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D4.13 - Framework Conditions and Impact Analysis - Draft

WP4 – Observatory Data Collection and Analysis

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Executive Summary

This deliverable, **D4.13 Framework Conditions and Impact Analysis**, offers a detailed exploration of the factors that influence the adoption and use of digital technologies in agriculture and forestry across Europe. Drawing data from the **4Growth project's observatories**, as well as insights from **T4.2** and **T4.3**, this report focuses on governance frameworks, data sharing practices, technical aspects, and socio-economic impacts related to digital technology uptake.

The primary objectives of this deliverable are to:

- Assess the influence of governance frameworks, policies, and regional incentives at EU, national, and local levels on the adoption of digital technologies.
- Examine data sharing practices and barriers among stakeholders, and how these impact technology uptake.
- Evaluate the technical suitability of digital solutions in meeting user needs, including their usability, interoperability, and integration with existing workflows.
- Analyze the socio-economic impacts of digital technologies, focusing on environmental, economic, and societal benefits.

This report presents the findings of the observatories structured into the following sections:

1. **Governance and Framework Conditions**: Explores the role of policies such as the Common Agricultural Policy (CAP) and EU Forest Strategy, and their influence on technology adoption.
2. **Data Sharing Practices**: Investigates how data is exchanged, managed, and owned among stakeholders in the agricultural and forestry sectors.
3. **Technical Aspects of Digital Technologies**: Assesses the usability, integration, and interoperability of digital technologies with existing operations.
4. **Socio-economic Impacts**: Looks into the economic, environmental, and societal benefits of adopting digital technologies.
5. **Conclusions and Recommendations**: Provides insights and recommendations for encouraging the further adoption of digital solutions.

The findings from this analysis will inform **policy recommendations (T4.5)** and contribute to the **4Growth Visualisation Platform (WP2)**. This deliverable will be updated in **M33 (D4.14)** to include further insights from ongoing research and stakeholder engagement.

1 Introduction

This report, **D4.13 Framework Conditions and Impact Analysis**, provides an in-depth look at the factors affecting the uptake and use of digital technologies in agriculture and forestry across Europe. It draws on data from the **4Growth project's observatories** and incorporates results from **T4.2** and **T4.3**, focusing on governance models, data sharing practices, technical aspects, and socio-economic impacts.

The goal of this deliverable is to synthesize the key factors that either facilitate or hinder the adoption of digital solutions in agriculture and forestry. The insights gathered will help guide future project activities, including the development of **policy recommendations (T4.5)** and the **4Growth Visualisation Platform (WP2)**.

1.1 Purpose

1.1.1 Objectives of the Analysis

The **Framework Conditions and Impact Analysis**, under **T4.4** of the **4Growth project**, provides a thorough examination of the factors that influence the adoption of digital technologies in agriculture and forestry. This deliverable builds on the outcomes of **T4.2** and **T4.3** and offers critical insights into the broader ecosystem of digital solutions. It is aligned with the objectives of the **Horizon Europe Programme** and directly contributes to the **4Growth Visualisation Platform (WP2)** and supports **policy recommendations and best practices (T4.5)**.

The objectives of this analysis are to provide insights into the following areas:

- **Governance Frameworks**: Assess the role of governance models, policies, and incentive mechanisms at EU, national, and local levels in promoting the adoption of digital technologies.
- **Data Sharing Practices**: Explore how value chain actors share, access, and use data, identifying barriers and solutions.
- **Technical Aspects**: Evaluate how well digital solutions meet end-user needs, focusing on usability, interoperability, and integration into existing workflows.
- **Socio-economic Impacts**: Analyze the environmental, economic, and societal benefits resulting from technology adoption.

The initial version of **D4.13**, delivered in **M18**, sets the foundation for understanding the factors that influence technology adoption. It will be updated in **M33 (D4.14)** to include new insights from ongoing research and stakeholder engagement.

1.1.2 Scope and Focus Areas

The scope of this deliverable covers a detailed aggregation of knowledge gathered from observatory data collection waves regarding governance models, technical aspects, data sharing practices, and the socio-economic impacts of adopting digital agriculture and forestry technologies.

1.1.1. Relation to other project documents

This deliverable complements the findings of T4.2 Data Collection via Observatories and T4.3 Synergy Building with Other European Initiatives, helping to integrate these insights and further guide the development of policy recommendations (T4.5) and the 4Growth Visualisation Platform (WP2).

In the event of discrepancy between documents, this document is overruled by the Grant Agreement including its Annexes and the Consortium Agreement with its possible addendums.

1.2 Abbreviations

SOTA	State-of-the-art	**HE**	Horizon Europe
FMIS	Farm Management Information Systems	**CTF**	Controlled Traffic Farming
VRT	Variable Rate Technology	**AI**	Artificial Intelligence
DSS	Decision Support Systems	**IoT**	Internet of Things
ERP	Enterprise Resource Planning	**RS**	Remote Sensing

2 Approach and Methodology

2.1 Observatory Data Collection

To ensure systematic collection of partner insights on the deployment and impact of digital technologies in agriculture and forestry, a structured **Observatory Survey on Framework Conditions and Impact Analysis** was developed and distributed to observatories across Europe (Annex A). The survey is divided into four key thematic areas, each designed to address specific aspects of the adoption and use of digital technologies:

Governance Models

This section explores how EU and national strategies—such as the Common Agricultural Policy (CAP) and the EU Forest Strategy—support the adoption of digital tools in agriculture and forestry. It investigates the effectiveness of these strategies, identifying key enabling or limiting policies at national and regional levels. The survey collects data on the overall supportiveness of governance frameworks, policies that have influenced adoption, the effectiveness of different governance levels (EU, national, regional), as well as the availability and accessibility of incentives and funding programmes. It also identifies key regulatory barriers, such as administrative burdens and policy misalignments, and asks for suggested policy improvements to facilitate wider technology adoption.

Data Sharing Practices

Given that digitalisation depends heavily on data exchange, this section examines how stakeholders generate, manage, and share digital data across the value chain. The focus is on ecosystem-level data practices rather than isolated technologies. It includes questions on common mechanisms for data exchange (e.g., open platforms, private agreements), the types and sources of data commonly used (such as remote sensing, IoT sensors, and field records), and stakeholder approaches to data ownership and access. This section also assesses the drivers and barriers to data sharing, including trust, the perceived value of data, and the clarity of data governance frameworks. Additionally, it explores how improved data sharing could facilitate digital technology adoption and captures any existing frameworks or best practices in data governance.

Technical Aspects of Digital Technologies

This section identifies the digital technologies in use, their specific applications, and the challenges they address. The survey delves into the core technologies being employed (such as precision agriculture, remote sensing, decision support systems, and AI), evaluating the operational problems they solve (e.g., yield prediction, fire detection, pest monitoring). It also assesses user experience, evaluating whether technologies meet end-user needs, their ease of use, and any integration challenges (e.g., skill gaps, cost, or interoperability). The section further explores the impact of data standards and compatibility issues and identifies any unintended downsides, such as increased complexity, high costs, or workforce displacement.

Socioeconomic Impact of Technology Adoption

This section offers a comprehensive assessment of the broader socio-economic impacts resulting from digitalisation in agriculture and forestry. It covers observed economic benefits, such as improved efficiency, cost savings, and yield increases. It also documents environmental advantages, including reduced emissions and better biodiversity management. Furthermore, it examines improvements in innovation, competitiveness, and regulatory compliance (e.g., CAP reporting). The survey also addresses social and labour-related effects, such as workforce transitions, digital stress, and broader societal implications of adopting digital tools.

Partner Contributions

Each observatory contributed region-specific insights based on local implementation experiences. This collaborative approach ensured that the survey results reflect both technical expertise and the on-the-ground realities of digital technology adoption across diverse European contexts. These contributions enrich the analysis by providing a comprehensive understanding of the challenges and opportunities in different regions, ensuring that the final report captures a holistic view of the impact of digital technologies in agriculture and forestry.

2.2 Data Triangulation

As part of the **T4.4 Framework Conditions and Impact Analysis**, this analysis integrates both qualitative and quantitative findings from the structured observatory questionnaire with existing data from **T4.2 Data Collection via Observatories** and **T4.3 Synergy Building with Other European Initiatives**. The triangulation process ensures a robust and comprehensive understanding of the factors influencing the adoption and use of digital technologies in agriculture and forestry. By cross-referencing and aligning insights from the observatory survey with data gathered from **T4.2**, **T4.3**, and additional sources such as the **Grid survey** and synergy-building activities, we can ensure a well-rounded analysis.

2.2.1 T4.2 Data Collection via Observatories - Data Analysis and Integration of Grid-Based Survey Results

Governance Models and Policy Landscape

Key findings from **T4.2** highlight significant regional variation in governance models. In **Southern Europe**, there is a high demand for better access to funding, improved training, and education to support the expansion of digital infrastructure. In **Finland**, respondents emphasized the importance of drone survey regulations and meeting established regulations for monitoring digital technology. **Greece** focused on investing in better connectivity and infrastructure to facilitate future technology integration. Across Europe, both agriculture and forestry sectors identified a skilled workforce with technological expertise as essential for successful technology adoption.

Data Sharing Practices and Digital Governance

Regarding data sharing, the most common actors involved in digitalization are **primary producers** such as farmers and foresters (59%), followed by advisory groups (15%) and cooperatives and associations (8%). Data providers have a geographically balanced reach, with services offered locally (33%), nationally (17%), continentally (17%), and globally (33%). More than half of service providers tailor their products and services specifically to agriculture and forestry, though many lock them behind subscription-based paywalls. Data collected includes crop yield (65%), soil data (31%), weather (44%), pest and disease information (50%), inventory and equipment (31%), market and economic data (23%), and geospatial information (23%). Data sharing is often restricted, with organizations sharing data only under controlled conditions, often through agreements. The primary challenges to data sharing include trust issues, privacy concerns, and data ownership disputes. **The Benelux region** specifically highlighted "limited knowledge in computer software" and a reluctance to connect further as significant barriers.

Technical Aspects of Digital Technologies

The survey results indicate that **66% of respondents** have integrated digital technologies into their workflows, but only **45%** reported using cloud services or data centers. Most cloud services are provided by American companies such as Microsoft Azure, Google Cloud, or iCloud. **49%** of respondents cited barriers to further integration, such as financial costs, lack of employee competencies, scattered information, platform interoperability issues, and an overload of options. Technological solutions are also limited by poor internet and GNSS coverage, especially in remote areas. Over half of respondents indicated that digital technologies only partially meet their organization's needs. In some cases, the "last mile" connectivity issues were identified as a hindrance to fully utilizing technologies, and the initial investment costs were the most widely mentioned barrier to technology adoption.

Socioeconomic Impact of Digital Technology Adoption

A notable impact of digital technologies is the **cost savings** and **efficiency improvements** experienced by **54% of respondents**, with **58%** reporting positive contributions to sustainability and environmental practices. In **Greece**, more than **70% of foresters** reported social benefits from the use of digital technologies, including substantial impacts on job creation, increased efficiency, cost savings, improved energy efficiency, and a reduction in their environmental footprint.

2.2.2 T4.3 Synergy Building with Other European Initiatives

Building on the activities under Task 4.3 and the insights reported in Deliverables D4.4 and D4.5, 4Growth has initiated targeted collaborations with related European initiatives to strengthen knowledge exchange on the uptake of digital technologies in agriculture and forestry. Through systematic mapping and engagement, synergies have been officially announced with the following EU initiatives: ICAERUS, Smart Droplets, QuantiFarm, BEATLES and PRUDENT. Furthermore, 4Growth is in close contact with FoodDataQuest, Data4Food2030, CODECS and D4AgEcol and has initiated communication for future collaboration with EU initiatives such as AgriDataValue, DigitAF, EU-FarmBook, FARMTOPIA, OpenAgri, PATH2DEA, PHITO Platform, ScaleAGData and SPADE. The collaboration activities have provided valuable insights into data governance practices, the use of data-sharing frameworks, policy incentives, and key barriers and enablers to technology adoption. Key findings from these collaborations highlight that trusted data-sharing ecosystems, often supported by cooperative platforms (e.g., DjustConnect, JoinData), are critical to building user confidence and encouraging broader technology uptake. The lack of standardised interoperability protocols and unclear data ownership frameworks remains a major barrier across projects. Policy incentives such as CAP eco-schemes and digital transition support mechanisms were identified as important enablers, although complexity and administrative burden often hinder full accessibility for smaller actors. The importance of user-centered design, targeted training programmes, and multi-actor co-creation approaches was consistently underlined as essential for overcoming digital literacy gaps and fostering sustainable digital transformation.

Building on these synergies, 4Growth will continue to integrate findings into its framework analysis (T4.4) and will leverage this knowledge to inform the development of targeted policy recommendations and best practices under Task 4.5. Participation in cross-project events such as Synergy Days 2025 and engagement with platforms like EU-FarmBook are also expected to further enrich 4Growth’s outputs in the coming months.

2.3 Desk Research & Expert Consultations

As part of the **T4.4 Framework Conditions and Impact Analysis**, **desk research** and **expert consultations** were conducted to complement the primary data collected from the observatories. These secondary research methods provided additional insights into the governance frameworks, data-sharing practices, technical aspects, and socio-economic impacts of adopting digital technologies in agriculture and forestry.

Desk Research Findings

The desk research involved a thorough review of recent literature, policy documents, and relevant case studies to understand the broader context of adoption of digital technology. The findings from this research revealed both opportunities and challenges associated with the use of digital solutions in agriculture and forestry.

The **literature review** highlighted the increasing recognition of **smart farming technologies** and **precision agriculture** as essential tools for improving efficiency, sustainability, and productivity. In the context of small-scale European farms, adoption is largely shaped by perceived usefulness and the availability of support infrastructure [1]. Sensor technologies have shown significant potential to increase food security and agricultural sustainability by supporting precision operations and real-time monitoring [2]. These technologies include applications such as **Remote Sensing (RS)**, **Farm Management Information Systems (FMIS)**, **Robotics, Decision Support Systems (DSS)** and **Variable Rate Technologies (VRT)**. The use of FMIS can bring several benefits for farmers; for instance, FMIS can support the decision-making process, improve farm efficiency, optimize resource allocation, enhance sustainability, and assist farmers with bureaucratic requirements [3]. Additionally, robotic technologies offer potential benefits for farming communities facing labour shortages due to urban migration. Furthermore, according to Rose and Chilvers (2018), precision agriculture, coupled with more productive crop varieties and decision support systems, can lead to smarter input use, enhanced productivity, and social and environmental benefits, including improved food and income security [4].

However, these technological advancements present challenges. In several studies, significant barriers have been highlighted including **high upfront costs, complexity of technologies, and substantial time and training requirements** that increase investment risks for farmers [5], [6]. Bolfe et al. (2020) also emphasised that a major hurdle in Brazil was farmers' limited understanding of how to use digital systems effectively, a concern shared across many European contexts [7]. Furthermore, poor internet connectivity, particularly in rural areas, remains a substantial obstacle to widespread adoption. This is especially true in small-scale and remote agricultural regions, where digital infrastructure and digital skills lag behind [1]. Eastwood et al. (2017) emphasize that smart farming adoption necessitates **new skills** across farming teams and advisory structures, potentially leading to displacement and increased demand for targeted training and capacity-building programmes [8]. In relation to data, trust and governance frameworks were consistently highlighted as central to digital technology adoption. Several studies report that stakeholders are hesitant to share agricultural data due to privacy concerns, unclear ownership rights, and a lack of transparent governance models [9], [10]. These findings underline a critical need for supportive measures to facilitate effective integration and maximize the benefits of smart farming technologies.

The **policy analysis** focused on evaluating EU-level initiatives such as the **Common Agricultural Policy (CAP)** and the **EU Forest Strategy**, which aim to drive digitalization in agriculture and forestry. The analysis found that while these policies provide strong frameworks for digitalization, their effectiveness varies significantly depending on local implementation. For example, **Southern European** countries, such as **Greece** and **Spain**, face greater challenges in accessing the necessary funding and infrastructure to support digital adoption. In contrast, **Northern European** countries like **Finland** and **Sweden** have made significant progress due to better governmental support, including regional initiatives that facilitate digital infrastructure and offer financial incentives. The analysis also highlighted the need for more **targeted funding** and **incentive schemes** to address the specific needs of farmers and foresters in these regions.

Several **case studies** were also reviewed, demonstrating the potential for digitalization in improving productivity and sustainability. For instance, in **Scandinavia**, the use of **open data platforms** has allowed farmers to share data across cooperatives, improving decision-making and resource management. Public-private partnerships and platforms like DjustConnect or JoinData have been shown to enable secure data sharing, promoting innovation and user trust [10]. These platforms have proven particularly effective in fostering collaboration between **public and private sector stakeholders**. This points to the importance of **public-private partnerships** in overcoming barriers related to data privacy and governance, which were identified as significant issues in the adoption of digital technologies in agriculture and forestry.

Expert Consultations Findings

To deepen the understanding of the factors influencing technology adoption, expert interviews were conducted with key stakeholders, including policymakers, technology providers, and industry experts. These consultations provided valuable qualitative insights into the governance frameworks, data-sharing practices, and technology adoption challenges faced by the agricultural and forestry sectors.

Experts noted that **governance models** play a critical role in shaping the adoption of digital technologies. In particular, they emphasized the need for **clearer regulations** and **targeted funding mechanisms** at the local level. While the EU provides a broad framework for digitalization, **national and regional governments** are responsible for translating these policies into actionable, region-specific programmes. Experts pointed out that **Southern and Eastern European countries** face challenges in implementing these policies effectively, often due to a lack of financial resources, technical infrastructure, and skilled personnel.

The expert consultations also highlighted that **data-sharing practices** remain a significant barrier to the adoption of digital technologies. A recurring theme was the **lack of trust** between stakeholders, particularly regarding the sharing of sensitive data such as crop yields, soil quality, and weather patterns. Privacy concerns and the **unclear ownership** of data were identified as key barriers that hinder collaboration between farmers, technology providers, and other value chain actors. Experts recommended the development of **clearer data governance frameworks** that would outline how data can be shared securely and equitably among stakeholders. They also emphasized the importance of **data interoperability**, noting that the lack of common standards for data formats and sharing practices remains a major challenge in enabling the seamless integration of digital solutions.

From a **technical perspective**, the consultations revealed that while many digital technologies are seen as beneficial, their **usability** and **integration** into existing workflows are often limited by financial barriers and **lack of technical expertise**. Experts noted that even when technologies are accessible, the complexity of integrating them into traditional farming and forestry practices can be a significant hurdle. Additionally, **cost** was consistently cited as a major barrier to adoption, with many farmers and foresters unable to afford the initial investment required for these technologies.

Finally, **socio-economic impacts** were also discussed, particularly with regard to the effects of adoption of digital technology on rural communities. Experts noted that while digital technologies have the potential to **improve productivity** and **reduce costs**, they also have the potential to disrupt traditional labor markets. In some regions, digitalization has led to **job displacement**, especially for workers with low technical skills. However, experts also pointed out that the adoption of these technologies could create new **job opportunities** in areas such as data analysis, IT support, and system maintenance, provided that adequate **training** and **upskilling** opportunities are available.

3 Framework Analysis Outcomes

This section consolidates the insights gathered from observatory partners across six European countries—**Greece**, **France**, **Spain**, **Netherlands**, **Belgium**, and **Finland**—as part of Task **T4.4 Framework Conditions and Impact Analysis** of the **4Growth project**. The analysis focuses on four primary aspects: governance models, data-sharing practices, technical aspects of digital technologies, and socio-economic impacts of digital technology adoption in agriculture and forestry. These aspects were explored across diverse regional contexts to provide a comprehensive understanding of the factors influencing digital technology uptake.

3.1 Governance Models

Observatories generally acknowledged that current EU and national strategies—such as the **Common Agricultural Policy (CAP)**, the **EU Forest Strategy**, national digitalisation plans, and innovation-driven recovery frameworks—provide moderate to strong support for the adoption of digital technologies. Initiatives such as the **Digital Europe Programme** and **NextGen technology schemes** were frequently cited as important enablers. Regional strategies also play a pivotal role, particularly where locally tailored funding programmes and digital infrastructure initiatives are available.

Despite the existence of these frameworks, several structural challenges persist. A recurring concern relates to the **administrative complexity** associated with applying for funding, particularly affecting small and medium-sized farms and forestry enterprises. Observatory partners highlighted that the fragmented landscape of support—distributed across EU, national, and regional levels—creates barriers to access, with language requirements, matching fund obligations, and procedural delays adding to the burden. The disparity in administrative capacity between larger and smaller actors was consistently noted as a critical issue.

Limited **digital literacy** among end-users, particularly in forestry and small agricultural holdings, was also identified as a major constraint on technology adoption. Many observatories called for training programmes and advisory support to be systematically embedded within governance frameworks to close this gap. Furthermore, the absence of coherent **data governance frameworks**, a lack of legal clarity on data usage, and weak interoperability standards were frequently cited as policy bottlenecks impeding progress.

Suggested improvements include the creation of unified application portals, simplification of compliance procedures, establishment of clear data-sharing norms, and the promotion of open innovation ecosystems. A coordinated approach to digital skills development—from field workers to policymakers—was deemed essential to ensure equitable and widespread technology uptake.

3.1.1 Supportiveness of Existing Strategies

Most observatories rated the supportiveness of existing EU and national strategies, such as the CAP and the EU Forest Strategy, as either "moderately" or "very supportive." This general positivity reflects a broad recognition of digital transformation as a fundamental pillar of sustainability and competitiveness goals. However, practical challenges related to administrative hurdles and limited end-user capacity persist across several regions.

3.1.2 Influential Policies

The CAP was cited across observatories as a cornerstone policy catalysing digital adoption through mechanisms such as subsidies, eco-schemes, and performance monitoring requirements. Forestry-focused policies, notably the EU Forest Strategy for 2030 and various national forest strategies (e.g., Greece and Finland), were also recognised for promoting the use of digital tools, including GIS, remote sensing, and forest mapping technologies. In addition, national digitalisation agendas (e.g., Lithuania, Netherlands) and targeted recovery plans, such as Greece's Recovery and Resilience Plan and Finland's METSO initiative, were viewed as essential complements to EU frameworks. Ultimately, some additional influential policies identified included the EAFRD, the France Relance Plan, the AgriTech and FoodTech Strategy, and the France 2030 programme, reflecting the increasing role of innovation-driven national strategies in promoting digital adoption.

3.1.3 Most Effective Level of Support

Observatories reported differing perspectives on which governance level provided the most effective support. Some, like France, Finland and the Netherlands, highlighted strong national-level implementation, while others emphasised the catalytic role of EU-level programmes and regulations (e.g., Greece, WR-NL). In regions such as Belgium and the Netherlands, regional initiatives and co-financed provincial programmes were also identified as highly impactful, pointing to the benefits of a multi-level governance approach.

3.1.4 Local Incentives and Accessibility

All observatories acknowledged the presence of local or regional funding instruments aimed at accelerating digitalisation. Examples include the Flemish Agricultural Investment Fund (VLIF), Lithuania's Recovery and Resilience Plan, and regional innovation subsidies in the Netherlands (POP3). These programmes target a wide range of stakeholders, including SMEs and agri-tech start-ups, and often encourage cross-sector collaboration.

Nonetheless, challenges remain regarding accessibility, particularly for smaller actors such as individual farmers or forest owners. Complex application procedures, co-financing requirements, language barriers, and limited awareness of available programmes were repeatedly mentioned as obstacles. Observatories recommended increasing the use of advisory services, digital vouchers, and targeted training schemes to improve inclusivity and impact. While investment grants and regional aids are widely available, observatories also pointed out challenges in programme visibility and the limited support provided to farmers for the operational integration of new technologies.

3.1.5 Key Regulatory Barriers

Common regulatory barriers identified across observatories include:

- Fragmented and complex administrative procedures for accessing funding.
- High compliance costs associated with adopting new digital technologies.
- Limited collaboration between public and private sectors.
- Insufficient communication regarding available support mechanisms.
- Lack of clear legal frameworks governing data sharing, ownership, and privacy.

In the forestry sector, some observatories highlighted a unique challenge related to the low level of digital skills among public sector employees, which limits the adoption and effective use of digital solutions even when funding is available.

3.1.6 Suggested Governance and Policy Improvements

To address the identified barriers, observatories put forward a range of forward-looking recommendations:

A consensus emerged around the need to streamline administrative procedures and create a "one-stop-shop" digital platform centralising all relevant funding opportunities and support services.

Several observatories advocated for targeted support for SMEs, including digital innovation vouchers, enhanced advisory services, and dedicated grants to lower entry barriers.

The promotion of national digital agrifood strategies, aligned with the EU Green Deal and Digital Decade, was also recommended. Such strategies should integrate education, policy, and innovation efforts to foster long-term, mission-oriented digitalisation.

Addressing digital literacy gaps was seen as essential. Observatories called for the expansion of professional development programs, the integration of digital skills into agricultural education, and the formal recognition of digital competencies.

Observatories stressed the urgency of developing improved data governance frameworks, particularly in the context of emerging European data spaces. Clear rules around data ownership, access, and sharing must be established, and efforts should be made to enhance interoperability standards and reduce reliance on proprietary systems.

Embedding digitalisation within the delivery mechanisms of the CAP—for instance by incorporating digital performance indicators and rewarding the use of precision technologies within eco-schemes—was suggested as a means of mainstreaming innovation across Europe's agricultural and forestry sectors.

Finally, the importance of building long-term strategies was also highlighted. In this way there is a coherent link of funding programmes, promoting societal investment in technologies with positive environmental and health impacts, and ensuring digital solutions are appropriately sized to the operational scale of different farms.

3.2 Data Sharing Practices

Data sharing practices among stakeholders in agriculture and forestry vary widely but show a gradual shift towards more collaborative and structured frameworks. Most observatories reported that while open data portals exist—for example, forest maps, meteorological datasets, and CAP registries—practical data exchange primarily occurs through trusted partnerships, cooperative systems, and private agreements. These forms of sharing are particularly prevalent among actors such as input suppliers, advisory services, research institutions, and government agencies.

The types of data most frequently used include satellite and drone imagery, LiDAR data, farm management records, IoT sensor outputs, climate information, and spatial data for land management. Data sources are diverse, ranging from public repositories and precision tools to proprietary platforms operated by service providers.

While strong drivers exist to encourage data sharing—such as efficiency gains, regulatory compliance, supply chain optimisation, and innovation acceleration—several barriers continue to hinder widespread and open data exchange. Concerns around data misuse, unclear value propositions for data providers, lack of standardisation, and proprietary lock-ins remain major obstacles. Particularly for farmers, the benefits of sharing data are not always evident, especially when data is monetised by third-party platforms without tangible returns for the original data generators.

Best practices and existing frameworks, such as DjustConnect (Flanders), JoinData and GreenLinq (Netherlands), and the Sitra Rulebook (Finland), offer encouraging examples of how secure, controlled, and transparent data sharing ecosystems can be operationalised. EU-wide legal frameworks like the INSPIRE Directive and GDPR provide important regulatory foundations, but practical application to agricultural and forestry data remains complex and often requires contextual interpretation and tailored support.

Collectively, observatories expressed strong belief that improved data sharing practices would significantly facilitate the adoption of digital technologies. The development of harmonised data formats, clear governance models, and interoperable infrastructures was consistently highlighted as key to unlocking the full potential of digitalisation.

3.2.1 Methods of Data Exchange

Data is exchanged through a variety of mechanisms, including open data platforms, private agreements, cooperative networks, bilateral contracts, and emerging digital data hubs. Public authorities often provide national-level databases—such as the Hellenic Cadastre in Greece or the Finnish Forest Centre—while private entities and cooperatives manage internal platforms like JoinData (Netherlands) and DjustConnect (Belgium). In Greece and Finland, government-backed initiatives such as data.gov.gr and open forest portals have further improved transparency. However, the development of fully functioning commercial data marketplaces remains limited across most observatories.

3.2.2 Types of Data and Sources

A wide range of data types supports digital agriculture and forestry operations, including:

- Farm-generated data: such as farm records, operational logs, and transaction histories.
- Sensor and IoT data: monitoring parameters like soil moisture, crop health, temperature, and livestock conditions.
- Satellite and remote sensing data: extensively used for forest monitoring, precision field mapping, and climate risk assessment.
- Climate and environmental data: drawn from meteorological services and environmental agencies.
- Market and administrative data: relevant for compliance, logistics, and broader business intelligence.

These datasets are typically sourced from a combination of public institutions, research organisations, service providers, and farm management systems.

3.2.3 Data Management Practices

Data sharing among stakeholders predominantly occurs with trusted partners, including cooperatives, agronomic advisors, and project consortia. Full open data sharing is comparatively rare, although examples exist in countries like Finland and Spain, where policy incentives and cooperative structures encourage wider access to certain datasets. The overall management approach is influenced by both cultural factors and the level of maturity of national digital infrastructures.

3.2.4 Drivers and Barriers to Data Sharing

Drivers for data sharing include compliance obligations under EU programmes such as CAP and Horizon Europe, operational efficiency improvements, shared research and innovation efforts, and the development of early warning systems for climate resilience. Nevertheless, barriers remain pronounced. Persistent distrust, concerns over data ownership, the unclear value of data sharing for individual farmers, technical incompatibility between platforms, and a general lack of enforceable data governance frameworks continue to limit open data exchange across sectors.

3.2.5 Impact of Improved Data Sharing on Digital Adoption

Observatories strongly agreed that better data sharing practices would substantially facilitate the adoption of digital technologies. Improved interoperability, streamlined data access, and transparent governance mechanisms are seen as essential to achieving key benefits, such as precision input management, automated regulatory compliance, and adaptive planning for climate resilience.

3.2.6 Existing Frameworks and Best Practices

Observatories highlighted a range of national and European frameworks supporting secure and effective data governance, including:

- At the EU level: GDPR, INSPIRE Directive, Data Governance Act, and the Code of Conduct for Agricultural Data Sharing.
- At the national level: DjustConnect (Belgium), JoinData and iShare (Netherlands), open forest data initiatives in Finland, and the Hellenic GIS platforms in Greece.
- Best practice examples: the Sitra Rulebook (Finland), the AgroDataCube (Netherlands), and various forest information systems promoting standardised geospatial data across Europe.
- Observatories also stressed the need to promote interoperability between sensors and farm management platforms, suggesting that harmonised data standards and communication protocols at the European level would substantially facilitate wider technology deployment.

These initiatives prioritize data sovereignty, trust, transparency, and interoperability, all recognised as fundamental principles for fostering a sustainable and digitally empowered agriculture and forestry ecosystem.

3.3 Technical Aspects of Digital Technologies

All observatories reported active use of digital technologies, although the level of integration and maturity differs between regions and sectors. Common technologies include precision agriculture tools (e.g., variable rate applicators, GPS-guided machinery), remote sensing (satellite, UAV, LiDAR), IoT devices, AI-driven analytics, digital field notebooks, and cloud-based farm management systems.

These technologies are used to address a wide range of sectoral challenges: real-time forest monitoring, climate adaptation, biodiversity protection, pest and disease control, input optimisation, yield estimation, and supply chain traceability. For example, in forestry, drone imagery and LiDAR support carbon stock estimation and wildfire risk monitoring, while in agriculture, sensors and automation systems enhance resource efficiency.

Nevertheless, technical integration remains problematic for many users. Issues of data compatibility, machine interoperability, and fragmented digital ecosystems present serious challenges. Observatories highlighted that most small and medium-sized users struggle with system maintenance, lack of training, and the burden of managing multiple tools or platforms. Multi-brand machinery creates particularly acute interoperability issues, leading to inefficiencies in implementation.

Furthermore, the high cost of initial investments and the ongoing need for software updates or system support limit adoption. In some regions, poor internet coverage and limited digital infrastructure exacerbate these issues. Unintended consequences, such as technology dependence, potential job displacement, increased complexity, and digital fatigue, were also acknowledged.

Despite these limitations, the consensus is that digital technologies contribute substantially to productivity, efficiency, and long-term sustainability. Continued investment in user-friendly solutions, cross-platform compatibility, and inclusive innovation ecosystems will be critical for wider uptake.

More specifically:

Across all observatories, it is evident that the agricultural and forestry sectors are increasingly integrating a wide range of digital technologies. These technologies are used to improve productivity, enable precision in operations, optimize resource use, and support sustainability goals. However, their adoption is not without challenges, particularly in terms of cost, complexity, interoperability, and end-user capability.

3.3.1 Core Technologies and Problem-Solving Capabilities

Observatories reported the adoption of a wide range of digital technologies, tailored to sector-specific and regional priorities. Core technologies include:

- **Precision Agriculture Tools** such as GPS-guided machinery, variable rate technology (VRT), and farm management systems.
- **Remote Sensing Technologies**, including satellite imagery, UAVs, and LiDAR, for monitoring forest health, land use changes, and crop performance.
- **IoT and Sensor Networks**, deployed in both crop and livestock systems for real-time monitoring of soil conditions, weather, and animal health.
- **Automation and Robotics**, especially in dairy and horticulture sectors (e.g., robotic milking, intelligent harvesting) to support labour reduction and operational efficiency. Additionally, new insights emphasized the growing role of crop modelling combined with precision agriculture tools to optimize pesticide and fertilization management, along with the emergence of automation and robotics addressing labour shortages.
- **GIS and Spatial Data Systems**, widely used in forestry for inventory mapping, biodiversity monitoring, and wildfire risk assessments.
- **AI-driven Analytics and Decision Support Systems**, supporting yield prediction, disease detection, forest growth modelling, and supply chain optimisation.

- **Cloud and Blockchain Technologies**, selectively used for ensuring data traceability, transparency, and secure exchanges in agricultural value chains.

These technologies collectively address key sectoral challenges such as labour shortages, climate risks, operational planning, and environmental footprint reduction.

3.3.2 Effectiveness of Technology

The majority of partners reported that digital technologies addressed “most needs” (typically rated 4 out of 5). Technologies tend to perform best where there is a clear problem-solution fit and when they are complemented by advisory support or integrated into broader digital infrastructures. However, limitations in operational environments, such as fragmented farm structures or limited IT support, were noted to affect performance in certain cases.

3.3.3 Ease of Use for End-Users

Ease of operation and maintenance remains a significant barrier to adoption. Most observatories assessed user-friendliness as “difficult” (rated 2 out of 5). Steep learning curves, particularly for older farmers and small-scale operators, were cited as major obstacles. Nevertheless, some partners observed “neutral” or even “easy” experiences in cases where advisory support, targeted training, or mature digital ecosystems were available.

3.3.4 Challenges in Integration and Adoption

Several common challenges were consistently reported across observatories:

- **High Costs**, including initial investments, maintenance, and software subscriptions.
- **Skill Gaps and Digital Literacy Issues**, with many farmers and forestry staff lacking the necessary technical capabilities.
- **System Interoperability Problems**, especially due to multi-brand machinery and incompatible software platforms.
- **Infrastructure Gaps**, particularly poor internet coverage in rural areas undermining connectivity-dependent solutions.
- **Organisational Resistance and Cultural Barriers**, with reluctance to change established workflows and scepticism regarding digital returns on investment.
- In addition, the misalignment between technology sizing and farm needs, together with insufficient training across the value chain, were underlined as key challenges limiting effective integration.

3.3.5 Unintended Downsides and Limitations

Several unintended consequences of digital technology adoption were noted:

- **Increased Operational Complexity**, requiring new competencies and decision-making processes.
- **Technology Dependence and Vendor Lock-In**, limiting flexibility and creating dependencies on proprietary systems.
- **Equity Gaps**, with large-scale operators benefiting disproportionately compared to smaller farms and forest owners.

- **System Failures and Reliability Issues**, particularly under harsh environmental conditions affecting drones and automation equipment.
- Concerns were also raised about the premature deployment of unvalidated technologies leading to operational disruptions, as well as the additional costs incurred when adjusting technical practices to accommodate new digital tools.

3.3.6 Impact of Data Standards and Interoperability

Issues around data standards and interoperability were flagged as major barriers to seamless digital integration. Most observatories rated the impact of interoperability challenges as “moderate” to “very much” (ratings of 3 to 5). Incompatible file formats, differing standards across machinery and service providers, and a general lack of open data protocols continue to hamper multi-stakeholder collaboration and efficient workflows.

Some optimism was expressed regarding ongoing efforts towards data standardisation and governance frameworks, but observatories agreed that adoption remains uneven and fragmented across regions and sectors. Ensuring consistent and open interoperability standards is seen as critical for enabling broader digital transformation.

3.4 Socioeconomic Impact of Technology Adoption

All observatories reported observed or expected socio-economic benefits associated with digitalisation, though the extent and nature of these benefits vary across regions. Economically, digital tools have enabled cost reductions through precision input use, improved yields, and greater labour efficiencies. Examples cited include reduced pesticide and fertiliser usage, automated irrigation scheduling, and optimised harvesting routines. These efficiencies contribute to the development of more competitive and resilient agricultural and forestry production systems.

Environmental impacts were similarly positive, with observatories highlighting reduced greenhouse gas emissions, improved water and soil management, enhanced wildfire detection capabilities, and better protection of biodiversity-rich areas. In forestry, digital platforms are widely used to support habitat monitoring and conservation planning. In agriculture, digital tools contribute to environmental objectives through practices such as crop diversification, reduced tillage, and smart input application.

From an innovation perspective, digital technologies have catalysed the development of new service models, research collaborations, and agri-tech entrepreneurship. Data-driven advisory systems, smart machinery, and blockchain-enabled traceability solutions have enhanced competitiveness and improved market positioning in several regions. Compliance with environmental and CAP-related regulations has also become more efficient, aided by automated data logging and reporting capabilities.

However, the social impacts of digitalisation reveal a more complex picture. Labour dynamics are shifting, with manual roles increasingly replaced by digitally enabled jobs. While this creates opportunities for higher-skilled employment, it also risks marginalising workers with limited digital proficiency. Several observatories reported instances of digital fatigue among smallholder farmers, who often feel overwhelmed by the volume of data and alerts generated by multiple digital platforms.

Moreover, digitalisation has fostered improved rural connectivity and innovation ecosystems, helping to drive inclusive development in certain regions. Nevertheless, disparities persist, particularly in areas with limited access to training, advisory services, or digital infrastructure.

Bridging the digital divide remains a critical priority for ensuring equitable and sustainable rural transformation.

3.4.1 Economic Benefits

Observatories consistently highlighted significant economic gains resulting from the adoption of digital technologies. These benefits include:

- **Cost savings** through reduced use of inputs such as fertilisers, pesticides, water, and fuel, leading to lower operational expenses.
- **Labour efficiency**, with automation reducing the need for manual work in tasks such as milking, spraying, and weeding, allowing higher productivity with smaller workforces.
- **Yield and quality improvements** through data-driven decision support tools that enhance crop planning, enable timely interventions, and optimise harvest scheduling.
- **Market responsiveness and supply chain efficiencies**, with tools such as digital field notebooks and IoT-based tracking systems improving market access and inventory management.

Several observatories noted that digitalisation helps farms and forestry operators remain competitive despite structural disadvantages, such as small landholdings or high labour costs. Furthermore, digital technologies facilitate entry into premium and sustainability-certified markets.

3.4.2 Environmental Benefits

Environmental impacts associated with digitalisation were generally reported as positive across observatories. Specifically:

- **Reduced emissions** from optimised machinery use and fewer field passes, decreasing fuel consumption.
- **Resource optimisation** through precision application of water, agrochemicals, and fertilisers, minimising environmental degradation.
- **Soil and biodiversity improvements** through better planning of crop rotations, reduced tillage practices, and targeted conservation efforts.
- **Environmental sustainability** by supporting the reduction of pesticide usage.
- **Fire and risk management**, with remote sensing and UAV technologies enabling early detection of wildfire risks and supporting ecosystem health monitoring.

Partners particularly emphasised the value of digital technologies for enabling more sustainable, ecosystem-based land management approaches.

3.4.3 Innovation and Competitiveness

Observatories affirmed that digitalisation has significantly enhanced innovation capacity and competitiveness. Specific advances included:

- **Development of new tools and services** in collaboration with agri-tech startups and research institutions, facilitated by access to rich datasets.
- **Traceability systems**, which enable producers to differentiate products and gain access to premium markets by demonstrating compliance with environmental and food safety standards.

- **Smart specialisation strategies**, using real-time data and predictive analytics to better align production with market demand, boosting competitiveness at both farm and regional levels.

Some partners expressed concerns that vertically integrated companies may monopolise access to advanced digital tools, potentially limiting innovation opportunities for smaller players.

3.4.4 Regulatory Compliance

Digital tools have improved compliance with regulatory frameworks, particularly those associated with the **Common Agricultural Policy (CAP)**, environmental monitoring, and carbon accounting. Key contributions include:

- **Automated reporting systems** that simplify CAP-related submissions and regulatory compliance processes.
- **Real-time environmental monitoring**, reducing the burden of manual inspections and facilitating continuous tracking of key sustainability indicators.
- **Carbon footprint measurement tools**, supporting farmers and foresters in tracking emissions and documenting sequestration efforts.

While progress is significant, further investment in user training and platform simplification is required to fully integrate digital tools into everyday regulatory practices.

3.4.5 Labour and Social Dynamics

The labour impacts of digitalisation present a complex and evolving picture:

- **Job transformation** is evident, with manual roles being replaced by positions requiring digital skills such as system maintenance, data analysis, and programming.
- **Skill gaps** remain a pressing concern, particularly affecting older workers and seasonal labour forces who may struggle to adapt to digital workflows.
- **Digital stress and fatigue** have been observed, as farmers and foresters cope with managing multiple platforms, alerts, and technology updates.
- **Opportunities in rural areas** have emerged, with improved connectivity enabling new roles in tech support, agri-consulting, and innovation services.
- **Equity concerns** persist, as smaller farms and less digitally adept stakeholders risk exclusion from the benefits of digital transformation, potentially reinforcing existing structural inequalities.

Despite these challenges, most observatories agreed that with appropriate investments in skills development, advisory support, and inclusive governance, digital technologies can serve as a powerful catalyst for rural revitalisation and sustainable economic growth.

4 Conclusions and Next steps

The analysis conducted under T4.4 Framework Conditions and Impact Analysis, through a structured survey among observatory partner and complementary research activities, offers a detailed cross-regional understanding of the enabling conditions, barriers, and impacts associated with the adoption of digital technologies in agriculture and forestry. By integrating insights across governance frameworks, data-sharing practices, technical aspects, and socioeconomic effects, a holistic picture emerges that highlights both the transformative potential and the inherent complexity of digital transition in these sectors.

Governance frameworks at the EU, national, and regional levels are generally perceived as moderately to strongly supportive of digitalisation efforts. Initiatives such as the Common Agricultural Policy (CAP), the EU Forest Strategy, and national digitalisation and recovery plans have laid important foundations for innovation uptake. However, persistent challenges were identified, including administrative complexity, fragmented support mechanisms, and insufficiently targeted incentives for smaller and medium-sized actors. Across observatories, there is a strong call for simplifying funding access, promoting coherent national digital agrifood strategies, and investing in digital skills development through structured advisory and education programmes.

Data sharing practices are gradually evolving but remain fragmented. While trusted partnerships and cooperative frameworks enable some degree of data exchange, barriers such as trust deficits, data ownership concerns, interoperability limitations, and lack of clear governance frameworks continue to inhibit broader collaboration. Best practice initiatives such as DjustConnect, JoinData, and iShare demonstrate that secure, transparent, and user-centric data ecosystems are achievable and should serve as models for scaling responsible data sharing across the agriculture and forestry sectors.

On the technical front, a wide range of digital solutions—including precision agriculture tools, remote sensing systems, IoT networks, and AI-driven decision support platforms—are increasingly used to address challenges related to productivity, sustainability, and climate resilience. Nevertheless, integration challenges persist, notably concerning multi-brand machinery interoperability, limited connectivity in rural areas, and skill gaps among users. High upfront costs, ongoing maintenance needs, and operational complexity further constrain adoption among smaller actors. A recurring recommendation is the need for more user-friendly, interoperable, and adaptable digital solutions that align with the diverse operational realities of farms and forests across Europe.

Socioeconomic impacts of digitalisation are broadly positive, with partners reporting significant gains in efficiency, yield optimisation, environmental stewardship, and regulatory compliance. However, the digital transition also generates profound shifts in labour markets, replacing manual roles with digital-oriented tasks and increasing the need for continuous upskilling. While new economic opportunities emerge, risks related to digital exclusion, rural inequalities, and farmer wellbeing also surface. Ensuring that digitalisation contributes to rural cohesion and inclusivity will be vital for maximising its societal benefits.

In conclusion, digital technologies offer substantial potential to transform agriculture and forestry into more sustainable, efficient, and competitive sectors. However, unlocking this potential requires systemic action: aligning governance mechanisms, strengthening digital infrastructure, fostering data interoperability, promoting skill development, and ensuring that innovation pathways are inclusive and accessible to all actors across the value chain.

The findings presented in this deliverable (D4.13) provide a robust foundation for shaping the targeted policy recommendations and value chain interventions to be further developed under Task 4.5. They will also directly inform the content of the 4Growth Visualisation Platform

(WP2), ensuring that evidence-based insights are accessible to stakeholders, policymakers, and end-users.

The next steps will build on the findings of T4.4 to support the objectives of the 4Growth project. Insights from the Observatory surveys, desk research, and expert consultations will inform the development of targeted policy recommendations and best practices under Task 4.5, aiming to facilitate the broader adoption of digital technologies in agriculture and forestry. In addition, the results of this analysis will be integrated into the 4Growth Visualisation Platform (WP2), providing accessible, evidence-based information for stakeholders. An updated version of this report (D4.14) will be delivered in M33, incorporating further inputs from ongoing observatory monitoring, synergy-building activities, and stakeholder engagement, ensuring that the final recommendations are based on the most comprehensive evidence available.

5 References

[1] A. Gabriel and M. Gandorfer, 'Adoption of digital technologies in agriculture—an inventory in a european small-scale farming region', Precis. Agric., vol. 24, no. 1, pp. 68–91, Feb. 2023, doi: 10.1007/s11119-022-09931-1.

[2] A. Morchid, R. El Alami, A. A. Raezah, and Y. Sabbar, 'Applications of internet of things (IoT) and sensors technology to increase food security and agricultural Sustainability: Benefits and challenges', Ain Shams Eng. J., vol. 15, no. 3, p. 102509, Mar. 2024, doi: 10.1016/j.asej.2023.102509.

[3] J. Ammann, A. Walter, and N. El Benni, 'Adoption and perception of farm management information systems by future Swiss farm managers – An online study', J. Rural Stud., vol. 89, pp. 298–305, Jan. 2022, doi: 10.1016/j.jrurstud.2021.12.008.

[4] D. C. Rose and J. Chilvers, 'Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming', Front. Sustain. Food Syst., vol. 2, Dec. 2018, doi: 10.3389/fsufs.2018.00087.

[5] M. Gemtou, B. C. Guillén, and E. Anastasiou, 'Smart Farming Technologies and Sustainability', in Digital Sustainability: Leveraging Digital Technology to Combat Climate Change, T. Lynn, P. Rosati, D. Kreps, and K. Conboy, Eds., Cham: Springer Nature Switzerland, 2024, pp. 99–120. doi: 10.1007/978-3-031-61749-2_6.

[6] T. Kutter, S. Tiemann, R. Siebert, and S. Fountas, 'The role of communication and co-operation in the adoption of precision farming', Precis. Agric., vol. 12, pp. 2–17, Feb. 2011, doi: 10.1007/s11119-009-9150-0.

[7] É. L. Bolfe et al., 'Precision and Digital Agriculture: Adoption of Technologies and Perception of Brazilian Farmers', Agriculture, vol. 10, no. 12, Art. no. 12, Dec. 2020, doi: 10.3390/agriculture10120653.

[8] C. Eastwood, L. Klerkx, M. Ayre, and B. Dela Rue, 'Managing Socio-Ethical Challenges in the Development of Smart Farming: From a Fragmented to a Comprehensive Approach for Responsible Research and Innovation', J. Agric. Environ. Ethics, vol. 32, no. 5, pp. 741–768, Dec. 2019, doi: 10.1007/s10806-017-9704-5.

[9] M.-A. Jouanjean, F. Casalini, L. Wiseman, and E. Gray, 'Issues around data governance in the digital transformation of agriculture: The farmers' perspective', OECD Food Agric. Fish. Pap., Art. no. 146, Oct. 2020, Accessed: May 08, 2025. [Online]. Available: https://ideas.repec.org//p/oec/agraaa/146-en.html

[10] C. Brown, Á. Regan, and S. van der Burg, 'Farming futures: Perspectives of Irish agricultural stakeholders on data sharing and data governance', Agric. Hum. Values, vol. 40, no. 2, pp. 565–580, Jun. 2023, doi: 10.1007/s10460-022-10357-8.

ANNEX

A. Framework Conditions and Impact Analysis Survey template

1. Governance Models

1.1 To what extent do you think existing EU and national strategies (e.g., CAP, EU Forest Strategy) support the adoption of digital technologies in agriculture/forestry?

- 1 = Not supportive at all
- 2 = Slightly supportive
- 3 = Moderately supportive
- 4 = Very supportive
- 5 = Extremely supportive

1.2. What national or regional policies (e.g., CAP, EU Forest Strategy) have influenced the adoption of digital technologies in your sector/region?

(Open Answer)

1.3. At which level do you see more effective support for adopting digital technologies?

- EU/global level (e.g., EU policies, strategies)
- National level
- Regional/local level (e.g., regional programmes, local incentives)
- All equally
- None

1.4. Are there any local incentives, grants, or funding programmes that support technology adoption? If yes, how accessible and effective are they?

(Open Answer)

1.5. What are the main regulatory barriers that hinder the adoption of digital technologies? *(Select up to 3 most relevant)*

- Lack of targeted financial support or subsidies
- Complex administrative procedures for accessing funding
- Lack of clear data governance policies and legal frameworks
- Inadequate alignment of policies with technological needs
- High compliance costs for adopting new technologies
- Insufficient collaboration between public and private sectors
- Limited awareness or communication about available support programmes
- Other (please specify): ___________

1.6. In your opinion, what governance or policy changes would make it easier for actors like you to adopt digital solutions?
(Open Answer)

2. Data Sharing Practices

2.1. How do stakeholders in your sector share or exchange digital data? (e.g., open data, private agreements, data marketplaces)

(Open Answer)

2.2. What types of data are most commonly used, and what are their main sources (e.g., satellite, IoT sensors, farm records)? (Open Answer)
2.3. How do stakeholders in your region typically manage their data? Single choice: ○ Data is kept private and not shared ○ Data is shared only with trusted partners (e.g., cooperatives, advisors) ○ Data is openly shared (e.g., via open platforms, public databases) ○ Data is purchased from other sources ○ Data is sold to other entities ○ Other (please specify): ____________
2.4. What are the biggest drivers and barriers to data sharing among value chain actors? (e.g., privacy, security, lack of trust) (Open Answer)
2.5. To what extent do you think better data sharing practices would facilitate the adoption of digital technologies in agriculture/forestry? ○ 1 = Not at all ○ 2 = Slightly ○ 3 = Moderately ○ 4 = Very much ○ 5 = Extremely
2.6. Are there any existing frameworks or best practices for data governance that could enhance digital technology adoption? (Open answer)

3. Technical Aspects of Digital Technologies

3.1. What core digital technologies are currently used in your sector? (e.g., precision agriculture, remote sensing, automation, AI-driven analytics) What specific problems do they solve? (Open answer)
3.2. How well did the technology address your specific needs or problems? ○ 1 = Did not address my needs at all ○ 2 = Addressed only a limited number of my needs ○ 3 = Addressed few needs ○ 4 = Addressed most needs ○ 5 = Fully addressed my needs
3.3. How easy is it for end-users to operate and maintain these technologies? ○ 1 = Very difficult ○ 2 = Difficult ○ 3 = Neutral ○ 4 = Easy ○ 5 = Very easy

3.4. What are the key challenges in adopting and integrating digital solutions within existing workflows? (e.g., interoperability, skill gaps, costs) (Open answer)
3.6. To what extent do data standards and interoperability issues affect the adoption and integration of digital technologies in your region? (e.g., difficulties in combining data from different systems, lack of common formats, compatibility problems) ○ 1 = Not at all ○ 2 = Slightly ○ 3 = Moderately ○ 4 = Very much ○ 5 = Extremely
3.5. Have there been any unintended downsides or limitations associated with technology adoption (e.g., increased complexity, reliability issues, economic barriers) (Open answer)

4. Socioeconomic Impact of Technology Adoption

4.1. What economic benefits (e.g., cost savings, increased productivity) have you observed from adopting digital technologies? (Open answer)
4.2. Have these technologies contributed to environmental benefits such as reduced emissions, optimised resource use, or biodiversity improvements? (Open answer)
4.3. Have digital technologies improved innovation and competitiveness in your sector? If so, how? ○ Yes ○ No If yes, how? ___________
4.4. To what extent have digital technologies improved compliance with regulatory requirements (e.g., CAP reporting, environmental rules)? ○ 1 = No improvement ○ 2 = Very little improvement ○ 3 = Some improvement ○ 4 = Significant improvement ○ 5 = Fully improved compliance and reporting
4.5. What impact has digital technology adoption had on labour, employment, or broader social and community-level dynamics in agriculture and forestry? (Open answer)