Monthly] [Annually] [Never]
d) Input data (fertiliser, pesticides, etc.)	[Daily] [Weekly] [Monthly] [Annually] [Never]
e) Soil data (nutrient levels, pH, organic matter content)	[Daily] [Weekly] [Monthly] [Annually] [Never]
f) Crop-related data (crop health, growth)	[Daily] [Weekly] [Monthly] [Annually] [Never]
g) Livestock data (e.g. feed use, veterinary information)	[Daily] [Weekly] [Monthly] [Annually] [Never]
h) Market data (price trends, forecast models on prices)	[Daily] [Weekly] [Monthly] [Annually] [Never]
i) Irrigation data (water usage)	[Daily] [Weekly] [Monthly] [Annually] [Never]
j) Equipment data (fuel, energy, operating hours)	[Daily] [Weekly] [Monthly] [Annually] [Never]
k) Location data from the use of portable devices or vehicles	[Daily] [Weekly] [Monthly] [Annually] [Never]
l) Satellite data (e.g. satellite imagery, navigation signals, position signals)	[Daily] [Weekly] [Monthly] [Annually] [Never]
m) Weather data (forecast)	[Daily] [Weekly] [Monthly] [Annually] [Never]
n) Other	[Daily] [Weekly] [Monthly] [Annually] [Never]
Please specify:	
35b. How are data collected and managed?	[1. Mostly paper based] [2. Digitised in spreadsheets and/or scanned documents] [3. With specialised applications and software] [4. Using automated systems (sensors, drones, internet of things devices)] [5. Through external services] [6. Don't know]
35c. Who owns the collected data?	[1. Most collected data are my own] [2. Most collected data are in shared ownership (e.g. with tech, provider)] [3. Most collected data are owned by external provider/organisation] [4. Don't know]
36. Do you share data electronically with external parties (e.g. via websites or apps, telemetry, real-time sensors or	[Other farmers] [Consultants/advisors] [Supply chain actors] [Agri-tech companies] [Associations and cooperatives] [Researchers] [Public administrations] [Financial institutions] [Other] [No]

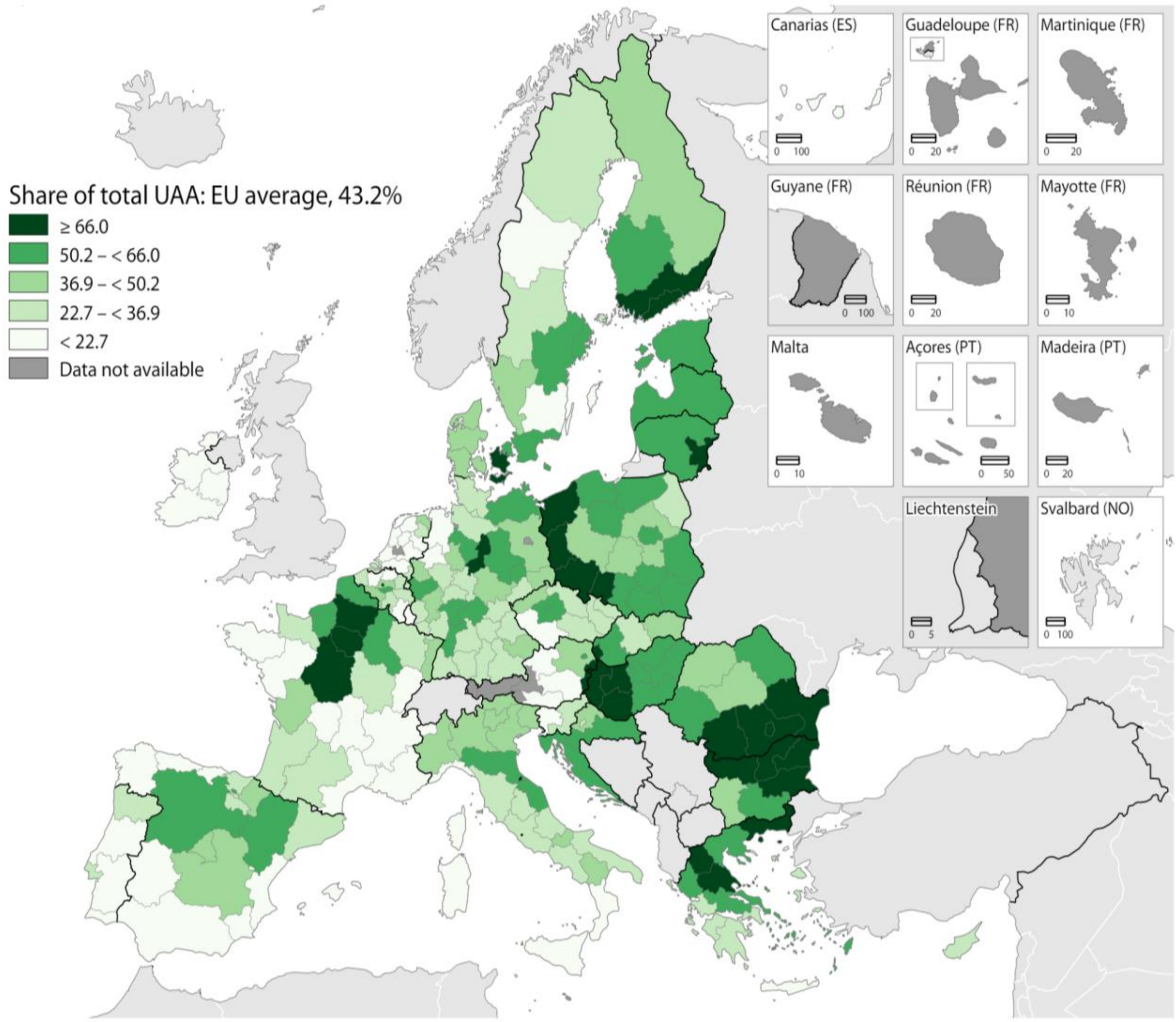
tracking)?	
Please specify:	
37. If you share data, how do you share them:	[On my own] [Though association/cooperatives] [Through external providers]
38. If you share data, what do you receive in exchange for sharing your data?	[Financial compensation] [Services (e.g. advice)] [Access to new technologies] [Other] [None of these]
Please specify:	
39. Which are the main reasons for you to share your data with external parties? Select max. 3.	[Financial compensation] [Receive services from the technology provider (e.g. personalised recommendations, benchmarking / performance evaluation)] [Access to new digital technologies] [Knowledge sharing] [Risk management] [Informed decision-making] [Supply management (traceability, transparency, product quality)] [Comply with legal requirements] [Contribute to research] [Contribute to policymaking] [Other]
No of reasons to share data selected:	
Please specify:	
40. Please indicate the main issues with regard to sharing data electronically with external parties? Select maximum 3 choices.	[Data privacy and security concerns] [Data ownership concerns] [Data usage concerns] [Competition] [Compliance concerns] [Lack of awareness] [Lack of (strong, clear) incentives] [Lack of know-how, skills] [Lack of support] [Lack of infrastructure (limited connectivity)] [Lack of (financial or non-financial) compensation] [Other]
No of issues for sharing data electronically:	
Please specify:	
One last question before completing this survey. We would like to measure your current broadband speed. It will only take a few seconds.	
Please share the following link in order to record the download and upload speed of the internet: https://www.nperf.com/	
41. Would you mind accessing the link I just shared on the chat and follow the instructions? If you share your screen, I can guide you through the process.	[Yes, I accept] [No, I do not accept]
42. Would you mind accessing this link through your. phone/laptop? I can guide you through the process.	[Yes, I accept] [No, I do not accept]
In case the farmer has no Wi-Fi or does not want to measure it, please measure through your device via this link: https://www.nperf.com/	
If you use decimals, please only use '.' and not ','	
43a. Download speed: (mb/s)	
43b. Upload speed: (mb/s)	
Thank you for completing this survey. Your feedback is invaluable to us.	
R.1 We may need to recontact you for clarification purposes only. Are you available to be recontacted?	[Yes] [No]

What time did you finish the interview?	
Please upload your audio recording after the interview:	
Please upload a photo of the location where the interview took place. In the case of an online interview, please upload a screenshot of the call.	

Annex 2. Maps of the area utilised by holdings specialised in crops and grazing

Figure 36. Share of total utilised agricultural area managed by holdings specialised in (a) field crops and (b) grazing livestock (%, NUTS 2, EU, 2020)

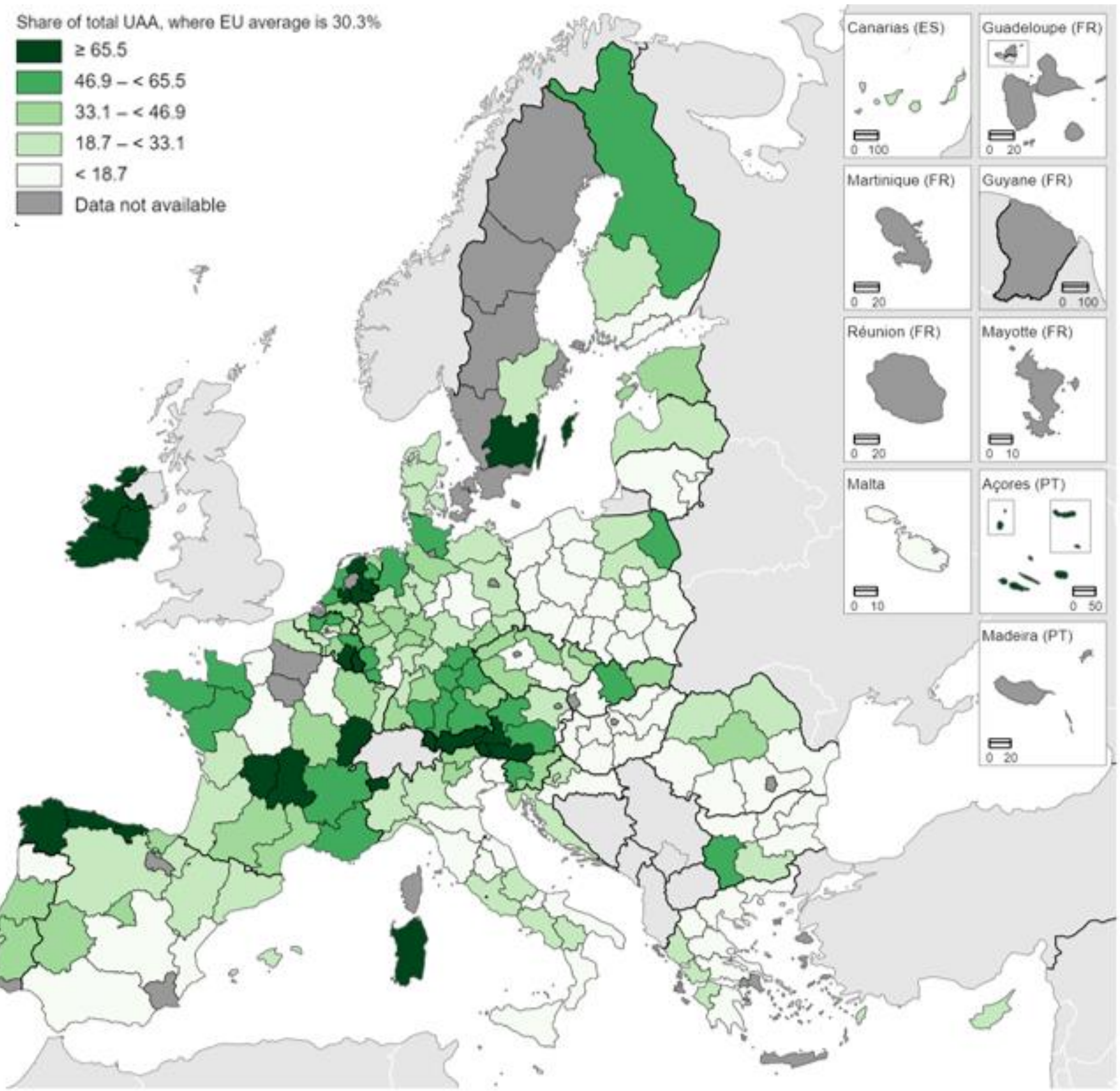
(a) Field crops



NB: Where data are shown as 'not available', this is usually to protect confidentiality due to the low number of specialist field crop farms.

Source: Eurostat (dataset ef_lus_main); administrative boundaries © EuroGeographics, Food and Agriculture Organization of the United Nations and Turkstat; cartography by Eurostat – Image 03/2023.

(b) Grazing livestock

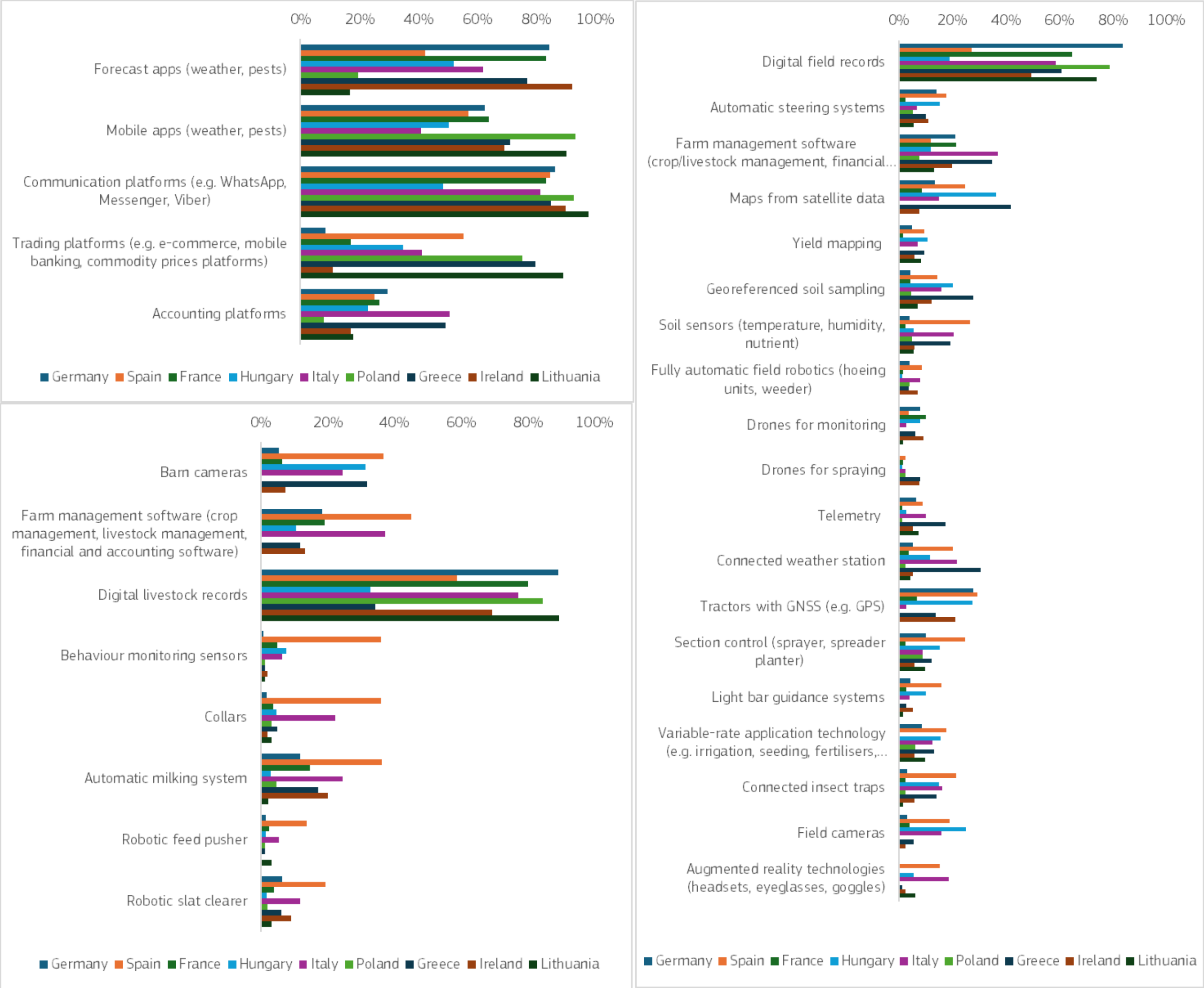


NB: Where data are shown as 'not available', this is usually to protect confidentiality due to the low number of specialist field crop farms.

Source: Eurostat (dataset ef_lus_main); administrative boundaries © EuroGeographics, Food and Agriculture Organization of the United Nations and Turkstat; cartography by Eurostat – Image 03/2023.

Annex 3. Adoption rates by Member State, farm size and farmer age

Figure 37. Adoption rates of IT and software technologies (top left), livestock production technologies (bottom left) and crop production technologies (right) by Member State (%)

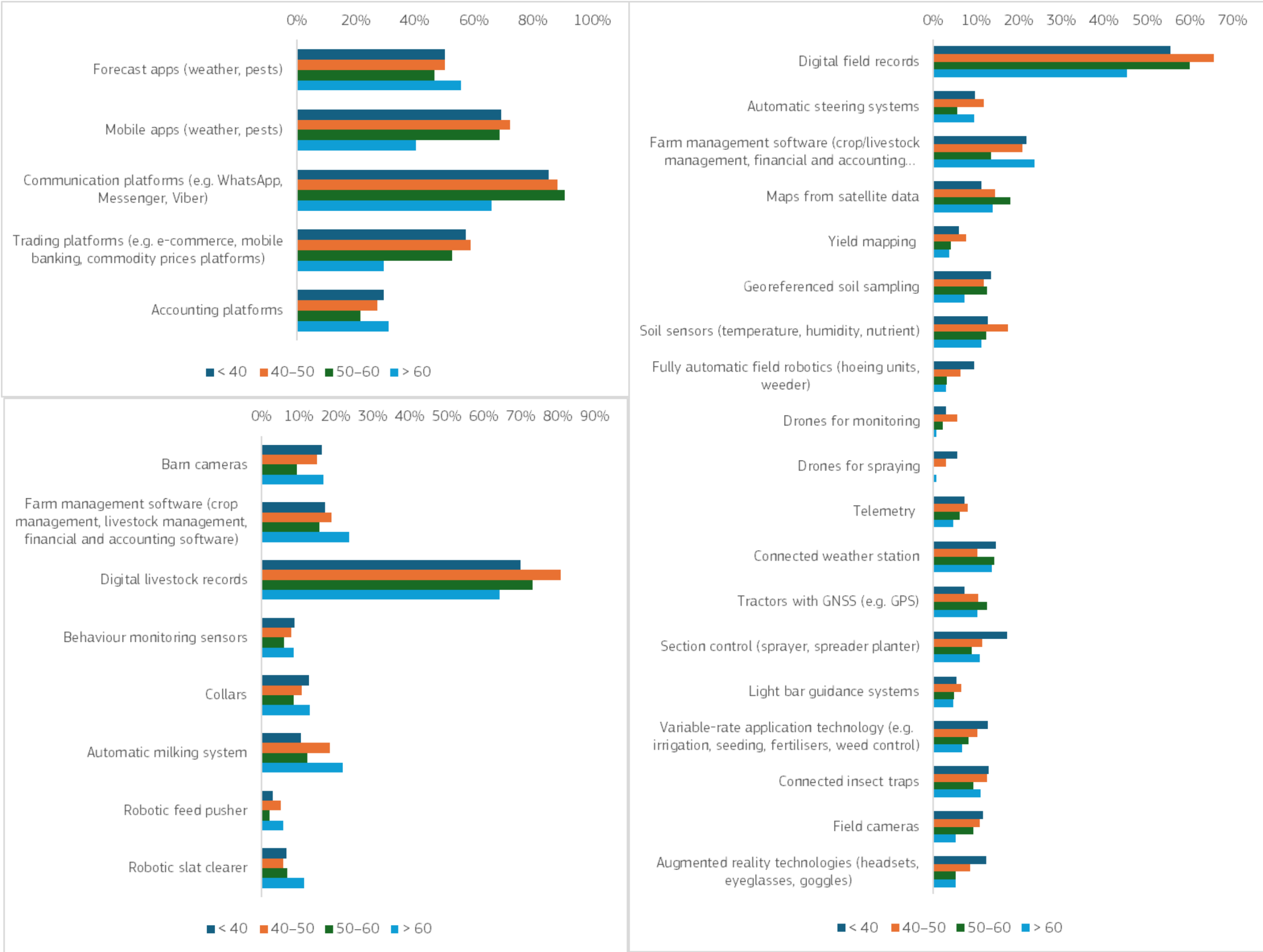


Source: Authors' own compilation based on the survey data.

Figure 38. Adoption rates of IT and software technologies (top left), livestock production technologies (bottom left) and crop production technologies (right) by farm size (%)

Source: Authors' own compilation based on the survey data.

Figure 39. Adoption rates of IT and software technologies (top left), livestock production technologies (bottom left) and crop production technologies (right) by age of the farmer (%)



Source: Authors' own compilation based on the survey data.

Annex 4. Redefined categories of drivers and barriers in the econometric estimation

The drivers and barriers presented to the respondents were grouped in order to reduce the number of explanatory variables in the econometric regression.

The drivers were grouped and redefined for the econometric estimation as follows.

- Regulatory pressure
    - Meet regulatory or legislative change requirements (EU or national)
    - Increase product traceability demands and requirements
- Market pressure
    - Meet new market demand (i.e. changes in consumer preferences)
    - Respond to pressure from competitors
    - Respond to demands from buyers
- Growth opportunities
    - Develop new business growth opportunities
    - Increase added value of my products/activities
- Efficiency and cost reduction
    - Improve input use efficiency and/or reduce environmental footprint
    - Reduce operational costs (input, time, etc.)
- Management and operational improvement
    - Better manage risks (climate, building safety, accidents) / respond to unforeseen events
    - Improve overall farm management based on data
- Quality of life and animal welfare
    - Improve well-being/safety (be healthier, less tired, less stressed, have more free time)
    - Improve animal welfare
- Personal motivation and influence
    - Personal manager's/owner's motivation to move to digitalise
    - Widely spread in the area (adopted or suggested by neighbours)
    - Suggested/recommended by farm advisor(s)

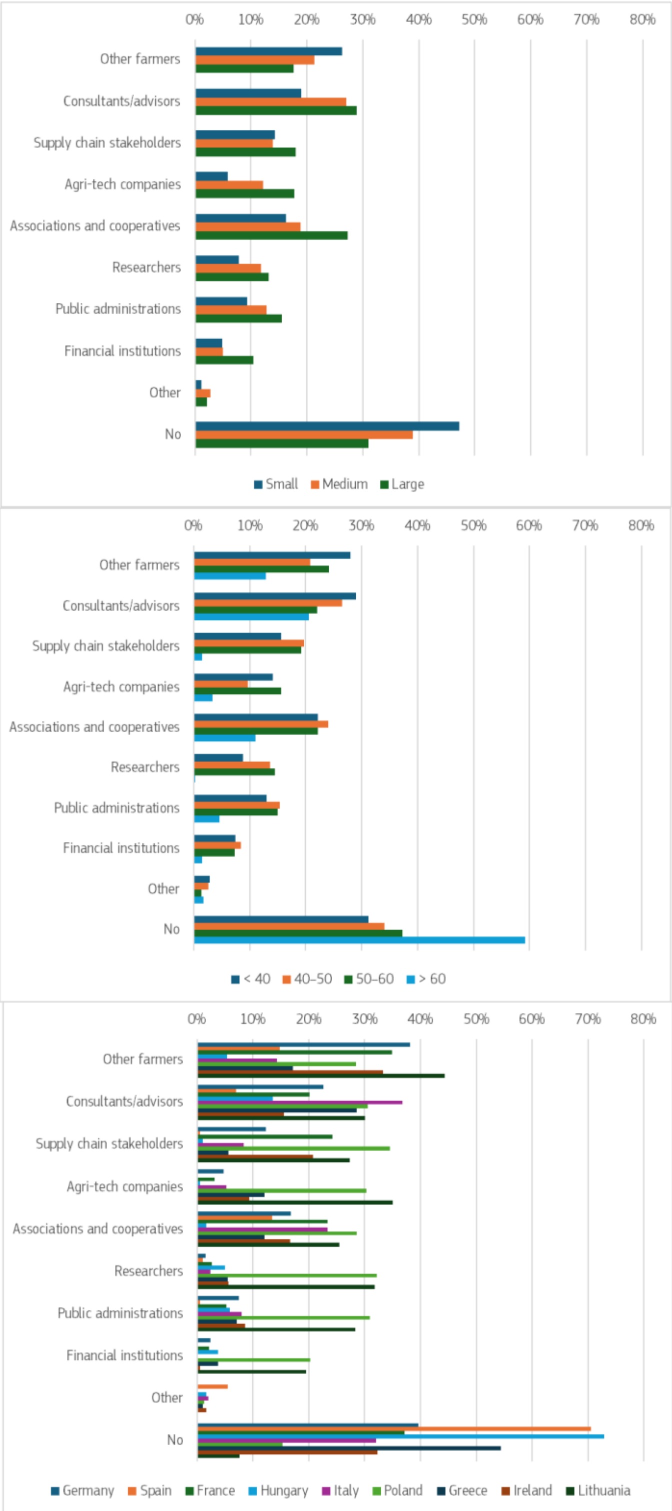
The barriers were grouped and redefined for the econometric estimation as follows.

- Knowledge and skills
    - Lack of knowledge on available digital technologies for farm application
    - Lack of IT know-how/skills (personally or on the farm overall)
    - Lack of available/trusted technical advice
- Lack of interest and low perceived value
    - Lack of interest in digital technologies
    - Low benefits of the digital technologies for the farm operations
    - Questionable profitability of digital technologies
- Access to infrastructure
    - Lack of availability of digital technology providers in my area
    - Lack of internet connectivity in rural areas

- Financial constraints
    - High cost of the digital technologies
    - Lack of internal financial resources
    - Lack of access to external finances (e.g. bank credit)
- Lack of policy support
    - Lack of government support
- Data privacy and ownership
    - Concerns about data privacy
    - Concerns about data ownership
- Susceptibility to errors
    - Digital technologies' susceptibility to errors

Annex 5. Data-sharing practices by farm size, farmer age and Member State

Figure 40. Share of farmers surveyed sharing data electronically with external stakeholders by farm size, farmer age and Member State (%)



NB: Multiple responses were allowed.

Source: Authors' own compilation based on the survey data.

Annex 6. Results of OLS econometric estimations

Table 7. OLS regression results explaining respondents' adoption of digital technologies for IT and software technologies, crop-specific technologies and livestock-specific technologies

		IT and software				Crop specific				Livestock specific			
		OLS		**OLS D & B**		**OLS**		**OLS D & B**		**OLS**		**OLS D & B**	
Size	Small (reference)												
	Medium	0.08		0.03		0.18		0.14		0.23	*	0.15	
	Large	0.34	***	0.27	***	1.67	***	1.51	***	0.59	***	0.45	***
Specialisation	Crop (reference)												
	Livestock	– 0.08		– 0.03									
	Mixed	0.02		0.05		– 0.54	***	– 0.53	***	– 0.37	***	– 0.33	***
Gender	Male (reference)												
	Female	– 0.04		– 0.04		– 0.09		– 0.20		0.01		0.03	
Age	Age of respondent	– 0.01	***	– 0.01	***	– 0.01		0.00		– 0.01		0.00	
Legal ownership	Shared ownership (reference)												
	Individual/family farm (sole holder)	– 0.15	**	– 0.07		– 0.30	*	– 0.16		– 0.17		– 0.13	
Land ownership	Fully owned (reference)												
	Mainly owned	– 0.04		– 0.04		– 0.16		– 0.18		0.43	***	0.43	***
	Mainly leased	0.01		0.01		0.05		0.00		0.23		0.20	
	Fully leased	– 0.26		– 0.29	*	– 0.27		– 0.33		0.46	**	0.38	
Farmer status	Full-time farmer (reference)												
	Part-time farmer	– 0.28	**	– 0.37	***	– 0.81	***	– 0.93	***	– 0.61	***	– 0.55	***
Education	Primary education (reference)												
	Secondary or vocational	0.38	***	0.36	***	– 0.04		– 0.07		– 0.24	*	– 0.23	*
	Post-secondary	0.38	***	0.22	*	0.28		0.11		0.08		0.00	
	University	0.49	***	0.37	***	– 0.01		– 0.12		– 0.30		– 0.29	
	Master's or PhD	0.53	***	0.34	**	1.07	***	0.82	**	0.31		0.24	
	No education	– 0.91	***	– 0.66	**	– 0.31		0.08		– 0.10		– 0.04	
Agricultural training	No specific agricultural training (reference)												
	Professional training related to agriculture	0.04		0.00		0.44	**	0.35	**	0.35	***	0.32	***
Retirement plans	No plans to retire (reference)												
	Retiring within the next 10 years	– 0.06		– 0.12		0.28		0.19		0.05		– 0.01	
	Retiring in more than 10 years	0.39	***	0.25	**	0.68	**	0.47	*	0.17		0.09	
Organic production	No organic production (reference)												
	Organic production	– 0.01		0.02		– 0.03		0.05		0.18	*	0.11	
Direct sales	No direct sales (reference)												
	Direct sales	0.39	***	0.37	***	0.61	***	0.55	***	0.52	***	0.48	***
Internet connection	Internet good (reference)												
	Internet sufficient	– 0.19	***	– 0.14	**	– 0.58	***	– 0.56	***	– 0.20	*	– 0.13	
	Internet deficient	– 0.54	***	– 0.35	***	– 0.46	*	– 0.30		– 0.33	**	– 0.21	
	Internet poor	– 0.64	***	– 0.48	***	– 0.63		– 0.44		– 0.62	**	– 0.49	*
Specific digitalisation training	No training (reference)												
	Undertook digitalisation training	0.51	***	0.44	***	1.86	***	1.70	***	0.39	***	0.35	***
Region	South (reference)												
	North	– 0.18	*	– 0.12		– 0.43	*	– 0.24		– 0.12		– 0.01	
	East	– 0.83	***	– 0.61	***	– 0.22		0.07		– 0.22		– 0.14	
	West	– 0.08		– 0.04		– 0.86	***	– 0.66	***	– 0.35	***	– 0.20	
Drivers	Regulatory pressure			0.24	***			0.62	***			0.25	**
	Market pressure			0.19	***			0.07				0.19	*
	Growth opportunities			– 0.05				0.13				0.28	**
	Efficiency and cost reduction			0.43	***			0.75	***			0.34	***
	Management and operational improvement			0.52	***			0.28				– 0.02	

		IT and software				Crop specific				Livestock specific			
		OLS		**OLS D & B**		**OLS**		**OLS D & B**		**OLS**		**OLS D & B**	
	Quality of life and animal welfare			0.12				0.25				0.41	***
	Personal motivation and influence			0.04				0.01				0.09	
Barriers	Knowledge and skills			– 0.23	***			0.04				0.09	
	Interest and perceived value			0.07				– 0.22				– 0.08	
	Access and infrastructure			0.01				0.17				– 0.05	
	Financial constraints			– 0.12				– 0.30	*			– 0.07	
	Support and policy			0.04				0.10				0.10	
	Data privacy and ownership			0.19	**			0.03				– 0.21	
	Susceptibility to errors			0.40	***			0.92	***			0.01	
Intercept		3.53	***	2.59	***	4.12	***	1.52	**	2.335	***	1.02	***
Number of observations		1 444		1 444		1 004		1 004		814		814	

NB: * significant at the 10 % level; ** significant at the 5 % level; *** significant at the 1 % level; D & B: drivers and barriers.

Source: Authors' own compilation based on the survey data.

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