Policy recommendations and toolbox

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D6.3 POLICY RECOMMENDATIONS AND TOOLBOX

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POLICY RECOMMENDATIONS AND TOOLBOX – VERSION 1.0

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CONTENTS

EXECUTIVE SUMMARY 4
1. INTRODUCTION 6
1.1. The strategic context 7
1.2. Empirical basis 9
1.3. Structure of the deliverable 10
2. KEY CODECS MESSAGES 12
2.1. Agricultural digitalisation is a systemic transformation 12
2.2. Agricultural digitalisation is a gradual, multi-stage process whose pace and direction vary widely across and within EU countries 14
2.3. Digital ecosystem conduciveness depends on more than funding and infrastructure: it requires aligned resources, capabilities, governance and collaboration 15
2.4. Digitalisation is reconfiguring knowledge flows, advisory roles and power relations within AKIS, while exposing gaps in how these systems are understood and governed 17
2.5. Digital skills gaps affect farmers, advisors and administrations alike 19
2.6. Poor interoperability and unclear data governance arrangements constrain agricultural digitalisation, while collective action offers a potential counterweight 20
2.7. Farmer uptake of digital tools reflects a balance between tangible benefits and perceived costs, risks and impacts on professional identity 21
2.8. Adoption is driven by whether digital tools are perceived as useful, trustworthy and supportive 23
2.9. Digitalisation can reinforce or reduce inequalities depending on how policies account for social capital, inclusion and local context 24
2.10. Evidence gaps continue to constrain informed decisions about both digitalisation and the effectiveness of policies designed to support it 25
2.11. The gap between the potential and the actual uptake of digital technologies reflects an implementation and coherence challenge, rather than a lack of knowledge 26
2.12. Existing policy instruments and innovation initiatives provide a foundation, but their impact depends on greater coherence, coordination and continuity to create a conducive environment for agricultural digitalisation 28
3. POLICY FORESIGHT 29
3.1. The scenarios 29
3.2. The results 30
3.2.1. Scenario-specific insights 31
3.2.2. Cross-cutting messages 32
3.3. Conclusions 33
4. APPROACH TO FORMULATING POLICY RECOMMENDATIONS 34
5. POLICY RECOMMENDATIONS 37
5.1. Long-term directionality, adaptive capacity & coherent policy design 37
5.1.1. Prioritise farm competitiveness and resilience 37
5.1.2. Adopt a holistic food-system view 38
5.1.3. Align standardisation with flexibility 38
5.1.4. Support dedicated, adaptive long-term national strategies 39

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5.1.5. Support reflexive and participatory governance ... 39
5.2. Infrastructure & urban-rural parity ... 40
5.2.1. Tackle the rural digital divide holistically ... 40
5.2.2. Strengthen rural connectivity ... 41
5.3. Data governance, collective management & provider accountability ... 41
5.3.1. Act against data power asymmetries ... 42
5.3.2. Empower collective data management ... 42
5.3.3. Demand full provider transparency ... 43
5.3.4. Coordinate interoperability with data governance ... 43
5.4. Funding, cost transparency & sustainability-linked investment ... 44
5.4.1. Incentivise rural investment to combat market failures ... 44
5.4.2. Support cost-effective tools that can serve diverse farm types ... 45
5.4.3. Link finance to sustainable practices ... 45
5.4.4. Eliminate duplication and fragmentation of funding instruments ... 46
5.4.5. Consider full lifecycle ownership costs ... 46
5.5. Human capital, knowledge flows & future-proofing expertise ... 48
5.5.1. Reframe digital literacy as an extension of farming expertise ... 47
5.5.2. Integrate digital pathways for new and young farmers ... 48
5.5.3. Educate on tangible data value ... 48
5.5.4. Address relational adoption conditions ... 49
5.5.5. Formalise advisory roles in co-design ... 49
5.6. Knowledge systems & advisory governance ... 50
5.6.1. Rethink role of knowledge intermediaries ... 50
5.6.2. Upskill advisory and administrative sector ... 51
5.6.3. Resource strategic demonstration activities ... 51
5.6.4. Embed digitalisation in AKIS governance ... 52
5.6.5. Co-create national digital curricula ... 52
5.6.6. Support two-way knowledge exchange ... 53
5.6.7. Provide continuous pre- and post-adoption advisory assistance ... 53
5.6.8. Ensure equal quality and transparency standards across advisory services ... 54
5.7. Farmer autonomy, agency & participatory co-creation ... 54
5.7.1. Frame digitalisation as support ... 55
5.7.2. Ensure meaningful farmer involvement ... 55
5.7.3. Fund co-design for cost-benefit alignment ... 56
5.7.4. Support collective bargaining power ... 56
5.8. Social equity, power dynamics & inclusive adaptation ... 57
5.8.1. Target dedicated support for disadvantaged groups ... 57
5.8.2. Mandate equitable service standards ... 58
5.8.3. Track and correct exclusionary dynamics ... 58
5.9. Research, monitoring and evidence ... 59
5.9.1. Move beyond simple adoption metrics ... 59
5.9.2. Learn from past implementation inaction ... 60
5.9.3. Monitor shifting power dynamics ... 60
5.9.4. Establish robust, granular evidence baselines ... 61
5.9.5. Map variety of intermediary actors ... 61
6. A PRACTICAL TOOLBOX FOR AGRICULTURAL DIGITALISATION ... 62
6.1. Tool 1: Guidelines for local digitalisation strategies ... 63

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6.1.1. What is the tool *63*
6.1.2. The problem this tool addresses *64*
6.1.3. Who should use the tool *65*
6.1.4. How the tool should be used *65*
6.1.5. Key added value of the tool *66*
6.2. Tool 2: Checklist for public investments 66
6.2.1. What is the tool *66*
6.2.2. The problem this tool addresses *66*
6.2.3. Who should use this tool *67*
6.2.4. How this tool should be used *67*
6.2.5. Key added value of this tool *68*
6.3. Tool 3: From evidence to decisions 68
6.3.1. What is the tool *68*
6.3.2. The problem this tool addresses *69*
6.3.3. Who should use the tool *69*
6.3.4. How should this tool be used *70*
6.3.5. Key added value of the tool *70*

7. CONCLUDING REMARKS 72

8. REFERENCES 74

TABLES

Table 1. CODECS key messages at a glance 4
Table 2. Three conceptual levels and guiding questions 7
Table 3. Empirical foundation of D6.3 10
Table 4. Key concepts of D6.3 12
Table 5. The four scenarios 30
Table 6. Thematic clusters of CODECS recommendations 36
Table 7. Summary table 72

FIGURES

Figure 1. Three levels 13
Figure 2. Four clusters of countries. Source: Hurtado et al., 2025 14
Figure 3. Different levels of farm digital maturity. Source: Hurtado et al., 2025 15
Figure 4. Conducive digital ecosystems 17
Figure 5. Closing the skills gap 19
Figure 6. Costs and benefits of digitalisation – according to farmers 21
Figure 7. Impact of digitalisation on identity 23
Figure 8. Need for overlap between availability, affordability and usability 24
Figure 9. Implementation gap 27
Figure 10. CODECS Conceptual Framework. Source: Soma et al., 2024b 35
Figure 11. EU policymaking cycle. Source: European Commission, 2021 35
Figure 12. Structure of the toolbox 63

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Executive summary

Agricultural digitalisation is increasingly seen as a strategic priority, and if directed appropriately, it can strengthen the competitiveness, resilience and sustainability of European agriculture. However, uptake remains uneven across farms, sectors and Member States. Structural barriers, from fragmented funding, governance and connectivity to skills shortages and inadequate data infrastructure, continue to widen the gap between advanced adopters and those left behind. Drawing on evidence from 20 Living Labs across Europe, a structured analysis of the EU policy environment, and a series of forward-looking foresight workshops, **this deliverable outlines a set of policy messages, recommendations and practical tools to address these issues**.

CODECS's key message – the challenge is no longer identifying what needs to be done but implementing it coherently and approaching agricultural digitalisation as a systemic transformation. The core policy challenges facing agricultural digitalisation have remained largely unchanged for over a decade, despite consistent flagging by researchers. This points to an implementation gap, and it is the problem this deliverable seeks to help address, working across three interconnected levels: (i) the **socio-ecological systems** that set the structural and institutional conditions for digitalisation, (ii) the **digital ecosystems** of relationships, standards and intermediaries that connect farmers to tools and to each other, and (iii) the **business processes** through which individual farmers adopt and use digital technologies day to day.

Key messages at a glance
1. Agricultural digitalisation is a systemic transformation.
2. Agricultural digitalisation is a gradual, multi-stage process whose pace and direction vary widely across and within EU countries.
3. Digital ecosystem conduciveness depends on more than funding and infrastructure: it requires aligned resources, capabilities, governance and collaboration.
4. Digitalisation is reconfiguring knowledge flows, advisory roles and power relations within AKIS, while exposing gaps in how these systems are understood and governed,
5. Digital skills gaps affect farmers, advisors and administrations alike.
6. Poor interoperability and unclear data governance arrangements constrain agricultural digitalisation, while collective action offers a potential counterweight.
7. Farmer uptake of digital tools reflects a balance between tangible benefits and perceived costs, risks and impacts on professional identity.
8. Adoption is driven by whether digital tools are perceived as useful, trustworthy and supportive.
9. Digitalisation can reinforce or reduce inequalities depending on how policies account for social capital, inclusion and local context.
10. Evidence gaps continue to constrain informed decisions about both digitalisation and the effectiveness of policies designed to support it.
11. The gap between the potential and the actual uptake of digital technologies reflects an implementation and coherence challenge, rather than a lack of knowledge.
12. Existing policy instruments and innovation initiatives provide a foundation, but their impact depends on greater coherence, coordination and continuity to create a conducive environment for agricultural digitalisation.

Table 1. CODECS key messages at a glance

At the socio-ecological level, sustainable digitalisation depends on context-sensitive, coherent, long-term policy design and adequate funding. Agricultural digitalisation sits at the intersection of agricultural, digital, and rural development policy streams that were designed separately. Existing Common Agricultural Policy (hereinafter – CAP) instruments, while providing a foundation (incl. through National Strategic Plans), vary considerably in ambition

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across countries. There is also no single pathway to digitalisation – farm structures, institutional capacity, digital divides and sustainability priorities differ markedly across the EU, meaning coherence has to be pursued across different contexts and levels of governance. Accordingly, **CODECS recommends** that Member States and the European Commission develop dedicated, adaptive long-term visions for agricultural digitalisation, consolidate fragmented funding instruments, link financial support explicitly to sustainability outcomes, and establish the granular evidence baselines and impact assessments needed to track whether digitalisation is advancing broader societal and environmental goals.

At the digital ecosystems level, the relationships, standards and intermediaries that connect farmers, advisors, and technology providers are currently suboptimal. CODECS highlights the importance of adopting an ecosystem perspective on the interaction of financial, technological, human and institutional resources and the role of capabilities, governance, collaboration, trust and knowledge exchange in shaping meaningful and sustainable outcomes. Currently, poor interoperability (incl. between different public platforms) limits the value of digital investment, unclear rules leave farmers uncertain who controls their data and information, individualistic approaches hamper collaborative efforts, and power is increasingly concentrated among large technology providers and producers. At the same time, the intermediaries who bridge complex technologies and farmer needs are being transformed by and need to adapt to digitalisation. **CODECS recommends** adopting a coordinated interoperability and data governance framework, mandating service and transparency standards for publicly supported technology providers, funding and upskilling knowledge intermediaries, embedding digitalisation within Agricultural Knowledge and Innovation Systems (hereinafter – AKIS) governance structures, facilitating collaborative approaches and ensuring that insights from participatory co-design and interactive innovation processes reach formal policy channels rather than remaining confined to individual projects.

At the level of business processes, farmers need clearer, more tangible reasons to adopt and trust digital tools. Farmers can be deterred by hidden or poorly understood costs, a perception that digital requirements are compliance burdens rather than genuine support, and a sense that digitalisation may displace their professional expertise. There are obstacles to collective action that would allow pooling resources and reducing costs, advisory support tends to be focused on the point of purchase rather than sustained during implementation, and the range of actors providing advisory assistance is changing and increasingly diverges from traditional AKIS representations. **CODECS recommends** explicitly reframing digital and CAP requirements as support, funding co-design processes that align tools with farmers' actual cost-benefit expectations, prioritising affordable and transparent technologies, accounting for the full lifecycle costs of ownership, encouraging collective action (to pool resources and strengthen market position) and providing continuous advisory assistance before and after adoption, with dedicated pathways for small farms, women farmers and new entrants who face additional structural barriers.

While primarily based on the structured analysis of policy environments and work done in CODECS Living Labs, these findings and recommendations are further informed by a set of foresight scenarios exploring how the digital transformation of agriculture might unfold by 2040, and are translated into practical use through a toolbox, covering local strategy design, public investment decisions, and evidence-based decision-making, developed to help public administrations put these recommendations into practice. Taken together, this deliverable's key messages, recommendations, and tools reflect CODECS's central contention that agricultural digitalisation is a systemic transformation that will only succeed if it is pursued coherently and with due consideration of the contextual practicalities of implementation and the sustainability outcomes it is supposed to enable.

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1. Introduction

Digital technologies can reshape agriculture across Europe and beyond, offering transformative potential to improve productivity, competitiveness, monitoring, sustainability, knowledge flows and resilience across diverse farming systems, and facilitate the government-farmer interface. Yet, despite policy rhetoric, prominence in policy and strategic documents, investment and growing political momentum, the digital transformation of agriculture remains uneven. Structural barriers (from fragmented governance and limited connectivity to skill shortages and inadequate data infrastructure) continue to slow adoption and widen the gap between early adopters, advanced users and the farmers (and countries) who have yet to benefit.

In this context, a well thought out and forward-looking policy framework and fit-for-purpose tools for agricultural digitalisation are necessary[1]**.** The rapid and continuous development of digital technologies introduces complex and cumulative challenges that actors (be they states or farmers) cannot navigate alone and are exacerbated by structural problems in European agriculture. There are several categories of potential failure (infrastructural, institutional, interaction-based, and capability-related) that can derail sustainable digitalisation efforts in the absence of appropriate policy guidance and instruments facilitating the development of digital strategies.

Coherence across national, regional, sectoral, and technological levels may help achieve stated policy objectives. Fragmented or misaligned policy environments risk exacerbating existing issues, accelerating unsustainable growth and concentration of power, rather than steering the agricultural sector toward meaningful change. Indeed, this is in line with the call of the Strategic Dialogue on the Future of Agriculture (European Commission, 2025a) to make use of the opportunities of digitalisation in a responsible manner.

CODECS aims to contribute to policy development. Through its 20 Living Labs and cross-cutting policy analyses, the project has generated evidence on digital ecosystems, costs, benefits and policy environments underpinning agricultural digitalisation. This knowledge is intended to support all phases of the policy cycle (from problem definition and agenda-setting through to design and implementation). Crucially, CODECS's contribution lies in explaining why known barriers to the uptake of digital tools and solutions in agriculture persist.

CODECS proceeds on the assumption that policies should aim to be transformative rather than merely supportive of "business as usual". Short-term pressures can dominate decision-making, often at the expense of longer-term sustainability considerations such as social sustainability, agroecology and ecosystem services. The role of policymakers (at regional, national and international levels) is to safeguard these long-term interests, balancing social, environmental, and economic objectives in ways that individual actors are unable to do on their own.

As outlined in the project's conceptual framework, policies operate across various interconnected levels (see Soma et al., 2024b). Transformative policies must exhibit three core characteristics: directionality, reflexivity, and market integration. Directionality means policies are coordinated around clear goals and a coherent policy mix. Reflexivity refers to a kind of learning-by-doing approach that incorporates lessons from experience back into the policy cycle. Market integration ensures that policies are designed with an understanding of their socio-economic consequences, avoiding situations where high costs and low benefits lead to policy failure or affect certain groups disproportionately.

These characteristics can be applied across business processes, digital ecosystems, and socio-ecological systems. Because interventions at one level shape outcomes at the others, technologies, skills, infrastructure, advisory services and data governance cannot be treated as separate policy domains. Sustainable digitalisation therefore requires coordinated policies that recognise these interdependencies. The deliverable operationalises the three levels via the guiding questions below.

[1] See for instance: https://www.fao.org/events/detail/global-conference-on-smart-farming/en

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Level	Guiding question for this deliverable
Business processes	*What do farmers need to adopt and use digital tools productively?*
Digital ecosystems	*What relationships, standards, and intermediaries need to be in place for tools to function as connected systems?*
Socio-ecological systems	*What macro-level coherence and structural conditions let digitalisation serve broader societal, economic and environmental goals?*

Table 2. Three conceptual levels and guiding questions

1.1. The strategic context

Over the past decade, policy and strategic documents have increasingly acknowledged digitalisation as a strategic priority to achieve the twin transition. The CAP (European Commission, n.d.), national strategic plans (hereinafter – NSPs), and a range of EU-wide initiatives and strategies on the digital transformation, data governance, connectivity, and rural development have placed digitalisation on the agricultural policy agenda. Rather than being addressed through a single strategy, this topic appears across a wide range of policy and strategic documents, each emphasising different aspects of the digital transition. Together, these documents frame digitalisation as an important contributor to the future competitiveness, sustainability and resilience of European agriculture, while reflecting the breadth of policy objectives that digital technologies are expected to support. This creates opportunities for policy coherence but also contributes to the fragmented policy landscape discussed below.

Agricultural digitalisation has become a cross-cutting policy agenda spanning digital policy, sustainability transitions, rural development, innovation, data governance and agricultural modernisation. For instance, the Digital Decade (European Commission, 2022b) establishes horizontal objectives relating to connectivity, digital infrastructure and skills that create the enabling conditions for digital agriculture. The Data Act (European Commission, 2023) and Data Governance Act (European Commission, 2022a) provide the regulatory foundations for agricultural data sharing, interoperability and trusted data exchange, while initiatives such as the Common European Agricultural Data Space (European Commission, 2024b) seek to develop the supporting data infrastructure. Other strategic documents primarily approach digitalisation as a means of achieving broader agricultural, environmental and rural development objectives. The European Green Deal (European Commission, n.d.) and Farm to Fork Strategy (European Commission, 2020) present digital technologies as tools for improving sustainability, resource efficiency, traceability and environmental monitoring. The Long-Term Vision for Rural Areas (European Union, n.d.) highlights connectivity, digital skills and innovation ecosystems as prerequisites for rural development, while the Vision for Agriculture and Food (European Commission, 2025b) treats digitalisation as a cross-cutting enabler of competitiveness, administrative simplification and sustainability monitoring. The Strategic Dialogue on the Future of EU Agriculture (European Commission, 2025a) similarly argues that digital technologies should support the transition towards sustainable agri-food systems, emphasising that digitalisation should be regarded as a means rather than an end in itself.

Likewise, artificial intelligence (hereinafter – AI) is becoming an increasingly important dimension of the EU's vision for agricultural digitalisation. Recent initiatives, including the AI Continent Action Plan ((European Commission, 2025c), the Apply AI Strategy (European Commission, 2026) and the Data Union Strategy (European Commission, n.d.), identify agriculture as one of the sectors expected to benefit from AI deployment and data-driven innovation. Alongside the AI Act, which establishes a harmonised risk-based regulatory framework for AI applications, these initiatives reflect a growing policy focus on integrating AI into farming and agri-food value chains while ensuring its responsible and trustworthy use (Hurtado et al., 2025).

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The CAP is the EU's main funding and policy instrument for agriculture and supports digital adoption through investment measures, advisory services, innovation partnerships, and monitoring systems. The CAP (2023-27) includes a cross-cutting objective to modernise agriculture and rural areas through fostering and sharing of knowledge, innovation, and digitalisation, and by encouraging their uptake through improved access to research, innovation, knowledge exchange and training. It is financed through two complementary funds: the European Agricultural Guarantee Fund (Pillar I), which primarily supports direct payments and market measures, and the European Agricultural Fund for Rural Development (Pillar II), through which most digitalisation-related support is channelled: via investment support, eco-schemes and agri-environmental climate commitments, advisory and knowledge-exchange measures, and cooperation instruments (such as EIP-AGRI Operational Groups, LEADER, and smart villages). At the planning stage of the current programming period, Member States signalled the allocation of approximately six billion euro for digitalisation-related interventions, though this figure represents an indicative commitment rather than a verified level of realised expenditure (Hurtado et al., 2025). For our purposes, the CAP represents an implementation channel for scaling digital agriculture technologies and data systems, and digitalisation is treated as a transformation of agricultural practices, administrative processes and rural value chains.

For the first time, EU countries have designed digitalisation strategies as part of their CAP NSPs, facilitating the advancement of digitalisation in agriculture and rural areas. These strategies are tailored to the unique situation of each country and explore the potential of digital technologies to align with CAP-specific and cross-cutting objectives. Progress is tracked through a small set of shared target indicators, including the share of farms receiving support for digital agricultural technologies (R.3) and the number of individuals or advisors reached through knowledge exchange, AKIS integration, and environmental or climate-related training (R.1, R.2, R.28). Analysis of these indicators across the CODECS partners countries illustrates just how differently countries have positioned digitalisation within their NSPs (see below). Furthermore, these figures reflect planned ambition, and some interviewees in CODECS countries expressed scepticism about the extent to which these strategies are being implemented in practice. Overall, the CAP NSPs incorporate digitalisation to improve productivity and modernise agriculture and rural areas.

Monitoring and research are developing to provide a continuous and coordinated understanding of ongoing processes. The Joint Research Centre has conducted analyses of the digital transformation in agriculture, including the adoption of technologies, their drivers and barriers, and farm-level data management and sharing practices (tur Cardona et al., 2025). In parallel, numerous EU-funded research and innovation projects under Horizon 2020 and Horizon Europe (e.g. DESIRA, QuantiFarm) demonstrate a shared, system-wide approach to digital transition. Initiatives like 4Growth and the European Partnership for Agriculture of Data further contribute by mapping digital adoption and providing policy insights, while the Common European Agricultural Data Space aims to facilitate data sharing across the European agri-food sector.

Nonetheless, the analysis of policy recommendations from successive projects and research programmes carried out as part of CODECS reveals that the same issues persist. The core challenges identified a decade ago (e.g. inadequate infrastructure, weak advisory capacity, fragmented governance, and insufficient digital skills) remain largely the same today. The persistence of largely unchanged recommendations across more than a decade of EU projects suggests that the central challenge is no longer diagnosing barriers (Hurtado et al., 2025). The problem is not a lack of knowledge about what needs to be done, but rather a systemic difficulty in turning available insights into coordinated, sustained action across institutions, funding streams and territories. In a sense, the challenge is not necessarily technology adoption or lack of skills per se, but the absence of policy coherence and monitoring precision across agriculture, digital policy, and regional development (among others). There is high-level political commitment to a sustainable digital transition in strategic documents, but the connective tissue between that commitment and national and farm-level reality has to be established in practice via CAP NSPs and other initiatives, and the results vary.

Furthermore, an additional layer of complexity is introduced by the fact that agricultural digitalisation exists at the intersection of strategies and policies pertaining to food, digitalisation and rural development. Digitalisation of agriculture sits at the intersection of several EU policy streams: agriculture (CAP), digital policy, research/innovation, and cohesion/rural development among others. Because these domains evolve separately, relevant instruments are scattered across multiple frameworks. The above illustrates that there are overlapping objectives across many policy and strategic documents. Even nationally, agricultural digitalisation is shaped not only

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by agricultural policy, but also by other policy domains (e.g. telecommunication, education, regional development, and competition law).

Fragmentation is, therefore, not just a presentational problem. It reflects a genuine structural feature of the policy landscape, which is that agricultural digitalisation sits at the intersection of multiple policy streams that were not designed with each other in mind. Even more so – while the broader cohesion policy extends beyond agriculture, its focus on regional development and investment indirectly drives the digital transformation of rural areas relevant to the CAP (European Commission, n.d.).

The envisioned transition to the National and Regional Partnership Plan (hereinafter – NRPP) framework offers a potential solution to this fragmentation. By replacing sector-specific funding streams with a single, overarching territorial framework, the NRPP could allow policymakers and civil servants to treat agricultural digitalisation as a genuinely transversal issue. Potentially, the NRPP could enable a holistic approach that combines agricultural modernisation with broader regional digital infrastructure, cross-sectoral funding, turning a fragmented policy landscape into a cohesive, ecosystem-wide transition. However, its net effect on agricultural digitalisation funding remains to be seen, and the proposal has generated some concern among agricultural stakeholders. Indeed, while the NRPP may be conducive to more integrated approaches, competition between different policy priorities may weaken dedicated support for, among other things, digitalisation and AKIS.

Crucially, agricultural digitalisation should be understood as an instrument rather than a policy objective in its own right. The purpose of digital technologies is to support the broader transformation of European agriculture towards greater economic resilience, environmental sustainability and social inclusion. Throughout this deliverable, digitalisation is considered in relation to its contribution to established European policy objectives (see above). Conversely, where digitalisation fails to contribute to these objectives, or actually generates unintended economic, environmental or social costs, it should be adapted or reconsidered. The recommendations presented in this deliverable should therefore be interpreted not as promoting digitalisation for its own sake. Rather, they help in identifying the conditions under which digital technologies can make a meaningful contribution to the EU's wider sustainability and resilience agenda.

1.2. Empirical basis

This deliverable presents the key messages, policy recommendations and policy tools of CODECS. The findings and policy recommendations presented in this report synthesise the outputs of a participatory, mixed-methods research design implemented across a network of 20 Living Labs throughout Europe. These Living Labs (representing arable, livestock, horticulture, viticulture, and mixed farming systems across Northern, Central, Southern, and Eastern Europe) were active co-producers of knowledge throughout the project, from the initial framing of research questions to the validation of final findings. The work done in Living Labs is complemented by an in-depth analysis of the policy environment. Overall, this participatory approach ensured that the project's conclusions are grounded in the **perspectives of different target groups** (farmers, advisors, technology providers, civil servants and policymakers) rather than derived solely from desk-based analysis.

Messages and recommendations based on participatory foundations and target group perspective

The project's conceptual foundations were revised through iterative co-creation: a literature-based value tree of digitalisation outcomes was adapted by Living Labs through stakeholder workshops, weighted via VARI pairwise-comparison surveys, and further tested through in-depth interviews exploring how the framework held up against local realities (see Soma et al., 2026).

Agricultural digitalisation was considered from an ecosystem perspective (see Giagnocavo et al., 2025; Hortigüela & Giagnocavo, 2026). Each Living Lab identified a Focal Action Situation (a concrete, locally meaningful problem) around which structured workshops mapped the resources, capabilities, collaborations and innovations (hereinafter – RCCIs) needed to address it, while parallel socio-technical process modelling

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captured how digitalisation reshaped farm-level workflows. This grounded, bottom-up approach was complemented by an AKIS analysis, mapping actors and their governance roles.

To assess the costs and benefits of digitalisation, the project combined qualitative and quantitative methods tailored to each dimension of sustainability (Gobrecht et al., 2025)**:** (i) focus groups captured stakeholder perceptions of costs and benefits; (ii) comparative Life Cycle Assessment quantified environmental trade-offs (with depth of analysis scaled to each Living Lab's digitalisation maturity and data availability); (iii) economic assessment varied from lightweight questionnaires to full budget and Net Present Value analyses where the necessary farm-level data existed; (iv) and social/human-centred assessment used semi-structured interviews, analysed through hybrid thematic coding, to identify impacts on farmer well-being, skills, and work organisation.

Finally, these farm and Living Lab insights were systematically connected to the wider policy landscape (see Hurtado et al., 2025). A structured review of 150 EU-funded projects, document analysis of CAP National Strategic Plans of CODECS partner countries, and 101 semi-structured interviews with policymakers and experts across 18 countries and EU institutions together enabled a comparative scoring of national digital readiness and policy momentum.

Table 3. Empirical foundation of D6.3

In addition to backward-looking analysis, CODECS has taken a forward-looking perspective through a series of foresight workshops bringing together diverse stakeholders and agents of change to explore how the future of agricultural digitalisation might unfold. These workshops discussed a set of future scenarios reflecting different trajectories shaped by varying governance choices, levels of investment, social dynamics, and technological development. These scenarios are presented alongside the policy recommendations in this report as strategic tools to consider the impacts of policy options and stimulate debate about the kinds of futures we want to build and those, we want to avoid. The foresight scenarios presented in this report illustrate how different foundational conditions and governance choices can lead to starkly different outcomes for farmers, rural communities, and the agri-food sector.

Finally, based on evidence gathered in the project and previous experience, several policy tools were developed. The tools are primarily aimed at civil servants and bridge the critical gap between high-level EU policy ambitions (such as the CAP and the upcoming NRPPs) and practical, context-specific regional actions, and are specifically intended for civil servants and public authorities operating at local, regional, and national levels. The toolbox is structured around three complementary pillars that address the strategic, financial, and analytical dimensions of public administration.

The key messages and recommendations were developed in collaboration with CODECS Living Labs and based on expert review. The conversation on key project messages was initiated in September 2025 during the project meeting in Ljubljana. Subsequently, a draft version of the key messages, results of the foresight workshops, recommendations and policy tools was discussed at a science-policy interface meeting on 19 May 2026. This allowed for finetuning the approach taken to align it with the perspectives of practitioners and policy experts. In addition, the written feedback of CODECS partners, Living Labs and the Advisory Board was collected in June-July 2026.

This combination of participatory evidence from Living Labs and a structured analysis of the policy environment allows the deliverable to translate on-the-ground experience into actionable, policy relevant recommendations. The analysis draws collectively on project deliverables, policy briefs and other outputs. To maintain readability, individual deliverables are referenced primarily where specific analyses, concepts or empirical findings originate, while broader synthesis statements are presented as project-level findings.

1.3. Structure of the deliverable

We start by summarising the key takeaway messages from across various project deliverables, covering conceptual approaches, digital ecosystems, costs and benefits and the policy environment. The messages are presented to

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create a foundation for the recommendations. We continue by presenting the results of the foresight exercise carried out as part of CODECS. The subsequent section is dedicated to outlining the key policy recommendations of the project, organised into nine thematic sections. The final section describes the policy toolbox developed as part of CODECS.

Ultimately, this report is addressed to policymakers, civil servants, and stakeholders at all levels who share a commitment and mandate to making the digital transformation of European agriculture sustainable and inclusive. The aim is to focus on targeted influence on policy implementation and policy adjustments in several ongoing processes, such as post-2027 CAP discussions (incl. NRPP, monitoring/classifying CAP interventions and the extent to which they relate to digitalisation), the EU digital strategy for agriculture, and future research and innovation agendas.

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2. Key CODECS messages

The development of CODECS policy-relevant messages followed a structured, iterative process designed to ground policy-relevant outputs in both the wider literature and the project's conceptual approach and empirical work. The process began with input from CODECS Living Labs and a review of recent reports from different organisations (such as the OECD (McFadden et al., 2022), EU CAP Network (EU CAP Network, 2025) and the Joint Research Centre (Tur Cardona et al., 2025), alongside relevant strategic and policy documents. This served to map the issues already prominent in the field and produced an initial inventory of topics that the key messages and recommendations would need to address, while implicitly serving as a point of reference for gaps in the content produced by CODECS. The review then turned to CODECS deliverables produced across the project's work packages to identify key policy-relevant insights.

2.1. Agricultural digitalisation is a systemic transformation

The overall approach of CODECS is based on exploring the **intersection between digitalisation in agriculture and sustainable digitalisation,** and encourages reflection on how extant and future innovation ecosystems enable different digitalisation routes.

Key concepts
Digitalisation in agriculture: The systematic adoption and use of digital technologies, data and networks across all facets of the agri-food sector and rural areas, including, where necessary, the development of corresponding infrastructures, with the aim to improve sustainable farm productivity, contribute to sustainable and inclusive development of rural areas and simplify the delivery of the policy.
Source: EU CAP Network (2025)
Sustainable digitalisation: A process of social transformation by which digital technologies are embodied into socio-economic life to promote intra-generational, inter-generational, inter-species wellbeing, reduce inequalities, and improve the health of ecosystems.
Source: Soma et al. (2024b)

Table 4. Key concepts of D6.3

Across the project findings, a key conclusion is that the principal constraint on agricultural digitalisation is whether the institutional, economic, social and territorial conditions exist for digital technologies to create practical value for farmers, advisors and public administrations**.** In view of the above, CODECS argues **that digitalisation is not a technological objective nor an end in itself**. **It is a policy challenge and a socio-technical transformation that must proceed sustainably and operate in contrasting digitalisation contexts.** The goal is a critically evaluated, better-fit digitalisation that resists the technopositive adoption of digital tools regardless of context and contributes to social, economic, environmental and governance goals.

Furthermore, **digitalisation changes the distribution of power among farmers, advisors, service providers and policymakers, restructuring dependencies and amplifying or disrupting hierarchies**. Digital technologies become embedded in pre-existing socio-technical networks. These pre-existing arrangements influence access to resources and decision-making power, creating path-dependencies and shaping the distribution of costs and benefits. Policies that ignore this dimension risk perpetuating exclusion and concentrating power in the hands of

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dominant actors. In addition, agricultural digitalisation is also shaped by broader policy domains such as telecommunications, education, regional development, innovation policy, data governance, and competition law.

Through its research and conceptual approach, **CODECS demonstrates that policy assessment cannot treat agricultural digitalisation as a uniform black box**. Instead, it must apply a system-wide lens that distinguishes between **three interconnected levels**: (1) business processes (farm-level inputs and automated actions), (2) digital ecosystems (networks, platforms, data spaces, and collaboration dynamics), and (3) digital transitioning within socio-ecological systems (the macro-scale). Policy interventions must target specific levels, acknowledging that actions at the business-process level potentially have socio-ecological consequences.

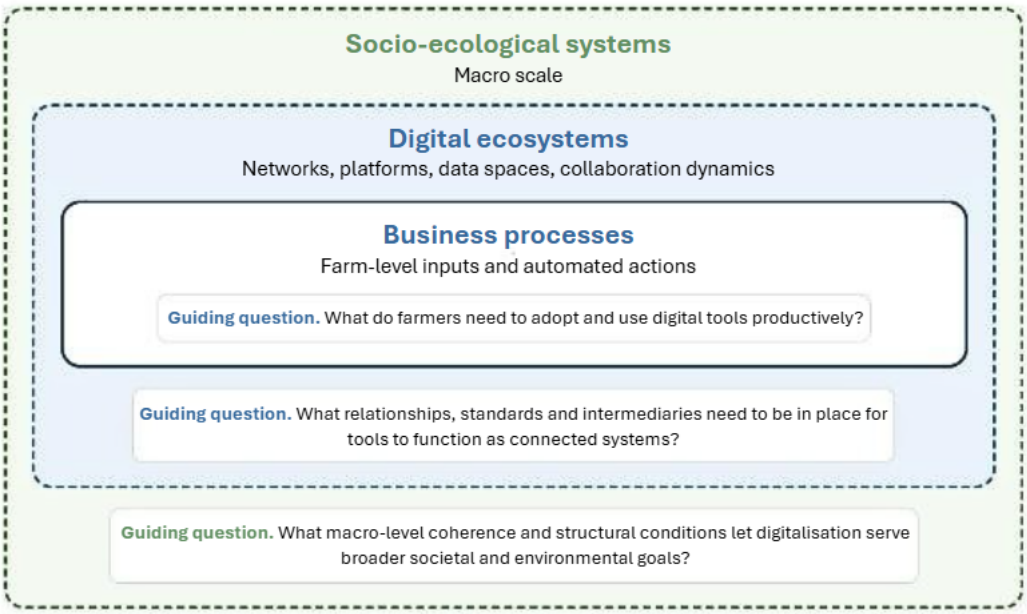

Figure 1. Three levels

Furthermore, CODECS posits that a meaningful assessment of digitalisation in the agricultural sector requires **a clear understanding of the diverse areas where digital technologies can have an impact**. CODECS (Hurtado et al., 2025) identifies four overlapping domains that reflect different forms of the digital transformation:

- digital communication and knowledge exchange;
- government-farmer interface;
- operational efficiency and productivity;
- transparency and market connectivity.

The thematic report on assessing digitalisation under the CAP's NSPs (see EU CAP Network 2025) proposes different but thematically congruent domains:

- infrastructure;
- smart production;
- market integration and knowledge networks;
- sustainability and rural areas integration;
- data economy and innovation ecosystems.

Regardless of which domains are chosen as points of reference, **a diversity of potential impact domains must be considered, and digitalisation in agriculture should not be approached as a uniform process.**

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2.2. Agricultural digitalisation is a gradual, multi-stage process whose pace and direction vary widely across and within EU countries

The **level of agricultural digitalisation is vastly different across Europe and within countries**. It largely mirrors a country's overall digital advancement, which is shaped by a range of factors (e.g. connectivity, human capital, governance, topography, economic conditions). Based on an original quantitative index (Hurtado et al., 2025), CODECS research on policy environments has identified four clusters of countries (See Figure 2.), each with their own challenges. This is further reflected in different levels of farm digital maturity.

Country	Digital Readiness	Farm size Structure	Demographic Structure	Ag-specific Momentum	Composite
Netherlands	100.00	100.00	13.00	5.19	86.56
Ireland	83.70	36.60	34.80	11.21	63.41
France	50.60	85.90	73.90	2.20	59.33
Belgium	40.00	95.80	30.40	87.49	55.36
Spain	76.80	23.90	4.30	5.46	52.76
Germany	49.10	70.40	47.80	5.76	52.13
Estonia	61.80	23.90	69.60	19.21	50.98
Czechia	35.90	39.40	73.90	2.96	38.93
Slovenia	50.80	2.80	8.70	8.28	32.46
Italy	36.30	31.00	13.00	0.94	30.88
Latvia	37.90	0	17.40	1.03	24.53
Slovakia	15.90	16.90	82.60	4.92	22.27
Poland	5.70	7.00	100	2.16	15.28
Hungary	17.00	5.60	13.00	19.56	13.88
Greece	0.00	4.20	0.00	28.43	2.47

Figure 2. Four clusters of countries. Source: Hurtado et al., 2025

Of note is the fact that a country's digital readiness is not always in line with the agriculture-specific momentum evident in stated policy objectives. Crucially, this diversity among countries extends beyond the level of digitalisation to encompass **institutional trust, cultural norms, and the varying absorptive capacity of farming communities**, meaning that digitalisation routes cannot be prescribed uniformly.

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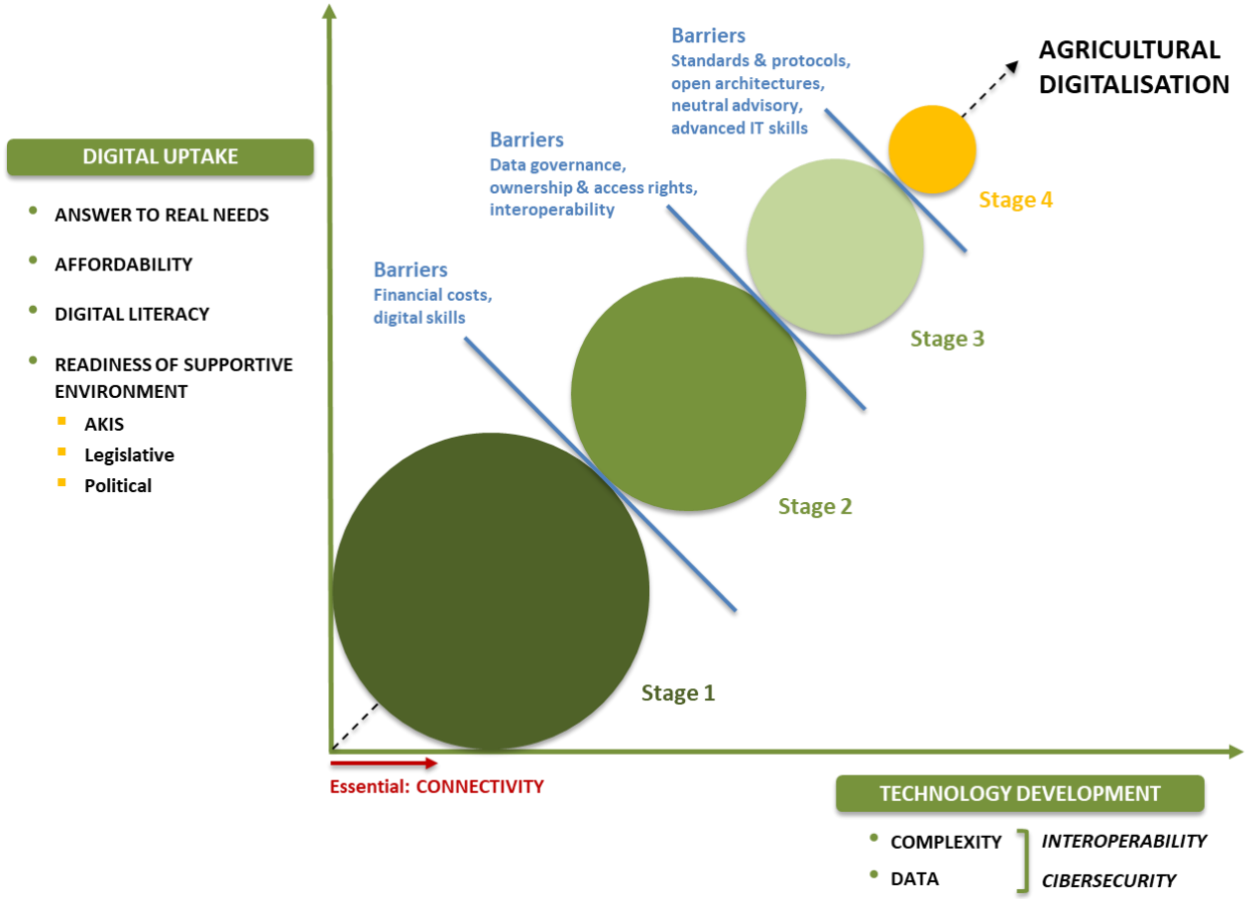

Figure 3. Different levels of farm digital maturity. Source: Hurtado et al., 2025

Ultimately, **the digitalisation transformation of agriculture is not a single event or a binary choice between adoption and resistance**. It is a gradual, multi-stage process shaped by a wide range of technical, economic, social, environmental and institutional factors. Its impacts span the entire food system, from production and processing to distribution and consumption. Its benefits and costs depend on contextual (ecosystem) conditions that vary significantly across farms, regions, and EU countries.

2.3. Digital ecosystem conduciveness depends on more than funding and infrastructure: it requires aligned resources, capabilities, governance and collaboration

In CODECS, digital ecosystems are

"dynamic systems where digital, socio-economic, organisational, knowledge, and physical components converge to support the production, storage, communication, and utilisation of digital technologies and data".

Source: Giagnocavo et al. (2025: 11)

Digital ecosystem conduciveness refers to how well an environment supports the growth and adoption of digital activities. Work done in CODECS WP3 (Giagnocavo et al., 2025) suggests that, without careful intervention, ecosystem conditions can channel transformative ambitions toward conforming (and not necessarily sustainable) pathways. Conducive ecosystems are built upon context-sensitive, multi-level interventions spanning financial support, skills development, infrastructure investment, and inclusive governance. CODECS argues that

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conduciveness is not defined by infrastructure or funding availability alone, but by an ecosystem's capacity to strengthen actors' adaptive and dynamic capabilities, including the ability to reorganise resources, integrate knowledge, and respond to evolving technological and environmental conditions. Conduciveness depends on all these elements functioning together.

I**n CODECS, the RCCIs framework has proved relevant to understand digital transitions.** It shows that resources alone could be insufficient because capabilities (and collaboration dynamics) are what enable actors to mobilise those resources and adapt to change. Conducive ecosystems depend not only on resource availability, but also on effective organisational and governance structures surrounding those resources. In view of the above, it is important to recognise that the successful uptake and integration of digital tools in agriculture requires more than funds, infrastructure, and technical literacy. It requires a **combination of skills and strategic thinking, both at the level of individual farms and across the broader enabling environment shaped by public institutions and the agri-tech industry**. This also indicates that the interaction between resources, actors, governance, and infrastructures determines whether digital tools generate real value in farming systems.

CODECS identifies **strategic combination of four categories of resources that are essential for modernising agriculture**:

- **Financial resources** that are currently lacking because conventional financing does not match the sector's needs;
- **Technological resources** must be tailored to agricultural contexts, and domestic providers should be engaged and supported to meet local demand. The principle of appropriate technology is paramount, and one of the main challenges for farmers in CODECS countries is the lack of support in assessing what is suitable in their specific contexts;
- **Human, knowledge**, **and informational resources** are needed to train stakeholders so they can critically analyse and interpret data, and affordable technical advice should be made available;
- Finally, **material and natural resources** such as testing and innovation infrastructure, together with a focus on digitising small non-industrial farms, emerged as priorities.

Effective resource systems hinge on several interconnected subsystems. For instance, in the human (knowledge and information) domain, there is a need for clear communication channels that convey farmers' requirements to IT developers. The IT system itself must be reliable, with robust broadband connectivity, open standards, and interoperable protocols, while also ensuring secure data storage, access, and control. The natural resource system should integrate ecological considerations, and the funding system must be adaptable to climate change scenarios.

Access to these resources is not gender neutral. Women's comparatively limited control over land and other productive assets restricts their access to credit on the same terms as men, a constraint reinforced by collateral-based risk-assessment models (Akello & Brunori 2025). This compounds the financial resource gap identified above and is a precondition for extending conducive digital ecosystems to women farmers on equal terms.

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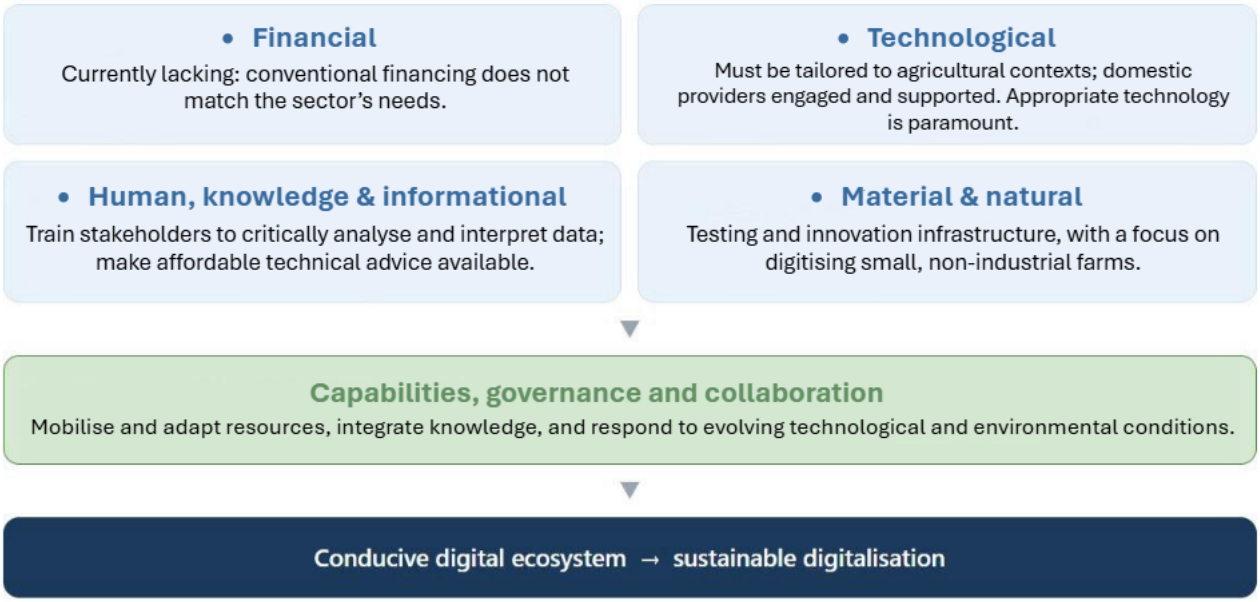

Figure 4. Conducive digital ecosystems

The need for collaboration among actors is emphasised throughout several reports, and it is noted that **skilled actors can effectively transform data into beneficial digitalisation outcomes**. For instance, stakeholder networks can facilitate collaboration, knowledge exchange, and resource access (Giagnocavo et al., 2025). However, reports also indicate that producer organisations sometimes lack capacity to articulate demands to large-scale retailers and food chain actors.

Collaborative approaches and collective action expand access to digital tools and ensure broader, more equitable usage. Pooling resources, joint negotiations with technology providers, or shared digital platforms reduce costs. Collaborative arrangements also support peer learning and promote consistent data practices. In conjunction, this increases technology adoption and helps distribute the benefits of digitalisation more widely across farm types and regions. However, reluctance to collaborate is a hurdle. For instance, in some countries the legacy of central planning and compulsory collectivisation hampers collaboration efforts (Hurtado et al., 2025).

Governance structures evolve alongside digitalisation, though not always appropriately. There is a lack of new informational resources, such as public data initiatives that could encourage innovation, and mechanisms to avoid duplicate data registration across systems, which in turn limits system openness and data transparency. In several CODECS Living Labs, stakeholders pointed to the disproportionate influence of industrial-scale actors and market lobbies as a governance barrier, calling for more inclusive regulatory processes.

2.4. Digitalisation is reconfiguring knowledge flows, advisory roles and power relations within AKIS, while exposing gaps in how these systems are understood and governed

Digitalisation reshapes knowledge flows and power relationships within farming communities and food systems. It can empower farmers with better information and decision-making tools, but it can also concentrate power in the hands of a small number of technology providers or large agri-businesses, potentially marginalising smallholders, women, and younger farmers and other groups in a precarious position. This risk is compounded by the fact that, for instance, extension and advisory services are frequently inaccessible or poorly adapted to women's schedules and caregiving responsibilities, creating a knowledge gap that is distinct from, and additional to, the

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general skills gap affecting rural populations (Akello & Brunori, 2026). Where advisory systems are redesigned around digital channels without accounting for these constraints, the reconfiguration of knowledge flows described above risks entrenching rather than tackling this disparity.

The importance of governing AKIS systems has increased in digital ecosystems. Digitalisation introduces new actors and hybrid knowledge flows which require stronger coordination and integration of informal knowledge within AKIS infrastructures. Knowledge intermediaries are essential actors in the adoption ecosystem, not optional extras. Furthermore, there is a mutually co-constitutive interdependence between AKIS and digitalisation. Digitalisation changes the structure and activities of AKIS, while AKIS is expected to support effective and sustainable digitalisation. Specifically, via online access to expertise (incl. from remote areas) and continuous learning, which can be delivered via digital means, but this requires that advisors themselves have the relevant knowledge and competence to aid farmers in the digital transition.

Studies on AKIS and digitalisation highlight the need to better connect farmers and other AKIS actors through instruments that promote networks and knowledge reservoirs. Regardless of structure, effective coordination ensures that public efforts complement rather than compete with private services, and that existing gaps (especially in digital expertise) are strategically addressed (see below).

Interviews with policy experts indicate that farmers may in some instances prefer advisors connected to companies or research institutions because their knowledge is more up to date and they have access to wider networks. While not reported widely (Hurtado et al., 2025), this points to the need to acknowledge the growing prominence of private firms, which should be debated and addressed in AKIS policies. While private and commercial actors may be in a better position to provide timely and technically advanced advice, commercial interests may shape both the content of advice and the sustainability pathways promoted. As a result, advice provision on current digital solutions will likely not always be fully impartial. Indeed, rather than being replaced, traditional advisory roles appear to be undergoing reconfiguration – adapting to new technological intermediaries and hybrid knowledge flows. A key question is whether this reconfigured advisory capacity can be scaled to meet demand across diverse farming contexts.

Research indicates a persistent knowledge gap regarding which actors are effectively fulfilling intermediation functions. CODECS work confirms the growing role of private firms (ICT, upstream and downstream) in AKIS, which were mentioned more frequently than the traditional AKIS actors that are typically placed at the centre of AKIS analyses (Giagnocavo et al., 2025; Labarthe, 2026). In Living Labs focused on digital technologies, agricultural technology companies and start-ups were strongly represented.

Another striking result is the divergence between the prominence of certain traditional AKIS actors and their varied engagement in Living Labs, according to their contexts and aims (see Labarthe, 2026). For instance, in five Living Labs across Eastern Europe (Estonia, Latvia, North Macedonia, Poland, Slovenia), public authorities were the most frequently cited AKIS actor overall, yet they were rarely identified as being close to the Living Lab's actual digital ecosystem. This contrasts with two other patterns found elsewhere in the CODECS Living Labs where IT firms and upstream and, to a lesser extent, downstream companies dominate both the wider AKIS and the digital ecosystem itself (Belgium, Czech Republic, Italy, Spain), or where no single actor category dominates the representation (Germany, France, Hungary, Serbia, Slovakia, Scotland). This regional variation suggests that AKIS is not perceived in the same way across different countries.

A related but distinct form of segmentation emerged from examining the practices of intermediary actors directly. A survey of intermediaries across five countries (France, Germany, Italy, Latvia, Scotland) identified three groups distinguished by their functions, economic models, networks, and links to policy (Labarthe, 2026). The first group is closely integrated into Living Labs and innovation policy frameworks and drives initial co-design and testing of digital solutions, but invests little in personalised advice to farmers. The second group is more loosely tied to Living Labs, though still dependent on public support, and plays the central role in evaluating digital technologies through a network of advisory organisations, researchers, and industry. The third group provides the most personalised, direct advice to farmers, but has the weakest ties of the three to AKIS networks, Living Labs, and public funding. While this finding is based on a small sample, it points to a possible divide between the innovation support embedded in EU policy frameworks and the advice farmers rely on day to day.

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CODECS further observes discrepancies between the AKIS perceptions of researchers, practitioners and policymakers. There appears to be a disconnection between the traditional conception of AKIS (centred on public authorities, research, and bridging organisations), and the bottom-up perspectives of Living Lab participants (greater emphasis on private firms and farmers) These discrepancies, in turn, can hinder AKIS policies, the uptake of AKIS-supported measures and reduce the willingness of certain actors to participate. They may also create opportunities for certain actors to instrumentalise these measures to their own advantage.

2.5. Digital skills gaps affect farmers, advisors and administrations alike

One of the most persistent barriers to sustainable agricultural digitalisation and ecosystems conducive to it is the digital skills gap. The report on policy environments (Hurtado et al., 2025) shows that countries that have resolved infrastructural and connectivity challenges have to contend with human capital bottlenecks, while those with infrastructural challenges are simultaneously dealing with human capital gaps. This concerns not only farmers, but also the advisors and administrative bodies that are meant to support them. Current advisory systems often lack the digital expertise needed to guide farmers through the transition, leading to a disconnect between what policymakers envision, what advisors can deliver and what farmers need. Upskilling programmes for AKIS actors, agricultural administrations, and extension services could be a solution. Furthermore, embedding digital skills in vocational training, agricultural curricula, and lifelong learning frameworks, alongside business and management competencies could help farmers assess the real costs and benefits of adopting new technologies, reduce the skills gap and respond to generational differences in digital literacy.

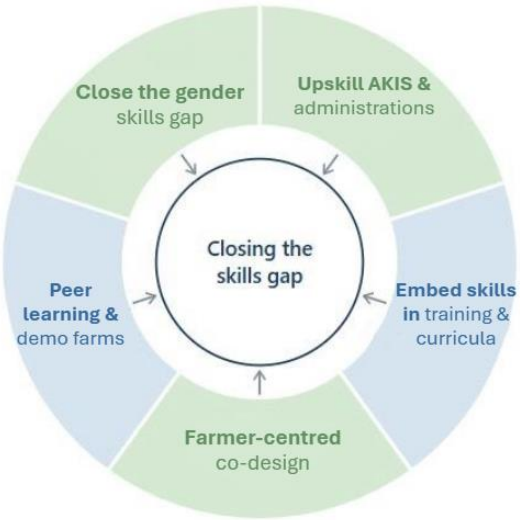

Figure 5. Closing the skills gap

The digital skills gap also has a gendered dimension that generic upskilling programmes do not automatically resolve. Rural women frequently have access to devices such as smartphones but lack the specific skills to convert that access into economic advantage. This is compounded by women's continued underrepresentation in digital research and innovation, which limits their influence over the design of the tools rural women are asked to adopt.

Capacity building also means investing in farmer-centred design. Publicly funded research and technology development projects can benefit from genuine end-user involvement. Co-design workshops that bring together technologists, agronomists, researchers, and farmers help ensure that digital solutions are aligned with actual needs and perceived as useful rather than burdensome. Peer-to-peer learning networks and demonstration farms offer particularly effective and accessible models for spreading practical knowledge. Peer-to-peer exchange among

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farmers is a trusted channel for sharing the real costs and benefits of digitalisation, a form of knowledge transfer that is often uniquely credible to farmers. However, individualistic tendencies among farmers should also be considered and addressed to facilitate behavioural change.

Demonstration and training events are important levers for innovation uptake and knowledge exchange, but these are processes that require structured preparation before and meaningful follow-up after the event itself (see Menadi 2025). Continuity between demonstration, evaluation and adoption phases is required to generate real impact. Digitalisation allows for combining physical and virtual demonstration formats. On-farm visits enable hands-on interaction and contextualisation, while virtual formats (webinars, virtual tours, farminars) broaden accessibility and reduce logistical barriers. The choice of format can be matched to the type of technology being showcased. In addition, demonstration events generate practice-based evidence on the performance of digital technologies, especially regarding sustainability. They make it possible to gather empirical data on technology assessment and performance, as well as users' feedback on the demonstrated technologies and participants' feedback on the demonstration itself. This can support cost-benefit analyses, while helping to reduce uncertainty around technologies.

Demonstration events work best when they facilitate farmer-to-farmer and cross-project knowledge exchange, not just top-down knowledge transfer. Sharing successful examples and good practices associated with digitalisation in agriculture prevents duplication of effort and builds on accumulated experience. Furthermore, demonstrations must be embedded in the wider agricultural innovation system. Rather than treating demonstrations as standalone events, they should be integrated into local stakeholder and learning networks. Understanding micro-level dynamics (how individual farmers actually seek and process information) is key to designing relevant, accessible and trusted advice and activities.

2.6. Poor interoperability and unclear data governance arrangements constrain agricultural digitalisation, while collective action offers a potential counterweight

Digital knowledge and data are not merely private assets. They are increasingly collected, stored and shared and are akin to common pool resources whose value depends on collective governance arrangements, trust, and rules regarding access, sharing, exclusion, and ownership.

Poor interoperability between the products of different providers and even between the systems maintained by ministries and government agencies hampers agricultural digitalisation. This creates barriers (and costs) for agricultural businesses, coordination, data sharing, and coherent policy implementation. Interoperability standards would allow different tools and datasets to communicate, unlocking synergies that fragmented, proprietary systems currently prevent.

At the same time, farmers and other actors across the food system note the need for clear, transparent rules on data ownership, access, and use. Robust data governance legislation, covering cybersecurity requirements, liability frameworks, and farmers' data rights, is a strategic enabler of the digital transition and precondition for farmers' trust. However, there is a need for technology providers to be held to standards of accountability, transparency and reliability, including fair cost structures and openness to platform integration.

Collective action can be a counterweight to undesirable trends in the data economy. Cooperatives and other collective organisations offer a practical means of pooling data, sharing infrastructure costs, negotiating more favourable terms with technology providers and, consequently, increasing technology uptake. Data partnership models involving agreements between farmers, member states, and EU institutions offer a promising format for operationalising this governance dialogue, ensuring that data use is both transparent and equitable. Legal recognition and dedicated incentives for such models remain underdeveloped within existing policy toolkits and greater legal clarity may be needed within EU competition frameworks to ensure that farmer-led initiatives can develop without regulatory uncertainty (Hurtado et al., 2025).

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2.7. Farmer uptake of digital tools reflects a balance between tangible benefits and perceived costs, risks and impacts on professional identity

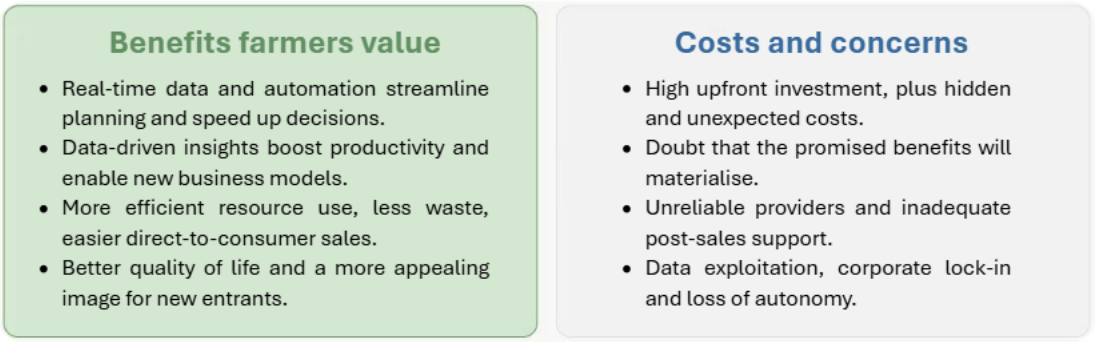

Figure 6. Costs and benefits of digitalisation – according to farmers

Digital technologies are and should be adopted if they solve practical problems, rather than being pursued as ends in themselves. From the perspective of farmers, there needs to be a value proposition (such as reduced costs, improved decisions, time savings, lower uncertainty or new market opportunities). Technologies that fail to generate visible value, regardless of their technical sophistication, are unlikely to achieve widespread uptake. **However, assessing the costs and benefits of digitalisation** requires recognising their variety (economic, environmental, and social) and the different ways they can be understood – through stakeholder perceptions on one hand, and dedicated assessment methodologies on the other. Both are significant in their own ways (Gobrecht et al., 2025).

Overall, research indicates a nuanced picture. **Environmental impacts** often depend on context-specific factors such as farm size, crop systems, and digital maturity. Environmental impacts should therefore be assessed case-by-case using appropriate environmental assessment methods rather than inferred from technology adoption alone. **Economic impacts** are contingent upon upfront investment and learning costs. **Social impacts** are visible in evolving farmer identities, values and social relationships.

Digitalisation offers potential advantages, which are acknowledged by farmers who embrace digital tools when they provide visible practical benefits. Some of these include:

- Real-time data and automation can streamline planning, reduce manual effort, and accelerate decision-making;
- Data-driven insights can boost productivity, facilitate the emergence of new business models, and modernise agriculture's public image, making the sector more attractive;
- Digitalisation can improve workflows through data-driven decision-making and automation, but also introduces new actors, dependencies, and coordination challenges;
- Direct consumer engagement and circular practices become easier, while the overall environmental impact is reduced through more efficient and precise resource use and lower waste.

These also translate into potential social and human-centred benefits, though there are trade-offs. Research in WP4 (Gobrecht et al., 2025) notes impacts on farmer autonomy, overall quality of life and work-life balance, social capital and job satisfaction. A more appealing image of the agricultural profession for new entrants and younger generations through innovation, and stronger community ties among digitally enabled farmers is a possible benefit. However, this potential is frequently unused or inaccessible, and there are also negative effects such as increased mental strain due to constant connectivity, need for continual upskilling and intra-team tensions due to job displacement and automation. Furthermore, reduced face-to-face interaction among farmers and between farmers and advisors represents a social cost that is rarely captured in formal impact assessments. Beyond social impacts, this also impacts knowledge exchange.

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Work on costs reveals that farmers are reluctant to adopt digital tools when they have doubts about technologies and the organisations behind it. Farmers worry about:

- the overall financial commitment required;
- hidden or unexpected costs;
- uncertainties associated with promised benefits;
- inadequate post-sales support, unreliable service providers, and the dependability of governmental or infrastructural bodies;
- high upfront investment, which can be prohibitive (esp. in case of individual small-scale farmers.

Overall, farmers express apprehension regarding data exploitation and potential corporate lock-in or regulatory penalties. Thus, where trust and perceived institutional fairness are absent, digital tools may be avoided as potentially risky burdens.

Small and medium sized farms (incl. with older owners) often lack staff with the specialised skills needed to implement and maintain digital solutions. When a system breaks down, the resulting burden increases frustration and distrust in digitalisation. Hiring skilled personnel can be costly, and many producers find it hard to balance the time spent learning and operating new tools against the tangible outcomes they expect. The steep learning curve at the beginning of adoption can cause anxiety and temporarily reduce productivity. Furthermore, work in WP3 identifies weak communication between farmers and technology developers as a major barrier to digitalisation (Giagnocavo et al., 2025). Many digital tools remain poorly adapted to the realities of small and diversified farming systems because co-creation processes between developers and end users remain limited.

Digitalisation introduces several intertwined risks. The **economic burden of purchasing and integrating new technologies** can be notable, especially when devices become obsolete quickly. Data security and privacy concerns, the complexity of integrating digital tools into existing practices, and the potential for rapid obsolescence all add to the perceived risk and can further discourage adoption. **Control over technology ownership, data stewardship, and the distribution of benefits** among stakeholders is a core challenge. Farmers seek transparent mechanisms that guarantee equitable access to digital tools, prevent concentration of power in large agribusinesses, and protect their autonomy over farming practices. Ownership of data and equipment becomes especially contentious when external entities (such as governments or technology firms) become involved. Unclear legal frameworks around data rights and liability for losses caused by digitalisation leave farmers uncertain about who ultimately controls their assets and information.

These concerns reflect a broader paradox. **Digitalisation can simultaneously enhance farmer autonomy – through real-time data and independent decision-making, while deepening reliance on external technology providers,** creating new forms of dependency that may erode the very autonomy it appears to grant. On top of this, farmers must meet evolving regulatory standards while adapting to new workflows. The inertia of established practices and the effort required to comply with new rules create friction, slowing or even halting the uptake of digital solutions.

Transition costs, transaction costs, and operational expenses remain significant barriers, particularly for small and medium-sized farms. Adoption decisions are often driven by considering the potential for indirect and hidden costs occurring after implementation. These include maintenance, integration, training and organisational adoption costs that farms incur in addition to up-front purchase costs. Targeted subsidies and low-interest financing can make adoption viable, and these costs can be outweighed by the projected benefits over time.

Environmental impacts are highly context-dependent and may vary considerably across technologies, farming systems and implementation contexts. While environmental benefits can arise from improved input management and decision support, they should be assessed alongside indirect effects such as energy consumption, digital infrastructure burdens, equipment obsolescence, changing production practices and possible rebound effects. For instance, digital tools may increase electricity consumption, both for operating hardware and maintaining supporting infrastructure. While this raises operational costs, it is noted by farmers that the adoption of renewable energy sources and energy efficient equipment can mitigate the impact and lower overall expenses. Accurate, timely data is essential for effective farm management, while a lack of reliable information hampers decision-making, negating the benefits of digital technologies.

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Alongside these economic and environmental impacts, the professional image of farming is shifting away from purely hands-on labour towards a hybrid model that blends traditional fieldwork with digital skills. Research done as part of suggests that digitalisation transforms the nature of agricultural labour rather than simply reducing it – shifting tasks, redistributing cognitive and physical effort, and demanding new competencies alongside traditional ones (Gobrecht et al., 2025). The socio-technical modelling done as part of WP3 shows that digitalisation restructures workflows, redistributes responsibilities, introduces new intermediary actors, and increases dependence on digital infrastructures and data flows (Giagnocavo et al., 2025). Thus, technology now plays a central role, which requires farmers to develop new skill sets. While digital technologies are making farming more appealing to young people, simultaneously there are concerns that farmers might become detached from the physical aspects of their work and that traditional knowledge could become obsolete.

The above tension can be understood as a clash of professional identities. The embodied, traditional knowledge-based identity of older farmers confronts an emerging identity of the "digital farmer", defined by new values, data literacy, connectivity, and technological fluency. This can also be understood as a trade-off between experience-based knowledge (grounded in tradition, embodied practice, and local context) and the evidence-based approaches enabled by digital data, each carrying its own legitimacy and risks of displacement.

This underlines that agricultural digitalisation is also a socio-psychological transition, not merely a technology procurement exercise. It actively alters traditional farm management practices and reconfigures professional identities. When digital tools displace agronomic expertise, they may encounter resistance rooted in identity protection. There is potential in supporting technologies that augment and respect, rather than replace, farmer agency and craft.

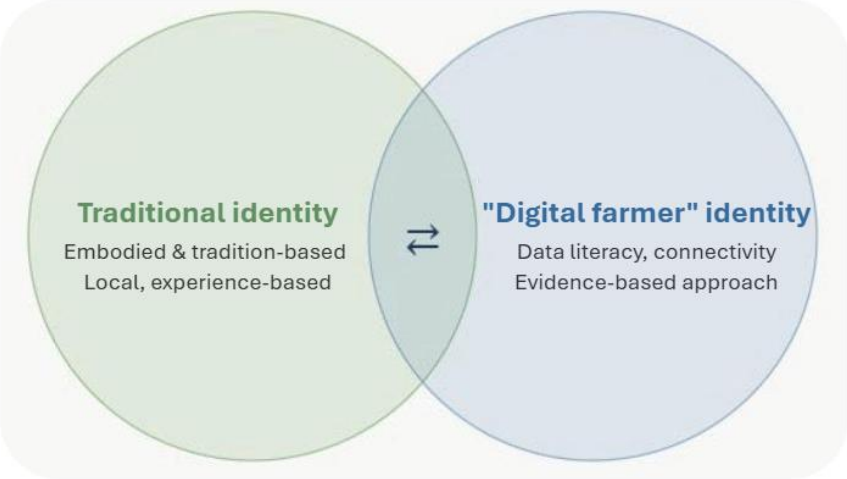

Figure 7. Impact of digitalisation on identity

2.8. Adoption is driven by whether digital tools are perceived as useful, trustworthy and supportive.

A critical challenge across all areas of agricultural digitalisation is the gap between technologies that are technically available and solutions that are genuinely affordable, user-friendly, and compelling for the end-user. Evidence in CODECS Living Labs shows that there is frequently a lack of ready-to-use digital solutions to farmers' problems and technologies are often designed without sufficient attention to everyday farming practices or are developed for different farming contexts. In conjunction, this can contribute to lower uptake and trust. Potential solutions are interactive innovation, targeted innovation support, procurement policies that prioritise low-cost and accessible solutions, and practical tools such as "digital toolbox" catalogues that help farmers navigate what is on offer, thus increasing transparency and trust.

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Figure 8. Need for overlap between availability, affordability and usability

Policies and digital solutions stand to gain by being perceived by farmers as genuinely supportive, rather than as new compliance and surveillance burdens. According to the policymakers interviewed in CODECS, this can be achieved by providing evidence for concrete quality-of-life and productivity gains such as reduced paperwork, better market access, and time savings. However, this needs to be tailored to different farm types as they each have different needs and capacities meaning that perceptions of what is support and what is an additional reporting burden will differ.

The perception of regulatory conditionality is an instructive example. For many producers, the obligation to meet digital compliance requirements under the CAP has triggered the adoption of specialised software for the first time. This dynamic has intensified in the current programming period, where eligibility is explicitly conditional on climate action, environmental stewardship, and digital record-keeping. In some Member States, this conditionality already extends beyond record-keeping and has become an incentive: in the Netherlands, for example, growers who upload GPS-tagged data documenting fertiliser application can earn an additional 250 euro per hectare under an eco-scheme, illustrating how data submission is increasingly becoming "the currency that unlocks higher payments" (Hurtado et al., 2025: 41). However, this compliance-driven adoption pathway is double-edged, with interviewees noting that rising documentation and monitoring requirements have fuelled frustration and even lead to protest, particularly where farmers feel that the pace of change has outstripped their capacity to adapt and administrative oversight is believed to be excessive. Reactions to data scrutiny also vary considerably: some farmers view remote monitoring as an opportunity to demonstrate good practice and reduce administrative burden, while others perceive it as a new form of surveillance and economic control. Whether conditionality accelerates or undermines the digital transition therefore appears to depend less on the requirement itself than on how it is communicated and implemented locally.

2.9. Digitalisation can reinforce or reduce inequalities depending on how policies account for social capital, inclusion and local context

The effects of agricultural digitalisation are not socially neutral. Specifically, digital divides in agriculture risk mirroring and reinforcing broader societal inequalities. Unequal access to connectivity, digital skills, advisory services, and investment capacity leave vulnerable groups and regions disproportionately exposed to exclusion and dependency as they have less bargaining power and are less able to absorb transition costs. Monitoring and correcting for the undesirable effects of agricultural digitalisation across different groups could reduce the risks of exclusion.

These digital and structural divides compound existing gender disparities in EU agriculture, producing what can be described as a triple divide of digital, gender and rural inequality (Akello & Brunori, 2026)**.** Women

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farmers are statistically less likely to access reliable connectivity and digital skills training than rural men, and where formal indicators show growth in female farm ownership, this often reflects statistical registration for subsidy purposes rather than a genuine increase in women's decision-making authority over land, technology or data. Left unaddressed, this compounding disadvantage risks excluding women disproportionately from the benefits of the data-driven agricultural economy, even as broader digitalisation indicators improve.

Rural communities rely on socio-technical networks and social capital that digitalisation interventions can inadvertently disrupt. Trust and collaboration are key determinants of uptake and whether digitalisation succeeds or fails in a given rural context (see Sections 2.7 and 2.8), and this is no less true of remote or underprivileged areas. Participatory governance mechanisms (such as Living Labs and stakeholder advisory boards) offer practical formats for co-creating inclusive digital ecosystems that better reflect the actual needs and realities of farmers, though their integration into mainstream policy design needs to be strengthened to reap the benefits (Soma et al., 2026).

Securing the long-term future of agricultural digitalisation could require sustained investment in the next generation of digitally skilled farmers – through incentives for land transfer, access to finance, targeted advisory support, and integration of digital competencies into agricultural education from the outset. While younger farmers and new entrants to the sector are frequently assumed to be more inclined to adopt digital tools, this assumption warrants further corroboration on adoption drivers, since farm size and access to capital may matter more consistently, meaning that an emphasis on skills may be insufficient if inclusion and renewal are targeted.

Public investment can democratise access to technology, but funding must be distributed fairly and accompanied by clear accountability. State-backed financing for education and digital literacy programmes can lower entry barriers and foster wider adoption, provided that the mechanisms are transparent and inclusive. In addition, **public–private collaboration can function as an equity mechanism, shaping whether the benefits of digitalisation reach the farms and regions most exposed to exclusion.** Beyond the general urban-rural divide, a further gap separates the connectivity available to farm households from what actually reaches the fields themselves, and this persists in remote and structurally disadvantaged areas even where overall rural broadband coverage has improved. Diversifying connectivity technologies, offers a partial solution, but deployment in the hardest-to-reach areas depends on coordinated public and private financing to address market failures that commercial provision alone does not resolve. Joint public-private undertakings can also shape the terms of inclusion more directly, through the co-development of interoperable platforms and business models designed to serve smallholders alongside large-scale farms, and by reducing the risk faced by early adopters in less favourable market conditions (Hurtado et al., 2025).

2.10. Evidence gaps continue to constrain informed decisions about both digitalisation and the effectiveness of policies designed to support it

Informed decision making is fundamental to ensure that policy interventions are fit for purpose, and farmers require clear vision regarding context-specific policies. **A lack of granular data on digitalisation at the farm level and digitalisation-related expenses is a persistent major barrier for the design and evaluation of digitalisation policies in agriculture**. While the EU publishes broad digital indicators (e.g. DESI until 2022 (European Commission, 2022c)), equivalent datasets for agricultural digitalisation remain underdeveloped, limiting the ability to benchmark progress and evaluate policy effectiveness accurately. Thus, existing indicators on digitalisation in agriculture can leave decision makers with an incomplete picture of digital readiness and use. **Building a strong evidential basis for decision making is needed for more targeted support** (incl. financial), better evaluation, and timely course correction. For instance, to facilitate the monitoring and evaluation of policies, there is a need to more effectively identify the interventions included in CAP NSPs (EU CAP Network, 2025) and perform periodic evaluations. Indeed, digitalisation is often only one element of the projects that can be financed under interventions.

Traditional monitoring approaches based on periodic surveys may no longer fully capture the dynamic nature of digitalisation in agriculture. As the digital technology market evolves faster than annual survey cycles, static snapshots of farmers' experience are no longer sufficient. Also, lack of real-time climate change data slows down proactive governance to anticipate potential future crises. Increasing digitalisation fundamentally relies on representing the physical world through numbers; via sensors, satellites, and metrics, a farm's soil, crops, and

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livestock are converted into data. This shift alters the governance requirements of agriculture and highlights the role of the digital representation in ensuring that policy is based on accurate assumptions.

This need for data also applies to the evaluation of the tools themselves. Currently, there appears to be very limited evidence on environmental impacts and social impacts. Farmers and policymakers require robust methods to assess realised economic, environmental and social outcomes, including unintended effects and trade-offs. Work on costs and benefits in WP4 (Gobrecht et al., 2025) suggests that the picture is nuanced and understanding it requires a context-sensitive approach to ensure sustainability transitions. Indeed, technologies themselves, when implemented without corresponding changes in farming practices, appear to have a negligible effect on overall environmental performance.

2.11. The gap between the potential and the actual uptake of digital technologies reflects an implementation and coherence challenge, rather than a lack of knowledge

Ensuring sustainable digitalisation in varied contexts requires **strong institutional capacity and a systemic approach to harness the potential of the digital transformation** for addressing various challenges, while mitigating potential downsides. Currently, research indicates coordination gaps across ministries and programmes (Hurtado et al., 2025). Countries in earlier stages of digitalisation face these challenges more acutely, but this is also evident in digitally advanced countries. Coordinating efforts across all policy layers to ensure alignment and continuity of digitalisation strategies will be necessary. Crucially, successful implementation also depends on the digital capability of public administrations themselves. Administrative readiness, including digital skills, interoperable systems, coordinated procedures and implementation capacity, determines whether policies can be delivered consistently and efficiently. Therefore, weak administrative capacity can become as significant a barrier to uptake as inadequate farm-level capabilities.

The potential of digital technologies substantially exceeds their current uptake, and this is an implementation gap rather than a knowledge gap. Digital technologies can offer practical and strategic value. They can strengthen farm competitiveness, improve value chain resilience, facilitate farmer–government interaction, and contribute to sustainability. Yet an analysis of policy recommendations on agricultural and rural digitalisation over the past decade converged on the same six thematic areas (infrastructure and connectivity; data and governance; AKIS, skills and capacity building; political, financial and legal frameworks; tools and technologies; and social aspects) and the core recommendations within them have changed little. This raises a fundamental question: do existing policies actually embody a coherent vision of change, or do they merely respond to technological momentum without a clear direction of travel?

Part of a potential answer lies in what actually drives uptake: internal ecosystem dynamics, combined with wide variation in local conditions. CODECS findings suggest that external policy incentives alone rarely drive digital transitions. Actual uptake depends on farmer motivations, local trust relationships, advisory support, collaborative culture, absorptive capacity, and perceived usefulness. Contextually, labour shortage, resource scarcity, input prices, market demands are also important contributing factors. At the same time, farm structures, geographic conditions, institutional capacity and continuity, and economic contexts differ markedly. Furthermore, work done in CODECS also demonstrated that sustainability priorities differ substantially across contexts. While some Living Labs primarily viewed digitalisation as a means of improving competitiveness, others prioritised environmental stewardship or social wellbeing (Soma et al., 2026). This diversity reinforces the need for policies that provide common objectives while allowing sufficient flexibility to accommodate local priorities and transition pathways. across and within the EU, so no single lever or pathway can deliver results in isolation.

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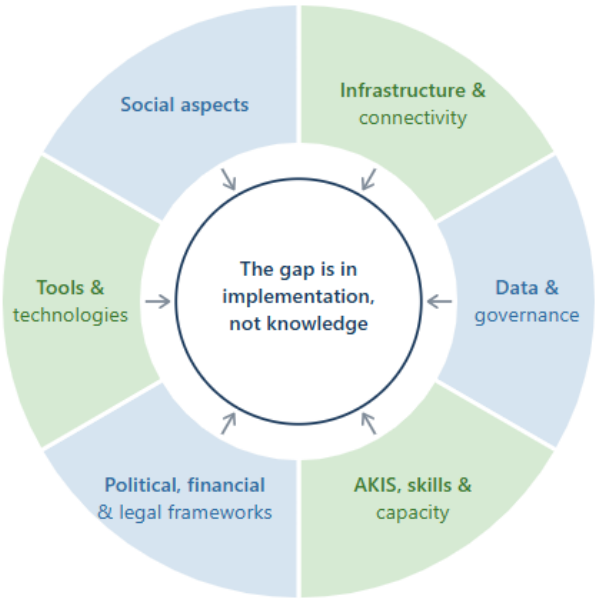

Figure 9. Implementation gap

This combination (locally driven uptake and highly variable contexts) points to a key policy design implication: coherence needs to operate across many levels. Effective policy should combine strong strategic guidance and regulatory clarity at EU level (including on data and cybersecurity), enabling frameworks at national level, and context-adapted programme design at regional and local level, with public-private partnerships helping extend infrastructure and services (such as connectivity) beyond urban centres. Coherence across funding instruments is also essential. Fragmented, short-term, and inconsistent financial support has been a persistent weakness of digitalisation policy, and sustained, regionally adapted, and well-coordinated investment can drive meaningful change. Where this coherence is missing, the gap is visible in practice.

As a case in point, the implementation of the NSPs under the CAP illustrates several challenges when it comes to digitalisation. While CAP supports digitalisation, some countries allocate limited funding to these measures, prioritising traditional agricultural subsidies. In addition, there are difficulties in identifying interventions focusing on digitalisation, as interventions that are not otherwise explicitly associated with digitalisation have (relevant) digital components (EU CAP Network, 2025).

Because uptake and impact follow non-linear, systemic dynamics rather than a simple input–output chain, evaluation approaches need to reflect that complexity too. There appears to be a reliance on simplistic evaluation models that assume a direct link between financial support, technology adoption, and wider impact. CODECS evidence instead points to non-linear interdependencies, feedback loops, and potential rebound effects that can only be identified and managed through systems thinking.

Taken together, this is why policy approaches that treat digitalisation as a one-off intervention are unlikely to succeed. What is needed instead are long-term, systemic programmes, multi-year roadmaps and adaptive governance mechanisms that recognise the evolving nature of the digital transition and allow strategies to be adjusted in response to emerging technologies and on-the-ground realities.

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2.12. Existing policy instruments and innovation initiatives provide a foundation, but their impact depends on greater coherence, coordination and continuity to create a conducive environment for agricultural digitalisation

Many Member States have already developed practical implementation mechanisms through CAP NSPs, advisory systems, Living Labs, innovation networks, and AKIS-based collaboration structures. Existing initiatives provide important institutional infrastructure, funding pathways, and experimentation spaces that can support further adoption of digital technologies in agriculture. Multi-actor approaches such as Living Labs, Operational Groups, and Digital Innovation Hubs are particularly valuable because they connect farmers, advisors, researchers, technology providers, and policymakers in more collaborative innovation ecosystems.

CAP is a key lever but should not be regarded as a silver bullet. The CAP has put digitalisation on the policy agenda, requires states to include a digital strategy in their NSPs, and states had committed approximately six billion euro over the course of the programming period. Digitalisation is integrated through eco-schemes, investments, and knowledge sharing or advisory services. Furthermore, CODECS interviews with policy experts highlighted the significant impact of EU-level policy in driving the pace of the digital transition across Member States (Hurtado et al., 2025). However, the CAP is also seen as a source of increased bureaucracy and frustration across the sector, particularly where farmers feel the pace and pressure of change have exceeded their capacity to adapt. Likewise, existing indicators may not be well suited to capture digital progress and there is no robust baseline against which to assess change and levels of expenditure on digitalisation. Furthermore, digitalisation strategies within the CAP NSPs vary considerably across Member States. These issues must be addressed to ensure that agricultural digitalisation is sustainable. However, even if digitalisation strategies remain uneven in ambition and detail, the requirement for Member States to include digitalisation strategies within CAP NSPs has already played an important role by encouraging governments to systematically reflect on digital transformation in agriculture.

Future progress will likely depend on improving coherence, coordination, and usability across existing policies and instruments. Fragmentation across governance systems, funding instruments, datasets, and institutional responsibilities remains a key structural barrier to sustainable digitalisation. Reducing this fragmentation, strengthening interoperability, simplifying implementation, supporting local advisory ecosystems, and improving collaboration between public and private actors could be the next steps needed to turn current policy momentum into widespread and inclusive digital transformation of agriculture.

In summary, agricultural digitalisation should be understood as a long-term socio-technical transition rather than a sequence of technology projects. Progress depends on creating the enabling conditions within which digital tools become useful, trusted and economically worthwhile. Technology will continue to evolve rapidly, but sustained uptake will depend on policy coherence, institutional capacity, farmer-centred implementation and the ability to adapt strategies to Europe's diverse territorial realities.

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3. Policy foresight

Understanding how the processes discussed above might unfold over time is essential for shaping policies and strategies that ensure digitalisation contributes to inclusive, sustainable, and farmer-centred futures. A structured foresight exercise provides a valuable approach to address this uncertainty by moving beyond short-term impacts and examining plausible long-term futures for European farming systems. A foresight exercise (sometimes referred to as "scenario planning" or "scenario development") is a structured activity that explores plausible future developments and uncertainties. The foresight workshops conducted as part of the CODECS project aimed to create a shared space for reflection and strategic dialogue at the European level, bringing together policymakers, researchers, farmers' representatives, agricultural advisors, and other key stakeholders.

This section synthesises insights from two policy foresight workshops, run as part of the CODECS project in March 2026 (M43). The workshops explored how digitalisation might evolve across different European farm settings by 2040. Using four scenarios pre-developed by the James Hutton Institute (hereinafter – JHI) team and a backcasting approach, participants examined the policy and support pathways required to achieve positive digital futures in agriculture. The discussions brought together a diverse group of stakeholders, including researchers, policymakers, advisors, and representatives from the agricultural sector.

Building on existing foresight work and scenario-based approaches (including foresight activities in the Horizon 2020 project DESIRA[2]), the workshops encouraged participants to collectively **explore how digitalisation pathways might shape agriculture in Europe over the next 14 years, and how policy trajectories might support the most beneficial digitalisation pathways**. A 14-year time horizon was used to align with that employed by the Long-Term Vision for Rural Areas (see European Commission, n.d.).

The outcomes of the workshops contribute directly to the objectives of the CODECS project, supporting evidence-based recommendations. In particular, the foresight exercise generated insights that will help identify priority areas for intervention, and highlight conditions under which digitalisation can best support sustainable, resilient, and equitable farming futures in Europe.

3.1. The scenarios

The two workshops were organised according to thematic clustering developed for the scenario workshops carried out at the 2025 CODECS General Assembly in Ljubljana. To direct the conversations on policy pathways required to reach desired futures and to guide discussions in a limited time in the workshops, only positive future scenarios were presented and discussed. The four scenarios, developed by the JHI team to guide the foresight workshop activities, are presented below (Table 6).

The four scenarios
Scenario 1: The Connected Greenhouse In 2040, rural and remote rural regions across Europe are serviced by **fast and reliable internet connectivity**. Digitalisation is more inclusive and although digital divides still exist, there are no large disparities between internet speeds in urban and rural regions. Farms adopt **selective, affordable digital tools and ethical AI applications to support viable and sustainable business models**. On medium-sized farms in Serbia, wireless nodes form a sensory mesh, providing farmers with valuable timely data about their vegetable greenhouse production. For greenhouse farming systems across Europe, digital tools integrate seamlessly into farm management systems, providing satellite images, weather information and powerful decision-making support. The technology saves time and physical labour for the farmers, enabling **better working conditions.** Environmental benefits arise through a

[2] See https://desira2020.agr.unipi.it/

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reduction in fertiliser, pesticide, water and energy use, thanks to accurate and timely data outputs. Economically, **yields and hence profits are increased**, as plants have better care thanks to advanced monitoring.

Scenario 2: Orchard 2.0

By 2040, fast, reliable internet spans rural Europe, bridging the urban-digital divide. Small-scale orchards and vineyards now thrive by **adopting affordable, selective digital tools**. On a farm in Czechia, **remote sensors and weather station**s optimise frost protection, pollination, and irrigation, **saving labour and resources.** These data-driven decision tools empower farmers with actionable insights, **building confidence and operational efficiency**. The environmental impact is significant: targeted applications of water and fertilizer, alongside reduced pesticide use, **promote sustainability**. Enhanced monitoring used alongside ethical AI applications also allows farmers to **mitigate the increasing threats of extreme climate events.** Today, orchards are celebrated as **"biodiversity hotspots"** that support diverse flora and fauna within agricultural landscapes. This sustainable future is built on **deep collaboration between farmers, tech providers, researchers, and NGOs.** This stakeholder alignment ensures policy coherence, driving digital innovation that serves both the environment and the public good.

Scenario 3: Smart Simplicity

By 2040, **high-speed internet reaches the most remote regions**. Digitalisation is now more inclusive, and the urban-rural divide is all but eradicated. Small-scale livestock farms now thrive using affordable, selective digital tools and platforms, and ethical AI applications. On a small sheep farm in Scotland, herd monitoring sensors and simple pasture management apps provide reliable data on animal health and grassland use, **reducing veterinary costs and input waste.** Interoperable systems and digital traceability allow farmers to bypass intermediaries, **selling directly to consumers via grower-owned cooperative platforms**. This ensures data sovereignty and stable pricing. Environmentally, **precision feeding and rotational grazing apps boost soil health, biodiversity, and climate resilience** while securing agri-environmental payments. Socially, success is rooted in **trusted peer networks and clear data governance**. These support systems **reduce stress, simplify skills development, and improve work-life balance**. By prioritizing accessible, high-impact technology, digitalisation strengthens the economic resilience of small farms, fostering vibrant rural communities and encouraging the next generation of farmers.

Scenario 4: Grassroots Tech

By 2040, in European livestock farming, digitalisation has evolved into a user-friendly ecosystem where high-tech tools serve traditional practices. In Latvia and Estonia, drones and remote sensing **protect semi-natural grasslands**, using machine learning to monitor clover and biodiversity, ensuring these vital carbon sinks remain healthy. In the Mediterranean, dairy sheep farms use integrated Farm Management Systems. Tools like digital milk meters and automatic concentrate distributors work with ethical AI applications to optimise individual ewe nutrition, **improving animal welfare while reducing waste**. By centralising health and production data into intuitive apps, farmers have **balanced their work-life schedules** and increased market transparency through "product passports" to stay **competitive in a global market**. This transformation is anchored by **collaborative networks** of farmers, advisors and other relevant peers. This cooperation ensures data sovereignty and provides the skills needed to navigate the digital transition. By merging heritage with smart innovation, digitalisation **preserves rural livelihoods**, enhances **environmental resilience**, and ensures **policy alignment** to secure long-term rural prosperity.

Table 5. The four scenarios

3.2. The results

The workshops were divided so that two scenarios were discussed in each workshop. In workshop one participants explored scenarios relevant to livestock and farm management systems; and short supply chains and digital platforms. The second workshop considered the scenarios relevant to greenhouses and irrigation; and orchards and

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vineyards. For each scenario, the facilitators asked for initial reflections on the scenarios before asking the following questions to prompt discussion:

- What policy pathways need to be put in place now, to enable this positive future?
- What other support pathways? (consider regulatory, financial, advisory, infrastructural, and capacity building measures)?
- How can we ensure inclusiveness, feasibility, and coherence with broader sustainability and agricultural policy objectives?

Notably, participants reflected that the scenarios were presenting a more positive outlook than they themselves could foresee, but this enabled the discussion to explore relevant challenges and opportunities facing these agricultural systems in the not-too-distant future.

In the following sections we first present the reflections and insights emerging from the scenario-specific discussions, and secondly, we present cross-cutting themes emerging across the two workshops.

3.2.1. Scenario-specific insights

Scenario 1: The Connected Greenhouse

Discussions around the greenhouse scenario highlighted the stark **contrast between high-tech and low-tech systems**. High-tech greenhouses, particularly in northern Europe, operate with advanced automation, climate control, and hydroponic production systems. Participants noted that these **environments resemble industrial facilities more than traditional farms** and are already optimised in terms of digital support. In contrast, Mediterranean greenhouses remain largely **soil-based and low-tech, with significant potential for digitalisation** to support efficiency, sustainability, and climate adaptation[3]. Participants noted the **risk of a widening digital divide** between these systems and emphasised the need for tailored advisory support and investment.

Scenario 2: Orchard 2.0

In the orchards and vineyards scenario, participants highlighted the **importance of collaboration between small producers**, particularly in sharing tools such as weather stations and pollination sensors. Orchards and vineyards often serve as biodiversity hotspots, and participants stressed the **need for digital tools that support rather than undermine ecological functions**. Climate change may shift production zones northwards, creating new opportunities but also new risks. Participants emphasised the **need for data-driven decision tools that build confidence** without overwhelming farmers, and for policies that support generational renewal and land access.

Scenario 3: Smart Simplicity

In this scenario, participants discussed how small-scale livestock farms could benefit from **simple, affordable digital tools that fit easily into everyday routines**. Basic herd-monitoring sensors and pasture-management apps were seen as realistic supports for improving animal health and reducing inputs and farm waste without adding additional complexity. The scenario's emphasis on the **need for interoperable systems and cooperative digital platforms** resonated strongly, particularly the idea that farmers should retain control over their data and be able to freely and easily sell the products directly to consumers. Participants also highlighted the **importance of trusted peer networks and clear data governance in building confidence**. Overall, this scenario was viewed as a credible pathway for strengthening the resilience of small farms through accessible, high-impact technologies rather than full-scale automation.

Scenario 4: Grassroots Tech

In the Grassroots Tech scenario, participants reflected on **how digitalisation could complement rather than replace traditional livestock practices**. In northern and eastern Europe, tools such as drones and remote sensing technologies were seen as valuable for monitoring semi-natural grasslands and supporting biodiversity. In Mediterranean dairy systems, **integrated farm management tools including digital milk meters and automated feeders were viewed as practical aids for improving animal welfare and managing workloads**. The scenario's

[3] It should be noted that this characterisation of Mediterranean greenhouses was challenged as stereotypical.

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focus on collaborative farmer-advisor networks was considered essential for ensuring data sovereignty and building digital skills. Participants also noted the potential of "product passports," helping farmers stay competitive in a global market by enhancing transparency and competitiveness. Overall, this scenario was seen as a balanced vision in which heritage and innovation work together to support environmental resilience and rural livelihoods.

3.2.2. Cross-cutting messages

Digitalisation is a contextual, not universal, solution

Participants consistently emphasised that digitalisation cannot be treated as a one size fits all "silver bullet" solution to the issues facing agriculture. Many of the challenges facing European agriculture, such as generational renewal, land access, economic pressures on small farms, and the impacts of climate change cannot be solved by the increasing adoption of novel technologies alone. Digitalisation may support adaptation, mitigation and resilience, but only when embedded within broader systemic change. As one participant noted, *"digitalisation is not the silver bullet that will solve everything."*

Co-creation and fit-for-purpose tools are key.

A strong theme across both workshops was the need for "making sure that digital tools are really, properly co-constructed with farmers for a particular use and not coming from commercial companies". Participants stressed that tools must be adapted to local conditions, production systems and user needs. Several noted that digital models and algorithms are not neutral: the assumptions embedded within them shape farming practices and sustainability outcomes. This underscores the need for transparency, participatory design and ongoing evaluation.

Trusted advisory systems and peer networks are important.

Trust emerged as a critical enabler of digital adoption with one participant noting that "*the impact and importance of trusted networks and advisors with use of digitalisation is sort of a growing field".* Farmers often rely on existing advisory networks, or close peers to help them navigate complex technologies, interpret data, and make informed decisions. Participants highlighted concerns about advisory services dominated by technology providers, which may compromise the neutrality of any advice given. Independent advisory systems, farmer-to-farmer networks and local knowledge hubs were seen as essential components of a supportive digital ecosystem.

Digital maturity varies across Europe.

The workshops highlighted significant differences in digital maturity across European regions and farm types: "big farms can easily or more easily absorb the costs of adopting technologies and are faster to take up these technologies. Small farms are often slower and can get left behind". High-tech Dutch greenhouses operate as highly controlled hydroponic environments with advanced automation, while Mediterranean greenhouses remain largely low-tech and soil-based. Small farms often juggle multiple enterprises and lack time for experimentation, while larger farms may have dedicated staff for digital tasks. Policy must recognise these differences and avoid assuming uniform progress.

The ethical and social implications of digitalisation must be considered.

Participants raised a range of ethical concerns, including data privacy, contractual fairness, AI transparency, labour impacts, and the potential erosion of community-based farming models. One participant proposed that there is *"a tension [regarding] ethical AI applications, because most of these proprietary tools, they need something in return"* - they are not neutral and could be using our inputs and data for an unseen agenda. Some worried that digitalisation could contribute to a growing farmer detachment from nature and traditional farming identities, particularly if farmers spend more time managing data in an office and less time 'in the field' observing their land and/or animals. These concerns highlight the need for governance frameworks that prioritise fairness, accountability, and sustainability.

Identity, values, and resistance are important to understand responses to digitalisation.

Not all resistance to digitalisation stems from lack of skills or resources. Some farmers may resist digital tools because they conflict with their identity as hands on land stewards or because they value a lifestyle connected to nature rather than screens. *"What happens when digital tools, you know, come into play? How does that change the*

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identity?". Participants noted that digitalisation strategies must respect these values and avoid framing increasing digital adoption as inevitable or universally desirable.

Intergenerational learning and youth engagement can ease the transition.

Younger family members often play a key role in supporting digital adoption, particularly in areas such as social media, drone use, and data interpretation: *"We've had examples too in Scotland of younger members of a family… that have helped when it comes to digital technologies and using platforms or using social media in particular for promoting their business".* Intergenerational collaboration can ease transitions and build confidence, especially on small and medium-sized farms.

Urban agriculture and new production systems are avenues worth exploring.

Participants also discussed the growing relevance of urban agriculture, including rooftop greenhouses, community orchards, and climate adaptive crops such as vineyards in northern European regions: *"I was thinking about the urban rooftop greenhouses. They're not always business-oriented farms, and they could also benefit from a high-tech digitalisation. So [digital tools] should be made affordable to these also".* Digital tools could support these systems, but affordability and accessibility remain key concerns.

3.3. Conclusions

The workshops demonstrated that digitalisation could play a meaningful role in supporting sustainability, resilience and farm viability in the future, but only if it is context sensitive, ethically governed, and co-created with farmers. Trusted advisory networks, peer learning and strong intermediaries are essential for building confidence and ensuring responsible adoption. Above all, digitalisation must be guided by policy frameworks that respect the diversity of European farming systems and align technological development with broader agricultural, environmental and rural development goals. When shaped deliberately and inclusively, digitalisation can contribute to thriving rural communities and sustainable agricultural futures by 2040.

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4. Approach to formulating policy recommendations

CODECS recommendations are derived from the analysis of policy environments, the findings across Living Labs and the policy foresight exercise. The suggested mix of policy options combines communicative, legislative and action-oriented elements, and is based on the assumption that digitalisation is a means to achieve the desired competitiveness, resilience and sustainability outcomes. While some recommendations reinforce priorities already reflected in previous research and existing European policy frameworks, the evidence generated in CODECS demonstrates that these challenges continue to constrain the digital transformation of European agriculture. Accordingly, the recommendations have been formulated to reflect the project's findings on the conditions that influence whether these widely recognised priorities translate into meaningful change. The objective is to strengthen the implementation of existing priorities by grounding them more explicitly in the evidence generated through the project.

The CODECS policy recommendations have been grouped into nine thematic clusters. These clusters were created inductively, by grouping the recommendations that derive from the key messages. The clusters are organised around a combination of governance domains, target groups, and enabling conditions. Their emergent characters means that some cross-cutting themes (particularly around evidence and advisory capacity) necessarily appear across multiple clusters.

Each of the thematic clusters has a self-contained section below. These sections are designed to situate each thematic area in relation to the project's findings and within the broader policy landscape. Each thematic section opens with a short introduction that places the category in relation to the CAP and the underlying regulation. Following this, a set of summary points drawn from the key messages highlights the most relevant findings for that thematic area, providing the foundation on which the recommendations rest. Each recommendation is described in terms of (i) the problem that was identified as part of CODECS, (ii) the action that is required and (iii) the intended effect.

Each recommendation is further classified according to the level of intervention it targets, drawing on the CODECS conceptual framework (business processes, digital ecosystems, and socio-ecological systems).

- Business processes refer to farm-level inputs and actions, and captures what farmers themselves need to adopt and use digital tools productively;
- Digital ecosystems refer to the networks, platforms, data spaces, and collaboration dynamics connecting farmers, advisors, technology providers, and other actors, and captures what relationships, standards, and intermediaries need to be in place for tools to function as connected systems;
- Socio-ecological systems refer to the macro-scale structural and institutional conditions that allow digitalisation to serve broader societal and environmental goals.

This classification identifies the level at **which a recommendation's underlying problem is located**, rather than the level at which its proposed instrument operates. This means that a recommendation addressing a socio-ecological problem, for example, may still rely on a business-process-level instrument, such as targeted advisory support, to bring about the intended change.

Each recommendation is also mapped onto the relevant phase(s) of the policy cycle, adapted from the European Commission's Better Regulation (European Commission, 2021) approach, following the stages of preparation, adoption, implementation, and application. Where a recommendation requires action at more than one point in the cycle, it is tagged with more than one phase, reflecting that most recommendations cannot be reduced to a single moment of policy activity. The vehicle they rely on (e.g. a formal legislative or regulatory instrument vs. a purely administrative or programmatic one) determines whether a distinct adoption stage applies. We deliberately introduce evaluation as a distinct fifth phase, consistent with the Better Regulation cycle's own recognition of evaluation as a core policy stage, in order to distinguish genuinely retrospective, evidence-based assessment activities. This applies to impact assessments or reviews of past implementation that are distinct from the continuous, operational monitoring that takes place during application.

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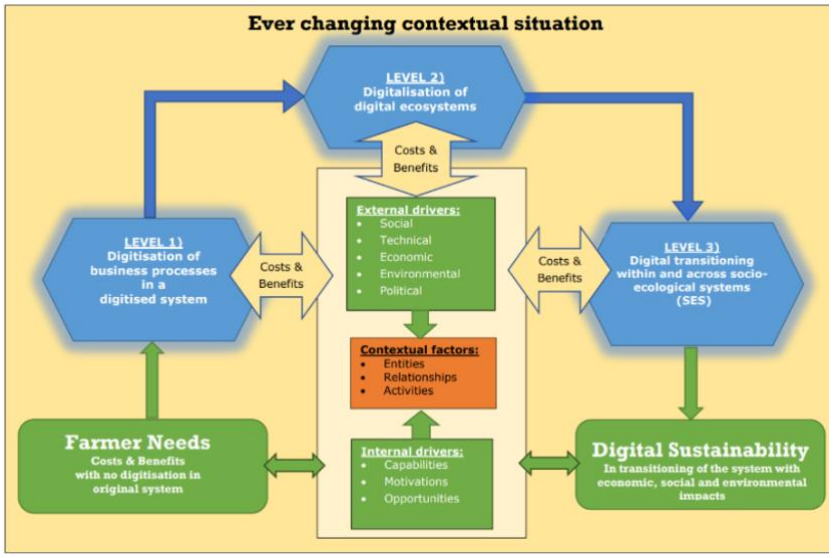

Figure 10. CODECS Conceptual Framework. Source: Soma et al., 2024b

Figure 11. EU policymaking cycle. Source: European Commission, 2021

The relationship between the key messages and the recommendation clusters is not linear and one-to-one. Several recommendations respond to the same underlying issue from different angles, and several messages raise issues that cut across more than one thematic cluster. This reflects the systemic character of agricultural digitalisation – the same finding may have implications for policy design, infrastructure, data governance, skills, advisory systems, farmer agency, or equity, depending on the specific barrier or opportunity it highlights. The clusters therefore organise the recommendations thematically, rather than by individual message and they do not map neatly onto the key messages.

Thematic cluster	Focus
Long-term directionality, adaptive capacity and coherent policy design	Treating digitalisation as a coherent, long-term structural transition rather than isolated interventions
Infrastructure & urban-rural parity	Closing connectivity, device, and support gaps as one integrated challenge
Data governance, collective management & provider accountability	Clarifying data ownership, enabling collective data stewardship, and holding providers accountable
Funding, cost transparency & sustainability-linked investment	Improving coordination between funding instruments, addressing full lifecycle costs and linking financial support to sustainability outcomes
Human capital, knowledge flows & future-proofing expertise	Building digital and advisory capacity across the farming workforce
Knowledge systems & advisory governance	Strengthening and coordinating the AKIS actors who bridge technology and farmer needs

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Thematic cluster	Focus
Farmer autonomy, agency & participatory co-creation	Ensuring farmers help shape the tools and policies meant to serve them
Social equity, power dynamics & inclusive adaptation	Preventing digitalisation from reinforcing existing inequalities
Research, monitoring and evidence	Building the evidence base needed to track and evaluate digital transformation and policy interventions

Table 6. Thematic clusters of CODECS recommendations

Importantly, the recommendations should not be understood as a checklist of isolated interventions. Rather, they are policy options that seek to strengthen the capacities required for agricultural digitalisation to become a strategic enabler of sustainability outcomes. Infrastructure, funding and regulation are important and create enabling conditions, but their effectiveness ultimately depends on the ability of different actors to coordinate, learn, adapt and make informed decisions. **Capacity building therefore represents a cross-cutting requirement underpinning all recommendations**, and different actors require different but complementary capacities:

- Policymakers need the capacity to design coherent, long-term cross-sectoral strategies and balance multiple policy objectives;
- Public administrations require implementation capacity, including digital competencies, adaptive governance and monitoring capabilities;
- Advisory organisations and intermediaries increasingly act as innovation brokers, requiring competencies in technology assessment, remote assistance, facilitation and data governance;
- Farmers require not only digital skills but also the ability to evaluate technologies critically, interpret data and integrate digital tools into farming practices and business strategies that are consistent with their own objectives and the opportunities provided by local ecosystems.

The effectiveness of each actor depends on the capacities of the others, reinforcing the importance of coordinated investment across the agricultural innovation system (in line with the connection between the three levels).

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5. Policy recommendations

5.1. Long-term directionality, adaptive capacity & coherent policy design

Article 1 of Regulation (EU) 2021/2115 (European Parliament & Council of the European Union, 2021) lays down rules on support, coordination and governance for the CAP. Recital 2 of preambular to Regulation, states that "policy coherence for development requires the taking into account of development objectives and principles when designing policies". It means, as it is explained further in Regulation, the future vision is to unify policies between all EU members (27) for "enhancing the sustainability of the policy" (44) and ensuring that "policy is implemented in accordance with the common objectives". In the context of the CAP evaluation framework, the new delivery mechanism is explicitly designed to modernise and simplify policy while maintaining a coherent, results-oriented direction that links structural policy choices to farm-level competitiveness and value chain resilience as measurable outcomes.

The recommendations in this category address the observation that agricultural digitalisation sits at the intersection of separate policy streams that were not designed to work together, leading to isolated, sector-specific and short-term interventions rather than coherent, long-term structural transitions with broader effects on the food system. Consequently, policies often fail to treat digitalisation as a transversal issue, resulting in limited directionality and adaptive capacity that prevents policymakers from navigating the cumulative challenges of continuous technological development. A tension also exists between the drive for standardisation and interoperability on one hand, and the need to accommodate region-specific infrastructures, production systems, and socio-economic conditions on the other. Addressing these challenges therefore requires not only a long-term vision with built-in adaptive mechanisms, but also reflexive and participatory governance structures that can contribute to a sustainable food system.

5.1.1. Prioritise farm competitiveness and resilience

Reframe the policy rationale for agricultural digitalisation around creating the institutional, economic and organisational conditions that enable digital technologies to improve (i) farm competitiveness and (ii) value-chain resilience as explicit strategic objectives	
Problem	Digital-agriculture policies often set adoption or connectivity targets (e.g. number of farms using a technology) without linking them to measurable competitiveness or resilience outcomes, so investment can appear successful without improving farm level performance.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation phase
Intended effect / impact	Investment decisions driven by a focus on competitiveness and farm outcomes.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

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5.1.2. Adopt a holistic food-system view

Ensure policy frameworks address the entire food system (production, processing, distribution, consumption) when supporting digital solutions in agriculture (e.g. require NSP digital strategies to demonstrate upstream/downstream linkages) and evaluate digital interventions against food system outcomes	
Problem	Narrow farm-only framings miss systemic interdependencies.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation, adoption and evaluation phase
Intended effect / impact	Digital investments are reinforced rather than undercut by disconnected processing, distribution, or market access constraints.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

5.1.3. Align standardisation with flexibility

Set minimum interoperability standards at EU level, while allowing Member States to test context-specific implementation through time-limited regulatory sandboxes and regional roadmaps that reflect local digital infrastructures, production systems, crop types, and socio-economic conditions	
Problem	A focus on standardisation risks insufficient sensitivity of region-specific needs, local digital infrastructures, production systems, and socio-economic conditions
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and adoption phase
Intended effect / impact	Common baselines while testing diverse regional approaches via regulatory sandboxes; context-appropriate digital tools for diverse farming systems.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

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5.1.4. Support dedicated, adaptive long-term national strategies

EU level policy should support Member States in developing, funding, and implementing dedicated national strategies for agricultural digitalisation, codified as multi-year roadmaps with built-in mid-term review mechanisms that treat digitalisation as a long-term, cross-cutting structural transition, with governance structures explicitly designed to adapt as technologies and field-level feedback evolve	
Problem	Digitalisation strategies within CAP NSPs vary considerably, often lacking a coherent, cross-cutting directional approach that treats digitalisation as a structural transformation
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation, adoption and implementation phase
Intended effect / impact	Unified policy direction; improved coordination across ministries; transversal national agricultural digitalisation strategy aligned with regional specificities and the long-term goals of the CAP.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.1.5. Support reflexive and participatory governance

Institutionalise reflexive, participatory governance mechanisms (e.g. stakeholder advisory boards, Living Labs) with formal roles for the relevant stakeholders (e.g. farmer representatives, experts) in the preparation and review of national digitalisation roadmaps and in the monitoring phase of CAP NSP/NRPP implementation	
Problem	Stakeholder views are not systematically integrated into strategy-setting and monitoring, leaving a gap between high-level political commitments and farm-level realities.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Policies that evolve based on field-level feedback; more targeted and effective public investment.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.2. Infrastructure & urban-rural parity

The Recital 32 of Regulation (EU) 2021/2115 directly names broadband as a structural problem: it states that "many rural areas in the Union suffer from structural problems such as <...> underinvestment in broadband and connectivity, digital and other infrastructures and essential services". This recognition is operationalised through Article 73, which addresses investment support, and Article 114, the key strategic planning article for the modernisation of agriculture and rural areas, both of which are interconnected with the cross-cutting modernisation objective established in Article 6(2). Infrastructure challenges are further addressed through local development mechanisms under CAP, where improvement of local services and infrastructure constitutes a core success factor (8.2.1).

This category focuses on the material preconditions for digitalisation. Reliable connectivity, device availability, and digital literacy, and advisory capacity remain uneven across rural areas, creating a multi-dimensional digital divide. Therefore, the policy objective is to achieve rural parity with national digital levels rather than merely incremental improvement. Without an integrated approach that treats these dimensions as a single coordinated challenge, investments risk delivering broadband to areas where the necessary skills, devices, and trusted advisory channels are absent to translate connectivity into actual adoption. This integrated challenge extends to advisory capacity, as farmers in underserved areas may lack access to trusted, locally relevant guidance on how to use digital tools effectively. Addressing the rural digital divide therefore requires simultaneous investment in physical infrastructure and human capacity.

5.2.1. Tackle the rural digital divide holistically

Address the interconnected dimensions of the rural digital divide (broadband access, device availability, digital literacy, and advisory capacity) as an integrated infrastructure and capacity challenge by setting measurable targets to achieve rural parity with national digital levels	
Problem	Digital transformation remains uneven due to structural barriers including broadband access, device availability, digital literacy, and advisory capacity that interact and reinforce one another.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Reduced gap between rural and national digital adoption rates, achieved by funding connectivity, device access, skills and advisory support as one coordinated package.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.2.2. Strengthen rural connectivity

Invest in infrastructure (e.g. broadband, Internet of Things) that guarantees reliable connectivity and data availability across regions to enable agricultural digitalisation (e.g. remote advisory assistance, data intensive applications, monitoring), with coverage targets aligned to the EU objectives for rural areas.	
Problem	Uneven connectivity limits the reach of digital solutions in rural areas, preventing data-driven agriculture and decision-making.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Reliable infrastructure becomes a foundation for agriculture, enabling data-driven decision-making and monitoring.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.3. Data governance, collective management & provider accountability

Although Regulation (EU) 2021/2115 does not contain a free-standing chapter on data governance[4], several of its articles establish the legal architecture from which data governance obligations flow. Article 151 addresses personal data protection, while Article 15(4)(f) explicitly requires farm advisory services to cover digital technologies as referred to in Article 114(b), which in turn obliges Member States to set out a national strategy for the development of digital technologies in agriculture and rural areas within their CAP Strategic Plans. Recital 23 reinforces this by calling for "improving the uptake and effective deployment of technologies, digital technologies in particular, and the access to, and increased sharing of, impartial, sound, relevant and new knowledge" – a formulation that presupposes a functioning data governance regime. The CAP Evaluation Framework, while not addressing data governance as a separate evaluation question, depends on data infrastructures to deliver on its monitoring obligations. Thus, data governance is an indirect but structural precondition of performance-based delivery to achieve CAP general objectives.

This category addresses the consequences arising from unclear rules on data ownership, access, and use, which leave farmers uncertain about who controls their assets and information. A key issue is that the current data economy often concentrates authority in the hands of technology providers or large agri-businesses, creating dependencies that can erode farmer autonomy and discourage adoption due to fears of data exploitation and corporate lock-in. Without robust legislation that establishes clear liability rules, cybersecurity standards, and transparency requirements for providers, farmers lack the necessary supportive framework to fully engage with digital tools, and the potential for data to serve as a common pool resource for the broader community remains underutilised. Interoperability must be understood not only as a technical challenge but as a data governance issue.

[4] We acknowledge the existence of other EU policy documents, addressing this topic in general. In this chapter we specifically address only the Regulation and CAP, as the entry point documents for agriculture digitalisation.

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5.3.1. Act against data power asymmetries

Design and adopt data governance rules that address power asymmetries between farmers/farmer NGOs and large technology providers, and include cybersecurity requirements, data ownership rights, and clear liability rules	
Problem	Perceived lack of clear and transparent rules on data ownership, access, and use leaves farmers uncertain about who controls their assets and information, eroding trust and discouraging adoption.
Level of intervention	Digital ecosystems
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and adoption phase
Intended effect / impact	Rebalanced power dynamics between farmers and large technology providers; increased farmer trust in digital tools.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

5.3.2. Empower collective data management

Clarify competition law treatment of collective farmer data initiatives to encourage collective organisations to manage data collection and sharing	
Problem	Collective organisations are not formally recognised or incentivised as data stewards, limiting their capacity to pool data and negotiate with technology providers; aggregated farm data is underutilised as a common pool resource for local rural and farming communities.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and adoption phase
Intended effect / impact	Strengthened collective negotiating position; more equitable distribution of data-related benefits among farmers.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.3.3. Demand full provider transparency

Condition public support on provider disclosure of pricing, data use, model training, contract terms, interoperability, post-sale service, and exit conditions	
Problem	Technology providers receiving public support are not required to meet transparency standards on pricing, data rights, and post-sale service, undermining farmer trust.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation, adoption and implementation phase
Intended effect / impact	Rebuilt farmer trust; reduced perceived hidden costs; more transparent digital marketplace.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation

5.3.4. Coordinate interoperability with data governance

Adopt a strategic interoperability framework to ensure different digital tools and data sets can communicate seamlessly, and coordinate this framework with data governance rules to ensure that data flows are governed by clear ownership and liability rules	
Problem	Poor interoperability between products and systems of different providers and agencies hampers coordination and, data sharing.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation, adoption and implementation phase
Intended effect / impact	Unlocked synergies through connected data systems; reduced farmer uncertainty regarding who controls their data and information.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

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5.4. Funding, cost transparency & sustainability-linked investment

Regulation (EU) 2021/2115 grounds investment support for agricultural digitalisation at multiple levels. Recital 28 of Regulation (EU) 2021/2115 underscores the necessity of “investments into farm restructuring, modernisation, innovation, diversification and uptake of new practices and technologies", while recital 32 expands on the idea of “underinvestment in broadband and connectivity, digital and other infrastructures and essential services” as a structural rural problem. Also, recital 76 states, that the “objectives of the CAP should also be pursued through support for investments”, explicitly including “infrastructures related to the development, modernisation or adaptation to climate change of agriculture” – an opening that directly links investment support to climate and sustainability objectives and provides the regulatory basis for conditioning digital finance on environmental compliance.

The recommendations target the financial barriers that extend beyond upfront purchase costs to include significant transition, integration, and operational expenses that can deter adoption, particularly for small and medium-sized farms. Conventional financing mechanisms are fragmented, short-term, and fail to match the sector's needs, often ignoring the full lifecycle cost structure and the risk of vendor lock-in. Additionally, the lack of consolidated funding instruments and long-term financing mechanisms creates uncertainty, while the absence of incentives linking financial support to sustainable practices fails to ensure that digital investments deliver environmental co-benefits and value chain resilience. This is compounded by fragmented public-private coordination and insufficient focus on inexpensive tools with a potentially significant userbase.

5.4.1. Incentivise rural investment to combat market failures

Use public–private partnership frameworks with incentive structures that direct investment towards underserved rural areas where market incentives alone are unlikely to deliver the digital infrastructure, advisory services, interoperable systems and innovation support needed for an inclusive agricultural digital transition	
Problem	Market failures leave remote agricultural territories commercially unviable and underserved.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Persistent market failures addressed by creating the enabling conditions for digital technologies to generate value across diverse farming systems, particularly in underserved rural areas.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

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5.4.2. Support cost-effective tools that can serve diverse farm types

Prioritise public procurement and funding for interoperable, low-cost, user-friendly digital solutions capable of serving diverse farm types, selected from a "digital toolbox" that provides farmers with transparent, comparable information on functionality, total cost of ownership and data rights	
Problem	Farmers lack transparent, comparable information on the functionality, true costs, and data rights of available digital tools.
Level of intervention	Business processes
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Procurement serves farmer needs rather than vendor interests, broadening access across farm types and reducing dependency on costly proprietary systems.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.4.3. Link finance to sustainable practices

Link financial support for implementation of digital tools to compliance with sustainable farming practices (e.g. climate-smart agriculture, emissions reduction, biodiversity monitoring, and resource efficiency) and demonstrated sustainability outcomes	
Problem	Digital investment support is not systematically conditioned on sustainability compliance, missing the opportunity to ensure environmental co-benefits.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation and adoption phase
Intended effect / impact	Financial investment is paired with verified biodiversity, emission, or efficiency gains; alignment of digitalisation with Green Deal objectives.
Relevant CODECS deliverables	D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

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5.4.4. Eliminate duplication and fragmentation of funding instruments

Map and consolidate agricultural digitalisation funding as a single implementation system rather than a collection of separate programmes, by aligning CAP, Horizon Europe and other relevant instruments[5] through coordinated objectives, complementary funding pathways, common monitoring approaches and simplified access for beneficiaries	
Problem	Existing funding instruments are often fragmented or insufficiently coordinated, making access more complex for potential beneficiaries.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and adoption phase
Intended effect / impact	Reduced administrative burden; coherent long-term investment; improved coordination between funding instruments; clearer pathways for farmers and implementing authorities.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.4.5. Consider full lifecycle ownership costs

Design incentives for digital tool adoption that explicitly address the full cost structure farmers face (not only upfront purchase costs but transition costs, integration costs, and ongoing operational expenses)	
Problem	Conventional financing mechanisms focus on upfront purchase costs, ignoring transition, integration, and ongoing operational expenses that often deter adoption, especially for small farms.
Level of intervention	Business processes level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation phase
Intended effect / impact	Reduced financial barriers to adoption; more equitable access to digital tools across farm sizes.
Relevant CODECS deliverables	D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation

[5] e.g. Recovery and Resilience Facility, cohesion and regional development funds, national innovation programmes, and other domestic co-financing instruments (see Hurtado et al., 2025)

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5.5. Human capital, knowledge flows & future-proofing expertise

Article 6(1)(g) of Regulation (EU) 2021/2115 establishes among the specific objectives of the CAP the attraction and sustainability of young farmers and other new farmers, while Article 6(2), as the cross-cutting objective, refers to "modernising agriculture and rural areas by fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas and by encouraging their uptake by farmers, through improved access to research, innovation, knowledge exchange and training", framing knowledge flows and capacity building as structural policy instruments rather than optional support measures. Article 15 reinforces this architecture by requiring Member States to establish farm advisory services that cover digital technologies, explicitly assigning a formal role to advisory and bridging organisations in delivering the knowledge exchange and skills development on which digital transition depends. Also, Recital 77 indicates the principle of investment prioritisation, directing priority to young farmers and structurally disadvantaged groups, signalling that equity of access is an explicit policy objective alongside efficiency (also see Recital 91). In the CAP framework topic of investments is included into the General objective 1, that aims "to foster a smart, competitive, resilient and diversified agricultural sector ensuring long-term food security", with investments identified as a key instrument to address the unfair distribution of support across farm types and regions.

These recommendations fall into a broader thematic category that can be described as the social platform for digital transformation. These recommendations treat capacity building as the continuous re-formation of professional identities and knowledge flows within farming communities. Without comprehensive upskilling programmes and support for the next generation of digitally skilled farmers, the sector risks a shortage of human capital capable of critically analysing data, negotiating with technology providers, and adapting to evolving technological landscapes. Critically, knowledge flows in farming communities are not only transmitted through formal training channels: they operate through peer networks, social trust, and collaborative infrastructure, meaning that adoption is a relational and collective process rather than an individual cost-benefit decision. Capacity building is, thus, the mechanism that converts physical infrastructure and data governance rights into actual agency of human capital on the ground.

5.5.1. Reframe digital literacy as an extension of farming expertise

Commission and disseminate evidence-based research on how digital tools complement tacit farming knowledge and agronomic judgement, and use this evidence to communicate digitalisation as an extension of farming expertise rather than a replacement for it, explicitly addressing farmer anxiety about professional obsolescence and integrating hands-on skills with digital literacy	
Problem	Digital literacy is sometimes perceived as a replacement for traditional farming knowledge rather than an extension of it, creating anxiety and resistance among farmers.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, implementation and application phase
Intended effect / impact	Digital literacy is recognised as reinforcing, not replacing, agronomic expertise, reducing resistance to adoption; digital literacy embedded as a core element of professional agricultural identity.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation

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5.5.2. Integrate digital pathways for new and young farmers

Design integrated digital entry pathways for new and young farmers (including as part of agricultural curricula) that bundle digital competency support with land access schemes, start-up financing, and mentoring programmes at the farm establishment stage, rather than offering digital skills as a standalone add-on	
Problem	Digital skills support is offered as a standalone add-on for new farmers rather than being integrated with land access, financing, and mentoring from the outset.
Level of intervention	Business processes and digital ecosystems levels
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	New entrants supported as digitally competent professionals from the outset; generational renewal of the farming workforce, digitally equipped from the outset.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.5.3. Educate on tangible data value

Provide practical guidance and training programmes that help farmers understand the economic value of the data they generate and the conditions under which sharing data with other farmers, governmental bodies, researchers and technology providers is in their long-term interests	
Problem	Farmers lack awareness of the economic value of the data they generate and under what conditions sharing it is in their long-term interests.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Implementation phase
Intended effect / impact	Farmers make more informed decisions about whether and how to share their data, based on a clearer understanding of its economic value and the terms under which sharing may or may not benefit them; where farmers do choose to share, they are better positioned to negotiate favourable terms.
Relevant CODECS deliverables	D2.1 Sustainable Digitalisation: A Conceptual Framework, D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.5.4. Address relational adoption conditions

Require policy frameworks for agricultural digitalisation to consider and address the social and relational conditions for adoption (including social capital, peer trust, and collaborative infrastructure) rather than treating uptake as an individual cost-benefit decision	
Problem	Adoption is frequently treated as an individual, isolated cost-benefit decision, ignoring the critical role of social capital, trust, and peer influence.
Level of intervention	Digital ecosystem level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation phase
Intended effect / impact	Improved uptake and knowledge exchange through peer-to-peer learning networks.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems

5.5.5. Formalise advisory roles in co-design

Assign public authorities and bridging organisations (including extension services, rural development agencies, and farmer organisations) defined roles in digital co-design and Living Lab processes, ensuring that insights generated through participatory processes feed into formal policy channels, rather than remaining confined to project outputs	
Problem	Insights generated through participatory processes frequently remain confined to project outputs and do not feed into formal policy channels.
Level of intervention	Digital ecosystems
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Participatory insights systematically translated into national digitalisation roadmaps and regional programmes.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.6. Knowledge systems & advisory governance

Regulation (EU) 2021/2115 establishes the AKIS as a structural component of CAP delivery. Article 6(2) sets the cross-cutting modernisation objective through "fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas, through improved access to research, innovation, knowledge exchange and training." Article 78 gives this operational substance: it covers knowledge exchange and information actions, requires Member States to ensure consistency with AKIS in their CAP Strategic Plans, and – crucially in Article 78(3) – mandates support for advisory bodies as essential nodes in the knowledge system. Article 15 further requires farm advisory services to cover digital technologies, embedding the advisory function into the formal CAP delivery architecture. Within this framework, demonstration activities and Living Labs function as strategic instruments for closing the gap between innovation potential and farm-level uptake – not as isolated project activities. Together, these provisions establish that knowledge systems and advisory governance are not peripheral to CAP implementation but structural preconditions for its performance-based delivery.

This category addresses the changes and reconfigurations of the AKIS. Well-established advisory roles and functions are being displaced or reconfigured, leading to a fragmentation of knowledge flows and a lack of trusted and impartial intermediaries who can bridge the gap between complex technologies and farmer needs. In addition, the growing role of commercially motivated intermediaries can compromise the sustainability focus that public digitalisation objectives require. Finally, the absence of structured mechanisms for two-way learning, peer networks, and the integration of informal knowledge hampers the ability of the system to support a sustainable, context-sensitive digital transition that respects local realities and farmer agency.

5.6.1. Rethink role of knowledge intermediaries

Rethink the role of essential knowledge intermediaries (agricultural education and extension agents, agronomists, tech facilitators) in the changing digitalisation landscape	
Problem	The key and changing role of advisors and other knowledge intermediaries is underappreciated. While traditional activities such as providing advice and counselling will remain indispensable due to the need for trust, new skills such as managing large volumes of information and acting as information gatekeepers will be required in future.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation phase
Intended effect / impact	Strengthened advisory capacity; trusted intermediaries available to guide farmers through the digital transition.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.6.2. Upskill advisory and administrative sector

Design and launch comprehensive digital upskilling programmes for AKIS actors and administrative staff designed to equip them to lead and facilitate the digital transition at farm and regional level	
Problem	Digital competencies and resources among AKIS actors and administrative staff are uneven, and some lack the digital expertise needed to guide farmers through the transition, creating a disconnect between policy ambitions and delivery capabilities to support farm transitions.
Level of intervention	Digital ecosystems
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	AKIS and administrative staff are equipped to lead the digital transition; reduced gap between policy ambition and advisory delivery.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems

5.6.3. Resource strategic demonstration activities

Fund demonstration activities as strategic instruments for innovation uptake and post-adoption support by adequately resourcing participation (including compensating farmers' time – both as organisers and participants), supporting Living Lab networks, clarifying regulatory barriers, and investing in post-demonstration monitoring to close the gap between awareness and actual adoption	
Problem	Demonstration activities are treated as isolated events rather than strategic instruments, limiting their impact on closing the gap between awareness and actual adoption.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Demonstration activities serve as a bridge between awareness and adoption; practice-based evidence on technology performance is generated.
Relevant CODECS deliverables	D5.3 Handbook of Demonstration of Digital Technologies

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5.6.4. Embed digitalisation in AKIS governance

Adapt AKIS governance to support the digital transformation and reflect the changing advisory landscape by establishing or adapting governance arrangements that clearly assign responsibility for coordinating digital advisory services, promoting interoperability and data standards, supporting digital capacity building across AKIS, and facilitating knowledge exchange among public and private actors	
Problem	AKIS governance arrangements have not always adapted to the changing digital innovation landscape. Responsibilities for coordinating digital advisory services, capacity-building, interoperability and knowledge exchange remain fragmented across actors and initiatives, limiting the system's capacity to support sustainable digital transformation.
Level of intervention	Digital ecosystems
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Permanent governance arrangements for digital AKIS coordination; consistently adapted standards and training content as the digital landscape evolves.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

5.6.5. Co-create national digital curricula

Create national digital skill curricula for AKIS institutions, and agricultural ministries through a collaborative process involving AKIS actors, digital platform providers, and farmer organisations, ensuring that curricula cover technical digital competencies and the capacity to evaluate digital tools thoroughly	
Problem	There is a lack of uniform training frameworks to help AKIS institutions, and agricultural ministries objectively evaluate market tools and aid farmers in the digital transition.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation phase
Intended effect / impact	Public advisory services staffed with personnel who have consistent, comparable digital competencies.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems

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5.6.6. Support two-way knowledge exchange

Strengthen the instruments (such as peer networks, demonstration farms, and digital knowledge platforms) that connect farmers and AKIS actors around digital knowledge exchange and design these instruments to support two-way learning rather than unidirectional technology transfer	
Problem	Knowledge exchange instruments are often designed for unidirectional technology transfer rather than two-way learning, leaving farmer-to-farmer and farmer-to-advisor exchanges unsupported, with insufficient acknowledgement of local farm agency or tacit knowledge.
Level of intervention	Digital ecosystem level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Bidirectional knowledge exchange; farmer-to-farmer learning networks sustained and scaled; peer networks and platforms to support continuous, two-way actor learning loops.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D5.3 Handbook of Demonstration of Digital Technologies

5.6.7. Provide continuous pre- and post-adoption advisory assistance

Supplement financial incentives with (i) pre-adoption advisory support to help farmers assess whether long-run benefits are likely to outweigh adoption costs, and (ii) continuous post-adoption advisory support to evaluate realised costs and benefits	
Problem	Advisory support is concentrated at the point of purchase rather than throughout the adoption lifecycle, leaving farmers without impartial guidance when evaluating long-term costs and benefits.
Level of intervention	Business processes level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Advisory support embedded throughout the adoption lifecycle; better-informed farmer decisions on digital investments.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation

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5.6.8. Ensure equal quality and transparency standards across advisory services

Require that quality and transparency standards apply equally to publicly funded and commercially provided advisory services, and monitor the extent to which private actors are displacing public advisory functions	
Problem	Private and commercial actors are increasingly complementing public advisory services without being held to equivalent quality and transparency standards.
Level of intervention	Digital ecosystem level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, adoption and application phase
Intended effect / impact	Maintained public advisory function quality; impartial, transparent advisory services across the AKIS landscape.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

5.7. Farmer autonomy, agency & participatory co-creation

Article 5(c) of Regulation (EU) 2021/2115 establishes the strengthening of the socio-economic fabric of rural areas as a general objective of the CAP – a formulation that extends beyond income support to encompass the active role of farmers as agents in their own communities and in the design of the policies that affect them. Article 6(2) reinforces this by framing modernisation as working with farmers "by fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas and by encouraging their uptake by farmers, through improved access to research, innovation, knowledge exchange and training" – positioning farmers as engaged participants in a knowledge system rather than passive recipients of technology. Article 15, which establishes farm advisory services, and Article 78, which governs knowledge exchange and AKIS coordination, further embed participatory and co-design principles into the CAP's delivery architecture. Article 71, which supports cooperation among farmers and other rural actors, provides the regulatory foundation for collective arrangements – including cooperatives and joint ventures – through which farmers can pool resources, share infrastructure costs, and negotiate collectively with technology providers. Together, these provisions establish that farmer autonomy, participatory processes, and collective agency are structural components of the CAP's modernisation model.

These recommendations address the mismatch between the design of (i) digitalisation policies and strategies and (ii) digital solutions, and the professional context of farmers, where tools can be perceived as surveillance burdens or sources of hidden costs rather than supportive instruments. Furthermore, limited meaningful farmer involvement in early-stage co-design processes means that tools often do not align with farmers' actual cost-benefit expectations or operational realities, leading to resistance, reluctance and a disconnect between technological potential and field-level uptake. In addition, insufficient collaboration and collective action limits the ability of farmers to share costs and negotiate favourable terms with technology providers. Addressing farmer autonomy and agency therefore requires a reframing of digitalisation as a supportive instrument that reduces rather than adds administrative burden, encouraging collaboration and the institutionalisation of co-creation as a standard requirement for publicly funded agricultural digitalisation projects.

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5.7.1. Frame digitalisation as support

Frame digitalisation policy as a tool for reducing administrative burden for agricultural entities and improving farm-level decision-making, emphasising the availability of capacity-building grants and advisory services	
Problem	Farmers sometimes perceive the CAP and digital tools as sources of additional burden and surveillance rather than supportive instruments.
Level of intervention	Business process level
Primary characteristic of transformative policies	Directional, reflexive and market integration
Phase of policy cycle	Preparation and application phase
Intended effect / impact	Farmers perceive digital tools and CAP digital requirements as supportive rather than burdensome; voluntary uptake of digital tools increases for both compliance and general farm management.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.7.2. Ensure meaningful farmer involvement

Require publicly funded agricultural digitalisation projects to (i) demonstrate continuous and meaningful farmer involvement at design, piloting, implementation and evaluation stages, and (ii) assess fitness for purpose against farmers' own expectations, not solely against technical performance criteria	
Problem	Absence of genuine end-user involvement creates tools that are not aligned with field and operational realities.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Directional
Phase of policy cycle	Preparation, implementation and application
Intended effect / impact	Development of more relevant, user-centric technologies; increased trust between developers and the farming community.
Relevant CODECS deliverables	D2.2 Sustainable Digitalisation: A Conceptual Framework D3.1 Analysis of Digital Ecosystems

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5.7.3. Fund co-design for cost-benefit alignment

Fund structured co-design processes that bring together technology developers, researchers, advisors and farmers at the pre-development stage of digital tools, with the explicit objective of aligning solutions with farmers' perceived cost-benefit expectations (including transition and operational costs), not only upfront purchase price	
Problem	Farmers are often reluctant to adopt tools due to uncertainty regarding long-term cost-benefit ratios and fear of hidden costs.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Reduced farmer uncertainty about financial risk; development of more affordable and economically viable solutions for small-scale farmers.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation

5.7.4. Support collective bargaining power

Actively promote and financially support farmer co-operatives and collaborative arrangements as mechanisms for sharing the costs of digital infrastructure investment and for negotiating collectively with technology providers on pricing, data rights, and service standards	
Problem	Individual farms lack the capacity to negotiate with technology providers and share infrastructure costs; collective arrangements are underutilised, occasionally due to collectivisation legacy resistance.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation and implementation phase
Intended effect / impact	Reduced operational costs through shared infrastructure; strengthened farmer negotiating power on pricing, data rights, and service standards.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.8. Social equity, power dynamics & inclusive adaptation

Regulation (EU) 2021/2115 embeds equity and inclusion as structural objectives of the CAP, not merely as aspirational principles. As stated in Article 6 of Regulation (EU) 2021/2115, one of the specific objectives of European common agriculture policy is to "to promote employment, growth, gender equality, including the participation of women in farming, social inclusion and local development in rural areas, including the circular bio-economy and sustainable forestry". This is reinforced by a series of recitals that identify the specific groups and dimensions requiring targeted attention: the necessity to foster a small and resilient agricultural sector (Recital 28), gender equality (Recital 33), fair distribution of income support (Recitals 53, 60), support for farmers across all age groups including young entrants (Recitals 61, 77, 81), and territorial equality across rural areas (Recitals 62, 75, 89). The CAP evaluation framework operationalises these commitments under General Objective 3 – strengthening rural socio-economics – through measurable success factors including women's employment (8.3.1), fair distribution of support (8.3.2), and poverty reduction (8.3.3). Regulation's (EU) 2021/2115 performance monitoring architecture (Articles 128-133) further establishes that Member States must collect, report, and act on outcome data – a framework that creates the legal basis for disaggregated monitoring of digital adoption by farm size, location, gender, and age, and for corrective action when monitoring identifies exclusionary dynamics.

This category tackles the risk that digital divides in agriculture can mirror and reinforce broader societal inequalities, while concentrating power and benefits among large-scale actors and technology providers. Power concentration is not merely a market outcome but a policy design problem: the absence of impact assessments on how digitalisation reshapes relationships between farmers, advisors, providers, can lead to the unintended reinforcement of inequalities without triggering corrective responses. Without impact assessments and targeted support pathways, digitalisation risks deepening territorial and social fractures, leaving vulnerable groups marginalised by high costs, data sovereignty concerns, and a lack of access to user-friendly, affordable solutions.

5.8.1. Target dedicated support for disadvantaged groups

Provide dedicated financing, training, and advisory pathways for smallholders, women farmers, and young entrants	
Problem	Generic support programmes favour already-advantaged actors, thus creating structural barriers to meaningful participation.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation, implementation and application phase
Intended effect / impact	Narrowed gap between vulnerable and advantaged actors in the digital transition.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

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5.8.2. Mandate equitable service standards

Require publicly supported technology and software providers to meet minimum service standards, including post-sale support, maintenance, updates, accessibility, and data portability	
Problem	Limited post-sale service obligations on technology providers, thus leaving farmers without adequate maintenance.
Level of intervention	Digital ecosystems level
Primary characteristic of transformative policies	Market integration
Phase of policy cycle	Preparation, adoption and implementation phase
Intended effect / impact	Guaranteed baseline quality of ongoing service; public investment delivers sustained value rather than one-off access.
Relevant CODECS deliverables	D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

5.8.3. Track and correct exclusionary dynamics

Monitor digital adoption and outcomes by farm size, location, gender, and age so that exclusionary effects are visible from the outset rather than obscured by aggregate statistics. Establish a requirement that corrective action is triggered when monitoring identifies an issue	
Problem	Systemic inequalities persist undetected and unaddressed throughout policy cycles as aggregate statistics on digital agriculture adoption mask the disproportionate exclusion of certain farmer groups.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, application and evaluation phase.
Intended effect / impact	Exclusionary dynamics become visible through disaggregated data, mandatory corrective actions are launched before disparities become entrenched.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D4.2 Synthesis Report on Environmental, Economic, and Social C&B of Farm Digitalisation D6.2 Report on Policy Environments for Digitalisation in Europe

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5.9. Research, monitoring and evidence

Regulation (EU) 2021/2115 places research, monitoring, and evidence at the heart of CAP governance. Article 1 explicitly lays down rules on monitoring, reporting, and evaluation as structural components of Regulation (EU) 2021/2115, while Article 6 establishes a specific objective of giving "a greater focus on research, technology and digitalisation." Several recitals give operational substance to these commitments: Recitals 6 and 23 call for making the best use of research and innovation results and embracing digital technologies; Recitals 82 and 85 address the evaluation of potential risks and the exchange of knowledge; and Recitals 113, 116, 118, 121, and 138 establish monitoring responsibilities, define indicator frameworks, and assign reporting obligations to Member States. The cross-cutting modernisation objective of Article 6(2) reinforces this by calling for "fostering and sharing of knowledge, innovation and digitalisation, and by encouraging their uptake by farmers through improved access to research, innovation, knowledge exchange and training." The CAP's result indicator framework – including indicators R.1-R.3 and R.28 – translates these obligations into measurable baselines, though as currently designed these indicators provide an incomplete foundation against which to track the differentiated progress of agricultural digitalisation. The performance monitoring architecture under Articles 128-133 further creates the legal basis for systematic impact assessment of how policy interventions - including digital support measures – shift outcomes and power balances across actor groups.

The recommendations in this category address the observation that the core challenges identified over a decade ago remain unresolved despite repeated policy advice. The recommendations also respond to limited granular, high-quality data on digitalisation at the farm level, which hinders informed decision-making and leads to an over-reliance on simplistic binary metrics (adopt vs. resist) that fail to capture nuanced trajectories. A core problem is that existing monitoring frameworks and periodic surveys cannot keep pace with the rapid evolution of digital technologies and intermediaries leaving policymakers with an incomplete picture of digital readiness, the advisory landscape, and actual impacts. This evidence deficit prevents the identification of differentiated adoption pathways and makes it impossible to accurately evaluate whether policy interventions are effectively advancing sustainability goals or merely supporting business-as-usual practices.

5.9.1. Move beyond simple adoption metrics

Use analytical frameworks that capture differentiated adoption trajectories across domains, explicitly moving beyond binary adopt/resist framings, and fund mixed-method research programmes to investigate how and why digitalisation unfolds differently across farming contexts	
Problem	Digitalisation assessments rely on binary adopt/resist frameworks that fail to capture nuanced use and uptake trajectories.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, application and evaluation phase
Intended effect / impact	More nuanced policy design informed by differentiated adoption trajectories; improved evaluation of whether policies advance sustainability goals.
Relevant CODECS deliverables	D2.1 Sustainable Digitalisation: A Conceptual Framework D6.2 Report on Policy Environments for Digitalisation in Europe

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5.9.2. Learn from past implementation inaction

Commission a retrospective analysis of why previous EU/national digitalisation recommendations have not been implemented or have not produced the expected results, and use findings to inform the design of new CAP post-2027 digital support measures	
Problem	There is a systemic failure to translate available knowledge into coordinated, sustained action; the same recommendations have circulated for a decade.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and evaluation phase
Intended effect / impact	Evidence-based design of post-2027 CAP digital support measures; a shift in framing, from treating this as a knowledge gap to treating it as an implementation gap requiring action-oriented design.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.9.3. Monitor shifting power dynamics

Track how digitalisation shifts power balances among farmers, advisors, technology providers and regulators and ensure that findings are used to redesign instruments that would otherwise concentrate power or deepen existing inequalities.	
Problem	Digitalisation of agriculture risks concentrating power among technology providers, advisors, and regulators at the expense of farmers.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, application and evaluation phase
Intended effect / impact	Evidence on who gains and loses from digitalisation feeds into redesign of instruments so that power does not concentrate among any single actor group.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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5.9.4. Establish robust, granular evidence baselines

Establish granular and comparable data collection on agricultural digitalisation as the primary evidence base for policy design and evaluation, setting shared data-quality standards co-designed by researchers, administrators, and farmers and piloted before scaling. Apply this specifically to refining CAP indicators (e.g. R.1–R.3, R.28), which currently provide an incomplete baseline against which to track change and progress.	
Problem	Limited availability of granular, comparable data on agricultural digitalisation at the farm level leaves policymakers with an incomplete picture and prevents accurate evaluation of policy effectiveness.
Level of intervention	Socio-ecological level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation, implementation and application phase
Intended effect / impact	Robust baseline for tracking digitalisation progress; evaluation of policy interventions grounded in reliable farm-level data.
Relevant CODECS deliverables	D6.2 Report on Policy Environments for Digitalisation in Europe

5.9.5. Map variety of intermediary actors

Conduct a periodic mapping of the full range of actors now performing intermediation functions in agricultural knowledge systems both from a bottom-up and top-down perspective, with explicit attention to digitalisation.	
Problem	There is a persistent knowledge gap regarding which actors are effectively fulfilling intermediation functions in the digital era, as current AKIS mappings underestimate the role of new actors.
Level of intervention	Digital ecosystem level
Primary characteristic of transformative policies	Reflexive
Phase of policy cycle	Preparation and application phase
Intended effect / impact	A more complete picture of the intermediation landscape; AKIS policies informed by an accurate understanding of who is performing which roles.
Relevant CODECS deliverables	D3.1 Analysis of Digital Ecosystems D6.2 Report on Policy Environments for Digitalisation in Europe

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6. A practical toolbox for agricultural digitalisation

This section outlines a practical, policy-oriented toolbox aimed at supporting civil servants in navigating the complex landscape of agricultural digitalisation. The shift to the forthcoming Multiannual Financial Framework (2028-2034) (European Commission, 2025d) and the development of National and Regional Partnership Plans (hereinafter – NRPPs) present a crucial opportunity to integrate agricultural digitalisation plans into programming documents prior to the establishment of budget allocations. The EU Digital Decade 2030 objectives impose explicit expectations on Member States to quicken digital transformation across all sectors, including agriculture. Therefore, the CODECS toolbox is consciously designed to complement the recommendations which operate at higher policy levels.

Indeed, while digitalisation is increasingly recognised as a key lever for achieving the objectives of the CAP, its operationalisation remains challenging. One of the key challenges, as noted above (see Key messages), lies in the multi-dimensional nature of digitalisation. Digitalisation is not limited to the adoption of specific technologies. Rather, it represents a systemic socio-technical transformation that affects how farms operate, how decisions are made, how governments interact with farmers and how knowledge circulates within agricultural systems. As such, it is shaped by a wide range of factors, including farm structure, farmer characteristics, access to infrastructure, availability of advisory services, and the broader institutional environment.

This toolbox serves as the practical extension to the policy recommendations outlined in the previous section. The empirical findings from previous CODECS deliverables ensures that the tools are rooted in the realities of diverse agricultural systems and governance contexts, rather than being only developed from theoretical frameworks or general best-practice models. Thus, this toolbox bridges the critical gap between high-level EU policy ambitions (such as the CAP and the upcoming NRPPs) and practical, context-specific regional actions, and is specifically intended for civil servants and public authorities operating at local, regional, and national levels – including personnel in Ministries of Agriculture, Managing Authorities, rural agencies, and sub-regional administrations – who are responsible for designing, funding, or evaluating digital agriculture initiatives, yet may lack specialised technical expertise in digitalisation. It is equally relevant for AKIS actors, advisory services, and consultants assisting public administrations in translating policy agendas into operational programmes.

The toolbox is structured around three complementary pillars that address the strategic, financial, and analytical dimensions of public administration. Each tool covers aspects of governance, knowledge dissemination, inclusion, and capacity, acknowledging that the impact of digital agriculture relies equally on institutional frameworks, advisory mechanisms, and farmer agency, in addition to connectivity infrastructure and technology adoption rates. Collectively, the three tools developed under WP6 provide an integrated decision-support framework for public authorities. Rather than addressing isolated aspects of agricultural digitalisation, they accompany policymakers through the different phases of the policy cycle.

- The first stage (see Guidelines for Local Digitalisation Strategies) focuses on evidence gathering and diagnosis of digitalisation ecosystems. This tool provides a planning guide and self-assessment template spanning the entire policy lifecycle to establish clear local baselines and governance frameworks.
- The second stage (see Checklist for Public Investments) focuses on the design of territorial and place-based digitalisation strategies. This tool provides an interactive, multi-phase decision support framework that translates complex technical, economic, and environmental factors into quantifiable criteria, ensuring that public funds are well-targeted.
- The third stage (see From Evidence to Decisions framework) on the appraisal and governance of public investment decisions. This tool focuses heavily on the analytical side of policymaking, offering civil servants a methodology to leverage existing national and EU indicators, conduct expert reality checks, and turn data into informed policy interventions.

Together these tools operationalise CODECS findings and recommendations by translating research evidence into practical instruments that can support planning, implementation and monitoring activities at local, regional and national levels.

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Although each tool can be used independently, they are intended to work as a unified analytical and planning toolbox. Authorities initiating a new digitalisation strategy will typically proceed with the *From Evidence to Decision* framework to create an evidence base and establish the local context, subsequently employing the *Guidelines for Local Digitalisation Strategies* to translate that assessment into a coherent strategic plan. The *Checklist for Public Investments* thereafter supports the finance and procurement decisions derived from the plan. Authorities at a more advanced stage or with a specific objective may utilise the tools independently, as each tool is presented with a description of the issue it resolves, its target users, and instructions for its application. This enables authorities to select the instrument most suitable to their current phase in the policy cycle. In this deliverable you will find the short description of each tool, the problem each tool address, guidelines for application and key added values. The complete versions of the tools are available on Zenodo.

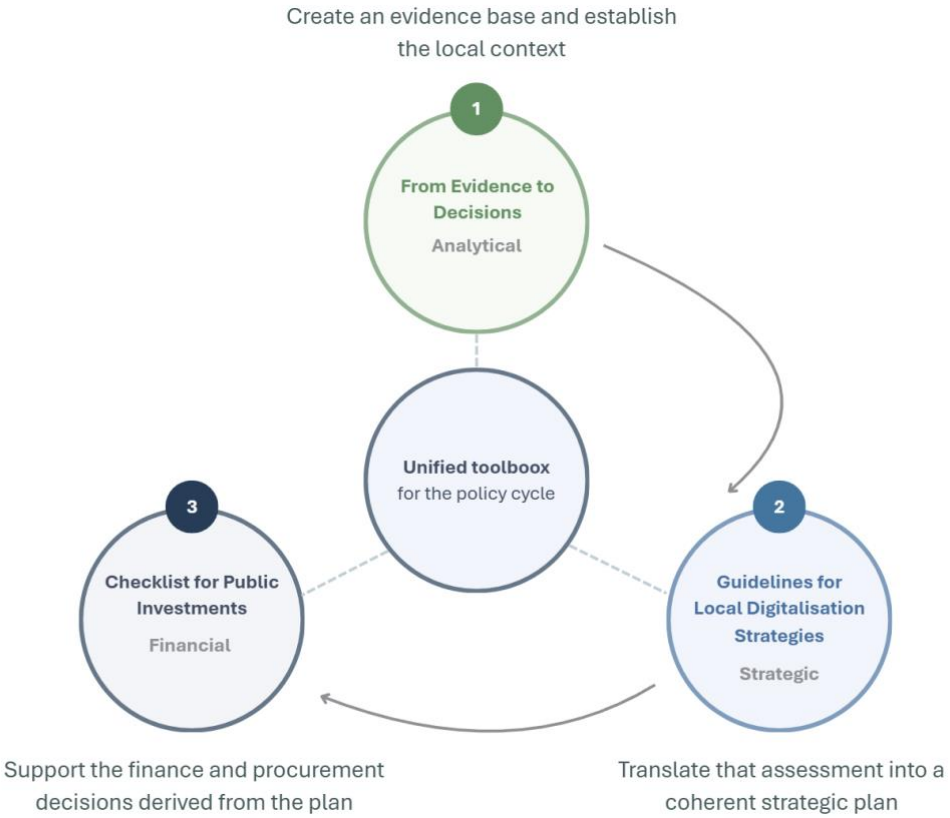

Figure 12. Structure of the toolbox

6.1. Tool 1: Guidelines for local digitalisation strategies[6]

6.1.1. What is the tool

- A step-by-step guide designed to help local public authorities design, implement, and monitor place-based digital transitions in agriculture and rural communities.
- It addresses fragmented digital development and uneven digital maturity by providing a template that spans the full policy cycle (from initial diagnosis and baseline assessment to phased implementation roadmap and long-term evaluation).

[6] Full tool description available here: https://zenodo.org/records/21279015

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- The tool utilises a combination of closed-ended and open-ended guiding questions to help authorities identify gaps, align local initiatives with broader EU funding frameworks, and foster multi-level participatory governance among farmers, advisory services, and tech providers.
- It bridges the gap between high-level policy ambitions and practical regional action, ensuring that digital growth in the agri-food sector remains inclusive, sustainable, and data driven.
- Beyond supporting strategy formulation, the guidelines provide a structured framework for assessing local digital maturity, identifying ecosystem strengths and weaknesses, organising stakeholder participation processes and developing implementation roadmaps, with particular attention on governance arrangements, data management considerations, monitoring systems and long-term sustainability of digital interventions.
- The tool operationalises several recommendations emerging from D6.3, particularly those related to place-based approaches, digital ecosystems, governance models, skills development and multi-actor engagement, and therefore serves as a practical bridge between the strategic recommendations identified by CODECS and their implementation at local and regional level.

6.1.2. The problem this tool addresses

Local and regional authorities are increasingly expected to translate EU priorities into effective, place-based action, particularly in the context of the upcoming **Multiannual Financial Framework (2028-2034)** (European Commission, 2025d) and the implementation of **NRPPs**. This challenge is especially critical in the **domain of digital agriculture**, where digitalisation is rapidly transforming production systems, value chains, and rural economies.

In **a context marked by demographic change, regional disparities, and the push for climate neutrality, local digitalisation strategies will help ensure that no region is left behind**. However, in rural areas and the agricultural sector, this transition is constrained by persistent structural challenges:

- Fragmented digital development and lack of alignment across governance levels;
- Uneven digital maturity, particularly in rural territories, affecting infrastructure, skills, and access to technologies;
- Limited strategic and institutional capacity at local level to design and implement coherent digital strategies;
- Risks of exclusion and inefficiency, especially for smallholders and rural SMEs;
- Insufficient integration of sustainability objectives within digitalisation processes.

At the same time, digital technologies are reshaping agriculture and offer significant potential to enhance productivity, support rural entrepreneurship, strengthen innovation ecosystems, and contribute to more sustainable and resilient agri-food systems.

Underlying all these changes is the increasing role of data. Data-driven innovation is becoming a key enabler for decision-making, new business models, and efficient resource management in agriculture. However, the challenge is not only technological, but also institutional and strategic: how to ensure that digitalisation is governed, implemented, and scaled effectively at local level, in a way that is inclusive, sustainable, and aligned with territorial needs.

This tool is intended to:

- Facilitate the **development of actionable local digitalisation strategies,** while ensuring aligment and coordination with broader regional, national, and EU digital agendas;
- Design and implement **place-based digital strategies in agriculture** aligned with EU priorities and funding frameworks;
- Enable the **transition from fragmented initiatives towards integrated local digitalisation strategies in agriculture;**
- **Assist local authorities to lead inclusive, data-informed digital transitions in agriculture communities;** and
- Strengthen **governance, coordination, and stakeholder engagement** across the agri-digital ecosystem (including AKIS, SMEs, and advisory services).

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These guidelines respond directly to this gap by providing a **structured, policy-oriented and practical framework** to support local actors in developing coherent digital strategies for agriculture.

6.1.3. Who should use the tool

These guidelines are primarily intended for **local public authorities** – including municipalities, rural agencies, and sub-regional administrations, responsible for designing, implementing, and coordinating digitalisation strategies in the agricultural sector. Positioned at the interface between policy and practice, they play a key role in translating EU, national, and regional priorities into concrete, place-based actions adapted to rural needs.

The tool supports a broader **multi-actor and multi-level governance ecosystem**, involving advisory services and AKIS actors, farmer organisations, cooperatives, SMEs, research institutions, and agri-tech providers, who contribute to implementation, innovation, and the uptake of digital solutions. **Regional and national authorities** ensure policy coherence, coordination, and alignment with frameworks such as the CAP, the Digital Decade, and the NRPPs.

This governance system is structured across **three interconnected levels**:

- a **strategic level**, providing policy direction and alignment;
- an **operational level**, responsible for implementation and coordination;
- and an **advisory level**, ensuring stakeholder engagement, co-creation, and responsiveness to local needs.

Overall, the tool is not only technical but also **institutional**, enabling coordination across governance levels and supporting local actors in leading inclusive, sustainable, and data-driven digital transitions in agriculture.

6.1.4. How the tool should be used

The development of the Guidelines for Local Digitalisation Strategies, with a particular focus on the agricultural sector, follows a **structured and integrated methodological approach**. Building on the Horizon Europe CODECS project and its conceptual framework, the tool combines a strategic foundation with a **practical template and step-by-step guide**, enabling policymakers to design and implement effective local digitalisation strategies.

The tool supports the **full policy cycle – from diagnosis to implementation and evaluation** – and is specifically tailored to the needs of local authorities in rural and agricultural contexts. It provides a clear and operational framework to ensure alignment between local priorities, governance structures, and funding opportunities.

At its core, the tool is organised around a **structured template for strategy development**, divided into **at least seven main sections**, each guiding policymakers through a logical and actionable planning process:

- a **strategic backdrop**, defining the local context, digital maturity, and alignment with EU and national frameworks;
- **priority action areas**, covering key domains such as infrastructure, digital services, data governance, inclusion, and innovation;
- a **governance and coordination framework**, clarifying roles, responsibilities, and stakeholder engagement;
- **capabilities and skills development**, addressing capacity-building needs;
- an **implementation roadmap**, setting out phased actions, timelines, responsibilities, and KPIs;
- **funding and resources**, ensuring coherence with EU, national, and regional financing instruments;
- a **vision with targets, monitoring, and evaluation**, supporting performance tracking and continuous improvement.

For each of these areas, the tool includes **structured guiding questions**, combining closed-ended formats (e.g. yes/partly/no) with open-ended questions. This approach enables users to **assess their current situation, identify gaps, and prioritise actions** in a systematic and evidence-based manner.

In practice, the tool can be used both as:

- a **planning guide**, to build a local digitalisation strategy in agriculture from scratch; and

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- a **self-assessment tool**, to improve or validate existing strategies and support the **identification of key gaps and areas for action**.

The tool integrates key principles of the CODECS approach, including:

- **systems thinking**, linking farms, digital ecosystems, and socio-economic systems;
- **participatory governance**, through co-creation with farmers, SMEs, and advisory services;
- **data-informed decision-making**;
- and **alignment with funding instruments**.

6.1.5. Key added value of the tool

The added value of this tool lies in its ability to **translate complex policy ambitions into practical, actionable strategies at local level,** specifically tailored to the digital transformation of the agricultural sector.

Unlikely purely conceptual framework, it combines **methodological rigour with operational guidance,** enabling local authorities not only to plan but also to implement, monitor, and adapt their digitalisation strategies over time.

Crucially, the tool supports the **preparation of local authorities for the upcoming programming period (2028-2034),** helping them position digitalisation strategies within the framework of the **National and Regional Partnership plans (NRPPs).** In doing so, it facilitates the transition from high-level priorities to **concrete initiatives, investments, and place-based actions** in the agricultural sector. In particular this tool:

- **Bridges policy and practice:** translates EU-level priorities into local action;
- **Ensures coherence:** aligns strategies across governance levels and funding streams;
- **Promotes inclusivity:** addresses digital divides and supports smallholders;
- **Supports sustainability:** integrates environmental and climate objectives;
- **Enhances accountability:** through the definition of target, indicators, and monitoring mechanisms.

6.2. Tool 2: Checklist for public investments[7]

6.2.1. What is the tool

- An evidence-based, multi-phase decision support framework designed as an interactive checklist to guide policymakers and funding authorities through the public investment lifecycle for the digitalisation of agriculture and rural areas.
- It translates complex technical, economic, environmental, and social sustainability considerations into structured, quantifiable criteria and standardised evaluation questions.
- The checklist is organised around eight key investment categories (such as digital infrastructure, advanced technologies, data governance, and human capital development) and maps them across four project stages: pre-investment, design/planning, monitoring, and impact evaluation.
- It serves as a practical, context-specific self-assessment tool to prevent the duplication of generic solutions, optimise the allocation of public funds, address market failures, and ensure that digital transformations remain inclusive and tailor-made to local rural realities.
- The tool provides a structured methodology for analysing investment proposals across multiple dimensions, including strategic relevance, governance arrangements, sustainability, inclusion, implementation feasibility and long-term impacts.

6.2.2. The problem this tool addresses

Public investments in the digital transformation of agriculture and rural areas face substantial, multi-layered challenges. A major problem is the widespread lack of technical interoperability and the absence of clear, standardised frameworks for data collection, which severely hampers multi-level coordination and communication.

[7] Full tool available here: https://zenodo.org/records/21277801

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Additionally, territories often suffer from structural disparities, such as a lack of public services and restricted market access, meaning that generic solutions are ineffective and fail to match diverse local contexts.

The tool also responds directly to one of the recurring challenges identified through CODECS research, namely the tendency for investment decisions to focus on technology acquisition without sufficiently considering enabling conditions, governance requirements and long-term adoption dynamics. By expanding the scope of assessment beyond technology itself, the tool supports more effective and sustainable public investment decisions.

Furthermore, significant divides exist regarding the digital skills and competencies of farmers, end-users, and technical staff. This is compounded by pressing global risks that threaten data safety and can undermine trust between administrations and agricultural communities. Without a disciplined evaluation framework, public authorities risk making uncritical, unsustainable investment choices that ignore local needs or fail to anticipate long-term operational and financial risks.

This tool is designed to address these problems. The framework reflects international good practices in public investment governance while adapting them to the specific characteristics of agricultural digitalisation. In particular, it recognises that digital investments generate value not only through technological deployment but also through improved knowledge exchange, ecosystem development, data management capacities and strengthened advisory services. This broader perspective aligns closely with the systemic approach promoted throughout the CODECS project.

6.2.3. Who should use this tool

Although presented as a checklist to maximise accessibility and ease of use, the tool effectively functions as a structured public investment assessment framework for agricultural digitalisation. It supports decision-makers throughout the investment lifecycle, from initial project appraisal and prioritisation to implementation monitoring and impact assessment. By considering governance, sustainability, inclusiveness, scalability and long-term value creation, the tool enables a more comprehensive assessment of digital investments than traditional financial appraisal approaches alone. It is designed as a collaborative resource for a wide range of stakeholders involved in creating, implementing, and vetting digitalisation strategies:

- **Policymakers:** Specifically, civil servants within agricultural departments and their technical advisors can utilise the tool to assess strategic policy alignment, territorial cohesion, and digital inclusion.
- **Financing agencies and authorities:** Operational bodies responsible for allocating public funds can use the checklist to objectively evaluate, prioritise, and check project proposals against standardised criteria, ensuring efficient resource distribution.
- **Territorial and sectoral agents:** Local organisations (including farmer associations, agricultural cooperatives, professional bodies, and LEADER Local Action Groups) can apply the checklist to cross-reference investments with genuine local demands, thereby fostering regional collaboration and project ownership.

6.2.4. How this tool should be used

The checklist functions as an interactive, multi-phase decision support framework structured across the entire lifecycle of a public investment:

- **Pre-investment phase:** Focuses on data-driven gap analysis, needs assessment, connectivity mapping, and testing strategic alignment with national or EU priorities.
- **Investment design and planning phase:** Guides the translation of identified needs into actionable project plans by defining explicit objectives, outlining KPIs, assessing cyber-security risks, and establishing transparent financial allocation models.
- **Investment monitoring phase:** Provides real-time oversight during deployment to track timelines, control budgets, manage deviations, and guarantee data transparency for the public.
- **Investment impact evaluation phase:** Assesses the post-project legacy by measuring tangible economic, social, and environmental outcomes, documenting best practices, and examining regional scalability.

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To provide an intuitive overview for decision-makers, the tool incorporates a clear scoring system and visual indicators, such as a colour-coded validation layout. This lifecycle methodology is applied across eight distinct investment categories, ranging from digital infrastructure and advanced technologies (like AI and IoT) to human capital development, regulatory dimensions, and innovative business models.

6.2.5. Key added value of this tool

The primary value of the CODECS checklist lies in its capacity to move public administration away from arbitrary spending towards evidence-based, sustainable strategies:

- **Contextual self-assessment:** It prevents the passive adoption of generic solutions by forcing authorities to conduct a critical analysis of regional strengths, bottlenecks, and enabling conditions.
- **Sustainability metrics:** The framework integrates a comprehensive cost-benefit lens that evaluates investments beyond mere financial returns, capturing critical social and environmental impacts.
- **Balanced and flexible governance:** It harmonises top-down strategic directives (such as EU Digital Strategy and CAP objectives) with essential bottom-up local consultations, mitigating the risk of marginalising smallholders, women, youth, or remote communities.
- **Risk mitigation:** By embedding strict evaluation questions regarding data sovereignty, state aid compliance, and vendor lock-in, it protects public funds and ensures the long-term resilience of the agricultural digital ecosystem.

6.3. Tool 3: From evidence to decisions[8]

6.3.1. What is the tool

- **From Evidence to Decisions tool is a practical decision-support guide developed within CODECS**. Its objective is to help public authorities better understand agricultural digitalisation and use available evidence to design more effective policies and investments under the CAP.
- **Rather than introducing a new monitoring framework, the guide provides a structured methodology for identifying, interpreting and combining existing evidence**. It recognises that agricultural digitalisation is a complex phenomenon that cannot be measured through a single indicator. Instead, users are encouraged to bring together information from a range of complementary sources, including European and national statistics, CAP Strategic Plans, scientific literature, innovation projects, Living Labs, advisory systems and stakeholder consultations. By integrating these different perspectives, the guide helps users move beyond isolated datasets and develop a more comprehensive understanding of digitalisation within their national context.
- **The guide is designed as a practical, step-by-step process that supports users throughout the policy cycle.** It begins by establishing a baseline through comparisons with other Member States, before moving to a detailed exploration of national evidence. The methodology then encourages validation of the findings through consultation with experts and stakeholders, ensuring that statistical evidence is complemented by practical experience from the field. Finally, it promotes continuous monitoring and feedback so that policy interventions can be refined over time.

In essence, the tool acts as a bridge between evidence and policymaking. Instead of simply presenting data, it provides a practical framework for transforming fragmented information into strategic decisions that support agricultural digitalisation, indeed for moving from evidence gathering to policy design. The tool essentially addresses one of the central challenges identified throughout the project: the lack of harmonised digitalisation indicators and the difficulty public authorities face when translating fragmented evidence into policy action.

[8] Full tool available here: https://zenodo.org/records/21279605

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6.3.2. The problem this tool addresses

Although digitalisation has become a strategic priority under the CAP, policymakers often lack the evidence needed to understand current levels of digitalisation and to design appropriate interventions.

One of the principal challenges is the **absence of a dedicated framework for measuring agricultural digitalisation.** The current CAP monitoring system makes it difficult for Managing Authorities to establish baselines, monitor progress or evaluate the effectiveness of investments. At the same time, comparable data across countries and regions remain limited, with relevant information often scattered across different institutions and datasets.

Another key challenge the tool addresses is repeatedly identified throughout CODECS: while significant quantities of information on digitalisation exist, policymakers often face **difficulties in locating, interpreting and combining evidence originating from multiple sources**. The methodology therefore focuses on helping public authorities transform fragmented data into actionable knowledge that can support policy design and implementation decisions.

Another challenge lies in the **fragmented nature of the available evidence**. Official statistics typically capture structural characteristics of agriculture (such as farm size, farmer demographics or internet connectivity) but provide relatively little information about the actual uptake and use of digital technologies on farms. Valuable evidence exists in policy documents, scientific publications, innovation projects and advisory systems, but these sources are rarely considered together in a systematic way.

The guide also recognises that **policymakers often face difficulties in translating data into meaningful policy action.** Statistics alone cannot explain why digital adoption differs between regions or farming systems, nor can they reveal the practical barriers that farmers experience, and similar statistical results may reflect very different realities depending on infrastructure, advisory services, digital skills or governance arrangements. Consequently, relying exclusively on quantitative indicators may lead to incomplete or even misleading conclusions.

Finally, the tool addresses the perception of digitalisation as the adoption of digital technologies. Instead, it proposes that digitalisation be viewed as a broader socio-technical transformation involving technology, knowledge exchange, advisory services, connectivity, governance, innovation ecosystems and human capacities. Understanding this wider context is essential for designing policies that promote not only technological uptake but also sustainable and inclusive digital transformation across the agricultural sector.

To overcome these challenges, the tool proposes a multi-source and evidence-based methodology that combines quantitative information with qualitative knowledge from stakeholders (statistical indicators, policy documents, scientific literature, innovation ecosystem mapping and stakeholder consultation. This triangulation approach enables policymakers to interpret data more accurately and to develop interventions that are better adapted to the realities of different farming systems. Through its four-step methodology, covering baseline diagnosis, national evidence mapping, expert validation and iterative monitoring, the tool provides public authorities with a practical process for building a continuously updated evidence base. This approach contributes to reducing uncertainty, strengthening policy learning processes and improving the design of targeted interventions under the CAP and related policy frameworks.

6.3.3. Who should use the tool

The guide is **primarily intended for public authorities responsible for developing, implementing and evaluating agricultural policies,** particularly within the framework of the CAP. It has been designed for users who may not have extensive prior knowledge of agricultural digitalisation, but who require a structured approach to understanding the topic and making informed decisions. The principal target audience consists of civil servants and policymakers working in Ministries of Agriculture and Managing Authorities. For these users, the guide provides practical support for interpreting available evidence, identifying structural barriers to digitalisation, prioritising investment needs and designing evidence-based CAP interventions. It also supports the justification of funding decisions. The guide is equally relevant for Managing Authorities responsible for preparing and implementing CAP Strategic Plans (and potentially NRPPs). By bringing together multiple sources, this guide helps these organisations better understand national digitalisation trends, compare different datasets and identify where public support is likely to have the greatest impact.

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Another important audience comprises AKIS officials. Since digitalisation is closely linked to knowledge exchange and advisory services, the guide helps AKIS actors identify weaknesses in innovation ecosystems, recognise gaps in advisory support and improve the integration of digital technologies into wider knowledge networks.

The methodology may also be valuable for consultants working with Ministries and Managing Authorities, as it offers a structured analytical framework that can support evaluations, strategic planning and policy development. Likewise, researchers, Living Labs and innovation organisations can benefit from the guide because it demonstrates how scientific evidence and practical experience can be integrated into policy processes.

Overall, the tool is intended for anyone involved in agricultural digitalisation who needs to transform diverse sources of evidence into coherent policy recommendations.

6.3.4. How should this tool be used

The guide should be used as a structured decision-support methodology when designing, reviewing or updating policies and interventions related to agricultural digitalisation. It helps users build an evidence base by following a four-step process:

1. establishing a baseline understanding of the country's digitalisation profile using comparable indicators;
2. identifying and analysing relevant national statistical, policy and scientific sources;
3. validating and contextualising the findings through structured consultation with experts and AKIS stakeholders;
4. maintaining an up-to-date evidence base through regular monitoring and feedback.

The tool is intended to support policy development throughout the policy cycle, from the identification of needs and priorities, through intervention design, to monitoring and revision. It is not intended for a one-off assessment.

The methodology should be applied using the principle of evidence triangulation. Users are encouraged to combine quantitative indicators, policy and programming documents, scientific evidence, implementation experience from innovation projects and Living Labs, and the practical knowledge of farmers, advisors and other AKIS actors. This allows statistical findings to be interpreted in their national and regional context, identifies barriers and opportunities that may not be visible in official datasets alone, and supports the design of interventions that are better aligned with the realities of different farming systems and territories. By repeating the consultation and evidence-gathering process over time, the guide helps create a living evidence base that can inform adaptive and evidence-based policymaking.

6.3.5. Key added value of the tool

The **main contribution of the CODECS tool lies in its ability to transform fragmented evidence into practical policy intelligence**. It provides a coherent methodology that helps decision-makers understand complex information and translate it into strategic interventions.

An important contribution of the guide is its multi-source approach. Instead of relying solely on official statistics, it combines quantitative data with policy documents, scientific research, innovation projects and stakeholder knowledge. This enables users to develop a richer and more nuanced understanding of agricultural digitalisation than would be possible through any single source of information.

Crucially, it encourages moving from evidence to decision-making. The guide encourages policymakers to examine what the available data show and also to interpret why certain patterns emerge, what barriers underlie them and which policy responses are most appropriate. In this way, the guide shifts the focus from descriptive analysis towards strategic planning.

The methodology is also highly adaptable to different national contexts. It recognises that agricultural digitalisation is influenced by country-specific governance structures, farming systems, institutional arrangements and innovation ecosystems. Rather than proposing a single standard model, the guide provides a flexible framework that can be applied across different Member States while remaining sensitive to local circumstances.

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Importantly, the tool **moves beyond descriptive analysis by explicitly linking diagnostic findings to possible policy responses**. In doing so, it helps bridge the gap between evidence generation and intervention design, supporting more informed, transparent and evidence-based decision-making processes.

A further strength is the systematic integration of stakeholder consultation into the analytical process. The guide acknowledges that many aspects of digitalisation, such as farmers' trust in technology, organisational barriers or advisory needs, cannot be captured through statistics alone. By validating findings with researchers, advisors, Living Labs, farmer organisations and other experts, policymakers obtain a more realistic understanding of the lived realities of digitalisation and are better equipped to design targeted interventions.

Finally, the guide has a strong practical orientation. Its step-by-step methodology, country-specific examples, suggested data sources, proxy indicators and monitoring framework make it immediately applicable for public administrations. Rather than prescribing fixed solutions, it equips users with a practical process for analysing evidence, identifying priorities and continuously improving policy interventions.

Overall, the CODECS tool represents an important contribution to evidence-based policymaking. By bridging the gap between fragmented information and strategic decision-making, the guide intends to enable public authorities to design more targeted, transparent and effective policies that support the digital transformation of European agriculture while contributing to the broader objectives of the CAP.

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7. Concluding remarks

The key messages, foresight analysis, recommendations, and toolbox presented in this deliverable make a substantive contribution to CODECS objectives. By synthesising CODECS empirical findings and situating them alongside the policy landscape already mapped in the report on policy environments, the deliverable has consolidated the evidence base needed to support a policy strategy for sustainable digitalisation and provide policy recommendations. The policy foresight workshops provided future scenarios and pathways that directly shaped the design of the recommendations. The toolbox, in turn, translates these recommendations into instruments that civil servants can apply, thus extending their practical relevance to the governance patterns and adoption pathways.

To summarise, CODECS posits that agricultural digitalisation is a systemic transformation that will continue to contribute to the CAP's broader ambitions for modernisation, competitiveness, sustainability, and generational renewal in European agriculture. The work done in CODECS suggests that much of the knowledge required to support this transformation already exists. What is necessary is the sustained political and institutional commitment to implement it coherently, at every level – from individual farms to the European Union as a whole. **Several of the challenges identified in this deliverable also echo findings from previous EU-funded projects and policy analyses**, which is itself a substantive finding. The distinct contribution of CODECS lies in connecting these long-standing challenges to the ecosystem level and behavioural dynamics uncovered through CODECS Living Labs and cost-benefit analyses. **CODECS shows that sustainable digitalisation depends on action at three interconnected levels:** business processes, digital ecosystems and socio-ecological systems. The table below aims to synthesise the findings and relate the recommendations to the guiding questions associated with each of the levels.

Level	Guiding question	Issues identified	Recommended actions
Business processes	What do farmers need to adopt and use digital tools productively?	Hidden/full lifecycle costs; digitalisation perceived as burden, not support; digitalisation seen as threat to expertise; lack of transparent cost/data information; insufficient advisory support; obstacles to collaborative efforts and collective action	Link investment to outcomes; address full-lifecycle costs; transparent, low-cost tool procurement; reframe messaging as support; position literacy as complementary; continuous advisory support; targeted pathways for disadvantaged groups; encourage collective action
Digital ecosystems	What relationships, standards, and intermediaries need to be in place for tools to function as connected systems?	Poor interoperability; unclear data governance; power concentrated among providers; underused collective bargaining and action; underfunded intermediaries; uneven public/private advisory standards; co-design insights do not reach policy	Align interoperability and data governance framework; mandate service and transparency standards; enable collective data stewardship and action; fund and upskill intermediaries; embed digitalisation in AKIS governance and curricula; equalise standards for advisors and intermediaries; formalise co-design-to-policy channels
Socio-ecological systems	What macro-level coherence and structural conditions let digitalisation serve broader societal, economic and environmental goals?	Fragmented, short-term policy; decade of similar recommendations; digital divides at risk of reinforcement; fragmented funding; weak monitoring and evidence baselines	Long-term adaptive vision; food system framing; consolidate funding instruments; link finance to sustainability; integrated rural divide strategy; retrospective learning for post-2027 design; better metrics and evidence baselines; regular assessments

Table 7. Summary table

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This deliverable's key messages and recommendations draw on a substantial evidence base. **However, as with any research-based policy document, there are several limitations.** While the project followed a mixed-methods approach, some claims are based on a comparatively small number of qualitative case studies or geographically bounded samples relative to the diversity of farming contexts in the EU. These should be read as illustrative of patterns worth further attention rather than robust and statistically representative conclusions. These limitations do not diminish the practical relevance of the project's findings, but are mentioned in the interest of transparency about how confidently different findings should be generalised across the range of national and regional contexts covered by the CAP. Indeed, the need for context-sensitivity also applies to the implementation of recommendations.

The key messages, recommendations, and toolbox presented in this deliverable are intended to serve different audiences at different points in the policy cycle. The key messages and recommendations offer the European Commission, Member States, and the wider CAP Network an evidence base to draw upon when designing or revising digitalisation strategies – most immediately as an input to the ongoing debate on the CAP's design beyond 2027. The toolbox, by contrast, is aimed more directly at civil servants who translate high-level commitments into day-to-day practice, offering instruments that can be applied without waiting for the broader legislative cycle to catch up. It should be understood as the practical implementation layer of the recommendations developed in this deliverable. The three tools collectively respond to a call for stronger digital ecosystems, improved governance arrangements, better evidence generation, enhanced stakeholder engagement and more strategic public investments – by providing operational methodologies, decision-support frameworks and implementation guidance capable of translating CODECS findings into concrete actions.

Beyond the lifetime of the CODECS project, the evidence, recommendations, and tools are intended to remain a usable resource for policymakers and practitioners. In this respect, this deliverable is a contribution to an ongoing policy conversation. Indeed, several of the key messages point explicitly to an implementation gap rather than a knowledge gap, and closing that gap will depend on sustained uptake and adaptation to ensure that agricultural digitalisation enables the achievement of the desired competitiveness, resilience and sustainability outcomes.

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