SYNTHESIS REPORT ON ENVIRONMENTAL, ECONOMIC, AND SOCIAL C&B OF FARM DIGITALISATION, DRAFT M24

30 SEPTEMBER 2024

ALEXIA GOBRECHT , VERONIQUE BELLON-MAUREL, MAURO FLOREZ (INRAE)

COSTAS ILIOPOULOS , IRINI THEODORAKOPOLOU , ALEXANDRA SINTORI, THOMAS GIOTIS (ELGO-DEMETER),

BEATRIZ HERRERA (UHOH), MAIJA USCA (BSC)

LEANNE TOWSEND (HUTTON)

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Authors	Alexia Gobrecht, Mauro Florez, Veronique Bellon-Maurel, (INRAE) Constantine Ilioupoulos, Irini Theodorakopoulou, Alexandra Sintori, Thomas Giotis (ELGO-DEMETER) Beatriz Herrera (UHOH), Leanne Townsend (HUTTON), Maija Usca (BSC)
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Contributors	INRAE, ELGO-DEMETER, UHOH, BSC, Hutton
Project Coordinator	University of Pisa

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Executive summary

The purpose of this deliverable is to present the methodologies and the first results of the analysis conducted in **WP4: Costs and benefits analysis – assessment of the potential of digital technologies in agriculture** during the first 24 months of CODECS.

Three main objectives underpin this work package are:

- Collecting data and analysing the perception of the Costs and Benefits of a variety of actors in the different Living Labs (LL) of CODECS (T4.2)
- Assessing the C&B of farm digitalisation with regards to the 3 dimensions of sustainability (economic, environmental and social impacts) (T4.3, T4.4 and T4.5)
- Facilitating a conversation on trade-offs and synergies between costs and benefits by setting up multicriteria assessment to help famers and policy makers to handle trade-offs. (T4.6)

These various objectives have necessitated the adaptation or the development of methodologies that have been translated into guidelines, transmitted to LL coordinators and accompanied by on-line training, for data collection in each living lab.

At M24, the general advancement is the following:

- All the methodologies have been adapted or developed (e.g for assessing social impacts) and translated into guidelines (T4.1)
- Training of LL coordinators has been carried out for data collection of perception of C&B (T4.2) and for social C&B assessment (T4.5)
- Data collection has been carried out for perception of C&B (first round), for social impact and for one pilot use-case for economic data (T4.4) and one pilot use-case for environmental data (T4.3)
- Content analysis has been carried out for perception of C&B, and first outcomes are available (T4.2)

The task devoted to integrated multicriteria C&B assessment (T4.6) will start M30 and is not included in this first deliverable.

Stakeholders Perception of C&B of digitalisation in agriculture (T4.2)

This task has been led by ELGO-DEMETER, who have developed the methodology and analysed the data collected by the LL coordinators during 18 focus group meetings conducted across Europe between October 2023 and January 2024. The focus groups involved a diverse range of participants, including farmers, policymakers, and farm advisors, who were engaged in discussions about specific digitalisation technologies introduced in the living labs in their respective countries. Focus group participants were asked a series of questions to address two key research questions. The first one aimed to explore the perceptions of the participants regarding the social, economic, and environmental costs and benefits associated with farm digitalisation, to elucidate the different perspectives of the impact of digital technologies on farming practices. The second research question investigated the current and future challenges faced by farmers as their operations become increasingly digitalized, to identify obstacles and concerns related to the adoption of digital technologies.

Regarding the perception of costs of farm digitalisation, several sources of concerns have been identified. They are related to (a) Trust, (b) Changes in allocation of time and resources on the farm, (c) Perceived risks, (d) Change in farmer's role and skills, (e) Energy consumption, (f) Issues of governance. Trust (a) relates to issues in the relationships between the farmers and (distrusted) governments, or agtech providers or consultants: the fear of hidden costs is real and the farmers ask for information presented in an accessible way about the technologies. Changes in allocation of time and resources (b) refers to the need of new skills to run the technologies, the cost of the learning curve, provoking anxiety, the issues related to the rapid obsolescence of the technology, the need for specific infrastructure and the balance of time investments vs returns. Risks (c) encompasses economic risks, operational risks, issues with technology reliability and obsolescence, data security and privacy, concerns with practical application of digital technologies. The Change in farmer's role and skills (d) is expressed through the concerns about becoming detached from traditional farming practices, the necessity for new skills, the potential

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obsolescence of traditional skills, and the emergence of new collaborative models to integrate. Regarding energy (e), digital technologies make emerge both concerns (additional consumption and costs) and a promise (energy saving), showing a more nuanced understanding. Last, but not least, issues related to governance (f) are numerous: who pays? who controls? who owns? who benefits more? who is responsible for losses?

Various favourable levers have been identified to mitigate these costs, e.g., (g) collaboration/ cooperation for access to digital technologies and (h) state support (training, infrastructure, subsidies, regulations). Cooperation (g) refers to pooling resources (i.e., sharing technology), collective bargaining or shard use of data and knowledge exchange. State support is expected for subsidies to lower the barrier to entry (with a concern related to the good an equitable use of public money), training (to enhance digital literacy) and regulations and other public policies to support the development and application of farm digitalisation technologies, protect data privacy and ensure fair competition in the digital agriculture market.

The **perceptions of benefits** can be categorized into 3 themes: (a) time saving, (b) new business models, (c) pride to be a digital farmer. **Time saving** (a) relates to **quicker and more efficient decision-making** based on Data-Driven Decision-Making, leading to improved farm management and productivity. **New business models** (b) are made possible by (i) enhanced decision-making and management, leveraged by digital tools, not only for input reduction but also for crop planning and resource allocation; (ii) more sustainability in practices and security against market and environmental fluctuations; (iii) better efficiency (cost reduction) and simplification (of farming practices) through automation and precision technologies; (iv) engagement in a modern image, making farming more attractive to younger generations and reshaping the perception of farming as a modern and innovative profession; (v) enhancing farm competitiveness and productivity through better farm management practices assisted by advanced digital technologies. **Pride/benefit to be a Digital Farmer** encompasses (i) the professional attraction for a renewed job with better working conditions and a modern image and a sense of belonging of digital farmers; (ii) the enhanced visibility given to farm by digital communication tools for showcasing farm outputs and practices, leading to a better understanding by customers and building trust with consumers and stakeholders; (iii) the reduction of administrative burdens and improvement of efficiency through automation, leading to faster and more efficient farm operations; (iv) inclusivity and cooperation, e.g., the promotion of inclusivity in farming practices and of cooperation with scientists and other farmers to share knowledge and experiences; (v) the implementation of healthier production practices and enhanced sustainability, with environmental benefits provided by precision farming and social benefits generated by knowledge sharing.

To assess the environmental, economic, and social/human impacts of digitalisation at farm/farmer level, the partners are using case studies from the Living Labs. Indeed, digitalisation transforms the farm production system and the farmer in a positive or negative way. The question we want to answer is: How can we objectify the impact of these transformations from an environmental, economic, and social point of view?

For each of these dimensions, the proposed approach is similar in that we will carry out comparative analyses (before and after digitalisation) at farm level, based on quantitative and qualitative data collection from the different Living Labs.

Assessing the environmental C&B of farm digitalisation (T4.3)

This task is led by INRAE and focuses on evaluating the environmental impacts of digital technologies applied at the farm level across various LLs. Using the Life Cycle Assessment (LCA) methodological framework, the report compares agricultural production processes before and after digitalisation. The aim is to identify the environmental benefits and hotspots, enabling advisors, farmers, and service providers to make informed decisions regarding the environmental impacts of digitalisation.

LCA is a well-established methodology that assesses the environmental impacts of a product or service throughout its entire life cycle, from raw material extraction to disposal. The LCA applied in CODECS adheres to international standards set by NF EN ISO 14040 and is part of the UN's environmental programs. The analysis categorizes environmental impacts such as global warming and ecotoxicity, providing a detailed multi-criteria evaluation of digitalized agricultural practices.

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The first key findings of this work stem from a systematic literature review on the environmental impacts of digital agriculture (Huck et al., 2024). The review indicates that digital tools can optimize input use, such as fertilizers and irrigation, thereby reducing environmental impacts. Robotics and automation increase precision and efficiency, though they often come with higher environmental costs due to their energy consumption and material requirements. Technologies related to strategic decision support and traceability, though less studied, offer significant potential to improve efficiency in supply chains. Most digital agriculture technologies demonstrate reduced environmental impacts, primarily through improved resource efficiency and the substitution of fossil fuels with electricity. However, high-tech solutions, such as robots and UAVs, tend to have increased environmental impacts due to their life cycle stages, including production and disposal.

The review also highlights several challenges, including limited data availability, particularly for the production and end-of-life phases of digital agriculture technologies, which introduces uncertainty. The system boundaries and functional units used in LCA assessments significantly influence the results, and many studies do not fully account for the entire life cycle of digital technologies.

The review proposes several recommendations. Future studies should account for the entire life cycle of digital technologies, including their production, use, and disposal. Both mass-based and land-use-based assessments should be employed to improve accuracy, and better collaboration with manufacturers and the use of more comprehensive databases will enhance data quality. Additionally, selecting a broader range of impact indicators will help capture the full spectrum of environmental effects.

These findings serve as a foundation for ongoing assessments within the CODECS project. The review emphasizes a comparative LCA between traditional (non-digital) and digital farming processes. It identifies key parameters contributing to environmental impacts and examines how digital technologies transform agricultural practices.

Data collection for the LCA has recently begun, with information being gathered from the Living Labs. The study uses quantitative data from farms and interviews with farmers to reflect real-world scenarios of digital technology usage. To support this effort, specific guidelines have been prepared for Living Lab coordinators to help them collect only the necessary data.

More detailed results are expected in future deliverables.

Assessing the economic C&B of farm digitalisation (T4.4)

Led by ELGO-DEMETER, Task 4.4 focuses on identifying, quantifying, and evaluating the financial implications of farm digitalisation. The goal is to offer valuable insights to the CODECS consortium, as well as to farmers, advisors, and policymakers, supporting the adoption of digital technologies in agriculture.

Research shows that the economic costs and benefits of digital farming technologies arise from the resources needed to implement them. These include both transition costs, such as the initial investment to adopt new systems, and operational costs related to their ongoing maintenance and usage. Moreover, studies highlight that digital technologies can significantly enhance farm profitability, labour productivity, and resource efficiency. However, a thorough economic evaluation is necessary to determine whether these investments are truly viable.

In the context of CODECS, the methodology for assessing the economic costs and benefits of farm digitalisation is tailored to the level of digital adoption across various farms within the project's Living Labs. A multi-step process has been developed, combining both quantitative and qualitative data for a comprehensive analysis. The first step involves a basic qualitative assessment, particularly useful in cases where detailed farm data may not be available. This initial phase identifies potential economic costs and benefits, even for farms that have yet to fully implement digital technologies. A simple, concise questionnaire captures key data points, including initial investment, operational costs, and possible financial outcomes.

For farms that have already adopted digital technologies, a more advanced method is applied. This involves constructing whole-farm or partial budget tables, allowing farmers to compare their costs and benefits before and after adopting the technology. The analysis also evaluates productivity indicators, such as labour and land efficiency, and financial metrics like net profit and income. A key component of this method is the use of Net Present Value (NPV) analysis, which calculates the projected future cash flows from digital technologies, accounting for the value

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of money over time. This helps determine if the investment is financially sound by comparing the present value of benefits against costs. If sufficient data is available, the analysis can also include various scenarios, such as the impact of subsidies, to predict different outcomes.

To address economic risks, an advanced form of NPV analysis is also used, where key factors like input costs and revenues are treated as variable. This provides a range of possible outcomes rather than a single prediction, giving farmers a better understanding of the risks and rewards of adopting digital technologies.

Data collection is crucial for the success of this analysis. Comprehensive guidelines have been developed, closely aligned with T4.3 (Environmental Impact Analysis), as both tasks require specific quantitative data on production systems, investment costs, and operational expenditures. Since each Living Lab involves unique use cases, the data collection protocols are customized for each Focal Action Situation.

A pilot study has already been conducted at an experimental vineyard in Athens, Greece, and some preliminary results are presented in this report. This ongoing research is expected to provide valuable tools and insights that will improve decision-making regarding the adoption of digital farming technologies.

Assessing the social C&B of farm digitalisation (T4.5)

This task has been led by INRAE and involved Institut Agro, the University of Hohenheim, the Baltic Studies Center and The James Hutton Institute, assuring a multidisciplinary approach to tackle the objective of assessing the Social/Human-centred costs and benefits of farm digitalisation.

The objective is to deepen our understanding of the social/human changes that digital technologies are bringing to farmers, with a focus on the intangible aspects of their use. No methodology existed to address this issue, so the first task of the team has been to build up a methodology, from indicator definition to data collection protocols. The document presents the methodology implemented in CODECS for the collection and analysis of data in order to ensure reliable and balanced results to address two research questions: (i) *How does the adoption and use of digital technologies affect farmers and farmers' practices?* and (ii) *How does the context in which digital technologies are adopted and used influence the results they produce for farmers and workers at the farm level?.* For this purpose, a qualitative study is conducted among farmers identified in the CODECS LLs, encompassing both positive and negative changes affecting farmers and their agricultural practices. To build the methodology and the framework of analysis, an interdisciplinary team (management sciences, sociologist, ergonomist, economist, agricultural engineers, etc.) has been set up by gathering various CODECS partners (INRAE, BSC, Hutton, University of Hohenheim). This team has built a framework identifying the various fields which illustrates social/human changes possibly occurring for farmers or other users (farm employees, advisors) of digital technologies. Five areas of social/ human impacts have been identified at farm level: i) user's health and well-being, ii) user's perception of quality of life at work, iii) time management, iv) user's skills and knowledge, and v) collaborative networks and enhanced communication among people. The relevance of these indicators might differ based on the specific context of living labs. Contrary to the study on perceptions of C&B, which was carried out on all LLs, only LLs already digitalised or in the process of digitalisation were studied. The semi-structured interviews with users are conducted by LL coordinators. Data processing is carried out in a multifaceted approach by different researchers of the T4.5 team.

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1 Introduction

1.1 Objectives of WP4

WP4 is mainly focused on CODECS Specific Objective 4 "**Providing data on the costs and benefits of digitalisation in a variety of European farming contexts, by setting up and carrying out user-friendly assessment methodologies**".

It also contributes to objective SO6 by feeding public policy recommendations with evidences and to SO7, by providing assessment tools and feeding the platform with examples in order to raise awareness. For doing so, the WP has been divided into 6 different tasks:

- To capture stakeholders' perception of various costs and benefits along the 3 axes of sustainability (T4.2).
- To assess the environmental, economic and social impacts of digital technologies in a participatory way (T4.3, T4.4 and T4.5).
- To facilitate a conversation on trade-offs and synergies between costs and benefits (WP4.6).

Methodologies had to be set up or adapted to be applied in points 1 and 2, which was carried out in T4.1 (guidelines). For sake of clarity, guidelines will be presented with each task, separately, in order to be associated with results, when available.

1.2 Articulation In CODECS

WP4 is strongly related with other workpackages of the project:

- With WP2, which has defined the general framework and to which WP4 provides methodologies and guidelines
- With WP3, which provides information and models of the processes before and after digitalisation, useful to carry out Life Cycle Assessment (T4.3)
- With WP5, in which demo events are a space for both data collection and presentation of the results to the stakeholders
- With WP7, where the platform supplies WP4 analysts with genuine data collected in the Living Labs and where WP4 provides WP7 with assessment data. Both collaborate to design and create an interactive and attractive presentation of assessment results, through Economic Cost Calculator (ECC) and Environmental Footprint Calculator (EFC) in order to raise awareness and help farmers and policy makers in their choices
- With WP8, especially the Living Lab coordination, as the analysis provided by WP4 strongly involve data to be collected in the Living Labs

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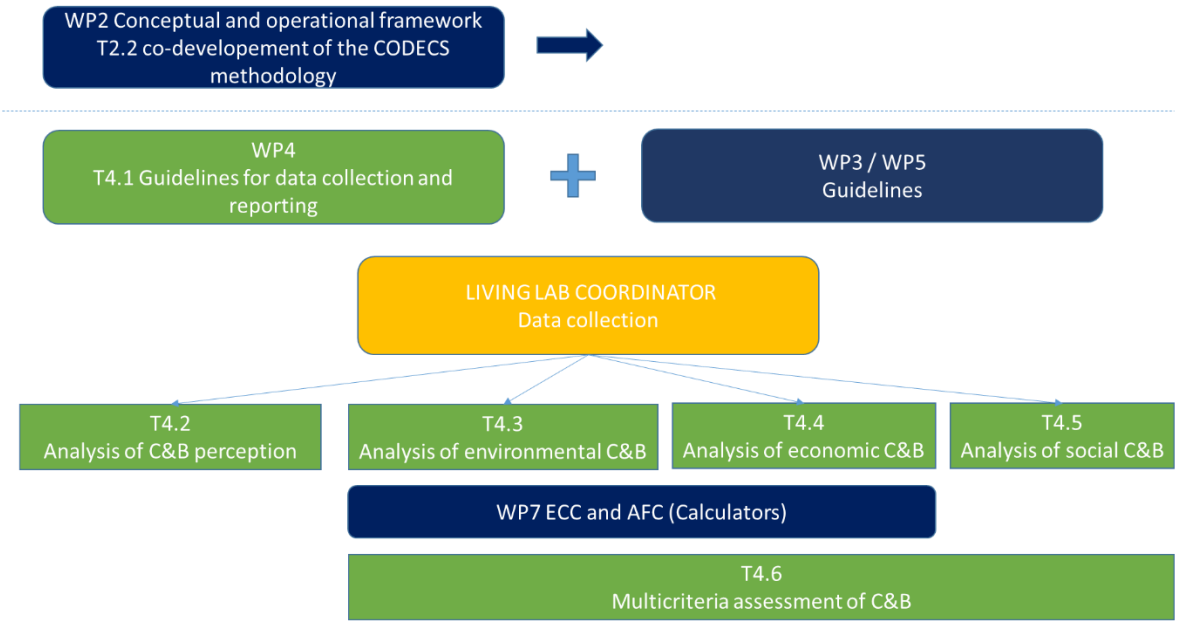

Figure 1: Articulation of WP 4 tasks

1.3 Advances of WP4

As said above, methodologies used in WP4 were at different stages: some were already well established, others had to be adapted or even built from scratch. In addition, the dynamics of data collection were heterogeneous regarding the criterion to be assessed. Data collection for Perception of Cost and benefits (T4.2) are carried out during annual Living Lab Workshops in 2023, whereas data collection for assessment of digitalisation C&B is carried out in each living lab, starting with data related to the social cost and benefits. This explains that some tasks already have results (T4.2) or first preliminary results (T4.4, T4.5) whereas others just have started collecting data (T4.3).

In the following we will introduce the advances of resp. T4.2, T4.3, T4.4 and T4.5. T4.6 has not started yet.

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2 Stakeholder perceptions of cost and benefits of digitalisation in agriculture

Authors: Constantine Iliopoulos, Irini Theodorakopoulou, and Thomas Giotis (ELGO-DEMETER)

2.1 Introduction

This chapter of the CODECS deliverable 4.1 presents a comprehensive analysis of stakeholder's perceptions of the costs and benefits of farm digitalisation. This analysis is based on content derived from 18 focus group meetings conducted across Europe between October 2023 and January 2024. The focus groups involved a diverse range of participants, including farmers, policymakers, and farm advisors, who were engaged in discussions about specific digitalisation technologies introduced in the living labs in their respective countries.

Farm digitalisation represents a significant shift in modern agriculture, integrating advanced technologies such as precision farming tools, digital irrigation systems, and data analytics to improve farm management. This transformation has been heralded as a pivotal advancement for the agricultural sector, promising to increase efficiency, productivity, and sustainability. However, the adoption and impact of these technologies can vary widely depending on regional contexts, farm sizes, and stakeholder perspectives.

To gain a nuanced understanding of these dynamics, focus group participants were asked a series of questions to address two key research questions. The first, RQ-1, explored the perceptions of farmers, farm advisors', and policymaker's regarding the social, economic, and environmental costs and benefits associated with farm digitalisation. This question aimed to elucidate the different perspectives of the impact of digital technologies on farming practices, from the tangible benefits such as increased operational efficiency and reduced environmental impact to the potential drawbacks, including financial burdens and changes in working patterns.

The second research question, RQ-2, investigated the current and future challenges faced by farmers as their operations become increasingly digitalized. This inquiry sought to identify obstacles and concerns related to the adoption of digital technologies, such as technical difficulties, training needs, and the broader implications for farm management and rural livelihoods.

The focus groups provided a rich tapestry of insights, capturing a wide range of stakeholder experiences and opinions. Participants were presented with digitalisation technologies relevant to their local contexts, allowing for a detailed exploration of how these innovations are perceived in terms of their value and impact. The discussions revealed both the optimism and scepticism about digitalisation, highlighting the complexity of integrating new technologies into traditional farming systems.

This deliverable presents a detailed content analysis of these focus group transcripts, offering a thorough examination of stakeholder perceptions. The findings aim to inform the development of targeted policies and support mechanisms that address the diverse needs and concerns of the agricultural community. By highlighting the perceived costs and benefits of farm digitalisation, as well as the challenges that lie ahead, this report contributes to a deeper understanding of how digital technologies can be effectively and equitably implemented in the agricultural sector.

In summary, this analysis sheds light on the multifaceted impacts of farm digitalisation, emphasizing the importance of considering diverse stakeholder perspectives to guide future developments in agricultural technology and policy. This chapter is organized into six sections. After this introduction, the second section outlines the research questions and theoretical underpinnings guiding our study. The third section details the methodology and sample used for analysing stakeholder perceptions. The fourth section presents the findings from our analysis, while the fifth section discusses these results and explores their implications for farm digitalisation policies. Finally, the sixth section offers a conclusion to the chapter.

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2.2 Theoretical Underpinnings and Research Questions

Given CODECS's explicit focus on farm digitalisation policies and this chapter's emphasis on stakeholder perceptions regarding the costs and benefits of digitalisation, we conducted a review of academic literature related to these topics. Our objective was to integrate these insights to inform policy recommendations based on stakeholder feedback. We begin by presenting a brief overview of existing literature on farm digitalisation policies, followed by a review of literature on stakeholder perceptions. While the reviews are not exhaustive, they proffer an overview of the most important contributions.

2.2.1 Policies on farm digitalisation

Digital technologies are becoming part of the agricultural policy toolbox to aid compliance monitoring, data exchange and analysis (European Court of Auditors, 2020; OECD, 2019). However, the use of digital technologies for agricultural policy remains patchy (OECD, 2019). It is unclear just how far their potential is being exploited and what issues arise from their application (Klerkx et al., 2019). The literature refers sporadically to digital aids in policy implementation (Coble et al., 2018), where the expected benefits of using digital technology for agricultural policy include increased effectiveness and efficiency, due to its monitoring and targeting abilities (Weersink et al., 2018), and more efficient use of environmentally harmful farming inputs (Finger et al., 2019). It can also reduce information asymmetry and transaction costs of policy implementation. However, the policy instruments and implementation technologies currently applied are largely aligned, as choices and design specifications of agricultural policy instruments are restricted to what is deemed feasible considering dominant discourses, political constraints, administrative resources and technology (Erjavec and Erjavec, 2015; Henke et al., 2018; McCann, 2013).

There are many adoption barriers of digital agriculture technologies, such as high investment costs (Rose and Chilvers, 2018) and lack of training and advisory services for farmers are some of the main barriers to adoption, especially for small- and medium-scale farmers (Paustian and Theuvsen, 2017). Policy can help surmount these barriers through offering financial assistance to farmers and innovators in the form of tax-breaks and/or subsidies that help compensate short-term opportunity costs and long-term financial risks associated with technological innovation and investment (Ehlers et al. 2021). As suggested in the literature and taken up in the 2035 in Europe, Arable Farming Strategy and the F2F Strategy, providing agriculture training (i.e., digital skill sets) and advisory services for farmers could foster a more inclusive digital agriculture for small-scale, agri-food businesses (Piñeiro et al., 2020; Long et al., 2016). Coupling advisory services and training with financial assistance for digital technologies will increase chances that digital agriculture will be leveraged to its fullest potential. Ultimately, these types of measures may help to avoid a digital divide between large-scale and small-scale farmers in the future (Rotz et al., 2019; Revenko and Revenko, 2019).

Digitalisation is expected to support more targeted and outcome-oriented policy through improved monitoring possibilities (Ehlers et al., 2021). Digitalisation renders policy designs with high information requirements more attractive (Ehlers et al., 2021). Digitalisation offers new options for agricultural policy, including novel designs to address challenges more effectively. The distinction must be made, between mere digitisation of existing data and digitalisation which is more extensive, involving the generation of novel data, processing and analytics of large amounts of data, including automated feedback (Parviainen et al., 2017). Agricultural policy in Europe shapes the adaptive capacity of farms, which is why anticipatory governance will be a critical for ensuring socially acceptable policies for digitalisation and agriculture (Barrett and Rose, 2020). Ehlers et al. (2022) results imply that European policy stakeholders need to prepare strategies to address digitalisation, even when underlying technology could be more widespread at later points in time.

In addition, in Europe, the European Commission set out as one of its objectives “fully connecting farmers and the countryside to the digital economy” to achieve a smarter, modern and sustainable future of food and farming (European Commission, 2017, p.7). This was followed by the Green Deal in which digital technologies are considered “a critical enabler for attaining the sustainability goals of the Green Deal in many different sectors” (European Commission, 2019, p.7). Also, it was followed in 2020 by the Farm to Fork strategy indicates that “the CAP [Common Agricultural Policy] must also increasingly facilitate investment support to improve the resilience and accelerate the green and digital transformation of farms“ (European Commission, 2020, p. 16).

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Besides research on governing the use of digital technology in agriculture, the use of digital technology in public policymaking and new agricultural policy challenges arising from digitalisation of the agri-food sector receive increased attention (Ehlers et al., 2022). The role for government in promoting an enabling environment for innovation and the adoption and diffusion of innovations throughout the agricultural sector and in supporting a well-functioning agriculture innovation system is well recognised (OECD, 2013). Novel data generated on farms and in food companies, from consumer behaviour, among others, and big data analytics could help make agricultural policy more effective (Klerkx et al., 2019; Weersink et al., 2018). It emerges that remote sensing and integration of digital databases can improve policy monitoring. The European Union (EU), for example, uses satellite-based earth observation for agricultural area and subsidy monitoring to reduce costly on-the-spot controls, which artificial intelligence can complement (Loudjani et al., 2020). Agriculture policymakers should focus on issues relating to infrastructure and connectivity, cost, relevance, user-friendliness and skills, and risk and trust building to enable digitalisation to take place (McFadden et al., 2022).

MacPherson et al. (2022) study showed that policies consider digital agriculture mostly in terms of resource use efficiency, while its benefits for achieving other sustainability principles such as biodiversity conservation, soil protection, and climate change adaptation and mitigation are not thoroughly reflected. Similar findings of policy from high-level institutions were found by Lajoie-O'Malley et al. (2020). Nevertheless, the reviewed policies converged on certain points concerning frame conditions for implementing digital agriculture, such as developing a statutory framework, working toward data harmonization, as well as increasing high speed internet availability to rural areas. Technologies that improve decision support, such as VRT, cloud computing, IoT, yield mapping, digital soil mapping, sensors, and UAVs are particularly relevant toward achieving most agriculture-related goals and, by extension, diverse sustainability principles. Further, technologies that enhance monitoring such as satellite imaging, AI, and agricultural census data are particularly relevant for promoting biomass production, climate change mitigation and adaption, as well as biodiversity conservation. Lastly, communication technologies such as RFIDs, QR codes, and distributed ledger technology (e.g., Blockchain) promote transparency along the value chain, thereby contributing to goals related to health and nutrition as well as biodiversity conservation. Given the rapid growth and innovation in digital agriculture, policy should do more to highlight these potential applications and refer to the burgeoning literature on the topic (MacPherson et al., 2022).

Scenario analysis supports strategic decision making and allows for 'values-based questioning' of the type of future agri-food sector that is desired. It also facilitates critical reflection on how digital technologies deliver that future (Bronson, 2018). Thus, by addressing future scenarios, policymakers are enabled to align policies to social values and needs (Borjeson et al., 2006). This should not only support responsible research and innovation in agricultural digitalisation, but also help avoiding costly and unintended or undesired impacts of policymaking. However, there is a lack of research on how a specific set of technologies, like digital technologies, could plausibly develop and affect policymaking and future challenges for agricultural policy (Ehlers et al., 2022). Digital agricultural policy does not simply replace analogue technologies used in traditional agricultural policy (e.g. for documenting compliance).

Currently, agricultural policy in Europe uses instruments that cover the full range of policy options from information provision to regulation and economic incentives. However, when implemented, they often fail to support environmental, economic and social sustainability effectively (Navarro and Lopez-Bao, 2018; Pe'er et al., 2019). The EU's Common Agricultural Policy (CAP) is also criticised for a lack of indicators and systems that enable effective monitoring and enforcement (Pe'er et al., 2020). Digital technology can enhance the effectiveness and efficiency of agricultural policy by supporting instruments in targeting precise spatial and time-bound objectives and enabling instrument designs tailored to specific attributes of locations and farms (van Tongeren, 2008). It makes

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trade-offs and jointness of production more transparent, mitigates asymmetric information, facilitates monitoring and the search for technologies and practices, spatial targeting and the development of alternative policy instruments and designs (Jacobsen and Hansen, 2016; OECD, 2019). Thus, the analysis of digital agricultural policy must dissect policy into its individual instruments and their design specifications. It can then show clearly how digital technology works in combinations of instruments. Policy can also target the use of digital technology on farms and in companies in the agri-food sector. Examples are precision farming technology or food quality tracking aimed at improving environmental footprints and food safety (Finger et al., 2019).

A key question, both for research and policy, is whether farms, interest groups and government are willing and able to cope with the ramifications of a more encompassing digitalisation of agricultural policy. This would depend on the capabilities and the willingness of government, farms and the other actors involved to use digital technologies. It also depends on developments in future policy demand and digitalisation. Systematic anticipation of plausible futures of digital agricultural policy is therefore needed (Ehlers et al., 2021).

2.2.2 Perceptions of the Costs and Benefits of Farm Digitalisation

Given the multifaceted nature of sustainability, it's understandable that perceptions of the costs and benefits of farm digitalisation can vary significantly among different individuals or groups. What one group might view as a benefit could be perceived as a cost by another. Understanding these differing viewpoints is crucial, as it can guide the development of effective policies (e.g., da Silveira et al., 2023).

In exploring these perceptions, it's essential to recognize that the impact of digital technologies can vary based on numerous contextual factors (e.g., Klerkx et al., 2019). For instance, digital irrigation systems may be highly effective for certain crop varieties but less so for others, depending on how sensitive the crops are to water stress. Similarly, the effectiveness of these technologies can be influenced by soil type, microclimate, farm size, level of existing equipment, and the skills and experience of users (Soma et al., 2024).

From a theoretical perspective, costs associated with digitalisation might encompass financial investments, resource allocation, training expenses, and potential disruptions to current operations. Conversely, expected benefits include increased efficiency, improved productivity, enhanced customer satisfaction, better work quality, reduced environmental impacts, competitive advantages, and long-term profitability (Soma et al., 2024).

The scientific literature offers diverse perspectives and methodologies to understand costs and benefits in digitalisation. Approaches range from IT investment evaluation to the economics of information technology, digital transformation and innovation, organisational change and management, and social and ethical implications. These studies examine the impact of digital technologies on productivity, innovation, market competition, economic growth, business models, customer experiences, operational processes, employee training, change management, privacy, data security, equity, and societal impacts. Traditional appraisal techniques encompass conventional economic, strategic, and analytical approaches. These methods have been supplemented with techniques designed to account for elusive indirect costs that are becoming more prevalent in digitalisation processes or by sympathetic techniques that ensure that the evaluation is appropriate, effective, and able to capture the relevant aspects and potential impacts of digitalisation (Soma et al., 2024).

Current research often lacks an integrative and interdisciplinary approach needed to fully understand the trade-offs, risks, challenges, and diverse factors that contribute to the overall costs and benefits of digitalisation. This gap limits our ability to grasp the complexities and dynamics of the relationship between costs and benefits. To address this limitation, CODECS proposes an integrated conceptual framework that considers a wide range of interconnected factors, including technical, technological, social, cultural, economic, financial, environmental, and political aspects (Soma et al., 2024). This approach will facilitate a comprehensive assessment of digitalisation's benefits and costs across various levels and stakeholders, offering a deeper understanding of its implications. Special attention will be given to the perspectives of farmers, as they are the primary users of these technologies and their documented experiences with costs and benefits are crucial for making informed decisions about digitalisation (ibid, 2024). However, CODECS does not only focus on collecting and analysing hard evidence on the costs and benefits of digitalisation. We are aware that perceptions play a key role in shaping the incentives of key stakeholders to invest time and money in farm digitalisation technologies (e.g., Bontsa et al., 2023; McFadden et al., 2022; Bucci, 2020).

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Understanding the perspectives of farmers, policymakers, and farm advisors on the costs and benefits of farm digitalisation is crucial. These perceptions significantly influence stakeholders' motivation to invest time, money, and energy into adopting digital technologies in agriculture (e.g., Arcuri et al., 2023). By comprehending how these costs and benefits are perceived, stakeholders can design and implement effective and efficient digitalisation policies that provide valuable tools and advantages for all parties involved (e.g., Arcuri et al., 2023).

Despite the significance of these perceptions, academic research on the topic is relatively sparse and often focuses exclusively on specific areas of implementation, such as precision agriculture. While some notable exceptions exist, they are few and far between, making it difficult to conduct a comprehensive assessment and gain an in-depth understanding of the perceptions of farm digitalisation's costs and benefits.

For instance, a study on the acceptance of farm digitalisation technologies in Germany found that farmers were more inclined to adopt these technologies when provided with a detailed and compelling description, along with state subsidies to offset associated costs (Pfeifer et al., 2020). The study concluded that the actual benefits of farm digitalisation alone were insufficient to persuade farmers to adopt these technologies.

In another study, Ferrari et al. (2022) conducted interviews with 30 experts from various fields across different European countries to indirectly identify their perceptions of the costs and benefits of farm digitalisation. The experts highlighted several benefits, including reduced economic costs, easier compliance with tracing and regulatory schemes, reduced manual labor, and increased productivity. However, they also pointed out significant costs, such as high dependency on technology and the marginalization of certain actors, including small farms and farmers with limited education.

A recent Swiss study by Ammann et al. (2022) focused on the perception of farm management information systems. Through an online survey of 150 teachers and students of farm vocational programs, the study found that the possibility of adoption depended on factors such as gender, perceived ease of use, and the intention to use more digital technologies in the future. The authors emphasized the crucial role of perceptions and highlighted the potential of education to modify these perceptions.

Schroeder et al. (2024) analyzed the perceptions of managers and employees regarding automation and digitalisation in the horticultural sector in Germany through an online survey of 156 horticultural managers and 132 horticultural employees. Their findings indicated that expected benefits included increased control over production and data, improved work conditions, enhanced industry image, reduced costs, and increased productivity. However, concerns were also raised, such as the potential shift towards large farms and the high cost of investing in automation and digitalisation.

Another study conducted in Africa explored the viewpoints of 195 respondents from different stakeholder categories in Benin, Kenya, Nigeria, and Mali (Daum et al., 2022). The results revealed previously neglected aspects, such as the role of animal traction, the continued appeal of state-led mechanization, and data sovereignty concerns. Factors such as gender, age, and education influenced viewpoints on certain topics. The authors emphasized the importance of paying attention to local stakeholders to choose and design the most promising policies and programs and ensure their successful implementation on the ground.

Finally, a survey of 504 Brazilian farmers' perceptions of precision and digital agriculture conducted by Bolfe et al. (2020) found that the primary perceived benefit was increased productivity. However, significant costs were associated with acquiring technology due to the high cost of machines, equipment, and software. Concerns were also expressed regarding the problematic connectivity of farms to the internet.

In summary, the perceptions of stakeholders regarding farm digitalisation are complex and multifaceted. While digitalisation offers numerous benefits, such as increased productivity and reduced costs, it also presents challenges, including high investment costs, technology dependency, and connectivity issues. Understanding and addressing these perceptions are essential for designing and implementing effective digitalisation policies that benefit all stakeholders.

While the reviewed literature provides valuable insights into the perceptions of farm digitalisation among various stakeholders, several significant gaps remain. Firstly, none of the existing studies have brought together all key participants—farmers, policymakers, and advisors—into a collaborative setting, such as a focus group meeting. This approach would allow for direct interaction and exchange of perspectives among stakeholders, facilitating a deeper

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understanding of shared and divergent views. Secondly, the current body of research does not focus exclusively on the perceptions of the economic, social, and environmental costs associated with farm digitalisation. By concentrating on these specific dimensions, future research could offer more comprehensive insights into the barriers hindering digital adoption in agriculture. Finally, no study has been conducted on a continental scale, such as across Europe, which limits the generalizability of findings. A pan-European study could account for regional variations and provide a broader understanding of how farm digitalisation is perceived across different cultural and economic contexts. Addressing these gaps is crucial to develop more targeted and effective digitalisation policies that reflect the complex realities of agricultural stakeholders across Europe.

In CODECS, we address this research gap by identifying and understanding how farmers, policy makers, and advisors perceive the various social, economic, and environmental costs and benefits associated with farm digitalisation. We started by identifying the following research questions that guide our research endeavour:

RQ-1: What are the perceptions of farmers, farm advisors, and policy makers regarding the social, economic, and environmental costs and benefits resulting from farm digitalisation?

RQ-2: What are the problems facing farmers now or in the future as farms become more and more digitalized?

In the following section, we outline our approach to identifying the perceptions of farmers, policymakers, and farm advisors and, ultimately, answering the above questions.

2.3 Methodology and Sample

Given the limited focus of previous research efforts on the perceptions of costs and benefits of farm digitalisation, we diagnose a lack of integrative theoretical frameworks on this issue. Therefore, in analysing stakeholder perceptions of the costs and benefits of farm digitalisation we adopt an inductive approach. This approach starts with stating general research questions and then derive more specific questions to pose to key farm digitalisation stakeholders. Subsequently, we try to understand stakeholder perceptions in a bottom-up approach, starting with what we observe to be happening in the field.

2.3.1 Data collection

To answer the research questions, we collected qualitative data from stakeholders on each dimension of costs and benefits (i.e., social, economic, and environmental). More specifically, the perceptions of stakeholders regarding the social, economic, and environmental costs resulting from farm digitalisation and the problems facing farmers now or in the future as farms become increasingly digitalized were collected. All data required to achieve the objectives were collected by each LL (Living Lab) during a focus groups meeting organized by each LL end of 2023, beginning of 2024 (in total, 18 FG meetings).

Similar data will be collected during the third year of CODECS (M37). This second FG meeting will enable ELGO-DEMETER researchers to identify the dynamic evolution of perceptions.

Two online training sessions of LL leaders on how to organize and conduct each focus group meeting were held on July 4, 2023, and on September 7, 2023, by the ELGO-DEMETER team. The first seminar was devoted on the process to be followed before the focus group meeting (e.g., how to identify and invite stakeholders, how to create the container, that is, a physical but also spiritual place where participants feel comfortable to discuss about the costs and benefits of farm digitalisation, etc.). The second seminar was focused on how to facilitate the focus group meeting efficiently and effectively, but also on what to do after the meeting is over.

Appendix 1 details all the specific instructions to organise the focus groups sessions in the Living Labs, the questions to be asked and the reports to be produced for the content analysis.

Each focus group consisted of six to ten individuals in an unstructured conversation leading by a proficient moderator while it was mentioned to the moderators that the optimal length for a focus group was between 45 and 90 minutes. Given the optimal size of a focus group (10 people), the moderators of the LL were asked to involve:

- 4 farmers, 2-3 of them engaged in farm digitalisation projects.

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- 3 policy makers engaged in designing farm digitalisation policies and regulations (e.g., those in regional authorities, ministries who are responsible for designing and/or implementing digitalisation policies in agriculture).
- 3 farm advisors or experts familiar with the issues facing farmers regarding farm digitalisation. These can come from both the public and the private sector, including academic researchers and professors whose research focuses on farm digitalisation.

However, in addition to these professions, other specialists in this scientific field, such as Technology providers and advisors, Researchers, Government representatives, firm Consultants, Business owners, Agronomists and faculty Professors, also participated. For the formation of each focus group, important criteria were considered, such as the presence of individuals of different ages and genders, with varying levels of influence/power, who did not know each other. This process was necessary to create a more homogenous and comfortable environment for focus group participants, which can lead to more honest and valuable insights.

The final decision for focus group participants was taken by LL leaders (key-individuals). The LL leaders selected stakeholders among their group, by taking into consideration the above-mentioned selection criteria.

As mentioned previously, specific and targeted questions were included in the list of questions asked during the focus groups. These questions had to be a maximum of 12 and a minimum of 8, and they were simple and understandable for the participants to be able to respond verbally.

The questions prepared by the ELGO DEMETER team for the first meeting of the focus group in each LL were based, initially, on information collected from the literature on the changes caused by farm digitalisation as well as particularly useful comments from the CODECS coordinator, Prof. Gianluca Brunori, whom we take the opportunity to thank again.

The set of Focus Group semi-structured questions follows:

A. Engagement Questions:

1. What comes to your mind when you hear the term “farm digitalisation”?

B. Exploration Questions:

2. Bearing in mind the proposed tool/service, do you think it might work? Why? Under what conditions?
3. How do you think the innovation would change farming activities (operations, organization, relations in the supply chain, relations with advisers, relations with suppliers)?
4. How would the innovation contribute to environmental sustainability? Under what conditions?
5. How would it contribute to farmers' incomes and welfare, quality of work, and gender equality? Under what conditions?
6. What do you think are the economic, social, and environmental costs associated with the introduction of the proposed digitalisation innovation and who will incur each type of cost?
7. Would you be willing to pay the associated costs? Up to which level would you be willing to pay?
8. What kind of problems do you expect to face as more and more farms will become digitalised in the future?
9. What kind of benefits (economic, social, and environmental) do you expect from digitalisation? Please provide some examples.

C. Exit Question:

10. Is there anything else you would like to share with us regarding farm digitalisation that you have not shared so far?

To ensure accurate data collection, managers of the live labs were given detailed instructions for each step of the process, from start to finish. Participants were informed about their anonymity and the rules for the discussion. After each focus group, participants provided feedback on the costs and benefits of the innovation presented. Moderators then held a debriefing session to summarize key insights, which were recorded and translated into English.

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Transcripts were to be sent to the ELOG-DEMETER team by January 31, 2024. If recordings were not possible, facilitators were instructed to either have assistants take detailed notes or record responses on paper, and inform the T4.2 leader of the method used.

2.3.2 Content analysis

After the data collection from each focus group, the transcripts and the debriefing notes we received were categorized by country and by LL. Subsequently, three independent researchers undertook the task of documenting in a Microsoft Word file the economic, social and environmental costs and benefits that emerged from the respondents' answers for each LL, as well as the problems that participants expect to arise as the digitization of agriculture expands. Each researcher carried out this process separately, and then the necessary cross-checking of the recorded data was conducted to ensure the accurate documentation of all the given answers. In each entry recorded in the file, the occupation of each participant in the respective focus group was also noted, I addition to the farm digitalisation technology introduced in each living lab where the focus group meeting took place.

This methodology was designed to analyze focus group discussions to uncover stakeholders' perceptions of the costs and benefits of farm digitalisation. The analysis followed **thematic-content data analysis** principles (ensuring a comprehensive and rigorous examination of qualitative data Green & Heart, 2001; Henning, Van Rensburg, and Smit, 2004; Du Plessis, Koen, & Bester, 2012; Blakeman, Samuelson & McEvoy, 2013; Ryan et al., 2013; Silverman, 2013).

Multiple focus group discussions were conducted with diverse stakeholders, including farmers, agricultural experts, technology providers, and policymakers. Each group consisted of 6-10 participants and was moderated to ensure balanced and in-depth discussions. The questions discussed were the same in all sessions, covering the topics that needed to be validated.

Shortly after each focus group event, the organizers prepared a brief report. The brief reports and translated transcripts from the notes were reviewed independently by two researchers to ensure consistency.

The data were open-coded and categorized into sets according to the research questions. The transcripts were closely read multiple times to gain a broad overview of the discussions and to develop an understanding of the key themes in relation to the participants' perspectives (Adler and Clark, 2011).

The content analysis method required multiple assessments of the data. The unit of analysis was words and phrases used by participants which then was grouped into thematic categories. Categories were developed inductively. The themes for the analysis were derived from the questions/topics discussed in the focus groups (economic, social and environmental costs and benefits of farm digitalisation).

Two researchers read the material provided by the focus group hosts, independently. When reading the transcripts researchers had in mind the general questions discussed in the focus groups and made notes on the transcripts related to the way each question was addressed. At this point researchers also marked and noted phrases and words most likely to describe or address the topics discussed.

At a second step, researchers went over their notes again and generated major and minor categories and linked these to words or phrases in the text. The two researchers met to discuss the approach they used and the results they generated. As a result, they devised a set of themes that were developed inductively, which best described perceptions on the costs and benefits of farm digitalisation.

2.4 Results

2.4.1 Perceptions of the Costs of Farm Digitalisation

Regarding the perception of costs of farm digitalisation, several sources of concerns have been identified and are listed in Table 1.

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Table 1 : Thematic concern of the perception of Costs of farm digitalisation

Thematic concern	Sub-thematic
Trust Issues in Farm Digitalisation	• Farmers and Governments • Farmers and Tech Providers • Farmers and Consultants • Key concerns and anxieties • Information and Decision-Making
Time and Resource Challenges	• Human Resources • Learning Curve • Obsolescence of Technology • Infrastructure Deficit • Time Investment
Risks in Farm Digitalisation	• Economic Risks • Operational Risks • Technological Risks • Data Security and Private Risks • Practical Application and User Resistance
The Changing Role of Farmers	• Detachment form Traditional Farming • New Vision for Farming • Skills Needed for Modern Farming • Obsolescence of Traditional Skills • New Collaboration Models
Energy Concerns	• Increase in Energy Demands • Costs Implications • Renewable Energy • Energy Efficiency • Integration with Digital Tools
Property Rights and Control	• Who pays and controls? • Ownership Concerns • Who Benefits?
Access Issues	• Collaboration Models • Cooperation for Access
Information for Decision Making	• Data Ownership • Transparency
State Support and Education	• Subsidies and Grants • Training and Education • Regulatory Frameworks

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Trust Issues in Farm Digitalisation

The adoption of digital technologies in agriculture has been met with a mixture of optimism and skepticism among farmers across Europe. A detailed analysis of focus group transcripts reveals a significant thematic concern around trust, manifesting in a distinct "us vs. them" dichotomy. This theme encompasses trust issues among farmers and various stakeholders, including governments, tech providers, and consultants.

- Trust Issues Among Farmers and Governments: Farmers express notable distrust towards governmental bodies, primarily rooted in concerns over infrastructure, accessibility, and the reliability of services *"We lack infrastructure to accommodate digitalisation*". Many farmers perceive government initiatives as being disconnected from their on-the-ground realities *"A small farmer needs a vision not a technology"*, leading to scepticism about the actual support and benefits these programs offer. The fragility of both digital technologies and the farmers' own positions amplify this distrust, as they fear the implementation of insufficient or inappropriate infrastructure might leave them vulnerable. One participant highlighted the time and energy required to adopt new technologies, stating, "...it is often a time and energy issue to … learn some new technology or digitalisation…" This sentiment underscores the perceived gap between government initiatives and practical farmer needs.
- Trust Issues Among Farmers and Tech Providers: The relationship between farmers and technology providers is fraught with tension *"They are very good at coming to sell…. They can come quite a few times for a breakdown. But after that, it stops there"*. Farmers are wary of hidden or unknown costs associated with digital tools, fearing unexpected expenses that could undermine their financial stability. One farmer expressed concern about this uncertainty, asking, "But why does the processing of drone data take so long?" This uncertainty extends to the efficiency and effectiveness of the technologies, with many questioning whether these innovations will truly enhance their farming practices. Furthermore, there is apprehension about the additional effort required to integrate new technologies, "The technology can do a lot, but it's not very accessible to farmers." This accessibility issue further erodes trust, as farmers feel left to navigate complex systems without adequate support.
- Trust Issues Among Farmers and Consultants: Agricultural consultants, who are expected to guide farmers through the digital transition, also face trust challenges. Farmers often view consultants with suspicion, concerned that their advice might be more commercially driven than genuinely beneficial. This perception is exacerbated by fears of hidden costs and additional efforts required to achieve the same returns, creating a barrier to the adoption of new technologies. One farmer pointed out, "I think the role of the agronomist will become very important," highlighting the need for trustworthy, expert guidance. However, this trust is hard to establish, as another participant noted, "A farmer's trust is hard to gain and easy to lose. If the detection tool is 9 times right and 1 time wrong at a farm, this 'news' is spreading fast among farmers." This emphasizes the fragility of trust within these relationships.
- Key Concerns and Anxieties: Several underlying anxieties fuel these trust issues. The fear of hidden and unknown costs looms large, as farmers are uncertain about the total financial commitment required for digitalisation. One farmer noted, "The cost of service (unknown)" as a significant concern. This is compounded by fears of additional efforts required to achieve the same returns, as stated, "..., if the farmers need to digitalize, there are too many platforms that don't communicate with each other for farmers to keep an overview." The perceived fragility of digital technologies adds another layer of apprehension, as farmers worry about the reliability and longevity of these investments.
- Information and Decision-Making: Trust and public relations play crucial roles in the decision-making process. Farmers need clear, transparent information to make informed decisions about adopting digital tools. One participant mentioned, "the innovations must be presented [to the farmer] in an accessible way." The uncertainty of positive effects from digitalisation creates hesitancy to fully embrace these innovations, as another farmer pointed out, "..., the learning curve is too steep for farmers to learn/do all this."

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Overall, the thematic analysis highlights a complex web of trust issues that need to be addressed to foster a more supportive environment for farm digitalisation. Building stronger, more transparent relationships between farmers and stakeholders is essential to overcome these barriers and realize the full potential of digital agriculture.

Time and Other Resources

The integration of digital technologies into agriculture introduces significant changes in the allocation of time and resources. Focus group discussions across various European countries reveal a spectrum of perceptions regarding these changes, highlighting key concerns about human resources, learning curves, technology obsolescence, and infrastructure requirements.

- New Human Resources Needed: Farm digitalisation often necessitates new skill sets, creating a demand for additional human resources. Farmers recognize the need to either develop these skills themselves or hire specialized personnel. One participant noted, "Bigger farms can hire specific people (masters) to do this data analysis and this technical work," emphasizing that larger farms might have the advantage of resources to invest in new human capital. This is in stark contrast to smaller farms, which might struggle with the additional financial burden. As another participant pointed out, “Digitizing it is to some extent a costly process for all parties to implement.” This sentiment underscores the financial and logistical challenges faced by farmers in acquiring the necessary human resources for digitalisation.
- The Learning Curve Theory Anxiety: The initial phase of adopting digital tools is often marked by a steep learning curve, leading to anxiety among farmers. This anxiety is driven by the significant time and effort required to become proficient with new technologies. One farmer expressed this concern, stating, "..., it is often a time and energy issue to … learn some new technology or digitalisation…” However, there is also an understanding that as proficiencies are gained, tasks will require less time and resources. This was echoed by another participant, who mentioned, “..., drones could be a new way to gather more data and knowledge,” indicating that over time, the efficiencies gained could outweigh the initial investment in learning.
- Obsolescence of Technology: A significant worry among farmers is the rapid obsolescence of digital technologies. Investing in new tools and systems is seen as a continuous financial drain, as technologies evolve and require regular updates or replacements. One participant highlighted this concern by saying, “If I buy one robot it will be … obsolete in 2-3 years, so it is an endless need for money…” This sentiment is further supported by another farmer’s observation, “Over the past year, the information technology has changed so much that what we do and what we have already seems terribly archaic,” illustrating the fast-paced nature of technological advancements.
- Infrastructure for Digitalisation: The necessary infrastructure for supporting digitalisation, such as reliable internet access and advanced machinery, is often lacking in rural areas. Farmers emphasize the importance of robust infrastructure to fully benefit from digital tools. One participant remarked, “We lack infrastructure to accommodate digitalisation,” underlining the gap between technological potential and practical implementation. Another farmer added, “And the fact that those systems don't connect with each other, that's just creates new problems, of course,” indicating that supportive policies and infrastructure development are crucial for successful digitalisation.
- Balancing Time Investment with Returns: Farmers are particularly concerned about the balance between the time invested in digitalisation and the returns it yields. One participant noted, “..., the farmer must be willing to spend another 20-30 minutes on every field to do these flights. I don’t know if that will be the case.” This highlights the hesitation to adopt practices perceived as time-consuming without clear, immediate benefits. Additionally, the concern that digital technologies might not significantly improve efficiency was expressed as, “They make it, they get the money and don't care how it works in real life afterwards. It's very common. Most of the time, that's what happens to us.”

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The thematic analysis of focus group discussions reveals a complex interplay of time and resource-related concerns in the digitalisation of agriculture. Farmers are apprehensive about the steep learning curves, the need for new human resources, the rapid obsolescence of technologies, and the inadequacy of current infrastructure. Addressing these issues through targeted support, training programs, and infrastructure development is essential to ease the transition and maximize the benefits of farm digitalisation. Building confidence in the long-term efficiency gains and ensuring that digital tools are accessible and user-friendly will be critical in fostering a positive perception among farmers.

Risk in Farm Digitalisation

The integration of digital technologies in agriculture presents various risks, as highlighted in discussions across European focus groups. These risks encompass economic, operational, and technological challenges that farmers must navigate. The insights reveal concerns about financial burdens, reliability, data security, and the practical application of digital tools.

- Economic Risks: One of the primary risks identified is the economic burden associated with digitalisation. The cost of implementing and maintaining digital tools can be prohibitively high, especially for smaller farms. A participant pointed out, "..., it is often a time and energy issue to … learn some new technology or digitalisation…". Another participant highlighted the ongoing costs, saying, "The costs will certainly come from maintaining any digital tool as it's designed as well, because it's not enough just to develop it. It needs to be kept up to date because all that information is up to date. So it really actively does its job well." This continuous investment can strain financial resources and impact the overall profitability of farms.
- Operational Risks: Operational risks include the challenges associated with integrating new technologies into existing farm practices. The complexity of digital systems and the potential for increased workload were noted by participants. One farmer expressed frustration, "And building this system is always so complicated that somewhere in the middle it requires more work to be done. If there's more data, that's cool, but everyone works more and even more than before, and the money doesn't increase." This indicates that instead of simplifying operations, digital tools might initially increase the burden on farmers, leading to resistance and skepticism about their efficacy.
- Technological Reliability and Obsolescence: The reliability of digital tools and the risk of rapid obsolescence are significant concerns. Farmers worry that investing in technology that quickly becomes outdated can lead to wasted resources. One participant shared, "Over the past year, the information technology has changed so much that what we do and what we have already seems terribly archaic." The fast-paced nature of technological advancements means that what is cutting-edge today can become obsolete tomorrow, creating a cycle of continuous investment without guaranteed long-term benefits.
- Data Security and Privacy Risks: Data security and privacy issues are also prominent concerns. The integration of digital tools often involves the collection and storage of large amounts of data, which can be vulnerable to breaches. A participant highlighted the ambiguity surrounding data use, stating, "The 'GDPR' issue is a big one. Not only because the farmer doesn't understand the 'data protection' issue and the right GDPR policy means additional costs for the farm." This concern about data security and the legal implications of data management can deter farmers from fully embracing digital tools.
- Practical Application and User Resistance: The practical application of digital tools and the potential for user resistance are additional risks. Farmers might find it challenging to adapt to new technologies, leading to underutilization or incorrect use. One participant noted, "Digitalisation is not just buying a sensor. They need maintenance. You need a team of people behind you." This emphasizes the need for ongoing support and training, which can be costly and time-consuming. Additionally, another participant mentioned, "Customers disappear when they realize they're being asked to order through an online store, that they can't just ask the farmer directly." This highlights the potential disconnect between digital tools and traditional practices, leading to customer dissatisfaction and reduced engagement.

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The thematic analysis of focus group discussions reveals a multifaceted landscape of risks associated with farm digitalisation. Economic burdens, operational complexities, technological reliability, data security, and practical application challenges are all significant concerns. Addressing these risks requires comprehensive strategies that include financial support, robust training programs, reliable technological solutions, and clear data management policies. By mitigating these risks, the transition to digital farming can be smoother and more beneficial for farmers, ultimately enhancing productivity and sustainability in the agricultural sector.

The New Farmer

The role of farmers is evolving due to the increasing digitalisation in agriculture, as discussed in various European focus groups. This transformation encompasses changes in daily activities, required skills, and forms of collaboration. Farmers express concerns about becoming detached from traditional farming practices, the necessity for new skills, and the potential obsolescence of traditional skills. Additionally, the emergence of new collaborative models is reshaping the agricultural landscape.

- Detachment from Traditional Farming: One of the prominent concerns is that farmers might become disconnected from the physical aspects of farming as they spend more time on digital tools. A participant expressed this sentiment, saying, “There’s fear that farmers are getting detached from the production process (spend more time in front of computer than field).” This shift towards digital management tools can lead to a perceived or actual detachment from the hands-on, tactile aspects of farming that many farmers value.
- New Vision for Farming: The digital revolution in agriculture is creating a new vision for farming, where technology plays a central role in enhancing efficiency and productivity. However, this vision is met with mixed feelings. While some farmers see the potential benefits, others are wary of the changes. One participant shared, “If the farmer wants to be open to visitors or users of the product, then over time there will be some kind of investment to arrange the farm in such a way as to accommodate guests.” This indicates a shift towards a more diversified and interactive farming model, integrating agritourism and direct consumer engagement.
- Skills Needed for Modern Farming: As digital tools become more prevalent, the skill set required for farming is expanding. Farmers need to be adept at using digital platforms, data analysis, and managing technological equipment. One participant highlighted this need, stating, “To manage all that, then comes logistics, training, specification, and design of new product development, because that is now, in five years there will be other sensors and other things.” The continuous evolution of technology means that farmers must be lifelong learners, constantly updating their skills to keep pace with new developments.
- Obsolescence of Traditional Skills: The focus on digital skills raises concerns about the potential obsolescence of traditional farming skills. A participant mentioned, “Really, for those who have cattle, I think it's easiest to maintain the meadow in good condition.” This statement reflects the importance of traditional knowledge in specific farming contexts, suggesting that while digital skills are essential, traditional skills still hold significant value and should not be overlooked. In the question “Do you think that digital can make you lose knowledge, skills? A farmer answered: Yes, That’s for sure.” Balancing the new and old is crucial to maintain the richness of agricultural expertise.
- New Forms of Collaboration: Digitalisation is also fostering new forms of collaboration among farmers. The ability to share data, access collective resources, and collaborate on digital platforms is reshaping how farmers interact and support each other. One participant noted, “There is no single system for all projects where cooperation is possible, and not just to build another one of the same.” This highlights the need for integrated systems that facilitate collaboration rather than creating isolated digital silos. The shift towards more collaborative models can lead to shared learning, resource optimization, and collective problem-solving.

The thematic analysis of focus group discussions reveals a complex transformation in the role of farmers. The new farmer is expected to navigate the balance between digital and traditional skills, embrace a broader vision of farming that includes direct consumer interaction and agritourism, and engage in new forms of collaboration. While there are

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concerns about detachment from traditional farming practices and the obsolescence of traditional skills, there is also a recognition of the potential benefits of digital tools. Addressing these concerns requires a holistic approach that values both new and traditional skills, fosters continuous learning, and promotes collaborative models to enhance the overall resilience and sustainability of the agricultural sector.

Energy

Energy consumption and management are critical aspects of modern agriculture, as highlighted in various European focus groups. The integration of digital tools and technologies has brought new challenges and opportunities for energy efficiency and sustainability. The discussions revolve around the increased energy demands of digitalisation, the cost implications, and the potential benefits of renewable energy sources.

- Increased Energy Demands: The digitalisation of agriculture has led to higher energy consumption, primarily due to the operation of digital tools, sensors, and data centres. One participant noted, "Maybe just a counter aspect that we always overlook. Digitization itself is a huge energy consumer and efforts should be made in the efficient use of the tools and devices. We use cloud services that is not in the cloud, it is a server that consumes a huge amount of energy. We should think about this." This statement underscores the significant energy requirements of digital infrastructure and the need for strategies to manage and reduce this consumption effectively.
- Cost Implications: The increased energy demands translate into higher operational costs for farmers. The cost of energy is a recurring concern in the focus group discussions. A participant remarked, "The cost of energy is increasing." This reflects the financial burden that farmers face due to rising energy prices, which can impact the overall profitability of their operations. Additionally, the maintenance and operation of digital tools further add to these costs. As another participant pointed out, "The costs will certainly come from maintaining any digital tool as it's designed as well, because it's not enough just to develop it. It needs to be kept up to date because all that information is up to date. So it really actively does its job well."
- Benefits of Renewable Energy Sources: Despite the challenges, there is a growing interest in renewable energy sources to mitigate the energy costs and promote sustainability. Renewable energy technologies, such as solar panels and wind turbines, are seen as viable solutions to reduce reliance on conventional energy sources and lower operational costs in the long run. One participant suggested, "Now during the winter, when daylight lasts for 8 hours, the whole area (in Netherlands) under greenhouses shines. Why it shines? You have to increase light from 8 hours to 15 or 16 hours per day." This indicates a potential area where renewable energy could play a crucial role in meeting the extended lighting needs without significantly increasing energy costs.
- Energy Efficiency Measures: Participants also discussed various energy efficiency measures that could be implemented to optimize energy use in farming operations. The use of energy-efficient equipment and the adoption of smart energy management systems were highlighted as important strategies. One participant mentioned, "For mass digitalisation this needs to have affordable (cheap), not just the devices, but to be affordable to deploy it." This suggests that making energy-efficient technologies accessible and affordable is essential for widespread adoption and effectiveness.
- Integration with Digital Tools: The integration of energy management with digital tools and sensors offers opportunities for more precise and efficient energy use. By leveraging data and analytics, farmers can monitor and optimize their energy consumption patterns. A participant shared, "You would need large amounts of data, we've already mentioned that each manufacturer has their own data formats. There is also the problem of direct access to that data." This highlights the importance of data integration and accessibility in managing energy use effectively.

The focus group discussions on energy in agriculture reveal a nuanced understanding of the challenges and opportunities associated with digitalisation. While increased energy consumption and rising costs are significant concerns, there is a clear recognition of the potential benefits of renewable energy sources and energy efficiency measures. The integration of energy management with digital tools and sensors presents a promising avenue for optimizing energy use. Addressing the energy demands of modern agriculture requires a holistic approach that

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combines technology, sustainability, and cost-efficiency to ensure the long-term viability and environmental responsibility of farming operations.

Property Rights in Farm Digitalisation

Thematic 2 centres on the concerns of focus group participants, particularly farmers, about the way costs and benefits are equitably distributed among all involved actors. These concerns can be conveniently summarized into the three basic questions asked by organizational economists when diagnosing any type of organization (e.g., Iliopoulos and Cook, 2023); Who owns? Who controls (but, also, who has access)? Who benefits?

Farm digitalisation encompasses the use of digital technologies in agricultural practices to enhance productivity, efficiency, and sustainability. However, the adoption of these technologies raises significant questions about property rights, including ownership, control, benefits, and access. Below, we delve into each aspect based on the identified codes.

Who Pays, Who Controls, Who Benefits Most?

Who Pays?

The question of who pays for digital technologies in farming is crucial. Typically, the financial burden can fall on individual farmers, co-operatives, or the state. When farmers invest in these technologies, they may gain control over their usage and data. However, if external entities such as tech companies or governments subsidize these technologies, they might retain some level of control or access to the data generated. For example, a technology provider in the Belgian focus group said, "…where is the place of the farmer in this 'drone-story'?" This constitutes a major concern of farmers that participated in the focus group meetings across Europe.

Payment for digitalisation can come from various sources, including:

- **Farmers**: Direct investment in technology and infrastructure. A farmer from the Czech Republic believes that "… in the end us-the producers-will pay for it". A Slovenian farmer suggests that "Technology will help, but anything technological can be a financial burden to a farm. If a farm can't afford the technology, there will be no contribution".
- **Farmers' Investment**: Farmers who invest their own resources might control the data and decision-making processes, but they also bear the financial risks. The lack of risk capital, particularly by owners of smaller farms is perceived as a constraint that might lead to less or no control of the digital technologies but, also, of the collected data.
  A business advisor from Slovenia suggests that, "Logically, it is the farmer or the user who will have to give money to get this solution". This is line with the argument of a farmer from Latvia, who said that "I feel it will be quite expensive [for the farmer]".
- **Government Grants/Subsidies**: Public funds allocated to support digital transformation in agriculture. A farmer from the Czech Republic argues that "…the state should bear the costs". Another farmer in the same group, however, argues that "… we will do it with or without the state". A little later, however, the same farmer comes back saying that "It is simply unthinkable that a small orchard, basically, without some intensive efforts of the state [will adopt digital technologies]". A policy maker from the Serbian focus group suggests that in her country, "… part of the expenses will be covered by farmers and another half by subsidies".
- **Private Sector**: Investments from agribusinesses and tech companies looking to integrate digital solutions in their supply chains. Farmers assume that private sector companies will pass at least part of their costs onto producers or the government. A technical product manager from the Serbian focus group provides an illustrative argument on why this will happen: "So you over there pay that services like … storage of data, consulting … so the hardware is the least costly. You get it [hardware] per affordable price as he [tech provider] want to bind you to himself, and then earn on you through the service".

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- **External Funding**: When external entities provide funding, there can be strings attached. For example, tech companies may require data-sharing agreements, or governments might impose regulations on technology use. This is yet another fear expressed by focus group participants in many living labs.

The source of funding can influence control and ownership, impacting overall adoption and success.

- **Ownership**: Farmers fear that the ultimate ownership of farm digitalisation technologies lie in the hands of technology providers or farm supply companies. One farmer from France fears that "… we're moving too fast. We're maybe not ready yet, but maybe we're not quite ready to take ownership".

Who is Responsible for Losses?

Responsibility for losses incurred from digitalisation is another complex issue. Losses can arise from technology failures, cybersecurity breaches, or mismanagement of digital tools.

- **Individual Farmers**: If farmers bear the cost of technology, they are often responsible for any losses, which can be a significant burden. This fear seems to act as a constraint to adopting some of the digital technologies in certain living labs of CODECS. As a farmer from a French focus group meeting said, "…we tend to rely on those things. And the problem is that the day it doesn't work. We're a bit in trouble".
- **Insurance and State Support**: Focus group participants think that some losses might be mitigated through insurance schemes or state support, emphasizing the need for policies that protect farmers from unforeseen digital risks. Some participants are somewhat pessimistic, like a Czech farmer who stated that, "…only 30% of those farmers [will adopt digitalisation] and 70% of orchards will disappear". The same farmer, however, in a different sentiment, argued that "…we will do it either with or without the state". Overall farmers, policy makers, farmer advisors and technology providers, tend to favour state subsidies: "Given the high costs of digitalisation, subsidies are necessary" (focus group Greece).

Who Benefits?

The benefits of farm digitalisation can vary depending on the stakeholders involved. The distribution of costs and benefits is a major concern for farmers, as expressed in the following statement of the representative of a producer group from Spain:

"At the end of the day, it has repercussions depending on who makes the investment or who takes the final data. In the end, a university, with a project wants to benefit that farmer. The farmer will want that project to benefit and have productivity, the farmer's co-operative to manage its prices and sell better, and a private company or a third-party company will want it to advertise its products. Then, the focus on the farmer´s benefit will be lost. For those applications to derive them to other sectors with things like the European Union wanting to have more controls, right? In other words, I think that the initial purpose could be badly diversified, and that could be a problem for tomorrow".

Generally, the primary beneficiaries include:

- **Farmers**: Increased efficiency, better yield predictions, and optimized resource use can lead to higher profitability. A farmer from the Belgian focus group suggests that "…the ideal scenario would be that the compensation of digitalisation will come from labour and input savings". Some farmers do not believe that farm digitalisation will work for smaller farms. For example, on farmer from the Czech Republic argues that "[smaller producers] if they were to sit here, they would look at you like aliens". The expected benefits are perceived as rather vague even for experts. For example, a soil lab representative from Germany thinks that "…, but I think that as long as you still have to rent it, as has been said, …, especially if the soil type is a bit strange, I don't think it's the right solution yet". A Belgian employee of a farm supplies company suggests that "If there will come legal obligations, but the farmer don't see additional value in the use of drones, they will indeed get the idea 'all my data is getting requested'".
- **Consumers**: Enhanced traceability and food safety due to better monitoring and data tracking. Lack of participants from this stakeholder group does not allow us to depict their perceptions of benefits associated with farm digitalisation. An NGO from Hungary, however, suggests that "In the long term, this can be a win-win situation for producers, processors, and consumers alike". A co-operative merchant from Latvia, having in mind the specific farm digitalisation technology in her living lab, is a bit sceptic: "Customers disappear

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when they realize they're being asked to order through an online store, that they can't ask the farmer directly".

- **Tech Companies**: Providers of digital solutions benefit from the sale and continuous service of their products. As expected, they are in favour of farm digitalisation, arguing that the benefits outweigh the costs. However, they are reluctant to explain what percentage of benefits accrues to farmers, consumers, and technology providers. This is derived from the lack of comments or arguments when the discussion in the focus group centred on this issue.

The distribution of benefits can be uneven, often favouring those with better access to capital and digital literacy. Depending on the technology adopted in each living lab, farmers express their concerns about themselves or other farmers in their community who fear that they will be driven out of farming because they own farms of small size. Another key concern is that farmers will bear most of the costs associated with developing and adopting farm digitalisation technologies. For example, a farmer from Hungary is rather pessimistic. She believes that "As with everything, the farmer will bear the cost". A policy maker in the same focus group meeting agrees with the aforementioned farmer:

"It is not the farmer who has to bear the cost of the tool, because they cannot read much from the output. Rather, the farmer's investment will be in the service of that service, which will be an input cost. He will have to pay this cost in any case".

Collaboration/Cooperation for Access to Funding and Joint Benefits

Collaborative approaches can help mitigate financial burdens and enhance access to digital tools. Co-operative models can be particularly effective in:

- **Pooling Resources**: Farmers can pool financial resources to invest in shared technologies. As suggested by a consortium member in one of the Italian living labs, "We could finance access to the App for consortium members". A Slovakian farmer argues that "However, we often reach stagnation in the control of individual digital production units. The individual units do not relate to each other and do not cooperate with each other. This causes some of the digital means of production to be wasted". So, collaborative solutions may indeed be required in order to address the issue of unbearable investment for individual farmers.
- **Collective Bargaining**: Groups can negotiate better terms with tech providers and influence policy decisions. This issue was broad up in the discussions within a Latvian and one of the Italian focus groups. For example, a farmer from Latvia insisted that "… united we can push policy makers to design digitalisation-support programs that do not exclude small farms".
- **Shared Resources and Knowledge Exchange**: Access to shared digital platforms and technologies, and enhanced opportunities for learning and innovation. Collaboration and formal cooperation schemes are expected by focus group participants to facilitate investment in shared digital platforms and technologies, but also facilitate knowledge exchange among supply chain participants. A farmer from Poland argues that farm digitalisation technologies will "…help us solve a number of problems related to production, logistics and sales processes that require us cooperate more effectively with one another and with our customers". A North Macedonian farmer seems to agree to this statement, since she believes that "[Farm digitalisation will lead to] …increased co-operative processing and sharing of experiences". A French pig farmer, however, suggests that "… the problem is really listening to each link of the chain … I think there should be more moments where we can listen to each other".

However, focus group participants, particularly in Eastern European countries, pointed out that there is a considerable lack of co-operation efforts in this field.

Information for Decision Making

Access to accurate and timely information is vital for decision-making in digitalized farming. This includes:

- **Data Ownership**: Farmers need clear rights to the data generated on their farms to make informed decisions. This seems to be a major concern of farmers. Data ownership and usage is also related to trust among participants in the farm digitalisation process. For example, a farmer from the Czech focus group

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fears that “Maybe in the future I think that the security of that data and those systems could be a problem”. The same issue is touched upon by a farmer from one of the French focus groups: “…risk of data security, hacking, so farmers would be more exposed”. Another aspect of the same issue is addressed by a Latvian co-operative merchant representative: “Again, I thought about the reliability of the data. The more the requirements are, the heavier they will be, then how reliable data will the farmer enter? Won't it sometimes just be writing to submit something, so that at the peak it takes me less time and so that I am less controlled after that?” A Scottish policy maker, also agrees: “The resilience of the systems as well as cybersecurity, you know, that's going to be up there as a concern if you're capturing all of your information online or doing transactions online.” As does a Slovakian farmer: “The ethical issues of data sharing are a big topic. And there is a real risk of misuse of data and technology.” And a Slovenian business advisor talks about “data overload”.

- **Transparency**: Transparent data practices ensure trust and reliability in the information used for farming decisions. A farm advisor from Slovakia argues that: *“The GDPR issue is a big one. Not only because the farmer does not understand the ‘data protection’ issue and the right GDPR policy means additional costs for the farm. The large amount of digital data available, but also the various case, have made it so that you don't know what can be done with the data legally and who … has access to your data”.*

Use of Public Money

Public investment in farm digitalisation can democratize access to technology and ensure broader benefits. However, the use of public money should be carefully monitored to ensure:

- **Equitable Distribution**: Funds should be distributed to benefit a wide range of farmers, including smallholders. Technology providers also expressed the need for state support, particularly for technologies at the infant stage of development, when the risks are high and a return to investment is far from secured. A Belgian farm advisor thinks that “…the integration of drones/digitalisation in general on farms will have to come from the effective capital gains that farmer can realize on their farms, because the consumer and society won’t pay for it.” A Czech farmer suggests that “…they won’t pay, the small businesses can’t pay for it, it (the cost) will not dissolve in such a volume of production”. A Serbian technical product manager talks about the high costs of farm digitalisation that farmers cannot bear alone: “if we want for this (LL) come to life in a bigger scale, it would be beneficial that state gives subsidies (for digitalisation) as it gives for some other means in agricultural sector. If we perceive like this, the state (Serbia) should cover part of the costs. Of course, farmers themselves should cover part of it”.

- **Accountability**: Transparent processes should be in place to track the impact and effectiveness of public investments. A policy maker from the Czech focus group suggests that “I think that now there is a limited budget, so it is probably necessary for the state to create a clear strategy about what it will support, because the funds are limited—to set priorities…” A French farmer complains about the sellers of farm digitalisation technologies and equipment: “They are very good at coming to sell. … They can come quite a few times for a breakdown. But after that, it stops there.” The lack of accountability is also associated with the trust between technology providers and farmers. For example, a consultant from Latvia argues that “I somehow get the feeling that we are starting to move in the direction where we are only digit[al]ising for the sake of digit[al]isation, and not because it is a meaningful measure so that farmers can further use this data on their practical farm and be able to change things based on the data.”

State Support

Government support is critical in facilitating the digital transformation of agriculture. This can include:

- **Subsidies and Grants**: Financial support to lower the barrier to entry for digital technologies. An employee of a farm supplies company from Belgium believes that “… in the short term, if those savings are not already the case, I see a role for the government through subsidies to compensate for this rather than start paying it on to consumers”.

- **Training and Education**: Programs to enhance digital literacy among farmers. A drone pilot from Belgium suggests that students are not trained on the basics of farm digitalisation: “Students should get the basics [of farm] digitalisation in bachelor’s education [but they don’t]”. And a researcher/policy advisor from the

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same focus group meeting goes even further by stating that “These courses are even missing from master[‘s] education”. A pig farmer from France also agrees: “And there is the problem of training… There is no training”. Also important is the lack of knowledgeable consultants in Greece, as agreed upon by all participants in the corresponding focus group: “In Greece there is a lack of consultants in the agricultural sector and especially with smart farming background”. In the Slovenian focus group, the issue was also identified: “Not enough professional staff to be able to use the data”. The same issue is identified by the representative of a Hungarian NGO: “…, too much data is difficult to process, so we need skilled and knowledgeable professionals who can provide useful advice to farmers once the results have been processed.” A North Macedonian sustainability leader agrees: “We need more digital literacy”. In Slovakia, however, “…there is a lack of modern Agriculture 4.0 programmes offered by a single university”.

A bottom-up approach to farm digitalisation is deemed to be a prerequisite for the widespread use of technologies: “Farmers are not trained to understand the different file formats of digit[al]isation, the maps, the incoming data, why it is important to have digital farm data. So, digit[al]isation has been imposed on farms over the last 10 years” (Policy Maker, Hungary).

A policy maker from Hungary taps on her experience to claim that “Farmers are not trained to understand the different file formats of digitisation, the maps, the incoming data, why it is important to have digital farm data. So digitisation has been imposed on farms over the last 10 years.” And later on, she insists that “…everyone up to the level of machine operator has to be trained”.

The issue of older farmers not being able or willing to learn new things, including the acquisition of knowledge on farm digitalisation technologies has surfaced in several countries. For example, a Latvian farmer argues that “Also in Latvia we mostly have older farmers. That's the problem. There are not so many pioneers. We, those elders, are confronted with lack of knowledge - how to use all these systems? This is the biggest problem - how to use them? Should work on that. That's the biggest problem”.

- **Regulatory Frameworks**: Policies to support the development and application of farm digitalisation technologies, protect data privacy and ensure fair competition in the digital agriculture market.

A soil expert and farm advisor from Hungary suggests that “…governmental support, subsidy programs, or involvement in community development projects may lead to the state or other organizations sharing the costs, especially if the technology brings long-term benefits to society, such as environmental protection or social development. Sustainable agriculture has to be a priority for the whole society”. A policy maker from the same focus group also agrees: “Successful digitalisation requires … the right regulatory environment”. However, the participants in one of the Latvian focus groups agree that “Increased vigilance of the authorities to insist on rigid reforms or maintenance regimes”. Others, like a consultant from Spain, declare ignorance about important aspects of the regulatory framework: “The regulatory issue of artificial intelligence within all these systems, where it’s going, I don't know”.

A co-operative representative from the Polish focus group thinks that other countries, outside the EU have addressed the issues associated with regulation in a more efficient way: “Countries such as Australia, and some of the states within Australia, they have invested substantially in your provision of grant support to allow farmers to define, and importantly, adopt digital tools, technology even linked the two”.

Implementing an efficient and just regulatory framework for farm digitalisation is also seen as an incentive to farmers to adopt digitalisation technologies: “From the point of view of the government, it is very important to establish the system where it can be tracked what was the impact of digitalisation. If digitalisation is not done in structural way, it will be hard to point out its benefits. On one side farmers will not be willing to implement it, on the other side government will not be willing to give subsidies” (Policy Maker, Serbia).

However, grant schemes may also distort investment incentives, as they sometimes might lead to adoption of technologies that do not create significant benefits for the farmers. For example, a Slovenian farmer argues that “If there is grant funding available, there is little room for thinking if you would or would not. If it is your own investment, then you must see a little more benefit in the long term. However, when it is a project, and as long as there are still grants available, especially for projects such as climate adaptation, I think it is important to make the most of it”.

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The issue of security resurfaced in most focus group meetings. For example, participants in one of the Latvian living labs stated their concerns: “Publicly available current maps could provide fishers and hunters with up-to-date information to aid their activities, but this could also include illegal activities, and this was of concern to the farmers, so also a security issue.”

Who Controls?

Control over digital technologies and data is a central issue. It involves:

- **Ownership of Technology**: Farmers vs. external entities (tech companies, governments). A policy advisor from Belgium suggests that “We can’t minimize the role of the farmer [in digitalisation]”, and that “You can put that decision in the hands of the farmer”. She also suggests that “Bigger farms can hire specific people (masters) to do this data analysis and this technical work”.
- **Data Governance**: Clear rules on who owns and controls the data generated on farms. A farm advisor from Belgium mentioned that “There is already a lot of data available, and you don't know who is doing what with the data and there is a lot of fear among farmers about exposing their expertise and knowledge.”
- **Autonomy**: Ensuring that farmers retain autonomy over their farming practices and decisions. A farmer from one of the French living labs is clear about his preferences when he states that “I like to have full control over the monitoring”.

Who Has Access?

Access to digital technologies and the benefits they offer should be inclusive. This involves:

- **Bridging the Digital Divide**: Ensuring that small-scale farmers and those in remote areas have access to digital tools. A researcher/policy advisor from Belgium suggests that “The technology can do a lot, but it’s not accessible to farmers”.
- **Inclusive Policies**: Policies that support access for all farmers, regardless of size or location. This represents a major concern, particularly for smaller farms. The participants in the Greek focus group argue that “The investment in digital technologies could be a significant barrier for small and medium sized farmers”. A researcher from North Macedonia views the costs of state-supported training and education of young people on farm digitalisation as a social cost that the society should cover: “Social costs would also focus on educating and training young people and existing farmers to implement digital technologies on their farms.”

However, a policy maker from Scotland raises a serious concern about “Digital exclusion, and on what scale could that potentially happen”.

The thematic of property rights in farm digitalisation encompasses a wide range of issues, from financial responsibilities and benefits to control and access. Addressing these issues requires a collaborative approach involving farmers, tech companies, governments, and other stakeholders. Clear policies and frameworks are essential to ensure that the benefits of digitalisation are distributed equitably and that farmers retain control over their data and farming practices. Cooperation and transparency are key to building a sustainable and inclusive digital agriculture ecosystem.

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2.4.2 Perceptions of the Benefits of Farm Digitalisation

Regarding the perception of **benefits** of farm digitalisation, several sources of concerns have been identified and are listed in Table 2.

Table 2: Thematic concerns of the perception of benefits of farm digitalisation

Thematic concern	Sub thematic
TIme	• Data driven Decision-Making • Efficiency gains • Enhanced planning and management with real-time data
New Business Models	• Enhanced Decision Making and Management • Sustainability and Security • Efficiency and Simplification • Competitivity and Productivity
Good To Be a Digital Farmer	• Professional Attraction and Sense of Belonging • Visualisation and Transparency • Administrative Efficiency and Speed • Inclusivity and Cooperation • Healthier Production and Sustainability

Thematic 1: Time

1. **Data-Driven Decision-Making**
    - **Description:** Utilizing data analytics and insights to make informed decisions quickly, leading to improved farm management and productivity.

The focus group discussions conducted across various European countries highlight how digitalisation in agriculture significantly enhances data-driven decision-making processes. Participants emphasized that utilizing data analytics and real-time information allows farmers and agricultural professionals to make informed decisions more quickly and efficiently, leading to improved farm management and productivity.

In France, equipment manufacturers and farmers underscored the importance of data in facilitating the rapid and efficient transmission of information. One equipment manufacturer noted that digital tools “help in quickly and efficiently transmitting information,” while a farmer appreciated the “reliable data” that aids in timely decision-making. A digital advisor added that data-driven insights could “aid in decision-making, better manage their forage, and thus save on farm inputs,” emphasizing the potential for cost reduction through improved resource management.

Germany's focus group participants highlighted the ability to integrate large volumes of data into practical decision-making tools. A soil lab representative observed that “a new Excel is created every time, and you can probably combine it all with three clicks,” illustrating the ease of data integration. Additionally, a vocational teacher explained how AI could process raw data to “answer a wide range of questions within a very short space of time,” enabling farmers to uncover insights that might otherwise go unnoticed and thereby streamline the decision-making process.

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The potential for cost savings is particularly evident in Greece and Hungary, where participants emphasized the precise application of inputs like water, fertilizers, and pesticides. An unidentified participant in Greece noted that "precise application of inputs based on data in real-time can lead to cost savings," highlighting the financial and environmental benefits. In Hungary, a farmer mentioned that "economic indicators can be tracked more clearly digitally, so decisions can be made faster," while a soil expert emphasized the expectation for "economic efficiency, better access to information, data-based decisions, and fast user-friendly services" from digitalisation.

In Italy, a collaborator in the feed industry described how digitalisation could speed up traditionally time-consuming tasks. The collaborator explained that building an archive for customized feed production is "a time-consuming job that keeps him and the farmer busy for a whole day," but a proposed app could facilitate data transfer, significantly reducing the time required for these activities and enhancing efficiency.

The advantages of digitalisation are further supported by participants from Latvia and North Macedonia, who recognized the benefits of real-time information for planning and implementation. A Latvian participant highlighted how digital tools "help to speed up planning for the year and in the long-term," reducing the need for labour-intensive information gathering. A researcher from North Macedonia stressed that "real-time information is an essential aspect of successfully implementing RAMAS," underscoring the critical role of timely data in agricultural management systems.

Finally, Spain's focus group participants emphasized the added value of interoperability within data systems. A farm advisor noted that "anything that can be connected to the data is going to be advantageous for the system," explaining how integrated data solutions could provide comprehensive recommendations and management guidelines. Additionally, a producer organization representative illustrated how data could balance crop production and prices: "We have, imagine, 2000 hectares of tomato, we do not need 1000 hectares of tomato…this can also be managed a little bit with data," ensuring profitability and reducing reliance on chance.

Overall, the focus group discussions underscore the transformative potential of digital tools in agriculture. By enabling faster, more informed decision-making, data-driven approaches empower farmers and agricultural professionals to optimize their operations, reduce costs, and enhance productivity across diverse European contexts.

Thematic 2: New Business Models

1. **Enhanced Decision-Making and Management**
    - **Description:** Leveraging digital tools for better decision-making and efficient management of farms, including crop planning and resource allocation.

The focus group discussions across various European countries illustrate how digitalisation is revolutionizing decision-making and management in farming, offering significant advantages in crop planning and resource allocation. Participants consistently highlighted how leveraging digital tools not only enhances precision and efficiency but also supports the development of new business models in agriculture.

In Belgium, a technology provider emphasized the value of data in enhancing decision-making capabilities: "It's the amount of data that provides the wealth to the farmer to start improving his sensing models in the future." This sentiment captures the transformative potential of data-driven agriculture, where access to comprehensive datasets enables farmers to refine their operations and improve future outcomes.

The discussions in France reveal both optimism and caution regarding digital tools. While a pig farmer from France noted that digitalisation is "supposed to ease the current tasks and help move towards better management of farming operations," there is still scepticism about the readiness of current technology. This is reflected in another farmer's comment: "I'm not sure we would do it [today]. Because today, I don't know if all the data analysis technology is ready enough." Despite these concerns, the potential for increased profitability through improved management remains a strong motivator, as a cultivation supervisor remarked: "If today we can invest in more efficient systems, it's because behind it, there's either profitability or a real concrete profitability goal."

In Greece, an unidentified participant underscored the economic benefits of digitalisation, stating, "It directly impacts the economic benefit of each producer." Similarly, a policy maker in Hungary pointed out the environmental

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advantages, explaining that “by being able to provide instant data, the scanner will save input material, thus reducing the environmental impact.”

The focus groups in Italy and Latvia emphasized the efficiency gains from digital tools. An ICT provider in Italy highlighted the benefits of “better time management and improved efficiency,” while a collaborator noted that digital tools could speed up the “time-consuming job” of building archives for customized feed production. A public administrator in Latvia echoed this by stating, “it’s a faster flow of information,” underscoring the role of digital tools in streamlining operations.

In North Macedonia and Serbia, the focus was on precision in management practices. A farm advisor in North Macedonia emphasized the importance of “decision support in crop management, fertilization, and protection models,” while a Serbian farmer highlighted how sensor technology allows for precise control: “The production that relies on sensors will demand my action when it is needed and in the duration that it is needed.”

Slovakia's participants discussed the role of IoT technologies in enhancing resource management. A technology provider noted that “automated irrigation systems are programmed based on this data, enabling accurate and efficient irrigation in real time without human intervention.” This precise application of technology helps optimize conditions for crop growth and streamline water use, as a researcher elaborated: “In combination, these technologies can help farmers improve the management of the supplemental irrigation process.”

In Slovenia, the focus group participants highlighted the dual benefits of environmental protection and cost savings. A technology developer explained, “If you have information on when you don’t need to use these pesticides, you save money on pesticides that you would otherwise spray.” This approach not only reduces costs but also minimizes the environmental impact, allowing farmers to make more informed decisions about their operations.

Finally, in Spain, discussions centred on the autonomy and self-reliance that digital tools provide. An advisor noted that with access to real-time data, farmers “can make decisions about our own, in this case, greenhouse. Without having to see what the neighbour is doing or what someone else is doing.” This self-sufficiency is further enhanced by the ability to control various environmental factors, as another advisor explained: “If I can control the water that my crop needs, I can manage well if I have salinity problems in my soil. If I don’t have salinity problems, my plant is less stressed. If it attacks less, I have to treat it less.”

Overall, the focus group discussions reveal that digitalisation offers farmers a suite of tools to enhance decision-making and management. By improving efficiency, reducing costs, and supporting environmental sustainability, digital tools are shaping new business models that empower farmers across Europe to optimize their operations and adapt to future challenges.

2. **Sustainability and Security**

    - **Description:** Implementing sustainable practices and ensuring security against market and environmental fluctuations through digital innovations.

In the Czech Republic, the focus group discussions revealed a strong belief in the synergy between ecological practices and economic benefits through digitalisation. Participants highlighted how sustainable farming practices not only protect the environment but also reduce costs. One expert succinctly stated, “What is ecological is also economic and vice versa,” emphasizing the dual advantages of adopting digital tools. This perspective was reinforced by an association representative who pointed out that combining cost savings with environmental protection by reducing fertilizer and chemical usage leads to fewer negative inputs. The consensus was clear: digital innovations enable farmers to achieve ecological goals while enhancing their economic viability.

French farmers are keenly aware of the potential for digital tools to enhance precision in farming, particularly in terms of environmental impact. A farmer noted the importance of applying fertilizer “in the right place and in the right dose,” highlighting how precision agriculture can significantly minimize environmental harm. However, there are concerns about the true extent of environmental benefits, as one cultivation supervisor expressed scepticism that increased efficiency would necessarily translate into reduced environmental effects. Despite these reservations, the drive to optimize resource use and rationalize treatments remains strong among French farmers, who see digital tools as essential for achieving sustainability goals.

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In Germany, participants were optimistic about the role of digital tools in promoting sustainability. The focus groups highlighted that "most of the positive aspects are in the areas of sustainability," according to a soil lab representative. This optimistic view is driven by the belief that farmers are more likely to adopt digital innovations when they realize they are contributing positively to the environment. The discussions underscored the importance of optimizing nutrient use and achieving environmental objectives through advanced digital technologies, which participants believe can lead to more sustainable agricultural practices.

Hungarian farmers emphasized the dual benefits of digitalisation in enhancing farm security and sustainability. An agricultural advisor highlighted that digital tools enable farmers to generate more income and maintain stability, even amidst market fluctuations. A soil expert noted that soil scanner technology contributes to environmental sustainability by optimizing fertilizer use and minimizing environmental impact. Furthermore, policy makers emphasized that digital innovations could lead to long-term sustainable soil conditions, decreased fuel consumption, and increased yields. The focus groups in Hungary underscored the transformative potential of digital technologies in achieving both economic and environmental security.

In Italy, the focus was on the role of digitalisation in reducing risks and maximizing economic benefits. A professional noted that better control of the sanitary situation of livestock through digital tools could reduce the risks of antibiotic resistance. This leads to more judicious use of medicines and healthier herds. Additionally, participants emphasized that "economic benefits are the most important," with digital technologies playing a critical role in optimizing cost structures and enhancing productivity. The Italian focus groups highlighted how digital tools can drive economic success while also contributing to broader sustainability goals.

In Serbia, participants discussed the significant role of digital tools in advancing sustainable production practices. A researcher highlighted the critical importance of soil sensors in monitoring soil and plant conditions. An advisor expressed confidence that digitalisation would "increase the production as well as stability of production," reflecting the belief that digital tools can enhance both productivity and sustainability. Additionally, the discussions touched on the transition to more controlled production systems, which could represent a major step forward in sustainable agricultural development over the next few years.

In Slovenia, the focus groups explored how digitalisation can help preserve local heritage while enhancing farm management. A researcher emphasized the importance of preserving cultural values alongside technological advancements. Policy makers highlighted the predictive capabilities of artificial intelligence, which can help farmers prepare for future challenges. The integration of digital tools allows farmers to control their cost structures efficiently, reaching precise measurements for various tasks. This, according to an advisor, embodies the essence of sustainability, enabling Slovenian farmers to balance traditional practices with modern innovations.

Spanish farmers are leveraging digital tools to achieve precision in resource management, particularly in water and fertilizer use. An advisor explained how digital tools enable efficient control of cost structures by providing precise data on resources like water, nitrogen, and fertilizers. This precision helps avoid excessive inputs, which can lead to pest and disease outbreaks. A consultant noted that managing these aspects effectively contributes to both environmental sustainability and economic success. The Spanish focus groups underscored the critical role of digital innovations in optimizing agricultural practices for better sustainability outcomes.

3. **Efficiency and Simplification**

    - **Description:** Streamlining operations, reducing input costs, and simplifying farming processes through automation and precision technologies.

Across Europe, farmers and agricultural stakeholders are embracing digitalisation as a transformative force reshaping the landscape of agriculture. Through innovative technologies, they are not only streamlining operations but also unlocking new business models that promise enhanced efficiency and simplicity. Here's how different countries are experiencing and interpreting these changes:

In Belgium, the ease of adopting digital tools like drones is opening new avenues for farm management. A technology provider emphasized that "it's pretty easy to learn to fly with a drone," highlighting the accessibility of technology. This ease of use is crucial for farmers who are looking to integrate digital tools into their operations with minimal disruption, allowing them to quickly leverage data for better decision-making and resource management.

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In France, the focus is on simplification and efficiency. A pig farmer shared insights about the transformative impact of digital tools, stating, “the main change with the technology will be simplification.” This simplification translates to significant cost savings, with some farmers reporting “we saved 90 euros per day over 3000 days of milking. That gave us 27,000 euros per year,” after investing in digital technologies. Despite some concerns about complexity, as one farmer remarked, “but it’s very complicated,” the overall sentiment is that these technologies eliminate manual tasks and enhance precision, ultimately making farm operations more efficient and comfortable.

A veterinarian added, “it should eliminate manual tasks, which are often left undone due to a lack of time,” underscoring how digital tools are freeing up valuable time for farmers to focus on core tasks.

German farmers and stakeholders are particularly enthusiastic about the cost-saving potential of digitalisation. A soil lab representative noted that “we would have less personnel costs, which would of course also be cheaper for the customer,” illustrating the economic benefits of automation. This reduction in costs is paired with logistical benefits, making operations smoother and more efficient. As noted, “logistically it’s definitely a plus,” digital tools are optimizing resource use and streamlining farm operations.

In Greece, digital tools are revolutionizing resource management, particularly water use. By targeting specific areas with precise irrigation, farmers can “minimize wastage,” as noted by a participant. This targeted approach not only conserves resources but also enhances productivity, illustrating how digitalisation is fostering more sustainable farming practices that align with modern environmental goals.

Another participant highlighted, “instead of applying water across the entire field, they can target specific areas with water needs,” emphasizing the precision and efficiency digital tools bring to resource management.

Hungarian farmers are leveraging digitalisation to optimize input use and increase efficiency. A farmer highlighted the potential of soil scanners to replace traditional laboratory testing, stating, “…the scanner can be used to replace laboratory soil testing and speed up the delivery of results.” By isolating areas of poor soil fertility, farmers can avoid unnecessary applications of nutrients, ultimately saving on input costs.

An agricultural advisor pointed out, “this will have the effect of reducing the use of input materials,” emphasizing how digitalisation directly contributes to cost savings. Additionally, a policy maker noted, “fuel consumption tends to decrease and yields tend to increase,” indicating the economic and productivity benefits of adopting modern technologies.

In Italy, digitalisation is synonymous with improved productivity and farm management. Multiple participants, including a breeder and an ICT provider, noted that digital tools can “improve income by working on increased productivity, farm management efficiency, and cost reduction.” The emphasis here is on maximizing outputs while minimizing inputs, allowing farmers to optimize resource allocation and enhance profitability through more strategic decision-making.

An academic reinforced this view, stating, “there could be impacts from the possible optimization in the use of the farmers’ farm resources,” highlighting the potential for digital tools to revolutionize resource management.

Latvian farmers are focusing on the efficiency gains brought by digitalisation. A consultant summed it up by saying, “I feel the key words here are - more efficient, faster and cheaper to make this whole process happen.” Digital tools are enabling farmers to streamline their operations, making processes more efficient and freeing up time for core farming activities. This newfound efficiency is crucial for maintaining competitiveness and adapting to evolving market demands.

A communication expert added, “I also see that it's a more efficient job for the farmer, so that he has more time for the real job,” indicating how digitalisation is reshaping labour dynamics on farms.

In North Macedonia, the focus is on improving production quality and yield through digital tools. A farmer emphasized the “improvement of production quality, increased yield,” showcasing how digitalisation is driving advancements in agricultural practices. By optimizing inputs and enhancing resource management, Macedonian farmers can boost productivity while reducing costs, leading to more sustainable and profitable farming operations.

A sustainability leader also highlighted “efficient water use” as a key benefit, reflecting the emphasis on sustainability and resource conservation.

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Scottish farmers are experiencing significant time savings through digital technologies. A farmer highlighted the benefits of an "electronic weighing system that saves a lot of time," demonstrating how time translates to money in agricultural settings. By automating routine tasks and improving efficiency, farmers can focus on more strategic aspects of their operations, ultimately enhancing their bottom line.

In Serbia, digitalisation is seen as a bridge between traditional farming practices and modern innovation. A faculty professor noted the extensive savings achieved through technological advancements, particularly in areas like irrigation and nutrient management. The integration of digital tools is enabling Serbian farmers to optimize their operations while preserving the essence of traditional agriculture, leading to more efficient and sustainable farming practices.

A business owner and tech provider emphasized, "technology that works for farmers, in a way that reduces the costs, making their life easier," highlighting the dual benefits of modernization and simplification.

Slovakian farmers are using digital tools to achieve precision in their farming practices. A farmer noted the potential for "a more efficient use of (digital) means of production," emphasizing how precision agriculture can lead to better resource management. By tailoring inputs to specific needs, farmers can enhance productivity while reducing waste, aligning with broader sustainability goals and enhancing economic viability.

A policy maker observed, "I definitely see a saving of resources there," indicating the widespread benefits of digitalisation for resource efficiency.

In Slovenia, digital tools are simplifying farm operations, allowing farmers to organize their work more effectively. A business advisor highlighted how digitalisation leads to "more efficient and better production," reducing dependency on external resources and improving economic stability. The ability to make informed decisions based on data insights is empowering Slovenian farmers to optimize their practices and achieve better outcomes.

A farmer commented, "the farmer will still have to work. But this will make it easier for him to organize his work," reinforcing the supportive role of digital tools in farming.

In Spain, digitalisation is viewed as a key enabler of sustainable farming. A representative from a digitalisation platform stated that investments in technology allow farmers to "produce more, to be more efficient and more effective," fulfilling the three pillars of sustainability. This holistic approach to digitalisation is driving Spanish farmers to adopt practices that not only enhance productivity but also contribute to long-term environmental and economic sustainability.

A digitalisation platform representative concluded, "in the end, you are fulfilling the three pillars of sustainability," encapsulating the broader impact of digital transformation in agriculture.

4. **Engagement and Modern Image**

    - **Description:** Making farming more attractive to younger generations and reshaping the perception of farming as a modern and innovative profession.

As agriculture evolves through digitalisation, a new image of farming is emerging—one that is modern, inclusive, and appealing to younger generations. Across Europe, digital tools are not only improving efficiency and productivity but also reshaping perceptions of agriculture as a cutting-edge and attractive profession. Here's how this transformation is unfolding across different countries:

In France, digitalisation is seen as a way to integrate different aspects of farm work, making the profession more appealing. A cultivation supervisor remarked, "and I believe that being able to link office work and on-site work could be very useful," highlighting how digital tools enable a seamless connection between administrative tasks and fieldwork. This integration is crucial for attracting a younger, tech-savvy workforce interested in diverse and dynamic career opportunities.

Additionally, the same supervisor noted, "it seems to me that digital agriculture can play a role in this, can modernize the image of agriculture with the general public, and enable more virtuous communication," underscoring the potential of digital tools to enhance the public perception of farming as an innovative and progressive industry.

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However, there are still challenges to overcome, as a pig farmer pointed out, “there are people more open to and there will be people who will never be open to computing,” indicating the ongoing need for education and training to ensure all farmers can benefit from digital advancements.

In Germany, digitalisation is creating new opportunities for those at the start of their careers. A vocational teacher emphasized the potential for young people to earn a good income, stating, “so, if you’re tech-savvy and I’m at the beginning of my career, I think you can earn a pretty good extra income.” This highlights how digital tools are not only modernizing farming practices but also creating pathways for lucrative careers, making the sector more attractive to younger generations who value innovation and technology.

In Greece, digital technologies are recognized for their potential to break down traditional barriers and promote inclusivity within the agricultural sector. An unidentified participant mentioned that digital tools “can make farming more attractive to younger generations and women, as there are user-friendly applications,” emphasizing how digitalisation is fostering a more inclusive and diverse farming community. By making farming more accessible and appealing, digital tools are encouraging a broader range of individuals to consider careers in agriculture.

In North Macedonia, digitalisation is seen as a means to reverse the trend of urban migration among young people. A farm advisor succinctly stated, “return of the younger generation,” capturing the hope that digital advancements will attract young people back to rural areas by offering modern and engaging career opportunities in farming. This shift not only revitalizes rural communities but also ensures the sustainability and continuity of agricultural practices.

In Scotland, digital transformation in agriculture is seen as an opportunity to create new, higher-value jobs within the sector. A policy maker noted that “one of the benefits might be that, you know, the next generation coming through will expect there to be an element of digital within the business, and it could be an opportunity to create new types of jobs, higher value jobs in the sector.” This perspective highlights the potential of digitalisation to drive economic growth and create exciting career prospects for young people in agriculture.

Moreover, digital tools are facilitating broader engagement and outreach, as a researcher pointed out, allowing farmers to “reach broader audiences and markets, access mental health support, develop community relations, and raise public awareness of farming issues.” This enhanced engagement not only elevates the profile of farming but also strengthens community ties and improves the overall wellbeing of farmers.

5. **Competitiveness and Productivity**

    - **Description:** Enhancing farm competitiveness and productivity through advanced digital technologies and better farm management practices.

In examining the focus group transcripts from various European countries on the topic of farm digitalisation, a significant theme emerged around **New Business Models**, particularly concerning competitiveness and productivity. This theme underscores how digital tools are reshaping agricultural practices and business strategies across different contexts, driving both economic and operational benefits.

One of the key insights is that digital tools are enhancing **competitiveness** by allowing farmers to adopt new business models that can significantly improve their efficiency and profitability. For instance, farmers in France noted that digital innovations like precise animal feed delivery systems enable them to save costs and enhance productivity. A farmer from France-2 observed, “Delivering the right amount [of animal feed] to the sheep that needs it… allows for savings,” highlighting the role of digital tools in optimizing resource use and increasing operational efficiency.

Moreover, the impact of digital tools extends to broader market strategies. In Poland, digital solutions are being implemented to streamline the supply chain, aiming to "achieve greater scale in sales and reducing costs of getting food products from producer to consumer,” as noted by an organiser of a food market. This reflects a shift towards more direct market engagement and cost-efficient operations, which can bolster a farm's competitive edge.

In Hungary, the discussion revealed that advanced technologies like soil scanners are transforming farm management by improving production processes and reducing waste. A soil expert in Hungary remarked, “The soil scanner technology can contribute to increasing farmers' income… by enabling more efficient management of production processes, optimizing fertilizer use, and increasing crop yields.” This not only underscores the direct economic benefits but also the broader implications for sustainability and resource management.

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Additionally, digitalisation is facilitating **new business models** that emphasize scalability and reduced dependence on intermediaries. For example, a farmer in Poland mentioned that digital tools are instrumental in "reaching the end customer without intermediaries," which can enhance profit margins and market reach. This trend is echoed in Spain, where a business advisor described advanced technologies as a “commercial weapon for co-operatives,” suggesting that digital innovations are pivotal for achieving competitive advantages in the agricultural sector.

The diversity of perspectives across Europe highlights a common theme: digitalisation is not merely a tool for operational improvement but a strategic asset that can redefine agricultural business models. From enhancing productivity and efficiency to enabling more direct market interactions and sustainable practices, digital tools are proving crucial for modernizing agriculture and maintaining competitiveness in a rapidly evolving industry landscape.

Thematic 3: Good to be a Digital Farmer

1. **Professional Attraction and Sense of Belonging**
    - **Description:** Improving the attractiveness of the farming profession and fostering a sense of community and belonging among digital farmers.

The analysis of focus group transcripts reveals that farm digitalisation is not only reshaping agricultural practices but also significantly influencing the **professional attraction** and **sense of belonging** within the sector. This thematic area highlights how digital tools are enhancing the appeal of farming careers and improving work conditions, contributing to a more positive image of the profession and fostering a stronger sense of community among farmers.

One of the most compelling findings is that digital tools are making farming more attractive to younger generations. Participants across various countries emphasized that technology in agriculture can act as a catalyst for interest and engagement. In France, a pig farmer noted, “If tomorrow these tools can help and attract young people, it can also be beneficial,” reflecting a belief that digital advancements can rejuvenate the industry by appealing to tech-savvy youth. This sentiment was echoed by digital advisors in France who observed, “With digital tools, it can become a kind of motivation for the new generations… a console in the tractor can be like a joystick video game.”

This shift towards modern technology is not just about attracting new talent but also about improving the quality of work and the overall professional experience. In Hungary, a policy maker highlighted how automation and digitalisation can enhance job satisfaction, noting that automated systems make long working hours “not as mentally demanding.” Similarly, a farmer in Hungary appreciated that digital tools like soil scanners improve work quality and efficiency, allowing more time for fieldwork and data analysis.

The convenience and improved work conditions resulting from digital tools also contribute to a stronger sense of belonging within the agricultural community. In Italy, a breeder discussed how digital tools that simplify bureaucratic tasks can provide more free time, which is crucial for the well-being of workers. This reduction in manual labor and administrative burden is seen as a significant benefit, aligning with broader trends of improving work-life balance.

Digitalisation is also enhancing the professional image of farming. In Latvia, a consultant noted that farms are proud to earn digital certifications, which adds value and motivates workers. Similarly, a media expert in Hungary observed that the high-tech nature of modern agriculture enhances the sector’s image, making it more appealing to advisors and other professionals.

Furthermore, the integration of digital tools is leading to the creation of new job opportunities and roles within the sector. In Scotland, a policy maker highlighted that digital transformation could introduce new types of high-value jobs in agriculture, which aligns with the growing expectation of digital elements in various business sectors. This is supported by a Serbian policy maker who noted that digitalisation will lead to new job positions, adding a layer of professional attraction through career development opportunities.

The analysis reveals that digital tools are playing a crucial role in transforming agriculture into a more appealing, efficient, and professional field. By attracting younger generations, enhancing job satisfaction, improving work quality, and creating new career opportunities, digitalisation is fostering a renewed sense of belonging and pride among those in the agricultural sector.

2. **Visualization and Transparency**

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- **Description:** Providing visual tools for better understanding and showcasing farm outputs, building trust with consumers and stakeholders.

In exploring the theme **Good to be a Digital Farmer** with a focus on **Visualisation and Transparency**, the analysis of focus group transcripts reveals how digital tools are revolutionizing farm management by enhancing visibility and fostering trust among stakeholders. The integration of visual tools in agriculture is not merely about operational efficiency but also about showcasing achievements, building credibility, and improving advocacy efforts.

One of the standout benefits of digitalisation is the enhanced ability to **visualize farm achievements**. As noted by an unidentified participant from Latvia, "The maps show the farmers what they have achieved and can feel proud about." This capability allows farmers to see and appreciate the scale of their work, which can be both motivating and rewarding. The ability to view farm operations from an aerial perspective provides a powerful sense of accomplishment, as another participant highlighted: "Benefits of seeing the picture from above to realize the work done is priceless."

The use of digital tools for **monitoring and documentation** also plays a crucial role in building trust and transparency. For instance, digital mapping and monitoring technologies enable farmers to document and display various aspects of farm management, such as wildlife damage, tree cover, and species diversity. An unidentified participant from Latvia pointed out that "Monitoring of wildlife damage by simple drones" and "Mapping of expansive species could show the improvements over time." These tools not only facilitate better management practices but also provide tangible proof of the farmer's efforts and achievements.

Furthermore, visual tools are invaluable for **advocacy and dispute resolution**. The capacity to provide clear, evidence-based documentation can be instrumental in addressing disputes and securing support. For example, digital mapping can be used to counter negative assessments by authorities or to argue for subsidies. As noted, "The mapping of various species and climatic conditions could be used as arguments for subsidies that would support the farmers," and "Ortho-photos in June could prove that the assessment was incorrect" in disputes related to perceived mismanagement.

Transparency is further enhanced by the ability to showcase farm practices and outcomes to external stakeholders. Digital tools make it easier to present farm operations and successes to visitors, stakeholders, and potential supporters. As one participant suggested, "Could be used to show visitors," emphasizing the role of visual data in fostering engagement and support for the agricultural sector.

In summary, the thematic focus on **Visualisation and Transparency** illustrates how digital tools in farming are transforming the way agricultural practices are perceived and managed. By providing clear visual evidence of achievements, facilitating advocacy, and enhancing stakeholder engagement, these tools are helping farmers not only to manage their operations more effectively but also to build a more transparent and trustworthy image of their work. This enhanced visibility and accountability are integral to modernizing the sector and ensuring its continued growth and support.

3. **Administrative Efficiency and Speed**

   - **Description:** Reducing administrative burdens through automation, leading to faster and more efficient farm operations.

In analysing the focus group discussions on the benefits of farm digitalisation, a compelling theme emerged around **Administrative Efficiency and Speed**. This theme highlights how the integration of digital tools is significantly reducing administrative burdens and accelerating farm operations, leading to more streamlined and effective management.

One of the primary benefits identified is the **reduction in administrative workload**. Digital tools are helping farmers manage the increasing demands of bureaucracy more efficiently. As a veterinarian from France-1 noted, "At the very least, this technology can help farmers comply with the law." The automation of processes such as record-keeping and compliance documentation alleviates the traditional paper-heavy requirements, enabling farmers to focus more on their core activities.

Farmers from various countries expressed their appreciation for the time-saving advantages of digital tools. A farmer from Slovenia emphasized, "It reduces time… the bureaucracy is getting more and more demanding. You certainly

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save time when you are skilled and have all the documents online, rather than printing out some paperwork and filling it in by hand." This shift not only reduces the time spent on administrative tasks but also allows farmers to allocate their efforts towards more productive aspects of their work, such as crop management and fieldwork.

The move towards digitalisation also enhances **operational efficiency**. As another participant from Hungary noted, "I expect automated digitisation processes to reduce the administrative burden on farmers." By automating routine administrative tasks, digital tools help streamline farm operations, leading to more efficient use of resources and time.

Additionally, there is a broader **educational impact** associated with digital tools. As highlighted by a technology developer from Slovenia, "Maybe even if you look at a farm deciding to go digital, then those digital skills are mapped to other areas." The process of adopting digital tools for farm management often introduces farmers to other digital services, such as eTaxes and eGovernment platforms. This initial foray into digitalisation can facilitate a smoother transition to broader digital applications, further enhancing administrative efficiency.

Overall, the thematic focus on **Administrative Efficiency and Speed** underscores the transformative impact of digital tools in agriculture. By automating bureaucratic tasks, reducing paperwork, and facilitating faster compliance with regulations, digitalisation is making farm operations more efficient. This not only frees up valuable time for farmers to focus on core activities but also sets the stage for broader adoption of digital solutions across various administrative functions.

4. **Inclusivity and Cooperation**
    - **Description:** Promoting inclusivity in farming practices and encouraging cooperation with scientists and other farmers to share knowledge and experiences.

The analysis of focus group transcripts on the benefits of farm digitalisation highlights a significant issue: **Inclusivity and Cooperation**. This theme reveals how digital tools are not only transforming farm management practices but also fostering greater inclusivity and collaboration within the agricultural community. Through digitalisation, the farming sector is becoming more accessible, co-operative, and integrated, enabling diverse stakeholders to work together more effectively.

One notable aspect of **inclusivity** is the enhanced appeal of farming to a broader demographic. For example, in Greece, it was observed that "The agricultural sector has become [due to digitalisation] more appealing to both genders." This shift is exemplified by the experiences of a breeder in Italy, who noted that "If the App can do in an automated way, or speed up, what she now does by hand, it can certainly help [to attract more women]." This indicates that digital tools can make farming more accessible and less labour-intensive, thereby encouraging a more diverse range of individuals to engage in agricultural work.

Digital tools also support **cooperation** among farmers and with external stakeholders. For instance, a farmer from North Macedonia mentioned "Increased co-operative processing and sharing of experiences," highlighting how digital platforms facilitate the exchange of knowledge and collaborative problem-solving. Similarly, a farmer from Poland emphasized the role of digitalisation in improving "cooperation with one another and with our customers" to address challenges related to production and sales.

Furthermore, digital tools enhance **co-operative learning** and shared knowledge. A technical product manager from Serbia explained that digital systems will allow for "exchange of recommendations (what to do in a specific agricultural operation) among each other's," thanks to the accumulation of data over time. This capacity to share insights and recommendations can help farmers make more informed decisions and adopt best practices collectively.

Inclusivity is also reflected in the way digital tools address diverse needs and skill levels. In Slovenia, a farmer noted the potential of co-operative models to facilitate technology adoption: "Why not have the co-operative buy one drone and have the advisory service or the co-operative provide one expert to teach the farmers how to operate it." This approach not only makes advanced technology more accessible but also supports skill development across the farming community.

Moreover, digitalisation can enhance **trust and transparency** between farmers and consumers. In Italy, a consortium member highlighted that "Gaining consumers' trust by improved traceability is key," underscoring how

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digital tools can provide clear, verifiable information about farm practices and product origins, fostering better consumer relationships.

In summary, the code of **Inclusivity and Cooperation** underscores the transformative potential of digitalisation in agriculture. By making farming more accessible to a wider range of individuals, facilitating collaborative learning and problem-solving, and enhancing transparency and trust, digital tools are reshaping the agricultural landscape. These advancements not only improve individual farm operations but also strengthen the collective fabric of the agricultural community, making it more inclusive and co-operative.

5. **Healthier Production and Sustainability**
    - **Description:** Ensuring healthier food production practices and sustainable farming methods, contributing to less waste and a better environment.

The focus group discussions on farm digitalisation reveal a significant sub-theme, namely, **Healthier Production and Sustainability**. This theme underscores how digital technologies are driving more sustainable and environmentally friendly farming practices, leading to healthier food production and reduced ecological impacts.

A key advantage of digitalisation is its ability to promote **precision farming**, which optimizes the use of resources such as water, fertilizers, and pesticides. In Greece, an unidentified participant noted, “One of the most important environmental benefits of digitalisation is precision farming, which could allow more targeted and optimized use of resources.” This precise application of inputs helps to minimize waste and reduces the overall chemical load on the environment. Similarly, the use of smart irrigation systems is highlighted to “preserve water resources and support sustainable agricultural practices,” ensuring that water is used more efficiently.

Digital tools also contribute to **reducing environmental impact** through better management of inputs. A farmer from Hungary emphasized, “As scanning provides instant information on the current nutrient supply, only the required amount of fertilizer is applied during the nutrient replenishment process, so the environment is not supplied with excess nutrients.” This approach not only protects soil health but also minimizes runoff and pollution, aligning with the broader goal of sustainable agriculture.

The theme of sustainability is further supported by the reduction in chemical usage. For instance, a media expert from Hungary highlighted that digitalisation leads to “pollution reduction, reducing or eliminating the ecological footprint of sending lab samples.” This shift is crucial for mitigating the ecological footprint of farming practices and fostering a healthier environment.

Social benefits are also a significant aspect of this theme. The NGO representative from Hungary pointed out that digital tools contribute to “healthier living spaces” and “better quality food raw material in agricultural production.” By reducing the use of harmful chemicals, digitalisation enhances food safety and quality, meeting the expectations of consumers who are increasingly concerned with health and environmental impacts.

The focus on **collaborative learning and support** in sustainability is evident from various insights. In Latvia, a farmer described how collaboration with scientists helps in “practicing healthier, more environmentally conscious farming.” This collaborative approach ensures that farming practices are continually refined to enhance sustainability, as scientists provide guidance on optimizing production methods to be more eco-friendly.

Moreover, the discussion in North Macedonia and Serbia highlights the broader ecological benefits of digitalisation. A researcher from North Macedonia noted that digital tools lead to “a reduction in carbon emissions and a decrease in chemical substances,” while a policy maker from Serbia emphasized “the protection and conservation of the environment” through reduced use of inputs.

The theme of **Healthier Production and Sustainability** demonstrates how digital technologies are revolutionizing farming by making it more environmentally friendly and efficient. Through precision farming, reduced chemical use, and improved resource management, digitalisation is fostering a more sustainable agricultural sector. These advancements not only benefit the environment but also contribute to healthier food production, aligning with the growing consumer demand for safe and sustainable agricultural practices.

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2.5 Discussion and Conclusion

The thematic analysis of focus group discussions, combined with insights from the literature, reveals a complex interplay of challenges and opportunities in the digitalisation of agriculture. It also highlights the transformative potential of digital tools in reshaping farm operations, enhancing efficiency, and fostering sustainability. To fully address these multifaceted issues and realize the emerging benefits, comprehensive policies must be developed to support the adoption and integration of digital tools in the agricultural sector.

Trust issues are a significant barrier to farm digitalisation. Policies should aim to build stronger, more transparent relationships between farmers and stakeholders through transparent communication, collaborative frameworks, and inclusive policy-making processes that consider the needs and concerns of all stakeholders. By fostering trust, policies can create a more supportive environment that encourages the adoption of digital technologies.

Farmers face significant challenges related to time, resources, and the rapid obsolescence of technologies. Policies must provide targeted support and training programs to help farmers navigate these challenges. Investment in infrastructure and ongoing technical support can ease the transition and ensure that digital tools are user-friendly and effective. Additionally, demonstrating long-term efficiency gains will be crucial in fostering a positive perception of digital tools among farmers.

Economic burdens, operational complexities, technological reliability, data security, and practical application challenges are significant concerns. Policies should offer financial support, robust training programs, reliable technological solutions, and clear data management policies to mitigate these risks. By addressing these challenges, the transition to digital farming can be smoother and more beneficial, enhancing productivity and sustainability in the agricultural sector.

The digital transformation in agriculture requires farmers to balance digital and traditional skills, embrace direct consumer interaction and agritourism, and engage in new forms of collaboration. Policies should promote a holistic approach that values both new and traditional skills, fosters continuous learning, and supports collaborative models. This will enhance the resilience and sustainability of the agricultural sector. Digital technologies are becoming part of the agricultural policy toolbox to aid compliance monitoring, data exchange, and analysis. However, the use of these technologies for agricultural policy remains patchy, and it is unclear how far their potential is being exploited. To address these gaps, policies should promote the integration of digital technologies in policy implementation to enhance monitoring, data exchange, and targeting capabilities, thus increasing the overall effectiveness and efficiency of agricultural policies.

There are many adoption barriers of digital agriculture technologies, such as high investment costs and lack of training and advisory services for farmers, especially for small- and medium-scale farmers. Policy can help surmount these barriers by offering financial assistance to farmers and innovators in the form of tax breaks and subsidies that help compensate short-term opportunity costs and long-term financial risks associated with technological innovation and investment. Providing agricultural training (i.e., digital skill sets) and advisory services for farmers could foster a more inclusive digital agriculture for small-scale agri-food businesses. Coupling advisory services and training with financial assistance for digital technologies will increase the chances that digital agriculture will be leveraged to its fullest potential and help avoid a digital divide between large-scale and small-scale farmers.

Digitalisation is expected to support more targeted and outcome-oriented policy through improved monitoring possibilities. Digitalisation renders policy designs with high information requirements more attractive and offers new options for agricultural policy, including novel designs to address challenges more effectively. The distinction must be made between mere digitization of existing data and digitalisation, which involves the generation of novel data, processing, and analytics of large amounts of data, including automated feedback. Agricultural policy in Europe shapes the adaptive capacity of farms, which is why anticipatory governance will be critical for ensuring socially acceptable policies for digitalisation and agriculture. Policymakers should prepare strategies to address digitalisation, even when underlying technology could be more widespread at later points in time.

In Europe, the European Commission set out as one of its objectives to fully connect farmers and the countryside to the digital economy to achieve a smarter, modern, and sustainable future of food and farming. This was followed by the Green Deal, where digital technologies are considered critical enablers for attaining sustainability goals in many sectors. The Farm to Fork strategy indicates that the Common Agricultural Policy must facilitate investment support

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to improve the resilience and accelerate the green and digital transformation of farms. Digitalisation is expected to support more targeted and outcome-oriented policy through improved monitoring possibilities and offers new options for agricultural policy, including novel designs to address challenges more effectively. Agriculture policymakers should focus on issues relating to infrastructure and connectivity, cost, relevance, user-friendliness and skills, and risk and trust building to enable digitalisation to take place.

Studies show that policies consider digital agriculture mostly in terms of resource use efficiency, while its benefits for achieving other sustainability principles such as biodiversity conservation, soil protection, and climate change adaptation and mitigation are not thoroughly reflected. Policies should focus on developing a statutory framework, working toward data harmonization, and increasing high-speed internet availability to rural areas. Technologies that improve decision support, such as VRT, cloud computing, IoT, yield mapping, digital soil mapping, sensors, and UAVs, are particularly relevant toward achieving most agriculture-related goals and diverse sustainability principles. Technologies that enhance monitoring, such as satellite imaging, AI, and agricultural census data, are particularly relevant for promoting biomass production, climate change mitigation and adaptation, and biodiversity conservation. Communication technologies such as RFIDs, QR codes, and distributed ledger technology (e.g., Blockchain) promote transparency along the value chain, contributing to goals related to health, nutrition, and biodiversity conservation. Given the rapid growth and innovation in digital agriculture, policy should do more to highlight these potential applications and refer to the burgeoning literature on the topic.

Scenario analysis supports strategic decision-making and allows for values-based questioning of the type of future agri-food sector that is desired. It also facilitates critical reflection on how digital technologies deliver that future. Thus, by addressing future scenarios, policymakers can align policies to social values and needs. This should support responsible research and innovation in agricultural digitalisation and help avoid costly and unintended impacts of policymaking. However, there is a lack of research on how specific sets of technologies, like digital technologies, could plausibly develop and affect policymaking and future challenges for agricultural policy. Digital agricultural policy does not simply replace analogue technologies used in traditional agricultural policy. Current agricultural policy in Europe uses instruments that cover the full range of policy options from information provision to regulation and economic incentives. However, when implemented, they often fail to support environmental, economic, and social sustainability effectively. The EU's Common Agricultural Policy is also criticized for a lack of indicators and systems that enable effective monitoring and enforcement. Digital technology can enhance the effectiveness and efficiency of agricultural policy by supporting instruments in targeting precise spatial and time-bound objectives and enabling instrument designs tailored to specific attributes of locations and farms. It makes trade-offs and jointness of production more transparent, mitigates asymmetric information, facilitates monitoring and the search for technologies and practices, spatial targeting, and the development of alternative policy instruments and designs. Thus, the analysis of digital agricultural policy must dissect policy into its individual instruments and their design specifications. It can then show clearly how digital technology works in combinations of instruments. Policy can also target the use of digital technology on farms and in companies in the agri-food sector. Examples are precision farming technology or food quality tracking aimed at improving environmental footprints and food safety.

A key question, both for research and policy, is whether farms, interest groups, and governments are willing and able to cope with the ramifications of a more encompassing digitalisation of agricultural policy. This would depend on the capabilities and the willingness of government, farms, and other actors involved to use digital technologies. It also depends on developments in future policy demand and digitalisation. Systematic anticipation of plausible futures of digital agricultural policy is therefore needed.

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3 Environmental assessment of farm digitalisation (T4.3)

Authors: Alexia Gobrecht, Véronique Bellon-Maurel, Baptiste de Massé, Clémence Huck (INRAE)

3.1 Introduction

The analysis of environmental impacts of the digitalisation process in the living labs is carried out at the agricultural process level and/or farm level. Life Cycle Analysis (LCA) allow us to compare environmental footprint of the agricultural production process before and after the adoption and use of digital technologies.

Adopting and using digital technologies is responsible of a certain number of changes in the production process, and as a consequence, the environmental impacts of this new process might differ from the original one (reference scenario). These changes due to the digitalisation of the farm can be captured by the comparative LCA of the two process (before and after digitalisation).

The outputs of these Life Cycle Analysis help provide insights for the farmers, advisors, and service providers about environmental impacts of digitalisation in real use case situations. This information also helps identifying the hotspots (i.e. the steps of the process that have a high environmental impact) of the process.

To do this, the environmental assessment of task 4.3 uses quantitative data that will be collected in farms in different Living Labs (LL), as well as data from the literature and databases.

After a short introduction on the LCA methodology and a synthesis of the state of the art that has been conducted during the first phase of CODECS, this chapter presents the methodology implemented in CODECS to assess the environmental impacts of farm digitalisation based on the use-cases of CODECS' Living Labs.

As the data collection and the analysis are ongoing, the first results will be presented in the next deliverable D4.2 due M36.

3.2 Introduction to Life Cycle Assessment

Life cycle assessment (LCA) is a standardised and recognised method to assess the environmental impacts of products and services (ISO, 2006a, 2006b). It is widely used to assess food products and agricultural systems (Boschiero et al., 2023; Dorr et al., 2021; Poore and Nemecek, 2018) as well as ICTs and digital technologies (Arushanyan et al., 2014). Therefore, it is one of the methods that can be used to assess the environmental impacts of DATs in a formalised way.

Life cycle assessment (LCA) is a method for quantifying the material and energy flows associated with the life cycle of a product or service and assessing its potential environmental impacts (Jolliet et al. 2016). It works by identifying the activities associated with this product or service over its entire life cycle, "from cradle to grave" (Figure 2).

It is a multi-criteria approach which enables the impact of a product/process to be assessed at different stages of production, manufacture and use.

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Figure 2: Scope of the LCA

The quantities of materials, products and energy used throughout the cycle are quantified. These values are also used to quantify the quantities of materials emitted at any point in the life cycle, which will be the outputs of the system. These outputs include emissions linked to energy production, the various residues released into nature during human activities and the waste discharged at the end of the cycle. The potential impacts of each of these elements are then characterized and aggregated to estimate the impact of the product's life cycle. (Jolliet et al. 2016)

The strength of LCA is that these potential impacts are broken down into numerous impact categories, such as global warming, ecotoxicity and water use etc. (Figure 3)

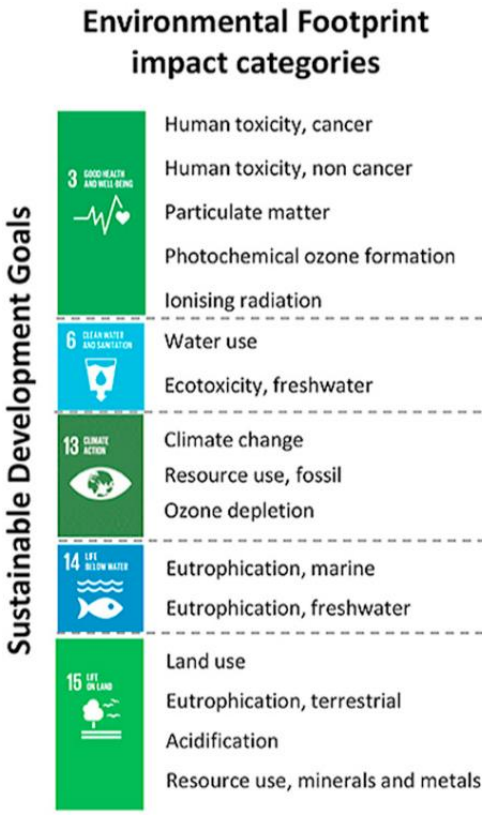

Figure 3: Environmental impact categories in LCA (and link to the SDG)

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The LCA methodology follows several steps (Figure 4) allowing to state the goal of the study, describing the involved processes, collect the data and calculate the impacts along diverse impact categories:

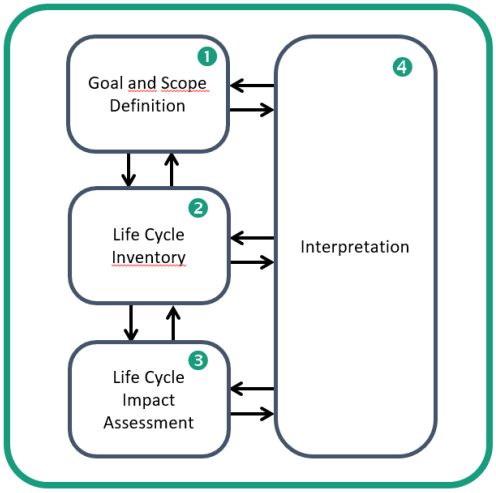

Figure 4: LCA steps

- **Goal & Scope**: Definition of the objectives and boundaries of the system under study
- **Life cycle inventory**: inventory of from and to the ecosphere for a system – it involves quantitative data collection on the processes under study
- **Impact assessment**: this phase aim at evaluating the potential environmental and human health impacts resulting from the flows identified for the system under study
- **Interpretation**: identifies, quantifies, checks, and evaluates information from the results of the life cycle impact assessment. The outcome of the interpretation phase is a set of conclusions and recommendations for the study.

Although this method presents a precise framework, its application to the context of digital agriculture is relatively recent. The following chapter therefore presents a summary of the state of the art on Environmental assessment of digitalisation in agriculture and how the LCA methodology has been applied to processes involving digital agriculture technologies.

3.3 Environmental assessment of digitalisation in agriculture: state of the art

This chapter provides a short synthesis of the state of the art of Environmental assessment of digitalisation in agriculture based on the following review paper: ***Huck, C., Gobrecht, A., Salou, T., Bellon-Maurel, V., & Loiseau, E. (2024). Environmental assessment of digitalisation in agriculture: a systematic review. Journal of Cleaner Production***, which systematically reviews the environmental impacts of digital agriculture technologies (DATs) and examines these impacts using the Life Cycle Analysis (LCA) framework.

3.3.1 Introduction

The agricultural sector is a significant contributor to environmental degradation, particularly in terms of greenhouse gas emissions, biodiversity loss, and freshwater depletion. In response, digital agriculture technologies (DATs) have been increasingly promoted as a means to mitigate these environmental impacts by improving efficiency and reducing resource use. However, the environmental benefits and trade-offs of these technologies have not been thoroughly assessed.

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3.3.2 Scope and Methodology

The review systematically analyzed 69 studies published between 2008 and 2024 that assessed the environmental impacts of DATs in agriculture. The majority of these studies focused on crop production, with a smaller number addressing livestock production and supply chains. The DATs reviewed were categorized into four main groups: technical production management (TPM), robotics and automation, strategic decision support, and traceability. The analysis was conducted using the PRISMA method and focused particularly on studies employing the LCA framework.

3.3.3 Key Findings

Digital Agriculture Technologies (Figure 5**) :**

- **Technical Production Management (TPM):** The majority of DATs reviewed fell under TPM, which includes technologies such as variable rate prescription maps, optical sensors, and satellite imagery. These technologies primarily aim to optimize input use, such as fertilizers and irrigation, thereby potentially reducing environmental impacts.
- **Robotics and Automation:** This category, representing nearly a third of the studies, includes robots and automated systems designed to reduce human labor and improve precision in agricultural operations. However, these high-tech solutions often come with significant environmental costs due to their energy use and the materials required for their production.
- **Strategic Decision Support and Traceability**: These categories were less represented in the literature but are crucial for improving logistics and reducing food wastage across the supply chain.

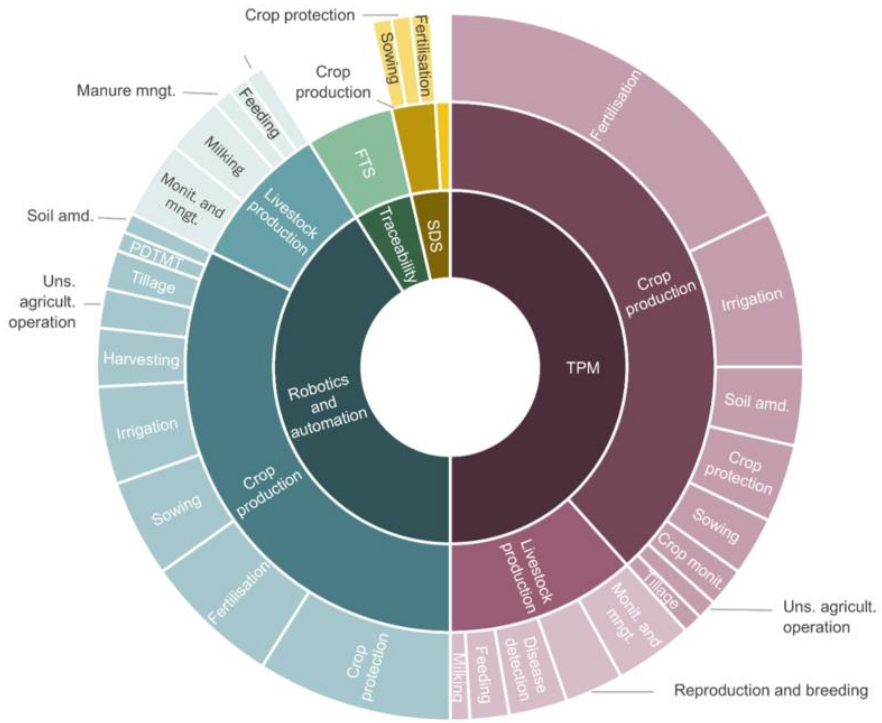

Figure 5: Service provided by type of digital technologies: TPM (technical production management), robotics and automation, traceability, and strategic decision support (SDS) in relation to the agricultural sector (crop and livestock) and agricultural operation (adapted from Huck et al. 2024).

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Environmental Impacts

- The review highlighted that most studies concluded DATs reduce environmental impacts, mainly through efficiency gains and the substitution of electricity for fossil fuels. However, the extent of these benefits varies widely depending on the specific technology and its application.
- Some studies reported increased environmental impacts, particularly when high-tech DATs such as robots and UAVs were considered. These impacts were primarily associated with toxicity, resource use, and the environmental burdens of the technology's life cycle (production, use, and disposal).

Methodological Challenges

- Functional Unit and System Boundaries: The choice of the functional unit (e.g., mass of product or cultivated area) and the system boundaries (what is included in the assessment) significantly influence the outcomes of the LCA. The review found that many studies did not fully include the DAT life cycle in their assessments, potentially underestimating their environmental impacts.
- Data Availability: There is a lack of comprehensive data on the environmental effects of DATs, particularly regarding their production and end-of-life phases. This has led to the use of proxies and assumptions, which can introduce uncertainty into the results.
- Impact Assessment: The choice of impact indicators, such as global warming potential or eutrophication, also varied across studies, influencing the interpretation of results. Most studies focused on midpoint indicators, but there is a growing interest in endpoint indicators that could provide a more holistic view of environmental impacts.

3.3.4 Recommandations

The review article provides several recommendations for improving the environmental assessment of DATs:

- Comprehensive System Boundaries: Future LCA studies should include the entire life cycle of DATs, especially for hardware-intensive technologies. This includes production, use, and disposal stages, as these often contribute significantly to environmental impacts.
- Use of Multiple Functional Units: Employing both mass-based and surface-based functional units can provide a more comprehensive assessment of the environmental performance of DATs, capturing both production efficiency and land-use efficiency.
- Enhanced Data Collection: Collaboration with DAT manufacturers and the use of up-to-date databases are crucial for improving the accuracy of LCA studies. Proxies should be used judiciously, and assumptions should be clearly stated and tested through sensitivity analyses.
- Broader Impact Indicators: Selecting a broad range of impact indicators and justifying their choice can help capture the full spectrum of environmental impacts associated with DATs.

3.3.5 Conclusion

This systematic review underscores the potential of DATs to reduce the environmental impacts of agriculture but also highlights significant challenges and uncertainties in their assessment. As digital agriculture continues to evolve, it is essential to refine LCA methodologies and expand data collection efforts to ensure that the environmental benefits of these technologies are accurately quantified. However, this review lays the foundations for the methodology to be applied to the CODECS Living Labs use cases.

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3.4 Methodology in CODECS

3.4.1 Comparative Life Cycle Assessment

To analyse the environmental impact of digitalisation in agriculture and gain a better understanding of the factors that contribute to this impact, the project is based on comparative life cycle analyses carried out on the farms of the CODECS Living Labs.

The principle is to assess the environmental impact of a non-digitalised process (same business as usual) and compare it with the same process that implements digital technology (Figure 6). These LCAs make it possible to:

- Analyse the key parameters that contribute most to environmental impact
- Understand how the use of a digital technology transforms processes (e.g. technical itineraries)
- Compare usage scenarios and their impacts.

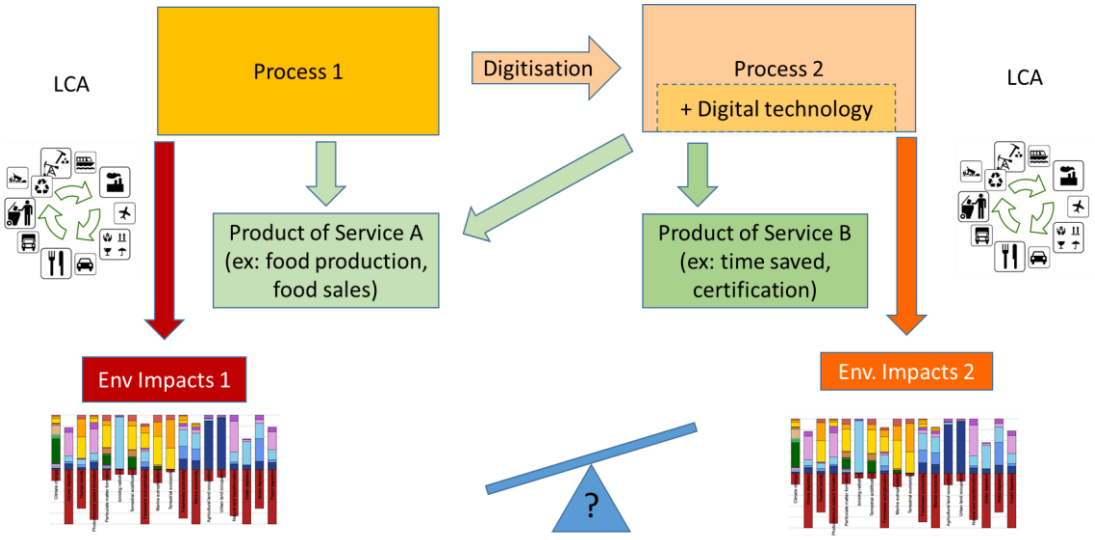

Figure 6: Principles of comparative LCA in the context of farm digitalisation in CODECS

3.4.2 Sample selection in CODECS LL

In order to study the environmental impact of farm digitalisation, it is necessary for them to have already implemented the technologies and adapted their processes. Given that the various CODECS Living Labs use cases are not at the same level of digitalisation, a first group of LLs has been identified, taking into account both the maturity of the technology and the possibility of accessing and collecting data from farms.

The LL identified for the first group are circled by the green circle in Figure 7. These Living Lab are able to provide use-cases with an already implemented digital technology and farmers willing to participate to the research :

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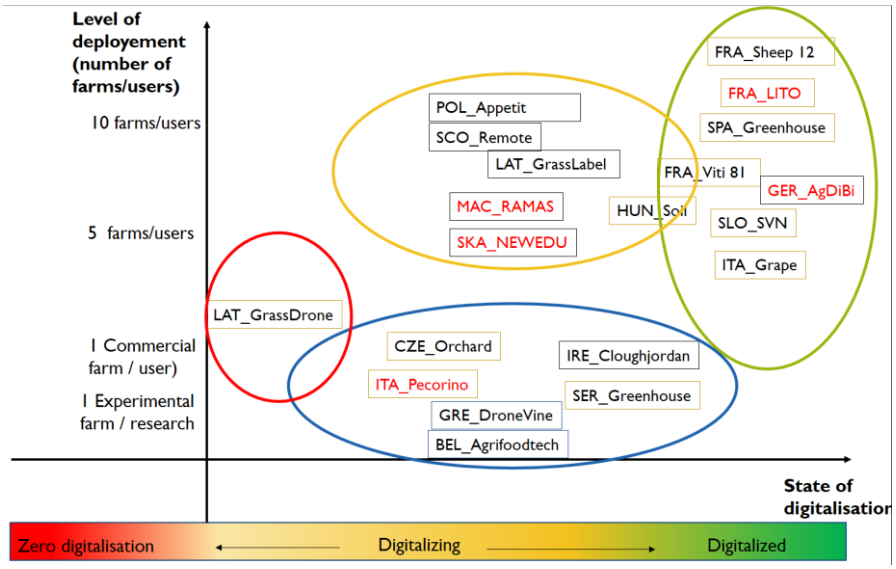

Figure 7 : Classification of the CODECS Use-cases in the LL according to their state of digitalisation and the level of deployment of the technologies in the farm (autodetermination at the CODECS GA Dec 2023)

3.4.3 Data collection steps

In order to carry out the life cycle inventory (LCI) stage, several sources of data are available:

- Data from the LLs produced for the other work packages in the project, mainly WP3, describing the processes used, the technology, etc.
- Data from interviews with farmers, which enable the quantitative data to be adjusted to real usage situations.

For this second source of data, surveys are organized in the living labs, and guidelines have been produced to assist the living lab coordinators in collecting this information.

In order to fulfill the Life Cycle Inventory, which comprises both the data about the agricultural production system and the digital technology, it is important to identify which data are mandatory for the analysis to be performed and which data are facultative. Our objective being also to limit the workload of the Living Lab coordinators and the interviewed farmers.

Therefore, we suggested to tailor the data collection file to each specific use-case and to do so, we based the definition of the Goal and Scope step on the information provided by the Living Lab Coordinators in the T3.3 Report, where the different processes (before and after digitalisation are described).

After this step is fulfilled, the data collection files are prepared for the Living Lab Coordinators.

As there are common data between LCA and Economic Costs and Benefits analysis (T4.4), the data collection guidelines have been prepared together with ELGO-DEMETER and contain a common part (See Appendix 2)

3.5 Forthcoming steps

In order to test the methodology and be able to show the results of the life cycle analysis, two pilot case studies have been launched: in the Slovenian Living Lab and in the Livestock Living Lab in France. For these two cases, the information from WP3 (Process report) was used to finalise the first stage of the LCA (the Goal and Scope) and to begin the life cycle inventory using the data collection protocol and guidelines.

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The next steps are to complete these two pilot cases in order to present the results to other Living Labs, adjust the methodology and pass on information to other wps (such as the WP7 with whom we plan developing an environmental footprint calculator dedicated to CODECS).

- M24 – M30 : LCA of 2/4 use-cases in CODECS LL
- M24 – M30 : adjustment of the protocols and guidelines
- M30 – M36 : second data collection phase in the other LL
- M 34 : synthesis report of the environmental impacts of farm digitalisation part 2 (in D4.2)

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4 Economic costs and benefits assessment of farm digitalisation

Authors: Alexandra Sintori (ELGO-DEMETER)

4.1 Introduction

The current chapter reflects the contribution of Task 4.4 of CODECS entitled “Analysis of Economic Costs and Benefits” which is dedicated to the identification and estimation of economic costs and benefits that derive from the adoption of digital technologies and their application in farming. The chapter describes the objectives of CODECS and of Task 4.4 followed by the proposed methodology as well as the data collection framework which has been developed in parallel with T4.3 “Environmental impact analysis”, since a common questionnaire will be used to facilitate both tasks.

4.2 Scope and Objectives of Economic C&B assessment of farm digitalisation

Task 4.4 focuses on the identification and assessment of the economic costs and benefits that derive from the digitization and consequently from the digitalisation of farming. Economic costs and benefits derive as the result of the use and combination of various resources and capabilities to provide outcomes and their estimation is necessary in order to further explore factors that facilitate or hinder the adoption of digital technologies. The results of Task 4.4 will be useful to the CODECS consortium but also to farmers, advisors and policy makers. Specifically:

- The economic costs and benefits will be integrated in the multicriteria assessment of Task 4.6 and trade-offs will be estimated.
- Partners involved in WP7 will use the data for the development of the economic cost and benefits calculator.
- Results will be presented at the annual LL Workshop (Task 8.3) and will become available for dissemination through the activities of WP1.
- The results of the task will also be available to policy makers that design and implement measures for farming digitalisation (Contribution to Policy Brief 9: Economic co-benefits and costs of digitalisation).
- The results will also be available to farmers and their advisors and assist them in understanding and predicting the benefits and costs of adopting digital technologies and explore optimal solutions and options for their farms.

Through the estimation of economic costs and benefits and identification of their main elements, barriers and bottlenecks of the digitalisation process will be revealed and ways to tackle them will be suggested.

In order to achieve its objective, the economic analysis of Task 4.4 will utilize qualitative and quantitative data gathered from LLs and demonstration farms, available literature, accountancy records, log books and other data bases.

4.3 Theoretical Background

It is often highlighted in the literature that one of the main economic outcomes of adopting digital technologies, such as precision agriculture, is the increased profitability of farmers (Bucci et al., 2020; Barrientos-Fuentes & Berg, 2013). According to Kolmykova et al. (2021), digital technologies in agricultural enterprises reduce labor intensity, enhance labor productivity, and increase both resource efficiency and the quantity and quality of crops.

Consequently, the primary focus of the economic analysis will be at the farm level, as this is where decisions about adopting digital technologies are made (see also Munz, 2024). Farms are where resources and system components interact to produce outcomes, making farmers the key actors in this economic analysis. Depending on the specific Focal Action Situation (FAS) under examination, the analysis may also focus on specific processes.

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At the farm level, the analysis will consider both transition costs, i.e., the initial investment required to adopt digital technologies, and operational costs, i.e., the annual production costs associated with maintaining these technologies.

It is also important to highlight that the adopted methodological framework for economic analysis follows a cost-benefit approach and relies on ex-post evaluations (Maredia et al., 2014). The analysis will compare pre-adoption and post-adoption periods to assess the associated costs and benefits (Bucci et al., 2020).

4.4 Methodology in CODECS

3.1.1 General methodological framework in CODECS

This section of the deliverable contains the general methodological framework for the estimation of the economic costs and benefits that derive from the digitalisation of farming. The economic analysis methodology is multistep and tailored for each Living Lab, according to the level of digitalisation and the availability of data.

It involves both quantitative and qualitative data collection from the farms in the Living Labs, as well as methods commonly used in agricultural economics. Figure 8 represents this proposed multi-step and data driven methodology for the economic analysis.

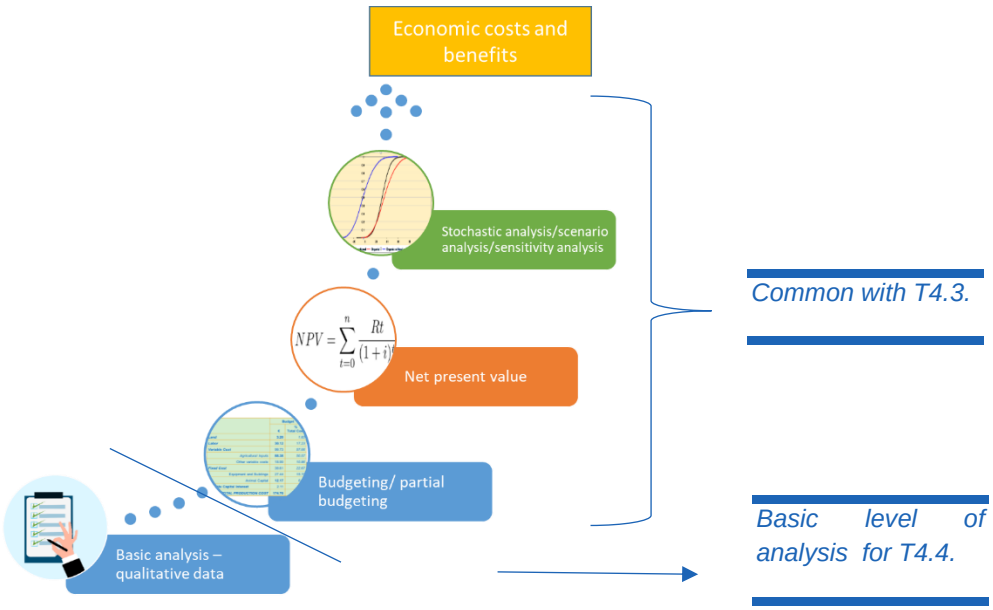

Figure 8 Mutli-step methodology for economic analysis, tailored for each LL

4.4.1 Basic economic analysis

The first level of the methodological framework, as shown in Figure 8, involves a qualitative analysis, particularly in cases where farm data are limited. This step can be applied to all Living Labs (LLs), including those that have not yet begun digitalizing, as it requires minimal quantitative information. The goal of this phase is to identify potential economic costs and benefits, even when quantitative farm data are unavailable or difficult to estimate.

Table 3 presents an indicative questionnaire designed for this purpose. The questionnaire is concise and easy to complete, focusing on key questions related to transition and operational costs and benefits. It has been developed based on existing literature and the D2.1 CODECS Conceptual Framework, which outlines the types of costs and benefits associated with the adoption of digital technologies.

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The required data can be collected by LL coordinators or completed directly by farmers using an online questionnaire. In some cases, additional data may be available from other tasks within the CODECS project. The research team will finalize the questionnaire's format and determine the timeline for this initial data collection phase, which will run in parallel with Task 4.3 (Environmental Analysis).

If quantitative data are limited for certain LLs, only preliminary qualitative data on economic costs and benefits will be presented as case studies. As a result, this basic economic analysis will complement the more detailed findings gathered from in-depth interviews.

Table 3: Indicative questionnaire for the preliminary data collection and economic analysis

Questions
1. What is the size of your farm ?
2. Is the investment in the digital technology annual or multiannual? / Do all investment costs occur during the first year?
3. How much is the initial investment cost for acquiring the technology?
4. What is the productive life of the investment (i.e. in how many years does the equipment need to be replaced?).
5. If part of the investment needs to be replaced after a few years, when does it need to be replaced and how much does this cost?
6. Does the new technology require any software? If yes, how much does the software cost? Is it a lump sum payment or annual payment?
7. Does the technology require extra labour cost for its establishment?
8. Does the establishment of the technology require adjustments of the existing farm infrastructure (e.g., land improvements)? What is the cost of these adjustments?
9. Does the use of the technology require special license? How much is the cost of this license? Is this a lump sum payment or annual?
10. Does the use of the technology require training of farmer/workers or contract labour of specialized workers? How much is the cost of training or contract labour? Is this a lump sum payment or annual?
11. Does the use of the technology require the use of special consumables? How much is the annual cost of these consumables?
12. Is the use of the technology expected to affect the labour requirements in the farm? Are labour costs expected to increase or decrease and how much?
13. Is the use of the technology expected to affect the cost of consumables of the farm (e.g.fertilizer or pestcide costs)? Are these costs expected to increase or decrease and how much?
14. Is the use of the technology expected to affect the cost of water consumption or/and the cost of energy consumption? Are these costs expected to increase or decrease and how much?
15. Is the use of the technology expected to affect the quantity produced? How much?
16. Is the use of the technology expected to affect the quality of the product? Will this reflect on product price increase or decrease? How much?

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Questions
17. Will there be any other changes on production costs or revenues that has not been mentioned in the previous questions?

4.4.2 Budget analysis

The main step of the economic analysis involves the construction of a whole-farm budget table or partial budget table depending on the use-case in the Living Lab. Budgeting and partial budgeting analysis is often used, to assist farmers in their decision-making regarding changes in production methods and adoption of new practices (Alimi, 2000; Munz, 2024), since it lets them compare economic costs and benefits before and after the change. It is a very useful and easy to apply management tool that summarizes input requirements and additional benefits, expressed in monetary terms either for the whole farm, a single enterprise or process within the farm. The construction of farm budget or partial budget will also allow for the estimation of productivity indicators for main resource units (e.g., labour or land productivity) and economic outcome indicators like net profit and income (see for example Ahmed et al., 2021).

4.4.3 Net present value

Net Present Value (NPV) analysis will also be performed for selected FASs, where quantitative data is available. NPV is a commonly used and well established methodology for cost-benefit analysis of the impact resulting from the adoption of technologies, practices and innovations (see for example Mburu et al., 2007; Wassmann and Pathak, 2007; Maredia et al., 2014; Mutenje et al., 2019). NPV sums up the discounted net cash flows (benefits minus costs) generated by the adopted digital technology over a period of time. A comparison of the NPV with or without the digital technology allows us to estimate if the investment in the digital technology is viable and profitable. The basic formula for the estimation of the NPV is the following (Truitt, 1978):

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where B_t=benefits at time t, C_t costs at time t, r=discount rate. According to the NPV criterion adopting digital technology is economically viable if the present value of benefits is greater than the present value of costs (NPV >0). It is evident that for the estimation of cash- flows required for the NPV, investment costs, input costs and benefits in the form of potential revenues is required (Medici et al., 2021). These information will be available from the Budget/Partial Budget, described in the previous paragraph.

Another advantage of using the NPV analysis in our methodology is that this formulation can be used in web-tools for the adoption of technology (Medici et al., 2021). Therefore, this methodological step will facilitate the development of the Economic Calculator of T7.4.

To account for economic risk, sensitivity analysis can be contacted, for basic variables used in NPV. Additionally, as previously explained, scenario analysis maybe performed to estimate alternative investment options.

4.4.4 Stochastic budgeting/NPV analysis

A more advanced methodology that can be used within the cost-benefit methodological framework to account for the economic risk is the Stochastic Budgeting Analysis or Stochastic NPV analysis (Bewley et al., 2009; Tzouramani et al., 2011; Liontakis et al., 2021). Most of the methods used in cost-benefit analysis assume deterministic values for cost and income elements (e.g., prices of inputs and products and yields). But deterministic economic models do not take into account possible differences in the riskiness of net income between alternative technologies or

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practices. In stochastic models, deterministic values of key cost and income elements are replaced with distributions of values and the stochastic model estimates the probability of an economic outcome (e.g., profit) to occur providing the farmer with a range of values (minimum, maximum and mean economic outcome). In the case of the NPV for example, the desirability of the investment is estimated not by producing a deterministic NPV but a whole distribution that links all feasible NPVs with specific probabilities (Liontakis et al., 2021).

In order to rank alternative technologies or practices first and second degree Stochastic Dominance analysis can also be implemented (see also Mutenje et al., 2019).

This step of the methodological framework will be performed only if data is available, since it requires the construction of distributions of main variables like prices or yields.

4.5 Data collection framework

Data is collected at the farm level through farmer interviews organized by the Living Lab Coordinators. This approach provides access to accountancy records, logbooks, and specific quantitative information. Common data collection materials are developed in collaboration with Task 4.3 (Environmental Analysis), as the same type of quantitative data is required for Life Cycle Analysis (LCA).

Appendix 3 contains specific guidelines for the Living Lab Coordinators on conducting the Economic Cost & Benefit (C&B) analysis, as well as the shared components with Task 4.3.

The Living Lab Facilitator and team will be responsible for the following tasks:

- **Identify the farm(s) to be assessed**: Check if the farm will be able to provide quantitative data about the production system, before and after the digitalisation process
- **Organise the in-depth interview**: set the date for a 1 – 2 h slot, if possible in presential. This meeting can also be articulated with other activities in the LL : in-depths interview for Social C&B for example, or for completing data collection for WP3.
- **Send the questions in advance** : this will help the farmer identify the sources of data (log books for example)
- **Conduct the interview**: With the help of the specific questionnaire prepared by task leaders.
- **Prepare the reporting**: Complete the data collection file

For each use case, data collectors will be trained and provided with instructions for the data collection process and reporting procedures.

Once the data is collected, it will be reviewed for inconsistencies and analyzed. Feedback from the living labs will be used to validate the findings, and the final results will contribute to the production of reports, briefs, and other deliverables.

The data requirements for the economic analysis, presented in the appendix (see questionnaire), include estimates of land costs, agricultural input costs, labor costs, and fixed costs (Gangwar et al., 2022). Costs specific to digital technologies, such as additional inputs, are also considered (Wassman & Pathak, 2007). Transition costs may include acquisition, installation, maintenance, software updates, hiring specialists, and staff training (Ivanov & Webster, 2017).

To account for the socio-economic environment in which decision-making occurs, scenario analysis, sensitivity analysis, and/or stochastic analysis can be applied, depending on the specific Focal Action Situation (FAS) and data availability. Financial risks and uncertainties, such as price fluctuations or production variability, along with actors' attitudes toward risk, can also be addressed using scenario or stochastic analysis. For example, governance system rules, such as subsidies on investment or production costs, may influence the adoption of digital technologies and can be incorporated into the economic analysis as alternative scenarios.

Additionally, factors that may hinder the adoption of digital technologies, such as a lack of legislation, legal restrictions, special permits, or requirements, can be included in the economic analysis, as they contribute to additional costs or impact other cost and benefit components.

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It is important to note that the current section, presents only some preliminary guidelines and good practices for data collection and data collection files and specific protocols will be prepared based on the information previously gathered by LL coordinators with the other workpackages activities (mainly T3.3 of WP3).

It is also important to emphasize that only a small number of cases/farms within the CODECS LLs have already adopted and used the digital technologies. Therefore the in-depth questionnaire for the economic and environmental evaluation will be used in a limited number of farms. Though this will not lead to statistical representation of European farms, the single-case design has been adopted in many studies and has scientific value since it may lead to a better in-depth understanding of the processes (Bucci et al., 2020).

4.6 Timeline for data collection

In order to tailor the data collection files to the specificities of each use case in each Living Lab, a preliminary work is conducted based on information provided by the Living Labs through the Process Modelling Report from WP3 (T3.3). This report permit to define more precisely the quantitative data to collect for the purpose of economic and environmental analysis.

An indicative calendar (Figure 9) has been set up but the data collection phase (June 2024 to June 2025) will be adapted depending on the availability of relevant use cases in the farms.

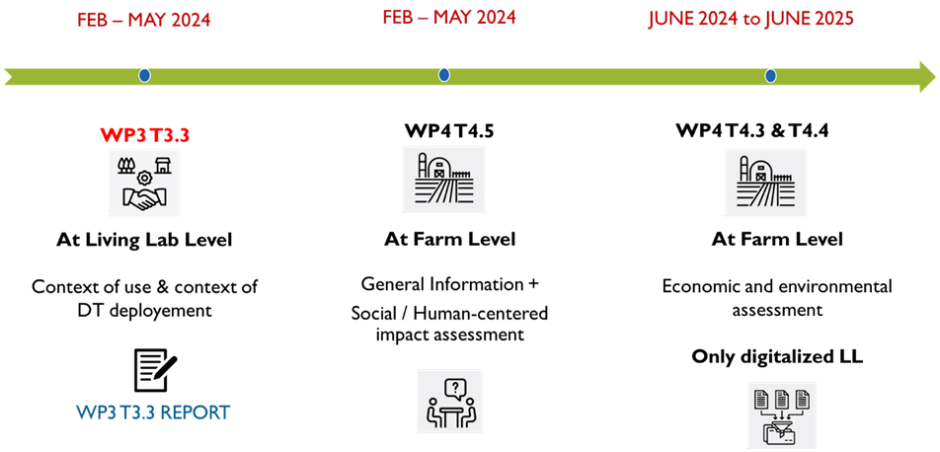

Figure 9: WP4 Data collection timeline at farm level

The next steps are closely related to the T4.3 (Environmental Analysis) and therefore follows the same timeline:

- M24 – M30: Economic analysis of 2/4 use-cases in CODECS LL
- M24 – M30: adjustment of the protocols and guidelines
- M30 – M36: second data collection phase in the other LL
- M 34: synthesis report of the economic Costs and Benefits of farm digitalisation part 2 (in D4.2)

4.7 Preliminary results

The basic economic questionnaire as well as the in-depth questionnaire developed to gather economic data was tested in the case of 1 CODECS LL, to estimate efficiency, adequacy and practicality as well as the time required for the interview. The example LL was also used to identify problematic or irrelevant questionnaire fields or duplication of data collection. The basic questionnaire was provided to the LL and was field out by their digital technology expert. For the in-depth questionnaire, an interview was conducted by a member of the ELGO-DEMETER research team with the digital technology expert. The interview lasted 1 hour and was performed on-line. Appropriate adjustments to increase the efficiency of the questionnaire(s) were adopted after the test with the LL. The description of the example LL and the preliminary results of the interview are included in the next paragraphs.

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4.7.1 Description of LL: The organic vineyard of the Agricultural University of Athens farm in Spata

For testing the extended questionnaire, the demo farm o**f** the Agricultural University of Athens was used. This demo farm refers to an experimental vineyard located in Spata, Greece. The experimental farm is used to gather data on drone spraying efficiency, including canopy droplet deposition, coverage, and penetration, as well as to assess its environmental impact in terms of ground residue and spraying drift. Within the demo farm, unmanned aerial vehicles (UAVs) equipped with a spraying capability are used and experiments are conducted on the premises, in order to identify the most effective operational parameters for drone spraying in vineyards, based on standardized procedures and measurements, such as the ISO standard. These UAV vehicles incorporate numerous digital technologies in their implementation pipeline, including, but not limited to, geospatial information systems (GIS) for flight planning, various environmental sensors connected to Internet of Things (IoT) stations for the constant monitoring of weather conditions, navigation sensors such as LiDAR sensors for altitude adjustments during spraying, and vision systems for obstacle avoidance. Subsequently, the data is analysed using image analysis techniques to obtain qualitative data on the spraying applications, or via laboratory retrieval of spraying tracers for the assessment o**f spraying displacement (drift)** UAV spraying.

4.7.2 Preliminary results of the example LL

The economic analysis of the example LL is not yet conducted. However, some preliminary results on identified costs and benefits are included in this deliverable.

The data collection revealed that the transition costs for adopting drone spraying consist of the cost of the main technology (UAV) and essential accessories such as batteries. The investment is generally made annually, though additional equipment may be purchased in subsequent years to improve autonomy and convenience.

A drone sprayer can range from 10 000 € to 30 000 € depending on its specifications, mainly its capacity in L, the manufacturer, and the accessories. The specific drone used in the experimental farm was purchased 1.5 years ago for €18,000 and has a capacity of 16 L. According to the expert, this capacity is suitable for a farm of 10 hectares, depending on the usage hours. The equipment's average lifespan is estimated to be 4-5 years. Like all agricultural machinery, it requires general inspection and repair every 2 to 3 years, with costs varying by manufacturer and dealer. The service cost is estimated to be around 200 € per year. Additionally, the drone requires insurance, which costs 200 € per semester.

No additional software costs have been identified for the use of drone spraying, as the appropriate software is typically provided as part of the package. Alternatively, some manufacturers use open-source software that can be installed on a tablet or smartphone, which then serves as the remote control. There is no significant change needed in farm facilities or structures to accommodate the use of this digital technology. However, there are benefits, such as reduced soil compaction since heavy machinery is not required for applying inputs. Furthermore, no extra labor is needed to establish the digital technology, although operator certification and knowledge are required. It is also worth noting that the storage space required for the drone is minimal, as it folds to occupy about 1 square meter.

The training costs for the operator are estimated at 350-400€, though this may vary according to the the training provider. However, the license of the operator requires no renewal, as it lasts for life.

Other legal expenses cannot be estimated, since the use of drone for spraying is still not eligible in Europe. In fact, one of the main obstacles in the adoption of drone spraying is that legislation.

All the necessary equipment for drone spraying is usually purchased by the farmer. No main or supplementary equipment is usually rented. However, there are cases where service providers offer full coverage (including operation) of drone sprays and usually price based on area and crop, which clearly determine the frequency and form of use.

Additional costs related to consumables, such as nozzle replacements, are minimal. These replacements are typically required annually or biannually, costing approximately 50 € to 100 €.

Regarding input use, the chemicals used for drone spraying are the same as those used in conventional spraying methods, as no special chemicals have been developed specifically for drones. Thus, drone spraying is not expected

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to alter the amount of active substances used per hectare. However, drone spraying requires significantly less water—estimated at 10% to 30% of the water needed for conventional spraying.

The energy requirements for drone spraying differ from traditional methods, as drones use lithium batteries and do not directly consume fossil fuels. However, it is difficult to estimate the total electric energy needed to fully charge the drone.

Drones are estimated to be about 25% faster than conventional machines. They move more easily across fields since they do not require turning and maneuvering, which can slow down vehicles and other machinery. However, drones do need frequent battery changes and tank refills. Overall, labor requirements are expected to decrease with drone spraying. According to the Agricultural University of Athens case study, the drone sprayer operates at a speed of 4-5 hectares per hour, which is lower than the manufacturer's claims.

The quantity and quality of the produce are not expected to change with the adoption of drone spraying. As a result, the use of this technology is unlikely to affect product prices or create added value for the produce. The impact of drone spraying on both the quantity and quality of the product is still being studied.

Other potential benefits of drone spraying include health advantages for farmers and consumers, due to increased precision in application, as well as greater ease of use and autonomy for the operator.

4.8 Conclusions

The previous paragraphs outline the methodology used, along with the general data collection guidelines, for identifying and estimating the economic costs and benefits of digitalisation. This task presents several challenges, as many of the CODECS Living Labs (LLs) have not yet fully digitalized, making it difficult to provide sufficient data for a comparison of “before” and “after” the adoption of digital technologies. As a result, the economic analysis methodology and data collection process will be adapted for each LL according to their level of digitalisation. For LLs currently in the process of digitalising, only qualitative data and/or quantitative data on transition costs will be collected.

For LLs that are already using digital technologies, an in-depth questionnaire will be used to estimate productivity and profitability indicators, as well as the Net Present Value (NPV) of the digital technology investment. Risk analysis will be conducted based on data availability, using either stochastic analysis or sensitivity analysis. Alternative scenarios may also be explored, such as comparing the NPV with or without subsidies, depending on the specific Farm Advisory System (FAS).

The economic analysis will provide valuable information for farmers considering the adoption of digital technologies, as well as for their advisors. It will offer a range of costs and benefits associated with these investments, whether qualitative or quantitative, and suggest options to maximise benefits and minimise risks. The results will also be useful for policymakers, giving them a clear understanding of the economic impact digital technologies can have on farms, and enabling them to design effective measures to promote the uptake of viable digital solutions.

The data collection process and materials for the economic analysis have been closely integrated with Task 4.3, reducing the workload for data collectors, LL coordinators, and the farmers providing the data. The generic questionnaire will be adapted for each LL and FAS to streamline the interview process and minimise its duration.

It is important to note that this deliverable will be updated, as both the data collection materials (e.g., the questionnaire) and the methodology may evolve based on the results of the first FAS analyses. Therefore, this document represents ongoing work by the partners involved in WP4.

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5 Social/human-centred costs and benefits assessment of farm digitalisation

Authors: Mauro Florez, Véronique Bellon-Maurel, Alexia Gobrecht (INRAE)

5.1 Introduction

This chapter is related to Task 4.5 of the WP4 in CODECS : Social/Human-centred costs and benefits analysis of farm digitalisation. We use the term "social/human-centred costs and benefits" to refer to the influence of digitalisation on farmers or all humans engaged in farming activities at the farm level, as outlined in Section 5.2.

The objective is to deepen our understanding of the social/human changes that digital technologies are bringing to farmers, with a focus on the intangible aspects of their use. By doing so, we aim to gain a comprehensive understanding of their impact on farmers and farmers practices.

This chapter first outlines the issues and challenges involved in studying these changes at the farm level. It then establishes the research objective of providing valuable insights to farmers and decision-makers through a comprehensive understanding of human transformations. Finally, the document presents the methodology implemented in the CODECS project, for the collection and analysis of data in order to ensure reliable and balanced results.

5.2 Social/human-centred aspects of the use of digital technologies at farm/farmers level

Research evaluating digital technologies in agriculture has primarily focused on their economic dimensions. Scholars have recently emphasized the need for further research that not only prioritizes profit generation but also focuses on improving the social aspects of digitalisation, adopting responsible innovation approaches (Roy 2021; Bronson 2019; Bellon-Maurel et al, 2022) and supporting skills development to enable more inclusive and sustainable digitalisation processes for farmers and other rural actors (Cowie et al. 2020). .

The study of the social dimension of sustainability has gained relevance in agriculture due to concerning social issues such as a decrease in the number of farmers and depopulation of rural areas. In general, it is acknowledged that social sustainability includes aspects from the farmer perspective but also on the social system around the farm. Although a universally accepted definition of the social dimension of sustainability in the agricultural context is still lacking (Ait 2018), research focusing on the social dimension of the intersection of agriculture and digitalisation can be classified into three scales of observation, in which studies are unequally distributed. Current knowledge predominantly concentrates on the macro level of stakeholders, perceiving impacts on society as a whole (Bronson 2019), on the meso-level, referring to implications of digitalisation at the regional level among farms (Carolan 2015), while the micro-level, points to humans at farm level remains nascent field (Klerkx et al. 2019; Rose et al. 2021; Van der Burg et al. 2019). Therefore, authors call for researching how digital technologies affect humans at the farm level to avoid causing more social problems than they solve (Rose et al., 2021), as well as to develop more inclusive and equitable approaches attending a greater diversity of human values with the digitalisation of agriculture, and those which include all types and scales of farms (Bronson, 2018).

Current research dedicated to changes on humans induced by farm digitalisation, although more and more active, still show some gaps. First, it focuses primarily on robotics and precision agriculture tools (Vik et al. 2019; Townsend and Noble 2022). Additionally, research is scattered across various issues related to human values, including health (Goutille et al. 2023; Sparrow and Howard 2020), skills, knowledge (Legun et al. 2022; Klerkx et al.2019), and work organization (Hidalgo et al. 2024;Prause 2021; Rose et al. 2021). Furthermore, defining and analysing the social dimension of sustainability presents challenges due to the dominant subjective factors, e.g. user health, user perceptions, that might impact such a dimension at the micro level (Ait 2018). The complex interconnections and relationships created by digital technologies among people, technologies, and institutions make it challenging for researchers to identify the resulting social changes (Benbya et al. 2020).

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It is essential to recognize that digital technologies should not be considered universal, as their impact is also shaped by socio-economic, cultural, and political factors within different contexts (Klerkx & Rose, 2020). This complexity makes studying the social-human aspects of digital technology adoption/use challenging. By understanding how digital technologies influence farmers and their farming activities, we can share valuable knowledge with other farmers and understand as well as in some cases diminish resistance to new technologies. Policymakers can leverage these insights to design and support policies that either reduce or promote any negative or positive social-human changes resulting from the adoption and use of digital technologies at the farm level.

5.3 Design research

The objective is to evaluate the social-human costs and benefits of digitalisation at the farm level, mainly, by identifying and enhancing the understanding of the adoption and use of digital technologies by farmers.

Based on the introduction and the aforementioned objective, the task will seek to address the following research questions:

RQ1: How does the adoption and use of digital technologies affect farmers and farmers' practices?

RQ2: How does the context in which digital technologies are adopted and used influence the results they produce for farmers and workers at the farm level?

To address the research questions concerning social-human costs and benefits, T4.5 researchers are conducting a qualitative study among farmers identified in the CODECS Living Labs. This encompasses both positive and negative human changes affecting farmers and their agricultural practices. Social-human aspects include exploring the changes of these technologies on farmers' well-being, social interactions, labor and overall quality of life within their specific socio-economic and cultural contexts. By collecting qualitative data, the researchers aim to gain a comprehensive understanding of the social-human implications of using and adopting digital technologies at the farm level.

5.4 Methodology

A two-step approach was implemented in this task. First, we organized a workshop that brought together T4.5 researchers from various disciplines to explore the potential transformations - both positive benefits and negative costs - that digitalisation may bring to farmers and farm operations. The insights gained from this workshop served as the foundation for developing semi-structured interviews for data collection among farmers in the various Living Labs.

5.4.1 Workshop on human costs and benefits resulting from farm digitalisation

We conducted the workshop in March 2023, following the recommendation of Rose et al. (2023) to explore more multidisciplinary fields that encompass changes at the farm level and its sustainable outcomes, placing human-centered aspects at the core of the discussion. The workshop's objective was to define, identify, discuss, gather, and organize the human-centered costs and benefits associated with digitalisation at the farm level

First, it was decided to deal with "human-centered" costs and benefits concept; the "human" aspect highlights the "soft impacts" in the literature, which can only be described in qualitative terms and tend to focus more on the human dimension (Van der Burg et al. 2019, p. 6). Moreover, the "costs and benefits" terminology encompasses the dual nature of digital transformations, spotlighting both the advantageous and adverse impacts on humans (Murphy and Simon 2004, p.302)

Second, participants delved into the discussion ultimately agreeing, and aligning with previous researches, that digitalisation introduces changes transforming three "key human components" on farms that can be seen as affected by "human costs and benefits"; (i) farmers, their employees, or family members engaged in agricultural activities (Rose et al. 2021), (ii) their work, tasks performed by people using digital technologies within farms (Klerkx et al.2019; Carolan 2018), and (iii) the organization of the production system on farms (Klerkx et al. 2019; Vik et al. 2019).

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In the second part of the workshop, participants questioned how digitalisation might affect the three “key human components” on farms, in order to define a span of “unitary indicators” of human-centered cost and benefits. The interactive nature of the workshop sparked a dynamic exchange of ideas among participants, leading to iterative discussions and refinements. Indicators concerning (i) farmers, defined also as any human engaged on farms such employees, or family members involved in agricultural activities, were categorized into two groups: Health & Wellbeing; Skills & Knowledge. Subsequently, participants delved into exploring indicators relating to (ii) Work, defined as the tasks carried out by the primary component.

Consensus was reached among participants to cluster the indicators into Quality of Work and Time. Lastly, participants exchanged insights regarding indicators pertaining to (iii) the Organization of the production system, defined as the interaction of humans with their working activities, where only one family of indicators emerged: communities and networks.

Figure 10 shows some examples found in France of human-centered costs and benefits of digitalisation for five groups, organized into three main human components.

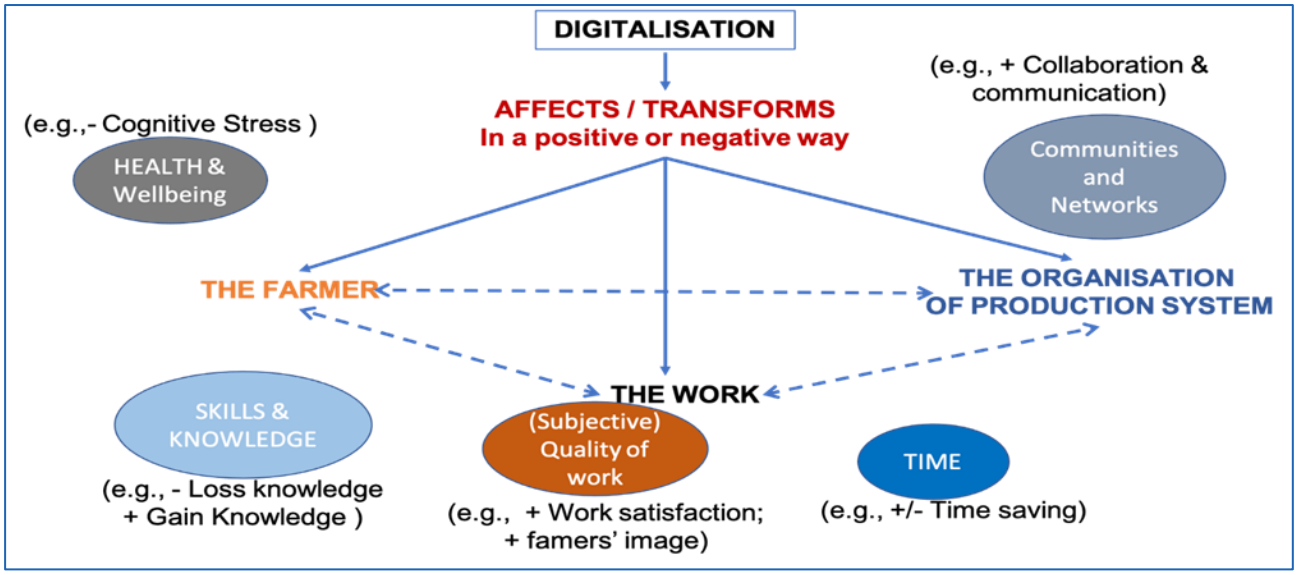

Figure 10: Human-centred Cost and Benefits digitalisation at the farm level

The workshop proved to be an effective tool for addressing the challenges outlined in the literature, particularly the fragmented research on human values and the difficulties in defining the social dimension of sustainability, which are complicated by dominant subjective factors. These factors, in turn, contribute to the complexity of identifying social changes driven by digital technologies (Benbya et al. 2020). Consequently, the workshop established a foundational definition that enabled the identification, discussion, and structuring of potential human-centred costs and benefits in digital agriculture

Below, we present our qualitative method for data collection and analysis, providing a description of expected human-centred cost and benefits, inclusion and exclusion criteria for farmers, the semi-structured interview questions, and some advice for interviewers.

5.4.2 Qualitative method

We chose to use a qualitative method to deeply understand the experiences and perspectives of farmers regarding the human-centred costs and benefits of adopting and using digital technologies in various situations, including living labs, different countries, farm conditions, and with different technologies.

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Considering our research questions, a qualitative approach is suitable for exploring a topic that has not been extensively studied in the literature and lacks strong theories (Trauth, 2001). Moreover, it acknowledges that the results, of adopting and using digital technologies, may vary depending on the specific context.

Data for this stage of research is collected through semi-structured interviews, enabling farmers from living labs to freely share their experiences and perspectives on adopting and using digital technologies (Furneaux & Wade, 2011). Additionally, this approach allows us to address the potential human-centred costs and benefits discussed, herebefore presented, by the members of T4.5 in terms of farmers, work, and the organisation of the production system.

5.4.3 Sample and semi-structured interview presentation

Sample

In this qualitative study, and building upon the digitalisation levels outlined in WP3.3, we include farmers or operators from various Living Labs (LL) who are actively using digital technologies on their farms (Digitalised) and those who are still in the process of adopting, testing, or integrating prototypes (Digitalising). While we are open to narratives on experiences with a wide spectrum of digital technologies, our primary focus is to investigate more thoroughly those technologies that have been selected for an in-depth study within the LL for the Focal Action Situation (FAS). Conversely, farmers and LL that are yet to identify suitable digital technologies are excluded from this study to maintain a concentrated exploration of the impact of technology usage.

Semi-structured interviews presentation

Semi-structured interviews are taken place to focus on gathering qualitative information related to the human-centred costs and benefits of the digital technologies being currently adopted and used. The outcomes of this qualitative research will deepen our comprehension of the social- human implications under different contexts by systematically identifying, collecting, and structuring the human-centered costs and benefits linked to digital technologies at the farm level. Also, they will serve as the foundation for constructing hypotheses, which will be tested in subsequent research phases (Venkatesh et al., 2013).

Appendix 4 details in a comprehensive guideline document all the information needed to organise the semi-structured interviews of the farmers in the Living Labs.

The semi-structured interviews are organized into four distinct sections to comprehensively explore different facets of farmers' contexts, experiences, and perceptions regarding the social-human changes brought about by the use of digital technologies at the farm level. Each section is further divided into specific research themes. In total, the semi-structured interview comprises nine main questions. Additionally, please note that the following semi-structured interview is designed for both types of Living Labs (Digitalised and Digitalising), with the exception of two themes detailed hereafter. Below, we provide the details of each section, along with the corresponding themes and questions.

Introduction

The first part of the interview serves as an introduction, aiming to establish a comfortable environment for both parties to engage in conversation. However, it can also yield valuable insights into the context of the farmer and their specific needs or challenges.

Theme: Context (both Digitalised and Digitalising)

Q1: Can you provide a description of your profession as a farmer and farming activities you engage in?

Specific

The second part is the core of the interview, where we delve into the farmers' stories and experiences with using or adopting digital technologies. Moreover, we aim to explore the human changes that arise from various experiences/contexts with digital tools at the farm level.

Theme: Use and experiences (only if your LL is Digitalised)

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Q2: I would like to hear your experience with using digital technology (Technology to study in the LL) in your day-to-day farming activities

Theme: Digital Readiness (all LL)

Q 3: How would you describe the readiness level of you/your farm business in order to adopt the digital technology necessary for you?

Theme: Use and changes (only if your LL is Digitalised)

Q4: Could you please share what changes have you observed because of using (Technology to study in the LL) digital technology in your day-to-day farming activities?

Theme: Use and expectation of changes (only if your LL is Digitalising)

Q : Could you please describe the changes you anticipate or expect to see from using digital technology (Technology to study in the LL) in your day-to-day farming activities

Theme: Meanings (all LL)

Q5: What is your understanding of human changes induced by the use of digital technologies?

Engagement with digital technologies

In the third part of the interview, we will ask a series of questions to collect information that would uncover farmer's reality on human changes. Also, to identify potential new digital technologies in their context and therefore potential new indicators on human changes through farmers' perceptions and experiences.

Theme: use and reasons (all LL)

Q6: I'm curious to know which other digital technologies you currently use or are adopting to support your day-to-day farming operations

Theme: Concerns/opportunities (all LL)

Q7: Could you please share any challenges or concerns related to first-hand observations or experiences with the changes brought about by using digital technologies in farming?

Q8: In your experience, what benefits or opportunities may arise for people as a result of the integration of digital technologies in farming?

Wrap up

In the final part of the interview, a set of closing questions is included to ensure comprehensive coverage of the topic. I invite the respondent to share any additional insights or perspectives they have that have not been discussed yet. Furthermore, I encourage them to consider any important aspects or noteworthy information regarding social-human changes that they believe would contribute to a more thorough understanding of the topic.

Q9 **(all LL)**: We have come to the end of my questions, now that you know what the interview was about, and you know what we have been talking about, what should I have asked you about that I did not give you an opportunity to share about social-human changes induced by digital technology use?

5.4.4 Data analysis

Analysing data is a pivotal phase of our research, and we will use content analysis to sort narrative (Weber, 1990) data according to the framework we introduced in the previous section, while also remaining open to uncovering new topics. In this method, phrases will serve as unit of analysis, enabling us to extract meaningful insights. These units of analysis will be meticulously scrutinized and grouped to form distinct categories. Thus, using content analysis technique is expected to yield a systematic and objective understanding of the themes and patterns related to the human costs and benefits of digitalisation. We will conduct the content analysis in separate teams using MAXQDA and NVivo software. Afterward, we will compare the results to ensure consistency.

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5.5 Preliminary results and upcoming steps

5.5.1 Data collected

Table 4 summarizes the collected data up to September 2023. The table provides an overview of two levels of digitalisation—**Digitalized** and **Digitalizing**—were data was collected.

- **Digitalized Farms**: Involve 4 Living Labs, 5 interviews, and 12,296 words transcribed. The type of farms participating in tihs groups include crop, livestock, and mixed operations. The digital technologies used are **Decision Support Tools**, **Monitoring Input Management**, and **Marketplaces**, aimed at improving **decision-making and sustainability**.
- **Digitalizing Farms**: Include 10 Living Labs, 14 interviews, and 44,543 words transcribed. Similar to digitalized farms, these also span crop, livestock, and mixed types. The technologies focus on **Monitoring Input Management** and **Marketplaces**, with additional purposes of improving **decision-making**, **local food economy**, **digital literacy**, and **sustainability**.

Table 4: Description of the collected data in T4.5 (M18 – M24)

Digitalisation Level	Living Lab	# interviews	# words transcription	Type of Farms	Digital Technology Cluster	Technology Purpose
Digitalised	4	5	12.296	Crop, livestock & mixed	Decision Support Tools, Monitoring Input Management & Marketplace	Improve decision-making & sustainability
Digitalising	10	14	44. 543	Crop, livestock & mixed	Monitoring Input Management & Marketplace	Improve decision-making, local food economy, digital literacy & sustainability

5.5.2 Upcoming steps

The next steps are dedicated to the content analysis of the interviews of farmers, which will involve all the different partners of the task as they are mobilizing different scientific disciplines and methodologies.

- M24 – M30: multidisciplinary content analysis performed by the partners involved in T4.5
- M24 – M30: completion of the data collection with additional use-cases when relevant
- M28 – M30: quantitative data collection protocols (second phase)
- M30 – M36: second data collection phase
- M 34: synthesis report of the Social-human centered costs and benefits part 2 (in D4.2)

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6 Conclusion

Authors: Alexia Gobrecht (INRAE)

This deliverable marks the completion of the first phase in the ongoing assessment of the costs and benefits (C&B) of farm digitalisation, the core objective of Work Package 4. The methodologies developed, data collected, and initial analyses provide valuable insights into the economic, environmental, and social dimensions of digital technologies in agriculture. The findings thus far highlight both opportunities for improved efficiency, sustainability, and competitiveness, as well as challenges related to trust, energy consumption, skill acquisition, and governance.

However, this deliverable represents only the beginning of a more comprehensive evaluation. Future phases will expand on these findings to provide a deeper, more nuanced understanding of how digitalisation transforms farming practices across the three dimensions of sustainability. With the multicriteria C&B assessment set to begin at month 30, the project will further explore trade-offs and synergies between economic, environmental, and social impacts. This continuing analysis will provide robust tools and insights for farmers, policymakers, and other stakeholders to make informed decisions about the adoption of digital technologies in agriculture.

As we progress, the ongoing evaluation will refine the understanding of digitalisation's impact at the farm level, ensuring that future recommendations are practical, scalable, and aligned with the goal of sustainable farming practices. By focusing on a detailed C&B assessment, the project remains committed to delivering actionable insights that support a balanced and beneficial digital transformation of agriculture.

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D4.1 SYNTHESIS REPORT

ENVIRONMENTAL, ECONOMIC, AND SOCIAL COSTS & BENEFITS OF FARM DIGITALISATION

VOL 1 M24

APPENDIXES

30 SEPTEMBER 2024

ALEXIA GOBRECHT , VERONIQUE BELLON-MAUREL, MAURO FLOREZ (INRAE)
COSTAS ILIOPOULOS , IRINI THEODOUROPOULOS , ALEXANDRA SINTORI, THOMAS GIOTIS (AEGRI),
BEATRIZ HERRERA (UHOH), MAIJA USCA (BSC)
LEANNE TOWSEND (HUTTON)

CC BY

7 Appendix

7.1 Appendix 1 Focus group protocol and guidelines

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T4.1 GUIDELINES

GUIDELINES FOR DATA COLLECTION AND REPORTING

APPENDIX 1 – PERCEPTION EN ECONOMIC, ENVIRONMENTAL AND SOCIAL COSTS AND BENEFITS

FOCUS GROUP PROTOCOL AND GUIDELINES (TASK 4.2)

02 OCTOBER 2023

CONSTANTINE ILIOPOULOS (ELGO-DEMETER), IRINI THEODORAKOPOULOU (ELGO-DEMETER)

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1. Introduction

The current shared document describes the scope and objective of Task 4.2, whose title is “Analysis of costs and benefits perception”. Additionally, the document presents the beneficiaries of T4.2 findings and outputs, as well as how the objective of the task will be achieved and the data collection methods to be implemented. This shared document will be distributed to colleagues who work on WPs (Work Packages) 2, 3, and 4 to collect comments and ideas on how to improve the research conducted in T4.2. Section 5 describes the Focus Group methodology to be used for data collection purposes.

2. Scope of Task 4.2

Task 4.2 focuses on the perceptions of farmers, policy makers, and advisors (stakeholders from now on) regarding the various costs and benefits associated with farm digitalisation. Identifying and analysing these perceptions is of paramount importance to understanding how costs and benefits are created and, thus, designing and implementing effective and efficient digitalisation policies. Due to the links established in the literature between perceptions, motivations, and accounting costs and benefits associated with the introduction of transformative technologies, the research conducted in T4.2 will be useful to, at least, the following audiences:

- Colleagues in all WP4 tasks, who will be informed on the perceptions of costs and benefits and use them in designing their data collection instruments in more efficient ways.
- Colleagues in T4.5, who will use the results of T4.2 as input in their research and results.
- Colleagues in WP2, who will use T4.2 stakeholder evaluations of the assessment grid developed in WP2 to improve it.
- Colleagues in WP3, who will use T4.2 stakeholder evaluations of the process maps developed in WP3 to improve them.
- Colleagues in WP6, who will use stakeholder perceptions in making policy recommendations.
- Policy makers whose farm digitalisation policies will be informed by our findings (also see Policy Brief 5: Analysing farmers’ motivations regarding digitalisation).
- Farmers, who will become aware of their own perceptions regarding the costs and benefits of farm digitalisation and how their mental models affect the agri-food system in which they are embedded.
- Farm advisors, who will become aware of the underlying motivations of farmers and, thus, will be able to design their services in more effective and efficient ways.

3. Objective of Task 4.2

Task 4.2’s objective is to identify and understand how farmers, policy makers, and advisors perceive the various social, economic, and environmental costs and benefits associated with farm digitalisation.

3.1. How the objective will be achieved

T4.2 will achieve its aforementioned objective by answering the following **research questions**:

RQ-1: What are the perceptions of farmers, farm advisors, and policy makers regarding the social, economic, and environmental costs and benefits resulting from farm digitalisation?

RQ-2: What are the problems facing farmers now or in the future as farms become more and more digitalized?

RQ-3: How do farmers, farm advisors, and policy makers assess the process maps developed in WP3?

To answer the above questions, T4.2 researchers will collect qualitative information from stakeholders on each dimension of costs and benefits (i.e., social, economic, and environmental). More specifically, qualitative data will be collected on:

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- The perceptions of stakeholders regarding the social, economic, and environmental costs resulting from farm digitalisation.
- Problems facing farmers now or in the future as farms become increasingly digitalized.

All data required to achieve the objective of Task 4.2 will be collected by each LL (Living Lab) in the following focus groups, preferably organized during the annual Living Lab workshops:

- One focus group meeting organized by each LL in M13 (total=20 FG meetings) on the perceptions regarding the social, economic, and environmental costs resulting from farm digitalisation.
- One focus group meeting organized by each LL in M25 (total=20 FG meetings) on the assessment of process maps developed in WP3.
- One focus group meeting organized by each LL in M37 (total=20 FG meetings) on the perceptions regarding the social, economic, and environmental costs resulting from farm digitalisation (this second FG meeting will enable T4.2 researchers to identify the dynamic evolution of perceptions).

The protocol and guidelines for each of these focus group meetings are produced as part of T4.1 and, subsequently, will be included in D4.1, to be used by LL leaders for organising and conducting the focus group meetings and collecting the data described above. The focus group protocol is presented next. Two online training sessions of LL leaders on how to organize and conduct each focus group meeting are planned for July 4, 2023, and September 7, 2023.

4. Focus Group Protocol

4.1. The Focus Group Method[1,2]

Although surveys assume people are self-aware of their emotions, it is not always the case, and they may require the input of others in a small and secure setting to form their thoughts and opinions. In such cases, focus groups are an appropriate choice.

Focus groups can provide in-depth knowledge and profound insights. A well-conducted focus group creates a welcoming atmosphere that enables participants to feel comfortable and express their thoughts in their own words, adding significance to their answers. While surveys are ideal for gathering information about people's attitudes and attributes, for a deeper comprehension, focus groups are more effective.

If you have taken part in a successful focus group, you might have found it natural and easy to talk to a group of unfamiliar people. However, you may not have realized the numerous concealed elements that underlie it all. Planning is crucial to a well-executed focus group, and it involves more than just inviting a few individuals to casually express their views on a subject. In any case, all LL coordinators, who will facilitate the focus groups, will be trained by the ELGO-DEMETER team on all the steps to be taken before, during, and after the focus group meeting. This training will be organized in two separate, online seminars; one on the 4th of July 2023 and the second on the 7th of September 2023. The first seminar will be devoted on the process to be followed before the focus group meeting (e.g., how to identify and invite stakeholders, how to create the container, that is, a physical but also spiritual place where participants feel comfortable to discuss about the costs and benefits of farm digitalisation, etc.). The second seminar will focus on how to facilitate the focus group meeting efficiently and effectively, but also on what to do after the meeting is over.

Outlined here are the details for conducting a high-quality focus group as an eight-step process. Also included are step-by- step instructions for making sense of all the information you collect in the groups.

[1] Liamputtong (2011).

[2] Williamson and Miller (2020).

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4.1.1. STEP 1: Defining Focus Group

A proficient moderator leads a focus group consisting of **six to ten** individuals in an unstructured conversation. The group size is significant enough to facilitate an abundant discussion, but small enough to prevent participants from feeling excluded. The moderator cultivates an environment of openness and spontaneity to encourage participants to disclose their thoughts and feelings. The goal is to elicit a diverse range of ideas and perspectives from the maximum number of participants within the allotted time.

The **optimal length** for a focus group is **between 45 and 90 minutes**. Beyond that, groups tend to become unproductive, and participants may become burdened. While a set of predetermined questions, typically no more than ten, guide the discussion, the conversation flows naturally. Ideally, participants' comments stimulate and influence the thinking and sharing of others, sometimes resulting in a change of opinions or perspectives.

To produce valid results, multiple focus groups on the same topic are necessary, so in CODECS each LL leader will organize three focus groups, each during the annual meeting of her/his LL (M13, M25, M37).

4.1.2. STEP 2: Recruitment and Participation

Given that the optimal size of a focus group is **ten people**, the following profiles will be used by LL leaders to invite focus group participants in their focus group:

- 4 farmers, 2-3 of them engaged in farm digitalisation projects.
- 3 policy makers engaged in designing farm digitalisation policies and regulations (e.g., those in regional authorities, ministries who are responsible for designing and/or implementing digitalisation policies in agriculture).
- 3 farm advisors or experts familiar with the issues facing farmers regarding farm digitalisation. These can come from both the public and the private sector, including academic researchers and professors whose research focuses on farm digitalisation.

Please keep in mind that some diversity is useful to generate discussion from a range of perspectives, although each focus group facilitator should be careful to keep an eye on group dynamics in mixed groups.

More specific profiles of focus group participants will be provided after the focal action situation of interest in LL is fully described in preceding WPs.

An optimal focus group is characterized by participants who are at ease with one another but unfamiliar with each other. To maximize disclosure among focus group participants, it is crucial to ensure that participants feel at ease with each other, and no previously known frictions exist between them. In selecting individuals for focus groups, consider the following criteria:

- Gender: Maintain balance by inviting both male and female participants unless you are sure that they will not be comfortable discussing the topic in a mixed-gender group. In CODECS, we expect no such issues.
- Age: Would a younger person feel intimidated being in a group with older adults? Conversely, would older adults feel comfortable in a group with younger participants? LL leaders who are familiar with the local cultural norms need to decide on this issue as well.
- Power: Would a participant in a group with a superior or authority figure feel comfortable making candid remarks? Please avoid inviting individuals that might block the candid conversation by their very participation in the focus group.
- Cliques: How influential might certain individuals or groups be in a group of their peers? Will these participants dominate the discussion?

By establishing selection criteria based on these factors, you can create a more homogenous and comfortable environment for focus group participants, which can lead to more honest and valuable insights.

To ensure that the study is appropriately targeted and yields reliable results, it is essential to establish explicit criteria for including or excluding participants at the outset. These criteria should be closely aligned with the research aims and used as a basis for screening all potential applicants.

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In general, to assemble a group of participants for a focus group, there are various effective strategies to consider. These include:

- Nomination: Participants can be nominated by key individuals who believe they have the necessary expertise and opinions to contribute to the discussion. These nominees should have some familiarity with the topic at hand and be willing to devote approximately two hours to the discussion.
- Group affiliation: Existing groups, a local agricultural cooperative, or an inner-professional organisation, can be ideal sources of participants who share similar backgrounds and perspectives.

In CODECS, focus group participants will be nominated by LL leaders (key-individuals). The LL leaders will choose stakeholders among their group, by taking into consideration the above-mentioned selection criteria.

In the case of farmers, LL leaders can either approach them directly or ask for nominations from agricultural co-operatives and/or producer organisations. Usually, these organisations have deep knowledge of who might be interested in participating and who is engaged in digitalisation projects. Similarly, farm advisors/experts can be contacted directly if the LL leader knows them personally or ask local associations of farm advisors to nominate individuals.

With respect to policy makers engaged in designing farm digitalisation policies and regulations, usually these are just a few individuals, well known at the national and/or regional level. So, in their case, focus group moderators do not have abundant choices.

It is advisable to over-invite in anticipation of a no-show rate of 10 to 20 percent. But you will need to keep the number of participants at a maximum of 10 individuals.

After assembling a group of potential participants, it is important to confirm their interest and availability before the focus group. To do so, contact each individual and provide them with the relevant details about the time and location of the focus group. Secure their verbal confirmation and inform them that you will send them a written confirmation via email or mail. Additionally, it is a good practice to remind participants of the upcoming focus group two days before the scheduled date via phone call or email.

The focus group organiser will also devise a form to track invitation phone calls. Additionally, the organizer will include an “Address” box for mailing the confirmation letter and a “Comments” box.

Next, the focus group organiser will schedule the times, locations and people involved for all focus groups planned (one focus group during the annual LL meetings).

Participants will be informed that the focus group will take about one and half to two hours. A starting time that is 15 minutes prior to the actual start of the focus group will be given to participants, to allow for filling out necessary paperwork, having a bite to eat, and settling into the group.

It is important to arrange for a comfortable room in a convenient location. The room should have a door for privacy and table and chairs to seat a circle of up to 12 people (10 participants and the moderator and assistant moderator).

Arrangements for food will be made in advance. At a minimum, LL leaders will offer a beverage and light snack (cookies, cheese/crackers, veggie tray, etc.).

In T4.2 focus groups, LL leaders will invite farmers, policy makers, and farm advisors/experts to participate in the three focus group meetings. LL leaders can find in **Appendix E** a **draft invitation letter**, which they will adapt to their local conditions. Regarding the composition of each focus group, we will invite 4-6 farmers, 3-4 policy makers, and 2-3 farm advisors.

With respect to the participants, two options are currently explored: (i) the same individuals participate in all meetings, or (ii) different individuals are invited to each meeting. Each of these options has its pros and cons. Inviting the same individuals enables us to understand how perceptions evolve from year to year, but it is difficult to ensure that the same persons will join us in all three meetings. In the case of different participants in the three meetings, the diversity of opinions and perceptions will enable researchers to understand more deeply how perceptions are constructed. However, it becomes impractical to compare the dynamics of perception evolution. Nevertheless, the task leader will consult with LL leaders prior to making the ultimate decision.

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4.1.3. STEP 3: Focus Group Questions

Twelve is the maximum number of questions for any one group. Ten is better, and eight is ideal.

Focus group participants will not have a chance to see the questions they are being asked. So, to make sure they understand and can fully respond to the questions posed, questions should be (Wilkinson, 1998):

- Short and to the point.
- Focused on one dimension each.
- Unambiguously worded.
- Open-ended or sentence completion types.
- Non-threatening or embarrassing.
- Worded in a way that they cannot be answered with a simple “yes” or “no” answer (use “why” and “how” instead).

There are three types of focus group questions:

- Engagement questions: introduce participants to and make them comfortable with the topic of discussion.
- Exploration questions: get to the meat of the discussion.
- Exit question: check to see if anything was missed in the discussion.

The structure and content of each focus group meeting dictates the questions asked in each meeting. The first focus group meeting, in M13, will be dedicated to answering research questions (RQ) 1 and 2 at a more generic level, while the other meeting (M37), when detailed information on costs and benefits will have been generated by CODECS WP4 researchers, will focus on the same research questions but now at a deeper level. In this second FG meeting the same participants will come together to discuss and researchers will identify their potentially modified perceptions of costs and benefits and, thus, the dynamic evolution of these perceptions.

The questions prepared by the ELGO-DEMETER team for the first meeting of the focus group in each LL are based, initially, on information collected from the literature on the changes caused by farm digitalisation as well as particularly useful comments from the CODECS coordinator, Prof. Gianluca Brunori, whom we take the opportunity to thank. Subsequently, as other work packages make progress in preparing the assessment grid (WP2) and concept maps (WP3), relevant information from those WPs will be used in drafting questions for the second focus group meeting in M25.

An initial set of Focus Group semi-structured questions follows:

D. Engagement Questions:

2. What comes to your mind when you hear the term “farm digitalisation”?

E. Exploration Questions:

11. Bearing in mind the proposed tool/service, do you think it might work? Why? Under what conditions?
12. How do you think the innovation would change farming activities (operations, organization, relations in the supply chain, relations with advisers, relations with suppliers)?
13. How would the innovation contribute to environmental sustainability? Under what conditions?
14. How would it contribute to farmers' incomes and welfare, quality of work, and gender equality? Under what conditions?
15. What do you think are the economic, social, and environmental costs associated with the introduction of the proposed digitalisation innovation and who will incur each type of cost?
16. Would you be willing to pay the associated costs? Up to which level would you be willing to pay?
17. What kind of problems do you expect to face as more and more farms will become digitalised in the future?
18. What kind of benefits (economic, social, and environmental) do you expect from digitalisation? Please provide some examples.

F. Exit Question:

19. Is there anything else you would like to share with us regarding farm digitalisation that you have not shared so far?

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The above questions will be pre-tested with CODECS partners who were not involved in the writing of them to ensure that they are not too loaded or leading and that they can assist with answering the research questions. A set of questions for the FG meeting on the assessment of process maps developed in WP3 will be provided to LL coordinators well in advance of the meeting so that they have enough time to prepare.

4.1.4. STEP 4: Conducting the focus group

What does the focus group facilitator need to take with her/him?

- Digital recorders or mobile phones (at least two), with new batteries and a spare set!
- Copies of information sheets and consent forms.
- Any other background information that might be needed or handouts.
- Signs, name badges as required.
- Writing materials, flipcharts, white-board pens and any other resources that might be needed.

What should the room look like?

When planning for a group gathering, it is important to consider the lighting, ventilation, and noise level of the room to ensure a conducive environment for your participants. You should also consider the layout and furniture to create a comfortable and distraction-free space. This can be achieved by minimizing external distractions and ensuring equal access to the facilitator.

Arriving early on the day of the event will give you ample time to set up the room and prepare yourself to welcome participants in a relaxed and calm manner. While there are no set rules for room layouts, it is essential to prioritize the comfort of the attendees and provide enough space to avoid feeling confined or stressed.

Make sure that there is access to water and any catering provided, such as tea or coffee and biscuits before the session begins to avoid interrupting the proceedings. Furthermore, the shape, layout, and seating arrangements of the room can affect the dynamic of the discussion, so consider the level of formality that would be appropriate for the research you are conducting.

Who runs the focus group and how?

Ideally, the focus group is conducted by a team consisting of a facilitator and assistant moderator. The moderator facilitates the discussion; the assistant takes notes and runs the tape recorder. The ideal focus group moderator has the following traits:

- Can listen attentively with sensitivity and empathy.
- Can listen and think at the same time.
- Believes that all group participants have something to offer no matter what their education, experience, or background.
- Has adequate knowledge of the topic.
- Can keep personal views and ego out of the facilitation.
- Is someone the group can relate to but also give authority to (e.g., a male moderator is most appropriate for a group of all men discussing sexual harassment in the workplace).
- Can appropriately manage challenging group dynamics.

The assistant moderator must be able to do the following:

- Record the session.
- Take notes in case the recording fails, or if participants do not agree in recording the session.
- Note/record body language or other subtle but relevant clues.
- Allow participants to do all the talking during the group.

Both moderator and assistant moderator are expected to welcome participants, offer beverages, help them make their name tents, and direct them in completing pre-group paperwork. Name tents should identify participants with a number written for anonymous identification of individuals as they make comments.

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At a minimum, all participants should complete a **consent form** (see **Appendix B** for a sample consent form).

It is important to collect demographic information from participants because age, gender and other attributes are important for correlation with focus group findings. Design a short half page form that requires no more than two or three minutes to complete. Administer it before the focus group begins (see **Appendix C**).

Once consent forms and demographic surveys are collected and reviewed for completeness, the questioning begins. The moderator uses a prepared script to welcome participants, remind them of the purpose of the group and sets ground rules. An example of prepared script follows.

When people arrive

As participants arrive, warmly welcome them and direct them to any refreshments available. Encourage a timely start for the focus group discussion, which should begin with an introduction from the facilitator outlining the purpose and process of the session.

To start off the session, the facilitator should welcome all the participants and introduce themselves and any other team members present, explaining their respective roles. They should also explain the general purpose of the discussion and why the participants were chosen.

If there is any audio recording equipment present, the facilitator should explain its presence and purpose to the participants. The structure of the focus group should then be outlined, including the duration and any ground rules or discussion guidelines that may apply. These could include guidelines for ensuring that everyone is heard, speaking one at a time, and allowing the moderator to interrupt to ensure that all topics can be covered fairly.

After the discussion guidelines have been covered, any housekeeping information should be reviewed. Finally, the facilitator should ensure that the group understands what will happen to the information that is shared. They should explain that the information will be analysed and written up in a report, emphasizing that no individual will be identified in any output from the research. It should be made clear that while what is said might be quoted, it will be done so in a way that ensures anonymity for all participants.

FOCUS GROUP INTRODUCTION

WELCOME

Thanks for agreeing to be part of the focus group. We appreciate your willingness to participate.

INTRODUCTIONS

Moderator; assistant moderator

PURPOSE OF FOCUS GROUPS

We are conducting this focus group as part of the EU's HORIZON RIA project **CODECS**, which focuses on the digitalisation of farms in Europe. The reason we are having these focus groups is to find out what are your views on the economic, social, and environmental costs and benefits associated with farm digitalisation.

We need your input and want you to share your honest and open thoughts with us.

This is one of three focus groups, the other two are to follow in one and two years from now. When we have finished the research, we will produce a report that describes what we have found in terms of the main themes that you and the other focus groups tell us about.

We are recording this focus group and we will use this recording for our analysis. When we write about our findings, we might use direct quotes from this focus group, but we will not identify you individually and any quotes that we do use will be attributable to an anonymous individual or to a role (e.g., farmer 1, farmer 2, policy maker 1, farm advisor/expert 1, etc.).

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You should all have an information sheet that describes the research if after today you have any questions about what we are doing, this information sheet contains our contact details, and we welcome you to get in touch.

Before proceeding, the moderator should present to participants (either in a presentation slide or, even better, in a flipchart sheet of paper) the three points on which all participants need to agree before starting:

- Presence: All participants are 100% active and engaged without allowing DISRUPTIONS, such as mobile phones, etc., to distract them.
- Confidentiality: "Whatever is said in this meeting, stays here."
- Democracy of time: Both in terms of quantity and quality, the time allotted to each participant to express herself/himself will be equal.

Subsequently, the focus group facilitator must present a **neutral description of the technology being introduced in their LL** to the participants. LL coordinators should send us a **description of the technology innovation** their focus group will focus on **at least one month before the meeting**. The statement should contain enough information on the technology, but not too much, as the way it is phrased can affect the participants' perceptions. The goal is not to promote or discourage the technology. During the first focus group meeting, participants will need to express their perceptions of costs and benefits without much hard evidence on costs and benefits. To assist LL coordinators in providing a brief description of their technology, an example from the French Occitanum LL is provided next.

Example Description of Technology at the Occitanum LL, France

Technology S: A tool for differentiated fertilisation in the vineyard

Starting point: Fertilization has to be tuned as precisely as possible: this is called precision fertilization. A plot is not uniform; therefore, it may be relevant to apply more of less fertilizer according to the needs of the vineyard.

Objective: Technology S is a system for variable rate application of fertilizer. It aims to apply differentiated fertilisation according to the needs of the vine in a plot. To do so, we have to (A) define the zones that need different rates; (B) define the rates to be applied in each zone; (C) allow the fertilizer spreader to apply the appropriate rate in the appropriate zone.

How it works: Techno S comprises these 3 functions:

- a function (A) for constructing the various zones to be fertilised at different rates: the zones are constructed, either manually by the wine grower (who can use vigour maps) by drawing them on a tablet or automatically by Techno S from satellite or drone images, and these zones can be modified manually by the wine grower;
- a GIS (Geographic Information System) interface in which the farmer can allocate a dedicated amount of fertilizer in each zone obtained in (A); it provides a map (B) of the different rates to be applied in the different zones;
- a software (C) to make the map (B) interoperable, i.e., usable, by any variable rate application platform / spreader, whatever the brand.

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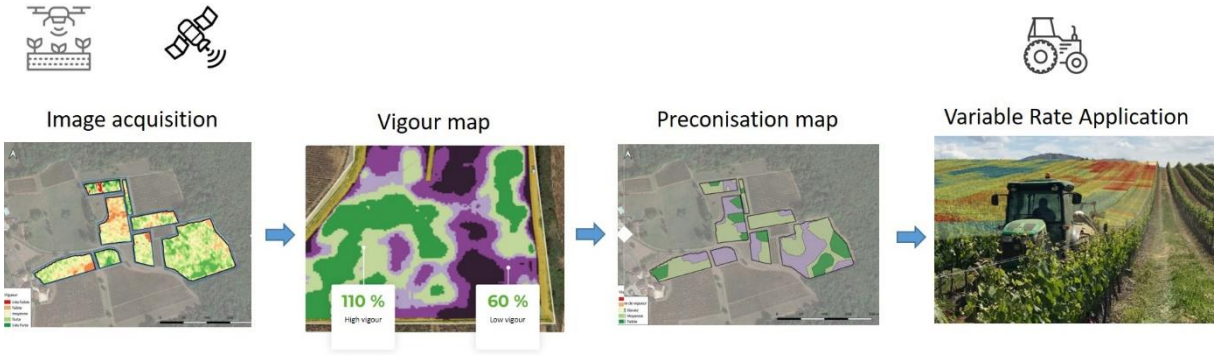

Price range:

Average price for the whole system (mapping system + platform + variable rate application spreader): 10 000 - 15 000 euros.

GROUND RULES

1. THREE AGREEMENTS

Before starting we need that all of us agree on three things:

- Presence.
- Confidentiality.
- Democracy of time (see preceding paragraphs).

2. WE WANT YOU TO DO THE TALKING.

We would like everyone to participate.

I may call on you if I have not heard from you in a while.

3. THERE ARE NO RIGHT OR WRONG ANSWERS

Every person's experience and opinion are important.

Speak up whether you agree or disagree.

We want to hear a wide range of opinions.

4. WHAT IS SAID IN THIS ROOM STAYS HERE

We want folks to feel comfortable sharing when sensitive issues come up.

5. WE WILL BE AUDIO RECORDING THE GROUP

We want to capture everything you have to say.

We do not identify anyone by name in our report. You will remain anonymous.

Before asking the first focus group question, an **icebreaker** can be inserted to increase comfort and make participants feel relaxed. Example: "If you had a limitless budget, where would you go for vacation?" Of course, each FG facilitator needs to apply common sense and avoid saying things that in her/his local context and particular LL might offend participants or be perceived in ways cause harm to participants' willingness to pen up and discuss freely. **A list of icebreakers to choose from, will be provided to the FG facilitators by ELGO-DEMETER**.

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The focus group moderator has a responsibility to adequately cover all prepared questions within the time allotted. S/he also has a responsibility to get all participants to talk and fully explain their answers. Some helpful probes include:

- "Can you talk about that more?".
- "Help me understand what you mean".
- "Can you give an example?".

It is good moderator practice to paraphrase and summarize long, complex, or ambiguous comments. It demonstrates active listening and clarifies the comment for everyone in the group.

Because the moderator holds a position of authority and perceived influence, s/he must remain neutral, refraining from nodding/raising eyebrows, agreeing/disagreeing, or praising/denigrating any comment made.

A moderator must tactfully deal with challenging participants. Here are some appropriate strategies:

- Self-appointed experts: "Thank you. What do other people think?"
- The dominator: "Let's have some other comments."
- The rambler: Stop eye contact; look at your watch; jump in at their inhale.
- The shy participant: Make eye contact; call on them; smile at them.
- The participant who talks very quietly: Ask them to repeat their response more loudly.

When people come together in a group setting, they will adopt a variety of distinct roles (often simultaneously and changing as the group changes). This interaction between the different participants and the roles that they adopt is vital to the group process, so it is useful to be aware of some of these roles:

- Assistant moderators.
- Complicators.
- Devil's advocates.
- Distractors.
- Dominators.
- Early adopters.
- Emotionalists.
- Explicators.
- Innovators.
- Investigators.
- Laggards.
- Late adopters.
- Leaders.
- Questioners.
- Simplifiers.
- Submissives.
- Supporters.

In these distinct roles, participants interact through a wide range of actions, some are submissive to other members, others supportive, conciliatory, or modifying and yet others can be confrontational or attempts to assert power. You will experience people doing a range of the following:

- Ask each other questions.
- Build on each other's ideas.
- Change their opinions.
- Draw each other out.
- Fill in incompletions and gaps in knowledge.
- Jog each other's memories.
- Modify each other's comments.
- Nudge each other out of ruts and habitual thinking.

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- Persuade each other.
- React to each other's comments.
- Spark new ideas.
- Take opposing positions.

There are times when the facilitator might need to take a more interventionist approach (if the discussion gets heated or dries up, for example). The facilitator can try to get the group to discuss inconsistencies between participants and within their own thinking. Disagreements can lead to clarifications and new understandings if handled properly; often misunderstandings can be resolved by the participants themselves. Reflection and seeking clarification are useful too as they can encourage deeper thinking on key issues. Just be sure not to lead the group thinking or suggest answers.

Different techniques can be used. Participants can be asked to say how much they agree or disagree with a statement relating to a research question (e.g., 'Digital technologies have no part to play in Agriculture'). Such 'closed' questions can get them to talk to each other rather than to the facilitator and can be used to re-direct, open up or re-start the conversation. It also goes without saying the reality of groups is certain people will often dominate; as the facilitator, it is part of your role to draw out the more reticent participants and manage any attempts to dominate the conversation.

Once the facilitator feels that sufficient questions have been covered (or the allotted time is running out), there can be a cooling-off period, during which participants should be encouraged to think about what has been said and reflect on the experience or to add any other comments that not been heard earlier. Opportunities can be provided for them to fill in a questionnaire, email thoughts or speak to the facilitator individually (following a period of reflection) to ensure that they have said everything that was on their mind (even if they did not say it during the group discussion).

Basic demographic profiles are valuable data, and you should attempt to collect these for all participants, including wherever possible an email address so that they can be sent a copy of the research findings (should they wish to receive them). Only ask for data that is relevant and useful to the study.

ADDITIONAL TIPS FOR FACILITATING THE FOCUS GROUP

Tip 1: Seek Clarity

When moderating a focus group, always keep in mind the transcript and the researchers responsible for analysing it. While this may seem like an unusual tip, it serves a purpose. Context plays a crucial role in conversations. Without proper context, researchers may not fully grasp the sentiment conveyed in a transcript or comment. It is important to clarify the meaning by asking questions like, "What do you mean by that?" or "Is that positive or negative?" This adds context to the conversation and helps eliminate any confusion during analysis or review.

Tip 2: Continuously Ask "Why"

Qualitative focus group research aims to delve deep into and explore subjects. Unlike surveys or quantitative research that focus on measurement and broad data collection, the goal here is to uncover insights. If you are not frequently asking "why" during a focus group, you may not be digging deep enough. After yes-no questions, rating scales, or other categorical responses, always follow up with an immediate "why or why not?" This encourages participants to critically think about the reasons behind their answers or ratings.

Tip 3: Take Charge

As the lead moderator or facilitator, it is crucial to remember that you are in control of the discussion. You guide the group's actions, determine who should speak, when to transition to the next section, when to seek more details, and when to shift feedback from one participant to another. Clearly establish this authority early in the discussion, guide and exhibit confidence in your leadership. While focus groups can become lively and talkative, it is your responsibility to steer the conversation back on track consistently.

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Tip 4: Engage Specific Participants

Certain individuals in your focus group may be more talkative than others. As the facilitator, it is your duty to ensure that everyone's voice is heard. Throughout the discussion, single out specific participants and invite them to provide feedback. This guarantees that input is received from all members of the group. Since remembering names can be challenging, especially with larger groups of 10 to 12 people, consider creating a seating chart or using name tents. These aids make it easier for you to address individuals by name and facilitate balanced participation.

Appendix D provides a checklist of things to do when organising your focus group.

After the focus group session has ended, the moderator will express gratitude to all participants, and ask them to provide each a quick overview of their experience and their main conclusions regarding the costs and benefits of the presented innovation. Following the departure of the participants, the moderator and assistant moderator will engage in a **debriefing session** while the recorder is still active. In this debriefing session, they will describe the main findings and the insights they have gained on the perceptions of costs and benefits participants have with respect to the presented farm digitalisation innovation. LL coordinators need to send the **translated transcript** of this debriefing session **to the ELGO-DEMETER team no later than November 30, 2023**.

4.1.5. STEP 5: Reporting the data

To ensure that all participant comments are comprehensible and valuable, they need to undergo a systematic and verifiable process that condenses them into essential information. Begin by transcribing all focus group recordings and inserting notes into transcribed material where appropriate. After the focus group is completed, each facilitator should create transcripts of the recorded discussions translated into English. These translated transcripts they should be sent to the **ELGO-DEMETER team**, responsible for analysing the data and making comparisons across LLs **no later than January 31, 2024**.

In the unfavourable case that recording of the discussions during the focus is not feasible or participants do not give their permission to record the session, facilitators should be prepared to do one of the following:

- Ask one or, better, two of their assistants to keep detailed notes of what was discussed, translate into English, and send them to the ELGO-DEMETER team in Microsoft Word format.
- Alternatively, the facilitator should provide participants with as many empty white pieces of paper as the number of questions (at the size of a big poster or flipchart paper) on which s/he will directly write all answers to each question and indicate how many agreed with each different answer. It is advisable, however, that the answers are written on post-it removable notes so that the facilitator can easily move them under a different question later, if the participant who gave that answer changes her/his mind later during the discussion. Each focus group facilitator should inform the T4.2 leader on which approach s/he plans to use and justify her/his approach.

4.1.6. STEP 6: Analysing the data

Data will be analysed by the ELGO-DEMETER research team using a content analysis method. Thus, data will be assessed and re-assessed several times. The unit of analysis will be phrases used by participants which will then be grouped into categories. Categories will be developed inductively. The themes for the analysis will be derived from the questions/topics discussed in focus groups. Content analysis will be performed through NVivo, or a similar software.

Once focus group findings are organized, findings will be presented in a narrative format and will be included in D4.1.

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4.1.7. STEP 7: Ethics

The research carried out in the focus groups should abide by good practice guidelines as prescribed by an appropriate professional organisation.

You must ensure that you adhere to any local regulations or human research ethical guidelines that are in place at the research location. For CODECS basic good practice means that you must ensure focus group participants are always provided with:

1. An **information sheet** outlining the purpose of the research, describing the process of the focus group and what will be done with the data. This will also confirm their right to withdraw from the research at any time and not to answer questions should they wish. [**See Appendix A**]
2. A **consent form** to confirm their agreement to take part in the research (email confirmation can be used for some groups). [**See Appendix B**]
3. A **basic demographic survey** (including contact details) unless this has been collected separately. [**See Appendix C**]

These are developed by the ELGO-DEMETER team but may require customisation and variation for different focus group settings and countries. Ensure that any requirements that we have under the privacy and data protection legislation is addressed in full. If the research involves minors (under 18 unless otherwise specified), any additional safeguards and caregiver consents have been put in place. CODECS's Data Management Plan (DMP) has to be consulted throughout the focus group process.

4.1.8. STEP 8: Confidentiality and anonymity

Research participants will never normally be identified by name and all efforts should be made to avoid identifying individuals wherever possible. One limitation is that maintaining anonymity can pose challenges when dealing with public figures or individuals in highly specific roles that are easily recognizable to those associated with them. Whilst all attempts should be made to protect the identity of participants there may be occasions where it is impossible to do so completely or where to do so invalidates what they are saying (for example if they are speaking 'ex-officio').

For the final report or any other publications, the location of the participants and the nature of the focus group can be used to identify a participant where it is appropriate but this needs to be done in such a way that it does not identify individuals, either through what they say or how they are described. If you do wish to identify people directly then you must ensure that you have their permission in writing on the consent form.

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APPENDIX A – Sample Participant Information Sheet

This research aims to find out what distinct groups of people think of the costs and benefits associated with farm digitalisation and what are the problems facing European farmers as more farms will become digitalised. This research is being conducted as part of the EU's Horizon RIA project **CODECS** by the [organisation name] on behalf of 5.

Before agreeing to take part in this research it is important that you understand why the research is being done and what it involves. Please read the following information carefully.

Your participation in this research is voluntary. You can withdraw from the study at any time and can refrain from answering any question.

The information provided by you remains anonymous. This means that you will not be identified in the results.

All information you provide will be treated as confidential. This means that it will not be passed on to anyone else in any way that could identify you.

The information you provide will be analysed by us and what you say might be presented as a direct quotation in a report or academic paper but not in a way that could identify you.

The data collected for this project will be stored by us on a computer network accessible only with the use of a password or in a locked and secure cabinet. Any personal or demographic information will be anonymised.

Some personal data might be required in order to satisfy the research requirements (for example, we might need to contact you for further information and update to our project). Where personal information is collected it will be treated in strict confidence and your personal information will not be used in the results. Only aggregate analysis will be used for publication.

If you would like more information about the project you can write, telephone, or email the principal researcher:

Dr. Constantine Iliopoulos

Director and Senior Researcher

Agricultural Economics Research Institute (ELGO-DEMETER)

Hellenic Agricultural Organisation-Demeter (ELGO-D)

Kourtidou 56-58, Athens, Greece, 111 45

Email: iliopoulos@elgo.gr

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APPENDIX B – Sample Consent Form

Project name	**Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems (CODECS)**
Project acronym	CODECS
Horizon Europe Call	HORIZON-CL6-2021-GOVERNANCE-01
Horizon Europe Topic	HORIZON-CL6-2021-GOVERNANCE-01-22

Your consent in writing is needed to confirm your involvement in this research. Signing this form means that you have agreed to be a part of the research but does not stop you from changing your mind at a later time. You can withdraw from the research at any time and doing so will not affect your public or community standing. To withdraw from the research please contact the Principal Researcher at the address shown on the Information Sheet.

	Please tick box
I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason	☐
I agree to take part in the above study	☐
I agree to the focus group consultation being recorded (audio and/or video)	☐
I agree to the anonymised quotes in publications	☐

Name	Signature	Date

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4.2. APPENDIX C – Basic Demographic Survey

Question	Answer
1. Age: How old are you?	
2. Gender: Are you male, female, or non-binary?	
3. Ethnicity/Race: What is your ethnic or racial background?	
4. Education: What is the highest level of education you have completed?	
5. Occupation: What is your current occupation?	
6. Income: What is your annual household income?	
7. Geographic Location: In what city or region do you live?	

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APPENDIX D – Focus Group Checklist

Two weeks to one month before

1. Agree date and time
2. Book the venue
3. Selected participants
4. Send out invitations

One week before

5. Order catering (if appropriate)
6. Prepare information sheets and consent forms ready
7. Prepare and test focus group question pro-forma
8. Send a reminder to the participants

One day before

9. Facilitation team briefed
10. Confirmed food and venue
11. If anything has changed, let participants know
12. Print information sheets and consent forms
13. Print list of participants
14. Print list of questions
15. Check recording equipment and replace batteries

On the day

16. Arrive early
17. Check the venue and arrange the room
18. After the focus group
19. Transfer digital recordings, video, and photographs to computer/network
20. Write-up hand-written notes
21. Debrief with the facilitation team (and document anything that emerges)
22. Return all data and notes to project management for analysis (note that digital audio/video files will need to be uploaded or not sent by email due to their size).

APPENDIX E – Sample invitation letter

[Your Name]

[Your Organization]

[Your Address] [City, State, ZIP] [Email Address] [Phone Number] [Date]

[Participant's Name]

[Participant's Address] [City, State, ZIP]

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Subject: Invitation to Participate in a Focus Group on Farm Digitalisation

Dear [Participant's Name],

I hope this letter finds you well. I am writing to extend an invitation to you to participate in a focus group discussion that aims to explore the perceptions of farmers, farm advisors, and policy makers regarding the social, economic, and environmental costs and benefits resulting from farm digitalisation. The discussion will provide input to the research being conducted as part of the EU's Horizon RIA project CODECS.

At [Your Organization], we are committed to fostering dialogue and understanding around the significant changes taking place in the agricultural sector due to advancements in technology. Farm digitalisation has emerged as a crucial topic with profound implications for the future of farming and sustainable agricultural practices. As a valued member of our community, your input is invaluable in shaping our understanding of this complex issue.

The focus group discussion will provide an opportunity for participants to engage in a constructive and open conversation about the various aspects of farm digitalisation. We are particularly interested in exploring the following key themes:

1. Perceptions of social impacts: How does farm digitalisation influence the relationships and interactions between farmers, farm advisors, and policy makers? What are the perceived social benefits or challenges arising from the adoption of digital technologies in agriculture?
2. Perceptions of economic implications: What are the perceptions about the economic costs and benefits associated with farm digitalisation? How does it impact the profitability, competitiveness, and financial sustainability of farming operations? Are there any concerns related to access and affordability of digital tools?
3. Perceptions of environmental considerations: What are the environmental impacts of farm digitalisation? How does it influence resource management, biodiversity, soil health, and overall sustainability? Are there any trade-offs or potential risks that need to be addressed?

The focus group discussion will take place on [Date] from [Time] at [Location]. The session is expected to last approximately [Duration]. Light refreshments will be provided, and your participation is entirely voluntary.

Your insights and experiences are vital in generating a comprehensive understanding of the benefits and challenges of farm digitalisation. By participating in this focus group, you will contribute to the development of strategies and policies that can maximize the positive impacts of technology while mitigating any potential drawbacks.

To confirm your participation or if you have any questions, please contact [Contact Person] at [Email Address] or [Phone Number]. We kindly request that you confirm your attendance no later than [RSVP Deadline].

We greatly appreciate your time and consideration in participating in this focus group. Your involvement will make a significant difference in shaping the future of agriculture. We look forward to your positive response and hope to see you at the event.

Thank you, and best regards,

[Your Name] [Your Title/Position] [Your Organization]

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APPENDIX F – Focus Group Results Reporting Guidelines and Template

Option #1 (**STRONGLY PREFERRABLE**)**:** Translated in English transcripts of the recorded Focus Group Sessions

In the unfavourable case that recording of the discussions during the focus is not feasible or participants do not give their permission to record the session, facilitators should be prepared to do one of the following:

Option #2: Ask one or, better, two of their assistants to keep detailed notes of what was discussed, translate into English, and send them to the ELGO-DEMETER team in Microsoft Word format (see Results Reporting Template below).

Option #3: Alternatively, the facilitator should provide participants with as many empty white pieces of paper as the number of questions (at the size of a big poster or flipchart paper) on which s/he will directly write all answers to each question and indicate how many agreed with each different answer. It is advisable, however, that the answers are written on post-it removable notes so that the facilitator can easily move them under a different question later, if the participant who gave that answer changes her/his mind later during the discussion. Each focus group facilitator should inform the T4.2 leader on which approach s/he plans to use and justify her/his approach. Please accompany these poster/flipchart papers with all the comments of the focus group facilitator/LL coordinator and her/his team.

CODECS: Results Reporting Template

Questions and Answers	Number of FG Participants Agreeing with each Answer	Focus Group Facilitation Team Comments
Question #1: What comes to your mind when you hear the term “farm digitalization”?		
Answers to Question #1 Answer-1: … Answer-2:… …		

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Question #2: Bearing in mind the proposed tool/service, do you think it might work? Why? Under what conditions?		
Answers to Question #2 Answer-1: … Answer-2:… …		
Question #3: How do you think the innovation would change farming activities (operations, organization, relations in the supply chain, relations to advisers, relations with suppliers)?		
Answers to Question #3 Answer-1: … Answer-2:… …		
Question #4: How would the innovation contribute to environmental sustainability? Under what conditions?		
Answers to Question #4 Answer-1: … Answer-2:…		

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…		
Question #5: How would it contribute to farmers' incomes and welfare, quality of work, and gender equality?		
Answers to Question #5Qu Answer-1: … Answer-2:… …		
Question #6: What do you think are the economic, social, and environmental costs associated with the introduction of the proposed digitalization innovation and who will incur each type of cost?		
Answers to Question #6 Answer-1: … Answer-2:… …		
Question #7: Would you be willing to pay the associated costs? Up to which level would you be willing to pay?		
Answers to Question #7 Answer-1: … Answer-2:…		

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…		
Question #8: What kind of problems do you expect to face as more and more farms will become digitalized in the future?		
Answers to Question #8 Answer-1: … Answer-2:…		
Question #9: What kind of benefits (economic, social, environmental) do you expect from digitalization? Please provide some examples.		
Answers to Question #9 Answer-1: … Answer-2:… …		
Question #10: Is there anything else you would like to share with us regarding farm digitalization that you have not shared so far?		
Answers to Question #10 Answer-1: … Answer-2:…		

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7.2 Appendix 2 Environmental C&B guidelines

T4.1 GUIDELINES

GUIDELINES FOR DATA COLLECTION AND REPORTING

APPENDIX 2 – ENVIRONMENTAL ANALYSIS OF FARM DIGITALISATION (TASK 4.3)

01.05.2024

ALEXIA GOBRECHT (INRAE), VERONIQUE BELLON-MAUREL (INRAE), BAPTISTE DE MASSÉ (INRAE)

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Glossary and common terms

Focal Action Situation (FAS) - LL situation where subsystems interact to provide an outcome to the problem statement (outcome =solution for the LL problem statement).

Living Lab (LL) a living lab is a network of farmers, knowledge intermediaries, stakeholders, policy makers, technology providers constituted around an emerging problem within a given application scenario and willing to develop solutions through collaboration.

Digitalisation

Digital Technology for agriculture (DTA)

Life Cycle Assessment (LCA)

1. Introduction

This document provides the guidelines for the assessment of the environmental impacts of the digitalisation process in the living Labs. The document has been prepared in parallel with T4.4 Economic C&B analysis and contains common appendixes.

The Guideline document starts with a reminder of the CODECS objectives and the objectives of the WP4. The second section details the methodology implemented for T4.3, based on the framework of Life Cycle, and how it is applied to the Focal Action Situations in the Living Labs. Section 3 presents the articulation of the data collection process between the different tasks of WP4 and the general timeline. A fourth section present the data collection protocols, in a generic format for this version of the guidelines, as the final list of required data has to be finalized according to each Living Lab's characteristics.

The appendix contain several documents and useful files to help the LL coordinator to organise the data collection activities (consent forms, interview sheets …). These appendixes are common with T4.4.

7.3 CODECS ambition

The overarching ambition of CODECS is to improve the collective capacity to understand, assess and foresee the full range of benefits and costs of farm digitalisation, and to build digital ecosystems that maximise the net benefits of digitalisation. It will be done by pursuing the following specific objectives:

- Mainstreaming the concept of "sustainable digitalisation" in the European AKIS and in the wider policy environments.
- Building the conceptual "system-approach / actor-centred" base for the "sustainable digitalisation" of agriculture and a layered cost-benefit assessment framework.
- Analysing, and understanding the implications, of the role of different contexts in the generation of costs and benefits of digitalisation through the analysis of "digital ecosystems".
- Providing data on the costs and benefits of digitalisation in a variety of European farming contexts, by setting up and carrying out user-friendly assessment methodologies.
- Setting up demonstrations to scale digital technologies adoption.
- Developing evidence-based and future-proof policy tools for sustainable digitalisation.
- Raising awareness and facilitating the uptake of digital technologies for sustainable development through the development of a platform and assessment tools. Insert text, paragraphs, etc.

7.4 Objectives of WP4

- To capture stakeholders' perception of various Costs and Benefits along the 3 axes of sustainability
- To assess the environmental, economic and social impacts of digital technologies in a participatory way
- To facilitate a conversation on trade-offs and synergies between costs and benefits

Those activities are oriented to the achievement of the mentioned *Specific Objective of CODECS (SO4) – Providing data on the costs and benefits of digitalisation in a variety of European farming contexts, by setting up and carrying out user-friendly assessment methodologies"*.

7.5 Objectives of the Task 4.3 Environmental assessment

Task 4.3 focuses on analysing the environmental impacts of the use of digital technologies in the agricultural production process. The objective is to capture how changes in production practices influence the environmental impacts (positively or negatively) and identify the sources of these variations.

The analysis of environmental impacts of the digitalization process in the living labs will be carried out at the agricultural process level and/or farm level. Life Cycle Analysis (LCA) will allow us to compare environmental footprint of the agricultural production process before and after the adoption and use.

Adopting and using digital technologies is responsible of a certain number of changes in the production process, and as a consequence, the environmental impacts of this new process might differ from the original one (reference scenario). As an example, the use of a Decision Support System to help rationalize fertilisation in a vineyard will certainly reduce the amount of inputs, and might also affect the yield. These changes due to the digitalization of the farm can be captured by the comparative LCA of the process.

The outputs of these Life Cycle Analysis will help providing insights for the farmers, advisors, and service providers about environmental impacts of digitalization in real use case situations. These information will also help identifying the hotspots (i.e. the steps of the process that have a high environmental impact) of the process.

To do this, the environmental assessment of task 4.3 will use quantitative data collected in farms in the different Living Labs (LL), as well as data from the literature and databases.

8 Life Cycle assessment of the digitalisation process in agriculture

8.1 LCA principles

Life cycle assessment (LCA) is a method for quantifying the material and energy flows associated with the life cycle of a product or service, and assessing its potential environmental impacts (Jolliet et al. 2016). It works by identifying the activities associated with this product or service over its entire life cycle, “from cradle to grave” (Figure 1).

It is a multi-criteria approach that is standardised internationally, with the NF EN ISO 14040 standard (REF), and through the Lifecycle Initiative (UN 2022) as part of the UN's environmental programmes. LCA enables the impact of a product/process to be assessed at different stages of production, manufacture and use.

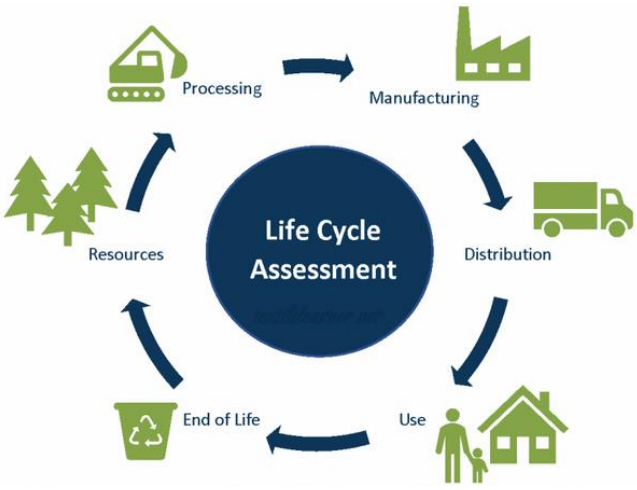

Figure 11 : Scope of the LCA

The quantities of materials, products and energy used throughout the cycle are quantified. These values are also used to quantify the quantities of materials emitted at any point in the life cycle, which will be the outputs of the system. These outputs include emissions linked to energy production, the various residues released into nature during human activities and the waste discharged at the end of the cycle. The potential impacts of each

of these elements are then characterized and aggregated to estimate the impact of the product's life cycle. (Jolliet et al. 2016)

The strength of LCA is that these potential impacts are broken down into numerous impact categories, such as global warming, ecotoxicity and water use.

8.2 LCA stages – generalities

According to standards in the ISO 14040 and 14044, an LCA is carried out in four distinct phases (Figure 2) :

1. Goal & Scope : Definition of the objectives and boundaries of the system under study
2. Life cycle inventory : inventory of from and to the ecosphere for a system – it involves quantitative data collection on the processes under study
3. Impact assessment: this phase aim at evaluating the potential environmental and human health impacts resulting from the flows identified for the system under study
4. Interpretation: identifies, quantifies, checks, and evaluate information from the results of the life cycle impact assessment. The outcome of the interpretation phase is a set of conclusions and recommendations for the study.

The phases are often interdependent in that the results if one phase will inform how other phases are completed.

In order to be able to carry out an LCA, the FAS require available data on agricultural practices before and after the adoption of the digital technology under study. The FAS on which the LCA can be carried out are determined on the basis of information provided by the LL, and require an advanced level of digitization.

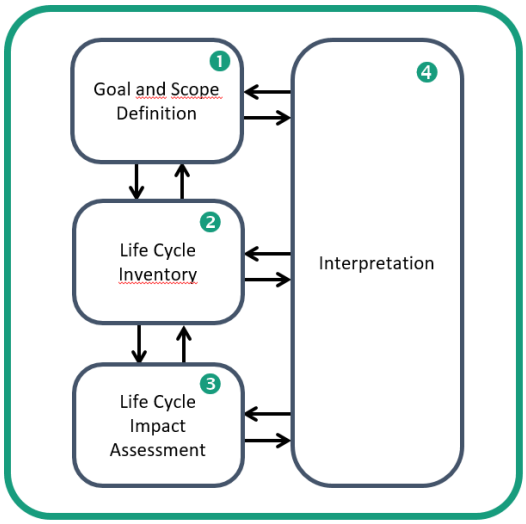

Figure 12 : LCA stages

8.3 LCA in the CODECS Living Labs

8.3.1 Preliminary considerations

Carrying out comparative life cycle analyses in the context of CODECS requires a number of prerequisites to be taken into account. First of all, it is necessary to be able to document situations in which the technology (or technological system) is used and to be able to identify substantive changes between the reference scenario (without use of the technology) and the digitised scenario.

The coordinators of the living labs will therefore have to ensure at the very least that:

- the technology identified for the use case (FAS) is sufficiently mature and technologically stable to be used in real production contexts
- That the technology has been in use for some time to be able to collect data for at least one full year of production
- That the methods of use are not too experimental for the conclusions of the study to be interpreted and validated
- That the farmer can also provide inventory data on practices prior to the introduction of the technology.

The activity organized by the WP4 leader during the General Assembly 2023 allow to provide a first classification of the Living Labs, according their level of digitalization and the potential availability of quantitative data (Figure 3).

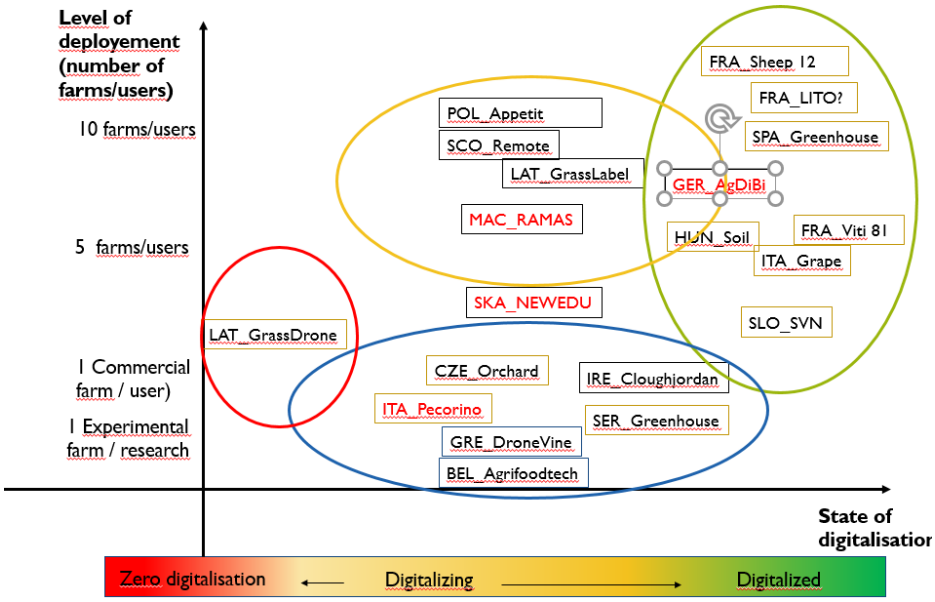

Figure 13 Classification (dec 2023) of the Living Labs according their digitalisation state

8.3.2 Goal and Scope

The first stage, Goal and Scope, begins by defining the objectives of the LCA and the scope of the study. We need to define why the LCA is being carried out, i.e. the process or system whose impact we are seeking to assess, and then the function of the system, called the functional unit (FU), which is the quantification of what we are seeking to assess (e.g. we want to measure the impact of wheat production in 2022, the FU will be 'the production of 1kg of wheat in 2022').

This step will be carried out independently for each FAS in each Living Lab, as the system and the related FU depend on the type of digital technology used and the steps of the production system that are affected by the digitalization process.

In addition, for each FAS, two systems will be modelled : one scenario representing the situation prior to the use of the digital tool, and one scenario representing the situation once the digital tool has been used (Figure 3). These two systems will be compared on the basis of an identical FU (area or mass of agricultural production), in order to highlight the differences in environmental impact caused by the adoption of the digital tool.

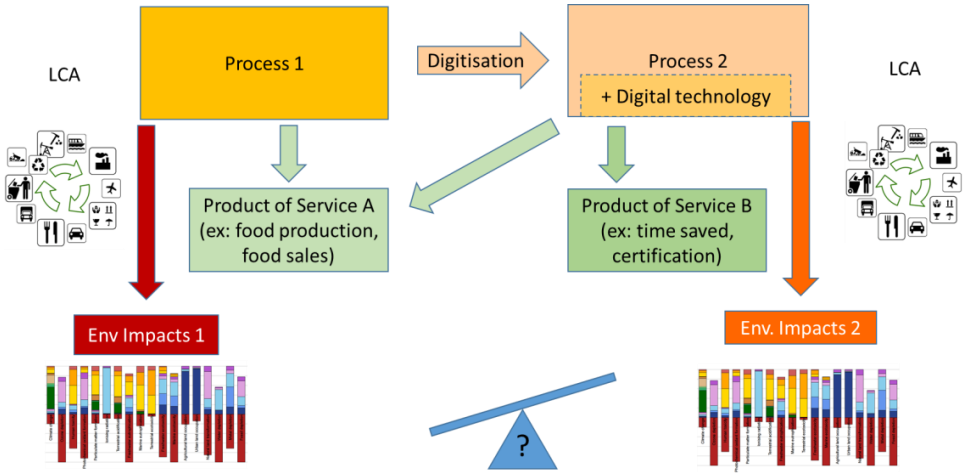

Figure 14: LCA scenario comparison

The differences highlighted may be a variation in the overall impact on production, but also a change in the phase of the technical itinerary with the greatest impact.
Once this comparative phase has been completed, it is also possible to refine the data collected, either to refine the comparison or to establish new technology adoption scenarios enabling a more in-depth analysis of the effects of this adoption.

- In order to be able to execute this phase, task leaders will first use the information provided by the Living Lab coordinators throughout the other activities carried out in the project (especially WP3 which focuses on process modelling) and will complete these information with an initial exchange with the LL coordinators to complete and dispel doubts.

This stage will clarify the data required for the life cycle inventory, which can be very time-consuming. It is therefore very important to complete accurately this stage to focus only on the necessary data to be collected in the Living Labs.

8.3.3 Life Cycle Inventory

All the flows involved in the system are defined, whether they be material or energy flows within a production chain, or exchanges of flows between the environment and human activities, such as resource extraction and human emissions. Once these flows are known, the quantities of inputs or emissions for each flow are inventoried. These quantities of materials will be the data used to carry out the LCAs.

These data must then be collected. It is either primary data, which corresponds to data over which we have the power to take action, or data that can be obtained directly, which provides accurate and appropriate in-situ data. Alternatively, secondary data can be obtained from the literature or from databases, to be used if the primary data is not available or not necessary (e.g. the type of tractor used is primary data, the manufacture of the tractor is secondary data).

- For this stage, the data collection will be performed at farm level with the help of questionnaires specifically prepared for the FAS under study. The type of data to be collected are in relation to the production process

implementing the digital technology. The questionnaire (see Appendix XX) has been constructed in cooperation with T4.4 (Economic C&B analysis) as some similar data are needed to perform the economic analysis.

8.3.4 Life Cycle Impact Assessment

This stage links the data collected previously in the LCI stage to their potential environmental impacts.

This is done using models which, for quantities of material produced or emitted, associate a certain impact on each of the environmental impact categories assessed in the LCA. These impacts can also be aggregated into damage, i.e. into 3 main categories: human health, natural resources and ecosystem quality (Figure 4).

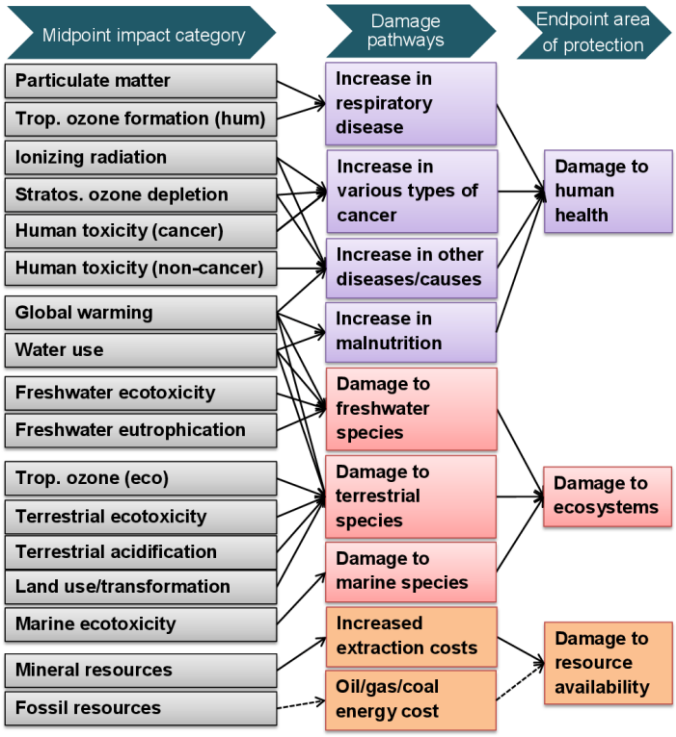

Figure 15 Impact and damages assessed in LCA

- These outputs will be calculated for each scenario in the farm (not digitalized and digitalized) to be able to compare their differences in each impact category. This stage will also help to better understand which step of the agricultural process has the higher impact (e.g. type of machinery, quantity of inputs, type of energy…).

8.3.5 Interpretation

The aim of this stage is to identify the hot spots in the product or process life cycle, and to assess the quality of the results obtained. It allows conclusions to be drawn about the main impacts and their origins, while explaining the limitations of the results obtained.

It is after this stage that the results of the study can be communicated.

It is also possible to return to stage 2, the data collection stage, to complete some of the data obtained, in order to be more precise in the results.

Once this comparative phase has been completed, it is also possible to refine the data collected, either to refine the comparison or to establish new technology adoption scenarios enabling a more in-depth analysis of the effects of this adoption.

These results will be shared with the LLs CoP to complete the interpretation and will also serve to build narratives on the environmental impacts of the use of digital technologies in agriculture.
Finally, these results will also be integrated in the Environmental Footprint simulator built in WP7.

9 General Roadmap for data collection (T4.3 & T4.4)

In order to conduct the environmental and the economic analysis, data from farms that have established the technologies under investigation within the LLs are required.

The data will be gathered using structured questionnaire(s) and instructions will be provided to the data collectors to avoid misconceptions and inconsistencies through online training sessions.

The material for data collection will be prepared taking into account the description of FASs and processes that are affected by the adoption of a digital technology and will accommodate the data collection for both LCA and economic analysis.

It is important to note that the current section, presents only some preliminary guidelines and good practices for data collection and aims to facilitate further discussions and cooperation with the CODECS consortium for the development of the data collection framework.

9.1 Timeline

The data collection for the environmental impact assessment and for the economic C&B at farm level have to be articulated with the other activities in the Living Lab. Figure6 shows the different activities for Year 2. The activites have been organised in order to be able to fill each other of general information about the FAS.

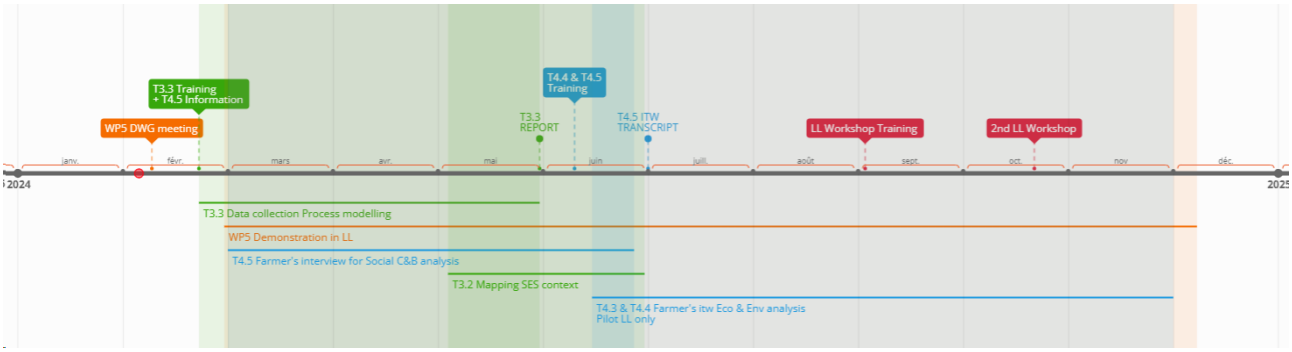

Figure 16 general timeline for activities in the LL Yean 2 of CODECS

Concerning WP4 T4.3 and 4.4, the data collection will start from June 2024, for a selection of Living Labs/

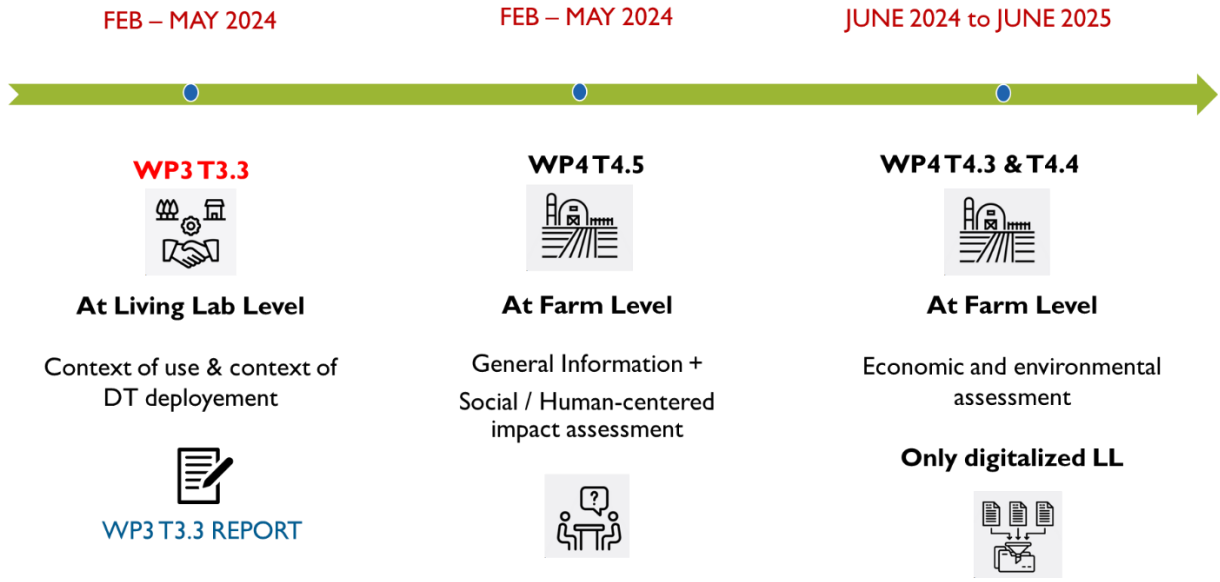

Figure 17 WP4 data collection timeline at farm level

9.2 General guidelines for farmer's interview

The Living Lab Facilitator and team will be responsible for the following tasks:

IDENTIFY THE FARM(S) TO BE ASSESSED	this includes to check if the farm will be able to provide quantitative data about the production system, before and after the digitalisation process
ORGANISE THE IN-DEPTH INTERVIEW	set the date for a 1 – 2 h slot, if possible in presential. This meeting can also be articulated with other activities in the LL : in-depths interview for Social C&B for example, or for completing data collection for WP3.
SEND IN ADVANCE THE LIST OF QUESTIONS AND LIST OF DATA	this will help the farmer to identify the sources of data (from log books for example
CONDUCT THE INTERVIEW	With the help of the questionnaire prepared specifically for the LLs (**See Appendix**), fill in the data collection file with the needed data. If two persons can be present for the interview, this would allow to gather more complete data and avoid errors or misunderstandings. If necessary, the interview can be recorded to be able to retrieve missing info afterwards.
COMPLETE THE DATA COLLECTION FILE	as precisely as possible. This can be done on word or in an excel file directly. Comment if and why data are missing, to help task leaders in the interpretation

SEND OR UPLAOD THE FILE IN THE TEAMS FOLDER	a specific folder will be prepared with all the material for data collection and reporting

For detailed instructions on the interview phase, please refer to the annexes.

10 Appendix

These appendices are structured in such a way that they can be printed out and used independently for the part involving the collection of quantitative data at farm level for use in the analyses of the environmental impacts (T4.3) and the economic costs and benefits (T4.4) of digitalization in agriculture.

As a reminder, the aim of collecting quantitative data at farm level in the Living Labs is to capture the transformative effects of the adoption and use of digital technologies in agricultural systems and to assess changes in terms of environmental impact on the one hand and economic indicators on the other.

This situated data (in the case of LL use) will thus make it possible to objectify these transformative effects and provide stakeholders with information to help them make decisions.

Appendix 1 Data workflow

Appendix 2 Checklist

Preparing for the interview with the farmer :

- Identify and contact one or more farmers to explain the purpose of the study : environmental and economic analysis of the digitalization process at farm level
- Identify the person who will interview the farmers, if it is a binome, it is better
- Schedule a 2h meeting, in person if possible.
- Read the provided material to understand the objectives of the study
- Read the questionnaire document and all the questions
- Identify the mandatory data and the facultative data to be collected, this will help if you are short in time
- Translate the questionnaire or part of it if necessary for the farmer's understanding
- Print the questionnaire if you plan to do it on paper or use the Excel form available here (URL)
- Send the questionnaire in advance to the farmer and ask him if he already has any material or documents that can provide answers to the questions (crop monitoring sheets, logbooks etc.), so that they can be prepared for the interview.
- Prepare the consent forms

During data collection :

- Start by explaining what the data will be used for (CODECS project, environmental assessment and economic C&B assessment of digitalisation).
- Present the consent forms and explain how it works.
- Explaine of the interview procedure (questions, time, etc)
- Ask if you can record the interview (this record will not be used for the analysis but will help to retrieve missing information or details afterwards)
- Ask the questions in the order given in the questionnaire. If some information is missing, ask if you can ask later.
- Also note any additional information that the farmer gives in response to the questions that could help for the interpretation of the results.
- Collect the useful documents (crop monitoring sheets, etc), if the farmer agrees to provide them

After data collection:

- If the interview was conducted on paper : transcribe the answers into the word of excel document
- Return the data collection files to the tasks leader in the dedicated team folder.
- Keep the record (if existing), the filled questionnaires and the relevant documents in order to be able to retrieve missing information or complete the inventory.

Appendix 3 General instructions for data collection

The good practices presented in this section will be part of the data collectors' training material and instructions and aim to increase the efficiency of the interviews.

- Data collectors are advised to take notes of all information that the farmer may provide (qualitative or quantitative). They will be very helpful for understanding the rationale behind the operation of the farm, to correct/adjust the raw data collected and to make comparisons.
- While collecting technical and economic data, data collectors should record them as the farmer gives them. For example, if the farmer provides data per hectare, the farmer should not be asked to aggregate this for the whole farm. This can be done by the data collector after the interview. However, if the data collector has doubt that the farmer has provided a correct/realistic number, the data collector can ask the question differently to verify the answer.
- The basic level of analysis if the farm. The purpose of the interview is to record data on all farm enterprises. However, if the digital technology affects only specific enterprises or processes within the farm, detailed data can be recorder only for them and the rest of the data can be recorded with less detail.
- Data collectors should try and build a trusting relationship with the interviewees. They should avoid judging or commenting on the data provided unless they require specifications.
- It is good practice to communicate with interviewees some days before the interview to let them know that data required is of economic nature. This will give them the chance to consult their log books, gather invoices and prepare for the interview.
- Data collectors should try to make the interviewees feel comfortable throughout the interview and guide them to provide accurate data. However, data collectors should not over-"push" interviewees as this will compromise the remaining part of the interview. Reluctant interviewees should be reassured that the interview is confidential.
- The interview should take place in a quiet place e.g., the farm and not at the presence of others, as this might make the interviewee feel uncomfortable.
- The data collector should be well prepared and possess good knowledge of the farming activities in the area and preferably some experience in data collection.
- If data is collected using printed questionnaires data should be entered in the data base as soon as possible, so that the interviewer will remember all the necessary information.
- It is very important to enter technicoeconomic data in accordance to the required reference units. If for example costs are required per hectare, entered cost data should be expressed per hectare and not as total farm costs.

Appendix 4. Questionnaire for DATA COLLECTION

This is a general questionnaire. According to the Living Lab and the Focal Action Situation, the number of requested data will be adjusted to each specific use case.

The questionnaire is the same for the Economic Analysis. Please refer to the appendix of Part 3 Economic Costs and Benefits analysis.

Appendix 5. Participant Information sheet (model)

Dear Participant,

Your participation in this study greatly contributes to our understanding the environmental and economic costs and benefits of digitalization, i.e. adoption and use of digital technologies, in you farm.

You are invited to join our research, part of the EU's Horizon RIA project CODECS, through an interview conducted by [Your Organization Name] on behalf of INRAE France and ELGO-DEMETER (Greece).

Task Objective:

We aim to comprehend how digitalization transforms the environmental impacts and the economic costs and benefits of the farm.

Voluntary Participation:

Participation is voluntary with no obligations or adverse consequences. You may withdraw at any time without any negative consequences.

Data Privacy:

Data will be anonymized to protect your identity and treated with the utmost confidentiality.

Personal Data Collection:

We may collect personal data to contact you for research updates, which will be kept strictly confidential by [Your organization Name] and not used in the research results.

For questions or participation, contact:

[LL coordinator's/contact Name]

[LL coordinator's/contact Email Address]

[LL coordinator's/contact Phone Number]

Thank you for considering our research.

Sincerely,

[Your Name]

[Your Organization - CODECS]

Appendix 6. Consent Form (model)

Project name Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems (CODECS)

Project acronym CODECS

Horizon Europe Call HORIZON-CL6-2021-GOVERNANCE-01

Horizon Europe Topic HORIZON-CL6-2021-GOVERNANCE-01-22

Your written consent is essential to verify your participation in this research. By signing this form, you indicate your agreement to be a part of the study; however, it does not restrict your right to reconsider your involvement at any point in the future.

I confirm that I have read and understood the study information sheet for "Evaluating the environmental and economic costs and benefits of digitalization, i.e. adoption and use of digital technologies, in you farm."

I had the opportunity to ask questions, and they have been satisfactorily answered.

I understand that:

- ☐ My participation is entirely voluntary, and I can withdraw at any time without providing a reason.
- ☐ I consent to the audio recording of the interview session to help the data collection, with the assurance of strict confidentiality
- ☐ I consent to the use of quantitative data I provide for the research, which will help to calculate C&B and impacts, provided the data are completely anonymised and will not contain personally identifiable information
- ☐ I consent to the publication of the results of the analysis.

By signing this form, I voluntarily agree to participate in the study.

Participant's Name: _____

Participant's Signature: _____

Date: _____

Thank you for your participation, which contributes to our understanding of digitalization's changes on farms and farmers.

Sincerely,

[Your Name]

[Your Organization - CODECS]

[Date]

10.1 Appendix 3 Economic C&B guidelines

T4.1 GUIDELINES

GUIDELINES FOR DATA COLLECTION AND REPORTING

APPENDIX 3 – ANALYSIS OF ECONOMIC COSTS AND BENEFITS (TASK 4.4)

01 05.2024

ALEXANDRA SINTORI & ATHANASIOS RAGKOS (ELGO-DEMETER)

T4.1 GUIDELINES FOR DATA COLLECTION AND REPORTING
PART 3: ANALYSIS OF ECONOMIC COSTS & BENEFITS (T4.4)

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Glossary and common terms

Focal Action Situation (FAS) - LL situation where subsystems interact to provide an outcome to the problem statement (outcome =solution for the LL problem statement).

Living Lab (LL) a living lab is a network of farmers, knowledge intermediaries, stakeholders, policy makers, technology providers constituted around an emerging problem within a given application scenario and willing to develop solutions through collaboration.

TBC

2. Introduction

The current document describes the contribution of Task 4.4 entitled “Analysis of Economic Costs and Benefits” on the assessment of the overall sustainability of digitalization in farming. The document has been prepared in parallel with T4.3 Environmental impact analysis and contains common appendixes.

The Guideline document starts with a reminder of the CODECS objectives and the objectives of the WP4.

The second section details the methodology implemented for T4.4, it describes the scope and objectives of the economic analysis as well as the usefulness and practicality of its results, inside and outside the codecs consortium. The following section presents the articulation of the data collection process between the different tasks of WP4 and the general timeline. A fourth section present the data collection protocols, in a generic format for this version of the guidelines, as the final list of required data has to be finalized according to each Living Lab’s characteristics.

The appendix contain several documents and useful files to help the LL coordinator to organise the data collection activities (consent forms, interview sheets …). These appendixes are common with T4.3.

4.3. CODECS ambition

The overarching ambition of CODECS is to improve the collective capacity to understand, assess and foresee the full range of benefits and costs of farm digitalisation, and to build digital ecosystems that maximise the net benefits of digitalisation. It will be done by pursuing the following specific objectives:

- Mainstreaming the concept of “sustainable digitalisation” in the European AKIS and in the wider policy environments.
- Building the conceptual “system-approach / actor-centred” base for the “sustainable digitalisation” of agriculture and a layered cost-benefit assessment framework.
- Analysing, and understanding the implications, of the role of different contexts in the generation of costs and benefits of digitalisation through the analysis of “digital ecosystems”.
- Providing data on the costs and benefits of digitalisation in a variety of European farming contexts, by setting up and carrying out user-friendly assessment methodologies.
- Setting up demonstrations to scale digital technologies adoption.
- Developing evidence-based and future-proof policy tools for sustainable digitalisation.
- Raising awareness and facilitating the uptake of digital technologies for sustainable development through the development of a platform and assessment tools. Insert text, paragraphs, etc.

4.4. Objectives of WP4

- To capture stakeholders' perception of various Costs and Benefits along the 3 axes of sustainability
- To assess the environmental, economic and social impacts of digital technologies in a participatory way
- To facilitate a conversation on trade-offs and synergies between costs and benefits

Those activities are oriented to the achievement of the mentioned *Specific Objective of CODECS (SO4) – Providing data on the costs and benefits of digitalisation in a variety of European farming contexts, by setting up and carrying out user-friendly assessment methodologies”*.

4.5. Scope and objectives of tast 4.4 Economic C&B assessment

Task 4.4. focuses on the identification and assessment of the economic costs and benefits that derive from the digitization and consequently from the digitalization of farming. Economic costs and benefits derive as the result of the use and combination of various resources and capabilities to provide outcomes and their estimation is necessary in order to further explore factors that facilitate or hinder the adoption of digital technologies. The results of Task 4.4 will be useful to the CODECS consortium but also to farmers, advisors and policy makers. Specifically:

- The economic costs and benefits will be integrated in the multicriteria assessment of Task 4.6 and trade-offs will be estimated.
- Partners involved in WP7 will use the data for the development of the economic calculator.
- Results will be presented at the annual LL Workshop (Task 8.3) and will become available for dissemination through the activities of WP1.
- The results of the task will also be available to policy makers that design and implement measures for farming digitalisation (Contribution to Policy Brief 9: Economic co-benefits and costs of digitalisation).
- The results will also be available to farmers and their advisors and assist them in understanding and predicting the benefits and costs of adopting digital technologies and explore optimal solutions and options.
- The current document will also contribute to the development of Methodological Handbook of Task.2.2.

Task 4.4 aims to identify and assess economic costs and benefits that derive from the digitization of processes and digitalization of farms and systems. Through the estimation of economic costs and benefits and identification of their main elements, barriers and bottlenecks of the digitalization process will be revealed and tackled.

In order to achieve its objective, the economic analysis of Task 4.4 will utilize qualitative and quantitative data gathered from LLs and demonstration farms, available literature, accountancy records, log books and other data bases.

5. Methodology

Figure 1 represents the proposed multi-step methodology that will be used for the economic analysis and that will be to some extent, data driven (see sub-sections for description of the steps). Preliminary data will be gathered by the LLs or will be provided by other tasks e.g., Task 4.2, that will allow the specification of the quantitative analysis, depending on the FAS examined. This will also facilitate the preparation of the necessary material for the data collection (e.g., questionnaire(s), instructions to interviewers). If data availability is limited, only qualitative data on economic costs and benefits will be provided.

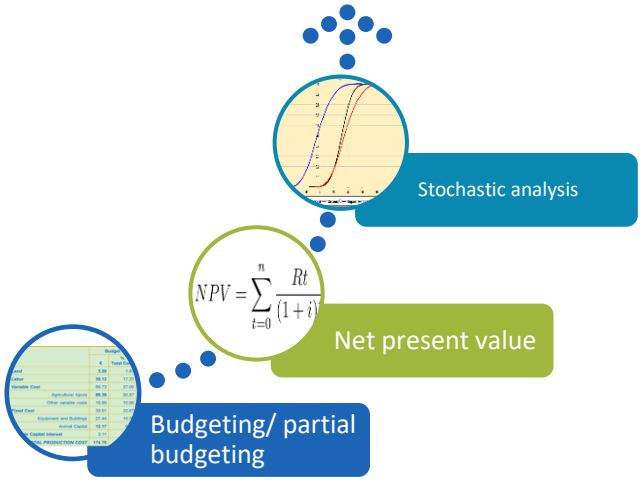

Figure 18 : Methdology for economic analysis

~~The implementation of the economic analysis is graphically presented in Figure 2. The data collection framework for the economic analysis will be common with the LCA to avoid the overload of LLs and their Leaders. Thus, a common questionnaire and guidelines for data collection for LCA and economic analysis will be developed. Additionally, LCA and economic analysis will focus on the same selected FASs. The selection of the FASs to be further analysed will depend on the description of the FASs that will be provided to WP4 partners. After the preparation of the common material, data collectors will be trained and provided with instructions. When data is collected, it will be checked for inconsistencies and analysed. Feedback from living labs will allow for validation and the final results will be used to produce reports, briefs and other deliverables.~~

The main level of the economic analysis will be the farm, since this is where decision making regarding the adoption of digital technologies is primarily taking place, and where resources and other system components interact to provide outcomes. Thus, farmers, are considered to be the main actors in the economic analysis. Depending on the specific FAS examined, the economic analysis may focus only on the process level.

At the farm level, the costs that will be taken under consideration in the economic analysis include transition costs, i.e., initial investment costs required for the adoption of digital technologies as well operation costs, i.e., annual production costs. The data requirements that are needed for the economic analysis are presented in the Appendix and involve the estimation of land costs, agricultural inputs costs, labour costs and fixed costs. (see also Gangwar et al., 2022).

To take into account the socio-economic environment that decision making takes place, scenario analysis and/or stochastic analysis can be utilized, depending on the specific FAS and the data availability. Financial risk and uncertainty due to price or production fluctuations and actors' attitude towards risk, can also be addressed through scenario/stochastic analysis. For example, rules and conditions set from the Governance system (see also Figure 2) that affect the adoption of a digital technology e.g., subsidies on investment or production costs can be incorporated in the economic analysis and examined as alternative scenarios. Also market prices may be affected by demand and supply rules or resource availability. These rules and market conditions can be addressed in the economic analysis by conducting sensitivity analysis or allowing for stochastic variables in the economic model (Stochastic analysis). Additionally, factors that hinder the adoption of digital technologies like legal restrictions, special permits or requirements, can also be taken into consideration in the economic analysis since they constitute additional costs or can affect other cost and benefit components (see also Figure 2).

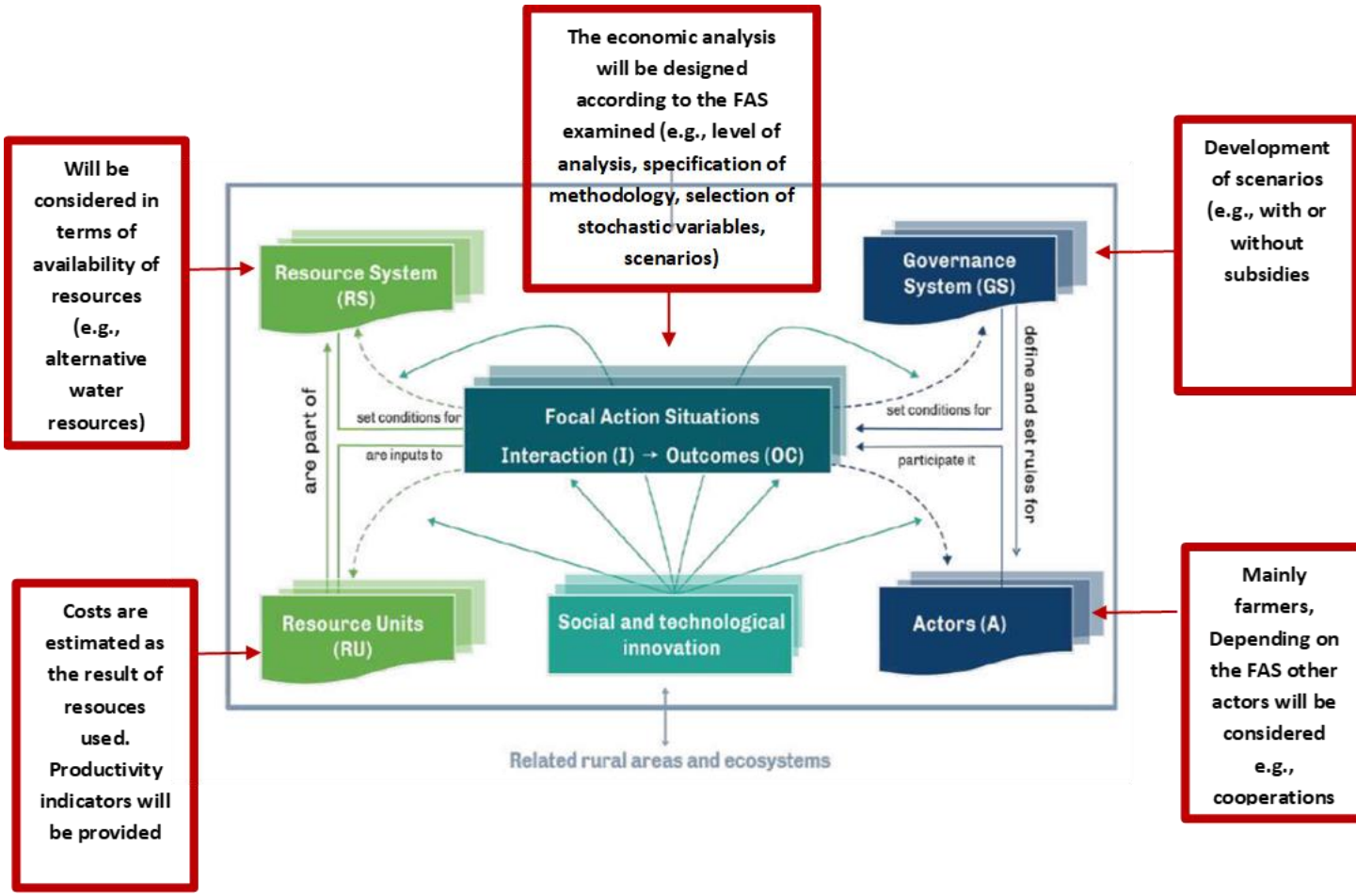

Figure 19 The CODECS economic analysis within the Ostrom's socio-ecological system framework

5.1. Budget analysis

The first step of the economic analysis involves the construction of a budget table (farm level) or partial budget table (process level) according to the FAS. Budgeting and partial budgeting analysis is often used, to assist farmers in their decision-making regarding changes in production methods and adoption of new practices (Alimi, 2000), since it lets them compare economic costs and benefits before and after the change. It is a very useful and easy to apply management tool that summarizes input requirements and additional benefits, expressed in monetary terms either for the whole farm, a single enterprise or process within the farm. The construction of farm budget or partial budget will also allow for the estimation of productivity indicators for main resource units (e.g., labour or land productivity) and economic outcome indicators like net profit and income (see for example Ahmed et al., 2021).

5.2. Net Present Value

Net Present Value (NPV) analysis will also be performed for selected FASs. NPV is a commonly used and well established methodology for cost-benefit analysis (see for example Mburu et al.., 2007; Wassmann and Pathak, 2007; Mutenje et al.., 2019). NPV sums up the discounted net benefits (benefits minus costs) generated by the adopted digital technology over a period of time. A comparison of the NPV with or without

the digital technology allows us to estimate if the investment in the digital technology is viable and profitable. The basic formula for the estimation of the NPV is the following (Truitt, 1978):

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+r)^t}$$

where B_t=benefits ar time t, C_t costs at time t, r=discount rate. According to the NPV criterion adopting in digital technology is economically viable if the present value of benefits is greater than the present value of costs (NPV >0).

5.3. Stochastic budgeting/NPV analysis

A more advanced methodology that can be used within the cost-benefit methodological framework is the Stochastic Budgeting Analysis or Stochastic NPV analysis (Bewley et al., 2009; Tzouramani et al., 2011; Liontakis et al., 2021). Most of the methods used in cost-benefit analysis assume deterministic values for cost and income elements (e.g., prices of inputs and products and yields). But deterministic economic models do not take into account possible differences in the riskiness of net income between alternative technologies or practices. In stochastic models, deterministic values of key cost and income elements are replaced with distributions of values and the stochastic model estimates the probability of an economic outcome (e.g., profit) to occur providing the farmer with a range of values (minimum, maximum and mean economic outcome). In the case of the NPV for example, the desirability of the investment is estimated not by producing a deterministic NPV but a whole distribution that links all feasible NPVs with specific probabilities (Liontakis et al., 2021).

In order to rank alternative technologies or practices first and second degree Stochastic Dominance analysis can also be implemented (see also Mutenje et al., 2019).

6. General Roadmap for data collection (T4.3 & T4.4)

As described in the project, Task 4.4 aims to provide economic sustainability assessments of the adoption of digital technologies in farming. In order to conduct the economic analysis, data from LLs and demonstration farms that have established the technologies under investigation are required.

The data will be gathered using structured questionnaire(s) and instructions will be provided to the data collectors to avoid misconceptions and inconsistencies through online training sessions.

The material for data collection will be prepared taking into account the description of FASs and processes that are affected by the adoption of a digital technology and will accommodate the data collection for both LCA and economic analysis.

It is important to note that the current section, presents only some preliminary guidelines and good practices for data collection and datacollection files and specific protocols will be prepared based on the information previously gathered by LL coordinators with the other workpackages activities (mainly T3.3 of WP3).

6.1. Timeline

The data collection for the environmental impact assessment and for the economic C&B at farm level have to be articulated with the other activities in the Living Lab. Figure6 shows the different activities for Year 2. The activities have been organised in order to be able to fill each other of general information about the FAS.

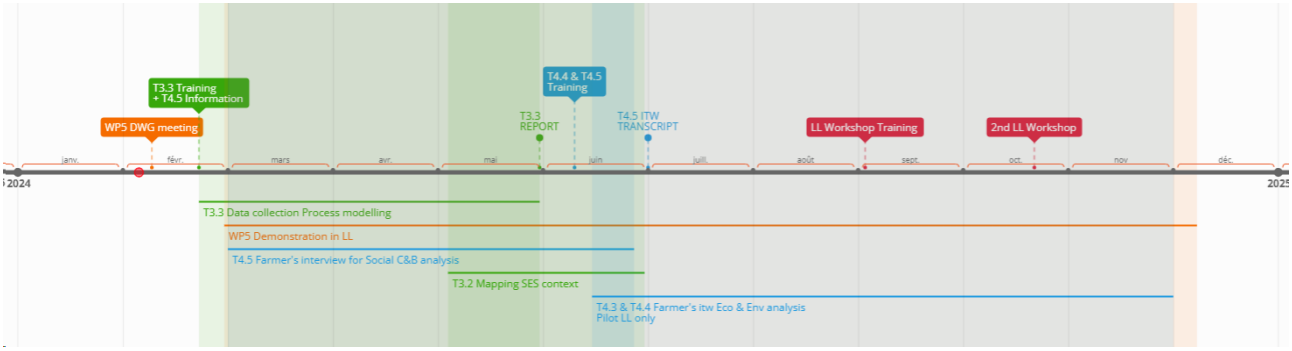

Figure 20 General Timeline data collection activities

Concerning WP4 T4.3 and 4.4, the data collection will start from June 2024, for a selection of Living Labs, constituting a pilot group (4 to 8 preselected Living Labs).

This data collection will start summer 2024 ans will take the form of in-depths interviews of farmers.

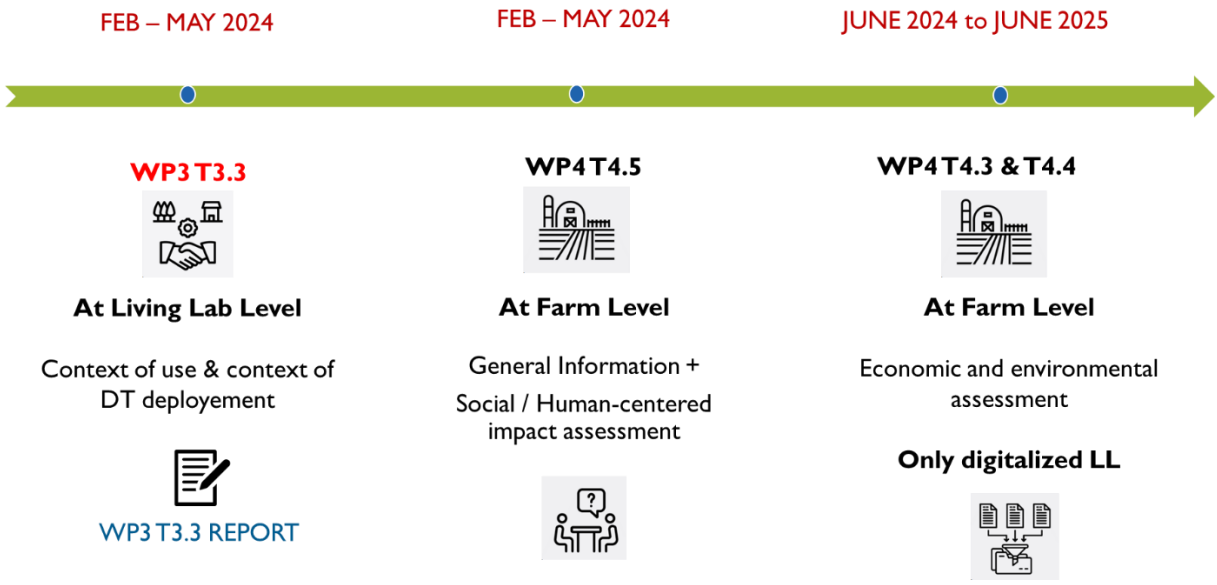

Figure 21 WP4 data collection timeline at farm level

6.2. General guidelines for farmer's interview

The Living Lab Facilitator and team will be responsible for the following tasks:

IDENTIFY THE FARM(S) TO BE ASSESSED	this includes to check if the farm will be able to provide quantitative data about the production system, before and after the digitalisation process
ORGANISE THE IN-DEPTH INTERVIEW	set the date for a 1 – 2 h slot, if possible in presential. This meeting can also be articulated with other activities

	in the LL : in-depths interview for Social C&B for example, or for completing data collection for WP3.
SEND IN ADVANCE THE LIST OF QUESTIONS AND LIST OF DATA REQUIERED	this will help the farmer to identify the sources of data (from log books for example)
CONDUCT THE INTERVIEW	With the help of the questionnaire prepared specifically for the LLs (**See Appendix**), fill in the data collection file with the needed data. If two persons can be present for the interview, this would allow to gather more complete data and avoid errors or misunderstandings. If necessary, the interview can be recorded to be able to retrieve missing info afterwards.
COMPLETE THE DATA COLLECTION FILE	as precisely as possible. This can be done on word or in an excel file directly. Comment if and why data are missing, to help task leaders in the interpretation
SEND OR UPLAOD THE FILE IN THE TEAMS FOLDER	a specific folder will be prepared with all the material for data collection and reporting

For detailed instructions on the interview phase, please refer to the annexes.

7. Concluding remarks

The current draft of the methodological document was prepared in order to inform the CODECS consortium of the scope, objectives and methods that will be used to estimate the economic costs and benefits and facilitate discussion amongst colleagues and partners on data requirements and possible data sources. The research work within the project relies on co-creation and co-development of methodologies and guidelines and unhindered flow of information between the partners. The current document clarifies the data requirements and their use, so as to avoid potential overlaps during data collection, analysis and estimations.

The level and steps of the economic analysis will, up to a point, depend on data availability and characteristics of the FASs examined. Qualitative information on costs and benefits will be provided if no quantitative data is available.

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9. Appendix

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- Data collectors are advised to take notes of all information that the farmer may provide (qualitative or quantitative). They will be very helpful for understanding the rationale behind the operation of the farm, to correct/adjust the raw data collected and to make comparisons.
- While collecting technical and economic data, data collectors should record them as the farmer gives them. For example, if the farmer provides data per hectare, the farmer should not be asked to aggregate this for the whole farm. This can be done by the data collector after the interview. However, if the data collector has doubt that the farmer has provided a correct/realistic number, the data collector can ask the question differently to verify the answer.
- The basic level of analysis if the farm. The purpose of the interview is to record data on all farm enterprises. However, if the digital technology affects only specific enterprises or processes within the farm, detailed data can be recorder only for them and the rest of the data can be recorded with less detail.
- Data collectors should try and build a trusting relationship with the interviewees. They should avoid judging or commenting on the data provided unless they require specifications.
- It is good practice to communicate with interviewees some days before the interview to let them know that data required is of economic nature. This will give them the chance to consult their log books, gather invoices and prepare for the interview.
- Data collectors should try to make the interviewees feel comfortable throughout the interview and guide them to provide accurate data. However, data collectors should not over-"push" interviewees as this will compromise the remaining part of the interview. Reluctant interviewees should be reassured that the interview is confidential.
- The interview should take place in a quiet place e.g., the farm and not at the presence of others, as this might make the interviewee feel uncomfortable.
- The data collector should be well prepared and possess good knowledge of the farming activities in the area and preferably some experience in data collection.
- If data is collected using printed questionnaires data should be entered in the data base as soon as possible, so that the interviewer will remember all the necessary information.
- It is very important to enter technicoeconomic data in accordance to the required reference units. If for example costs are required per hectare, entered cost data should be expressed per hectare and not as total farm costs.

Appendix 4 Source of data

1. Transition and investment costs					
		Type of data	Potential data sources		
			Questionnaire for LLs?	Other data base/accounting books	FAS description
Establishement period					
	Annual or multiannual investment (establishment period)	quantitative	x		
Fixed Capital and land costs					
	Type of machinery/ building / land imrpovement	qualitative	x		
	Value of machinery/constraction costs of buildings or land imrpovement	quantitative		x	
	Cost of land improvement	quantitative			
	Year of acquisition/constraction/improvement (for	quantitative	x		
	Insurance costs of mashinery/buildings (some maybe very machinery type-specific)	quantitative		x	
	Land requirements (ha/irrigated land)	quantitative	x		
	Rents (€/ha)	quantitative		x	
	Availability of specialized machinery (easy to find/ alternatives)	qualitative	x	x	
	Other costs directly linked to the use of specialized machinery (e.g. specific consumables)	qualitative/quantitative	x		
	Interest rates (long and short term loans)	quantitative		x	
	Funding options (eg. Access to credit, subsidy measures for farm modernization or new comers)	qualitative	x	x	
Labour inputs					
	Tasks required for establishment (e.g. for land improvements)	qualitative	x		
	Wages (€/hour)	quantitative		x	
	Hired labour in hours	quantitative	x		
	Contract labour type	qualitative	x		
	Contract labour costs	quantitative	x		
	Availability of specialized workers (yes/no or Likert perhaps	qualitative	x		
	Effect of inovation on labour requirements (e.g. on unskilled workers/ specialized workers/seasonal or permanent workers)	qualitative	x		
Other costs					
	Certification costs	quantitative		x	
	Licenses and permits (type and costs)	qualitative/ quantitative	x	x	
	Relative legislation	qualitative	x	x	
	Training and advisory costs	quantitative	x		
	Access to advisory services	qualitative	x		
	Quality of advisory services	qualitative	x		
	Marketing and research costs	quantitative	x		
	Software license and instalation costs	quantitative	x	x	
Other nformation on economic costs and benefits					
	Effect of innovation on quanity of product or sales (estimation)	qualitative/ quantitative	x		
	Effect of innovation on quality of product (estimation)	qualitative	x		
	Effect of innovation on marketing channels (alternative channels maybe?)	qualitative	x		
	Effect of innovation on prices (estimation)	qualitative	x		
	Effect of innovation on the management/structure of farm or other organizational changes	qualitative	x		

Appendix 5. Questionnaire for DATA COLLECTION

This is a general questionnaire. According to the Living Lab and the Focal Action Situation, the number of requested data will be adjusted to each specific use case.

1. General farm/system information

Questionnaire No*												
Name of owner												
Phone no												
email												
Date of interview*												
Type of digital technology applied												
Farm location (Prefecture, municipality, city, country)												
Soil quality	**Good**		**Average**		**Bad**							
Soil texture *(%)*	**Sand**		**Silt**		**Clay**							
Coordinates and Altitude of the farm location*												
Annual rainfall* *(mm)*												
Climate*												
Mean temperature *(^{o}C)**												
Soil pH												
Agricultural activities consist the main source of income	**Yes**						**No**					
Main production activity of your farm in 2023	Cereals		Oilseed and protein crops		Dry pulses		Root crops		Fibre crops, hop, tobacco, cotton, other industrial crops		Vegetables	
	Orchards		Wine		Olives		Dairy milk		Cattle		Sheep and goats	

	Pigs		Poultry		Mixed crops		Mixed livestock		Mixed crops and livestock		Other (please specify)	
Total land area in use at the farm (ha)	Arable land		Meadows and pasture		Orchards		Wood		Other (specify)		Other (specify)	

**to be field out by the interviewer*

2. Information of farmer and other farm workers

No	**Family member** [1] **Or worker**	**Gender** (*male/ female /prefer not to say)*	**Age in years**	**Educational level**[2]	**Employment rate in agriculture / livestock** *(%)*	**Percent of income from agriculture / livestock** *(%)*	**Years of experience in agriculture/qualifications**	**Cooperative member** *(yes/no)*	**Is employment affected by the digital technology ?**
1	*e.g. farm owner*								
2									
3									
4									
5									

[1]Family members and permanent workers

[2] None=1, Elementary=2, High School=3, University=3, Other=4

3. Farm characteristics

Crops *(please specify in order of significance to farm income)*	**Species**	**Type of production (organic)**	**Area** *(ha)*	**Characterization of area***	**Ownership ** **	**Rent *** *(€/ ha)*	**Total production** *(tn)*	**Is the activity affected by the digital technology** (yes/no)
1……								
2…..								
3……								
4…..								

Livestock *(please specify)*	**Breed**	**Number of productive females**	**Annual meat production** *(tn)*	**Annual milk production** *(tn)*	**Other product 1** *(please specify the annual production in tn)*	**Other product 2** *(please specify the annual production in tn)*	**Is the activity affected by the digital technology** (yes/no)
1…							
2…							

* Irrigated=1, No irrigation=2

**Owned=1, Rented=2

***Please fill in the information even if the rent is imputed

10.1.1.1.1.1.1 4. Techno-economic data

10.1.1.1.1.1.2 **4.1.a. Use of inputs** *(this table can be double for more crops)*

		Crop 1…(before digital technology)		**Crop 1….**(after digital technology)*		**Crop 2…**(before digital technology)		**Crop 2….**(after digital technology)*		**Crop 3…**(before digital technology)*		**Crop 3….**(after digital technology)*	
Fertilizers *(please specify ratio)*	**Price/ Unit**	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *units/ ha/ application)*
Ammonium nitrate													
Ammonium phosphate													
Ammonium sulfate													
Calcium ammonium nitrate													
Dolomite													
Lime													
Nitrate solution													
Compound (N/P/K)													
Potassium chloride													
Potassium nitrate													
Urea													
Other nitrogen													

Other potassium													
Other phosphorus													
Organic Fertilizer													
Other……													
		Crop 1…(before digital technology)		**Crop 1….**(after digital technology)*		**Crop 2…**(before digital technology)		**Crop 2….**(after digital technology)*		**Crop 3…**(before digital technology)		**Crop 3….**(after digital technology)*	
Pesticides *(please specify active substance)*	**Price/ Unit**	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*
Insecticide 1:													
Insecticide 2:													
Organic Insecticide:													
Fungicide 1:													
Fungicide 2:													
Organic Fungicide:													
Herbicide 1:													
Herbicide 2:													
Organic Herbicide:													
Seeds	**Price/ unit**	**Species/ Cultivars**	**Quantity** *(units/ha)*	**Species/ Cultivars**	**Quantity** *(units/ ha)*	**Species/ Cultivars**	**Quantity** *(units/ ha)*	**Species/ Cultivars**	**Quantity** *(units/ ha)*	**Species/ Cultivars**	**Quantity** *(units/ ha)*	**Species/ Cultivars**	**Quantity** *(units/ha)*

Crop 1 before													
Crop 1 after													
Other inputs	**Price/ unit**	**Number of applications**	**Quantity** *(units/ ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ha/ application)*	**Number of applications**	**Quantity** *(units/ ha/ application)*

**please fill the information only if the practice is affected by digital technology*

10.1.1.1.1.3 4.2 Cultivation practices (excluding irrigation) *

10.1.1.1.1.4 4.2.1. Crop 1 *(before digital technology)*

Type of practice	**Date of practice**	**Machinery used (1)**		**Machinery used (2)**		**Labour required** *(in hours/ha)*		**Work remuneration** *(€/hour)*	**Remuneration of contract labour** *(€/ha)***	**Fuel/electricity consumed** *(oil / gasoline/electricity)*	**Quantity of fuel** *(lt /ha)*	**Other input used** **(***e.g. fertilizer/pesticide***)**	**Price of input/Unit**	**Quantity of input** *(units/ha/ application)*
		Type	**Duration** *(hours/ha)*	**Type**	**Duration** *(hours/ha)*	**Family**	**Paid**							
Tillage														
Decompacting														
Drilling														
Forking														
Grubbing up														
Hurrowing														
Harvesting														
Hilling														
Hoeing														
Lister furrowing														
Rolling														
Stubble plough														
Stump clearing														

Subsoiling														
Pest control 1														
Pest control 2														
Harvest														
Management of crop residue														
Management of seed														
Thrashing														
Other …..														

* The route to and from the farmland is also included

** This information is filled out, if the specific task is not carried out using farm machinery but is assigned to a contractor (usually sowing / harvesting). In this case only the date that the task was carried out and the fee per ha are completed. Labor and fuel consumption are included in this remuneration and are therefore not filled out separately in the respective cells.

10.1.1.1.1.1.5 4.2.2. Crop 1 *(after digital technology)**

Type of practice	**Date of practice**	**Machinery used (1)**		**Machinery used (2)**		**Labour required** *(in hours/ ha)*		**Work remuneration** *(€/hour)*	**Remuneration of contract labour** *(€/100 ha)***	**Type of fuel consumed** *(oil / gasoline)*	**Quantity of fuel** *(lt /application/ ha)*
		Type	**Duration** *(hours/ha)*	**Type**	**Duration** *(hours/ha)*	**Family**	**Paid**				
Plowing 1											
Plowing 2											
Milling 1											
Milling 2											

Cultivator 1											
Cultivator 2											
Other tillage											
Removing herbs											
Sowing											
Fertilization 1											
Fertilization 2											
Fertilization 3											
Manure spreading											
Pest control 1											
Pest control 2											
Harvest											
Management of crop residue											
Management of seed											
Thrashing											
Other …..											

- To be filled out only if the practices are affected by digital technology

** This information is filled out, if the specific task is not carried out using farm machinery but is assigned to a contractor (usually sowing / harvesting). In this case only the date that the task was carried out and the fee per ha are completed. Labor and fuel consumption are included in this remuneration and are therefore not filled out separately in the respective cells.

10.1.1.1.1.6 4.3. Irrigation

10.1.1.1.1.7 4.3.1. Pumping method and irrigation system

Production system	Irrigated area *(ha)*	Irrigation water source*	Pumping method**	Water supply *(m^3/hour)*	Horsepower (HP)	Type of irrigation *(individual / collective)*	Water pressure in collective irrigation (low / low) medium / high)	Irrigation system***	Irrigation fees
Crop 1 *(before digital technology)*									
Crop 1 *(after digital technology)***									
Crop 2 *(before digital technology)*									
Crop 2 *(after digital technology)***									
Crop 3 *(before digital technology)*									
Crop 3 (*after digital technology)***									

* River, canal, private drilling, irrigation network etc., **tractor, diesel engine, electric pump etc., *** drip, cannon etc., ****to be filled out only if affected by digital technology

10.1.1.1.1.8 4.3.2. Number of irrigation and pumping hours

Production system	No of irrigation per month / Irrigation hours											
	January	February	March	April	May	June	July	August	September	October	November	December
Crop 1 *(before digital technology)*												
Crop 1 *(after digital technology)****												
Crop 2 *(before digital technology)*												
Crop 2 *(after digital technology)****												

Crop 3 *(before digital technology)*												
Crop 3 (*after digital technology)*****												

10.1.1.1.1.1.9 4.3.3. Prices of fuel and kilowatt hours

Price of oil *(€/lt)*	
Price of gasoline *(€/lt)*	
Price of kilowatt hours *(€/Kwh)*	

5. Fixed capital

10.1.1.1.1.1.10 5.1. Mechanical equipment (except investment of digital technology)

Type	**Characteristics**	**Age** *(years)*	**Purchase price (new)** ***(€)***	**Annual Operating Hours**	**Percentage of use on the farm** *(%)*	Maintenance / Improvements *(€/year)*	Insurance *(€/year)*	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	Use in Crop 3 after the DT* *(%)*
Means of transportation	Tones												
Car													
Truck													
Trolley													
Tractor	(HP)												
Tractor 1:													
Tractor 2:													
Tractor 3:													
Land cultivation													
Plow													
Milling machine													
Cultivator													
Other…													
Other…													
Other…													

Irrigation													
Pump													
Cannon													
Irrigation hoses													
Other…													
Other…													
Sowing-Harvesting													
Sowing machine													
Harvesting machine													
Other…													
Type	**Characteristics**	**Age** *(years)*	**Purchase price (new)** ***(€)***	**Annual Operating Hours**	**Percentage of use on the farm** *(%)*	Maintenance / Improvements *(€/year)*	Insurance *(€/year)*	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	Use in Crop 3 after the DT* *(%)*
Other equipment													
Fertilizer-distributor													
Pesticides spreader													
Other…													
Other…													

10.1.1.1.1.1.11 5.2. Building installations and land improvements

	Characteristics / Dimensions	Construction materials	**Age** *(years)*	**Value/ building cost (€)**	Maintenance / Improvements (€/year)	Insurance *(€/year)*	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	Use in Crop 3 after the DT* *(%)*
Building installations	m^2											
Shed												
Warehouse												
Pumping station												
Other:												
Other:												
Land improvements												
Drilling												
Pipes												
Other…												
Other..												
Other												
Fences												
Other…												
Other…												

- *To be filled out only if affected by the use of the digital technology

5.3. Initial investment required for Digital Technology

Year 1	**Year 2**	**Year 3**	**Year 4**					

Type investment *(e.g. type of equipment)*	**Purchase price** ***(€)***	**Type investment** *(e.g. type of equipment)*	**Purchase price** ***(€)***	**Type investment** *(e.g. type of equipment)*	**Purchase price** ***(€)***	**Type investment** *(e.g. type of equipment)*	**Purchase price** ***(€)***	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	
Other investment *(e.g. educational course, insurance, license)*	**Cost** ***(€)***	**Other investment** *(e.g. educational course)*	**Cost** ***(€)***	**Other investment** *(e.g. educational course)*	**Cost** ***(€)***	**Other investment** *(e.g. educational course)*	**Cost** ***(€)***	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	

6. Other technico-economic data

Type	**Quantity** *(per year)*	**Price** *(€/unit)*	**Value** *(€/year)*	Use in Crop 1 before the DT *(%)*	Use in Crop 1 after the DT* *(%)*	Use in Crop 2 before the DT *(%)*	Use in Crop 2 after the DT* *(%)*	Use in Crop 3 before the DT *(%)*	Use in Crop 3 after the DT* *(%)*
Electricity for farm use (excluding irrigation)	*Kwh:*								
Fuel (farm car) **	*lt:*								
Lubricants (farm car, tractor) ***	*lt:*								
Other consumables (eg packaging / lacing materials etc.)									
Insurance of crops									
Long term loan interest									
Short term loan interest									
Other…									

*To be filled out only if affected by the use of digital technology

**Only if the costs are not included in Tables 4.2.1., 4.2.2., 4.2.3, 4.2.4, 4.2.5 and 4.2.6

***Only if the costs are not included in maintenance (Table 5.1)

10.1.1.1.1.1.12 7. Other crop management data

	Crop 1 *before the DT*	**Crop** 1 *after the DT**	**Crop 2** *before the DT*	**Crop 2** *after the DT**	**Crop 3** *before the DT*	**Crop 3** *after the DT**	**All crops**
Crop residue management (incorporation / burning / removal)							
Quantity of burned residue							
Tillage (full /reduced/zero)							

Winter coverage *(yes/no)* **and type of winter coverage**							
Are coverage residues incorporated *(yes/no)*							
Is the land grazed *(yes/no)*							
Do you maintain hedgerows *(yes/no)* **and type of hedgerows**							
Do you apply crop rotation *(yes/no)*							
What did you cultivate in previous years?							
Are the soils drained? *(yes/no)*							

*To be filled out only if affected by the digital technology

10.1.1.1.1.1.13 8. Production and distribution of crop products

	Crop 1 *before the DT*		**Crop** 1 *after the DT**		**Crop 2** *before the DT*		**Crop 2** *after the DT**		**Crop 3** *before the DT*		**Crop 3** *after the DT**	
	Quantity *(kg per year)*	**Price** *(€/kg)*	**Quantity** *(kg per year)*	**Price** *(€/kg)*	Quantity *(kg per year)*	**Price** *(€/kg)*	**Quantity** *(kg per year)*	**Price** *(€/kg)*	**Quantity** *(kg per year)*	**Price** *(€/kg)*	**Quantity** *(kg per year)*	**Price** *(€/kg)*
Inventory at start of year												
Sales												
Payments in kind												
Self-consumption (feed)												
Self-consumption for seed												

Self-consumption (food)												

10.1.1.1.1.1.13.1												
10.1.1.1.1.1.13.2												

10.1.1.1.1.1.13.3						
Distribution of products	**Percentage of quantity produced (%)**	**Percentage of quantity produced (%)**	**Percentage of quantity produced (%)**	**Percentage of quantity produced (%)**	**Percentage of quantity produced (%)**	**Percentage of quantity produced (%)**
Traders						
Livestock farmers						
Retail stores						
Cooperative Organizations						
Directly to consumers						
Other…						

* to be filled out only if affected by digital technology

Thank you for your participation and collaboration!

Appendix 6. Participant Information sheet (model)

Dear Participant,

Your participation in this study greatly contributes to our understanding the environmental and economic costs and benefits of digitalization, i.e. adoption and use of digital technologies, in you farm.

You are invited to join our research, part of the EU's Horizon RIA project CODECS, through an interview conducted by [Your Organization Name] on behalf of INRAE France and ELGO-DEMETER (Greece).

Task Objective:

We aim to comprehend how digitalization transforms the environmental impacts and the economic costs and benefits of the farm.

Voluntary Participation:

Participation is voluntary with no obligations or adverse consequences. You may withdraw at any time without any negative consequences.

Data Privacy:

Data will be anonymized to protect your identity and treated with the utmost confidentiality.

Personal Data Collection:

We may collect personal data to contact you for research updates, which will be kept strictly confidential by [Your organization Name] and not used in the research results.

For questions or participation, contact:

[LL coordinator's/contact Name]

[LL coordinator's/contact Email Address]

[LL coordinator's/contact Phone Number]

[Your Organization - CODECS]

Appendix 7. Consent Form (model)

Project name Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems (CODECS)

Project acronym CODECS

Horizon Europe Call HORIZON-CL6-2021-GOVERNANCE-01

Horizon Europe Topic HORIZON-CL6-2021-GOVERNANCE-01-22

Your written consent is essential to verify your participation in this research. By signing this form, you indicate your agreement to be a part of the study; however, it does not restrict your right to reconsider your involvement at any point in the future.

I confirm that I have read and understood the study information sheet for "Evaluating the environmental and economic costs and benefits of digitalization, i.e. adoption and use of digital technologies, in you farm."

I had the opportunity to ask questions, and they have been satisfactorily answered.

I understand that:

- ☐ My participation is entirely voluntary, and I can withdraw at any time without providing a reason.
- ☐ I consent to the audio recording of the interview session to help the data collection, with the assurance of strict confidentiality
- ☐ I consent to the use of quantitative data I provide for the research, which will help to calculate C&B and impacts, provided the data are completely anonymised and will not contain personally identifiable information
- ☐ I consent to the publication of the results of the analysis.

By signing this form, I voluntarily agree to participate in the study.

Participant's Name: _____

Participant's Signature: _____

Date: _____

Thank you for your participation, which contributes to our understanding of digitalization's changes on farms and farmers.

Sincerely,

[Your Name]

[Your Organization - CODECS]

[Date]

10.2 Appendix 4 Social-human centred C&B guidelines

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

T4.1 GUIDELINES

GUIDELINES FOR DATA COLLECTION AND REPORTING

APPENDIX 4 – SOCIAL -HUMAN CENTERED C&B ANALYSIS OF FARM DIGITALISATION

(TASK 4.5)

01 MARCH 2024

MAURO FLOREZ (INRAE), ALEXIA GOBRECHT (INRAE), VERONIQUE BELLON (INRAE)
KARINE GAUCHE (INSTITUT AGRO),
BEATRIZ HERRERA (UHOH),
LEANNE TOWNSEND (HUTTON),
MAJIA USCA (BSC), EMILS KILLIS (BSC)

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12 Introduction

This guide focuses on Task 4.5, which involves assessing the social-human-centered costs and benefits of using digital technologies in agriculture. For the purposes of this task, we follow the OECD [Organization for Economic Cooperation and Development] definition of digital technologies:

> ICT [information communication technologies], including the Internet, mobile, technologies, and services, as well as data analytics used to improve the generation, collection, exchange aggregation, combination, analysis, access, searchability and presentation of digital content, including for the development of services and apps (OECD, 2014)

Our goal is to deepen our understanding of the social-human changes that digital technologies are bringing to farmers, with a focus on the intangible aspects of their use. By doing so, we aim to gain a comprehensive understanding of their impact on farmers and farming practices.

The guide first outlines the issues and challenges involved in studying these changes at the farm level. It then establishes the research objective of providing valuable insights to farmers and decision-makers through a comprehensive understanding of societal impacts. Finally, the document presents a systematic protocol for the collection and analysis of data in order to ensure reliable and balanced results.

13 Social-human centred aspects of the use of digital technologies at farm level

Research evaluating digital technologies in agriculture has primarily focused on their economic dimensions. However, to gain a comprehensive understanding of how digital technologies can contribute to a better world, it is crucial to recognize the significance of exploring their social dimension (Davison et al., 2023).

The existing literature on digital agriculture has identified potential social changes of digital technologies at various general levels, including rights (e.g., resilience), access (e.g., resources), and individuals (e.g., health and skills) within the agricultural sector (Rolandi et al., 2021). Rose et al.'s emphasize involving people at all levels of social changes induced by digital technologies use. They suggest researching how digital technologies affect humans at the farm level to avoid causing more social problems than they solve (Rose et al., 2021), as well as to develop more inclusive and equitable approaches attending a greater diversity of human values with the digitalization of agriculture (Bronson, 2018). These human impacts are also referred to as “intangible costs (negative) and benefits (positive)” related to the use of digital technologies (Murphy & Simon, 2002). Due to their complex nature, assessing these aspects poses challenges.

It is essential to recognize that digital technologies should not be considered universal, as their impact is also shaped by socio-economic, cultural, and political factors within different contexts (Klerkx & Rose, 2020). This complexity makes studying the social-human aspects of digital technology usage challenging. By understanding how digital technologies influence people and their farming activities and how users adapt them to new purposes, we can share valuable knowledge with other farmers and diminish resistance to new technologies. Policymakers can leverage these insights to design and support policies that either reduce or promote any negative or positive social-human changes resulting from the use of digital technologies at the farm level.

14 Objective of Task 4.5 and research questions

Task 4.5 objective is to evaluate the social-human costs and benefits of digitalization at the farm level, mainly, by identifying and enhancing the understanding of the use of digital technologies by farmers.

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Based on the introduction and the aforementioned objective, the task will seek to address the following research questions:

i. How does the adoption and use of digital technologies affect farmers and farmers' practices?
ii. How does the context in which digital technologies are adopted and used influence the results they produce for farmers and workers at the farm level?

To address the research questions concerning social-human costs and benefits, T4.5 researchers will conduct a qualitative study among farmers identified in the CODECS Living Labs. This encompasses both positive and negative human changes affecting farmers and their agricultural practices. Social-human aspects will include exploring the changes of these technologies on farmers' well-being, social interactions, labor and overall quality of life within their specific socio-economic and cultural contexts. By collecting qualitative data, the researchers aim to gain a comprehensive understanding of the social-human implications of using and adopting digital technologies at the farm level.

15 Design Research

In this first step, we will conduct a qualitative study among farmers identified in the CODECS Living Labs (LL). More precisely, semi-structured interviews will take place to focus on gathering qualitative information related to the social-human aspects of the costs and benefits of the digital technologies being currently adopted and used. The outcomes of this qualitative research will deepen our comprehension of the social- human implications under different contexts by systematically identifying, collecting, and structuring the human costs and benefits linked to digital technologies at the farm level. Also, they will serve as the foundation for constructing hypotheses, which will be tested in subsequent research phases (Venkatesh et al., 2013).

Below, we present our qualitative method, providing a description of expected human changes, inclusion and exclusion criteria for farmers, the semi-structured interview questions, and some advice for interviewers.

15.1 Qualitative method

We chose to use a qualitative method to deeply understand the experiences and perspectives of farmers regarding the social-human costs and benefits of using digital technologies in various situations, including living labs, different countries, farm conditions, and with different technologies.

Considering our research questions, a qualitative approach is suitable for exploring a topic that has not been extensively studied in the literature and lacks strong theories (Trauth, 2001). Moreover, it acknowledges that the results, of adopting and using digital technologies, may vary depending on the specific context.

Data for this stage of research will be collected through semi-structured interviews (see section 4.3), enabling farmers from living labs to freely share their experiences and perspectives on using and adopting digital technologies (Furneaux & Wade, 2011). Additionally, this approach will allow us to address the potential social-human costs and benefits discussed, hereafter presented, by the members of T4.5 in terms of farmers, work, and the organisation of the production system.

15.2 Clusters of human cost and benefits resulting from farm digitalisation

The partners of WP4.5 have reached a consensus and suggested the creation of a benchmark to guide the understanding of human costs and benefits associated with digitalisation. This benchmark is also intended to continuously evolve and adapt within various contexts. As a result, digitalisation may influence not only the farmers but also employees or relatives involved at the farm level, affecting their i) health and well-being, as well as ii) their perception of work quality. Another socio-human dimension potentially influenced by digitalisation includes the efficiency of tasks over iii) time and the evolution of iv) skills and knowledge. Additionally, digitalisation has the potential to reorganise the production system through v) collaborative networks and enhanced communication

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among people at the farm level. It is crucial to emphasise that the relevance of these indicators might differ based on the specific context of living labs. They are intended as an initial framework to deepen our understanding of how digitalisation could affect human dimensions at the farm level. Figure 1 represents human cost and benefits of digitalisation suggested with some real examples from France.

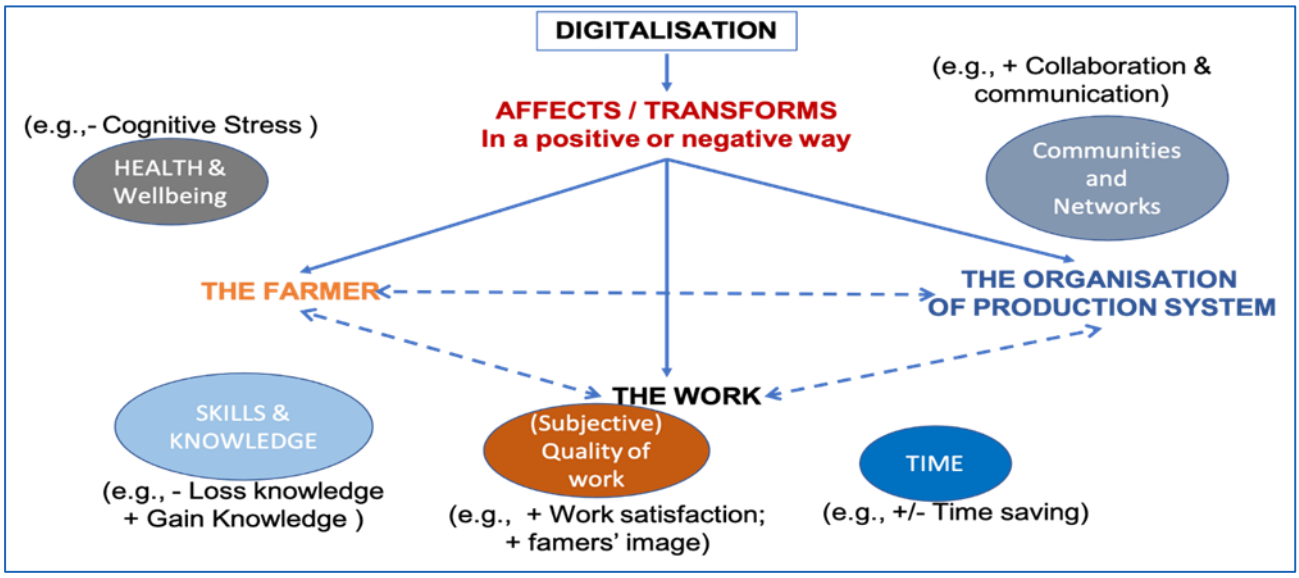

Figure 22 Cost and Benefits of the use of digital technologies on the farmer, his/her work and his/her organisation

15.3 Selection criteria for farmer

In this qualitative study, and building upon the digitalisation levels outlined in WP3.3, we aim to include farmers or operators from various Living Labs (LL) who are actively using digital technologies on their farms (Digitalised) and those who are still in the process of adopting, testing, or integrating prototypes (Digitalising). While we are open to narratives on experiences with a wide spectrum of digital technologies, our primary focus is to investigate more thoroughly those technologies that have been selected for an in-depth study within the LL for the Focal Action Situation (FAS). Conversely, farmers and LL that are yet to identify suitable digital technologies will be excluded from this study to maintain a concentrated exploration of the impact of technology usage.

16 Semi-structured interview presentation

The semi-structured interviews are organized into four distinct sections to comprehensively explore different facets of farmers' contexts, experiences, and perceptions regarding the social-human changes brought about by the use of digital technologies at the farm level. Each section is further divided into specific research themes. In total, the semi-structured interview comprises nine main questions. Additionally, please note that the following semi-structured interview is designed for both types of Living Labs (Digitalised and Digitalising), with the exception of two themes detailed hereafter. Below, we provide the details of each section, along with the corresponding themes and questions. Please refer to Table 1 for the complete layout of the semi-structured interview.

Interviews must be recorded, transcribed, and translated into English for analysis purposes. Consequently, farmers have to be informed about the study's objectives and asked for their consent to participate (please refer to Appendix the consent forms). Moreover, interviewers will be required to submit a short preliminary report, in English, detailing the farm context and some key findings and their impressions of the interview (please see Appendix for the template of the preliminary report).

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16.1 Introduction

The first part of the interview serves as an introduction, aiming to establish a comfortable environment for both parties to engage in conversation. However, it can also yield valuable insights into the context of the farmer and their specific needs or challenges.

Theme: Context (both Digitalised and Digitalising)

Q1: Can you provide a description of your profession as a farmer and farming activities you engage in?

16.2 Specific

The second part is the core of the interview, where we delve into the farmers' stories and experiences with using or adopting digital technologies. Moreover, we aim to explore the human changes that arise from various experiences/contexts with digital tools at the farm level.

Theme: Use and experiences (only if your LL is Digitalised)

Q2: I would like to hear your experience with using digital technology (Technology to study in the LL) in your day-to-day farming activities

Theme: Digital Readiness (all LL)

Q 3: How would you describe the readiness level of you/your farm business in order to adopt the digital technology necessary for you?

Theme: Use and changes (only if your LL is Digitalised)

Q4: Could you please share what changes have you observed because of using (Technology to study in the LL) digital technology in your day-to-day farming activities?

Theme: Use and expectation of changes (only if your LL is Digitalising)

Q : Could you please describe the changes you anticipate or expect to see from using digital technology (Technology to study in the LL) in your day-to-day farming activities

Theme: Meanings (all LL)

Q5: What is your understanding of human changes induced by the use of digital technologies?

16.3 Engagement with digital technologies

In the third part of the interview, we will ask a series of questions to collect information that would uncover farmer's reality on human changes. Also, to identify potential new digital technologies in their context and therefore potential new indicators on human changes through farmers' perceptions and experiences.

Theme: use and reasons (all LL)

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Q6: I'm curious to know which other digital technologies you currently use or are adopting to support your day-to-day farming operations

Theme: Concerns/opportunities (all LL)

Q7: Could you please share any challenges or concerns related to first-hand observations or experiences with the changes brought about by using digital technologies in farming?

Q8: In your experience, what benefits or opportunities may arise for people as a result of the integration of digital technologies in farming?

16.4 Wrap up

In the final part of the interview, a set of closing questions is included to ensure comprehensive coverage of the topic. I invite the respondent to share any additional insights or perspectives they have that have not been discussed yet. Furthermore, I encourage them to consider any important aspects or noteworthy information regarding social-human changes that they believe would contribute to a more thorough understanding of the topic.

Q9 **(all LL)**: We have come to the end of my questions, now that you know what the interview was about, and you know what we have been talking about, what should I have asked you about that I did not give you an opportunity to share about social-human changes induced by digital technology use?

Below, you will find Table 1 with the interview structure. The first column contains the section names, the second column lists the research themes, the third column presents the main questions, and the fourth column includes probing questions to follow up on farmers' responses.

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Table 5Semi structured interview for human centred social costs and benefits assessment at farm/farmers level

Section	Theme	Questions	Prompts
Introduction	Context (ALL LL)	Can you provide a **description of your profession as a farmer and farming activities** you engage in?	What thoughts about his/her profession What crops? / Seasonal ones? What agricultural practices? / Sustainable practices Could you share the **key factors/challenges that significantly influence your day-to-day operations** as a farmer? What needs? / Related to digitalization? Market demands, Institutional demands What challenges you face in your job? Weather conditions, Seasonal variations
Specific	Use and experiences (Digitalised)	I would like to hear **your experience with using digital technology (Technology to study of the LL**) in your day-to-day farming activities	Why do you use it? Can you share a specific story about how a digital technology you use on your farm has changed you and your farming activities? Health, When/ How Executing tasks, Which ones/ when/how Gaining/Losing insights, Which ones/When/how Addressing challenges, Which ones/ when/how

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			Communicating, When /how/With whom Gaining/losing time, When/How Have you observed any unexpected change from using these digital tools or services that you did not anticipate?

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Specific	Digital readiness (Both)	How would you describe the readiness level of your/your farm business in order to adopt the digital technology necessary for you?	Prompts could be and ranked to 1 up 10: • resources (i.e.., What technology(ies) do you have in place? How would you rate your technical knowledge? What are your human resources to deal with digitalization tasks? Would you consider your financial resources enough? etc.) • capabilities (i.e., Do you have skills? Motivation? Abilities to adapt your farms and procedures? Abilities to solve technical problems?, Are you able to collaborate to tackle the challenges of digitalization? Do you have the contacts or the attitude?)
	Use and changes (Digitalised)	Could you please share **what changes have you observed** because of using (Such particular) digital technology in your day-to-day farming activities?	How do they affect you? What changes have you observed in your way you get informed? What changes have you observed in your way of working? What changes have you observed in your health (Health, life balance, free time)? What changes have you observed in your way you relate others?
	Use and expected changes (Digitalising)	Could you please describe the changes you anticipate or expect to see from using digital technology (Technology to study in the LL) in your day-to-day farming activities	Do you expect to see changes in your way you get informed? Do you expect to see changes in your way of working? Do you expect to see changes in your health (Health, life balance, free time)? Do you expect to see changes in your way you relate others?
	Meaning (Both)	What is **your understanding of human changes induced by the use** of digital technologies?	

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Engagement with digital technologies	Use and reasons (all LL)	I'm curious to know **which other digital technologies you currently use or are adopting** to support your day-to-day farming operations	Why are you using/adopting them? (look for needs/challenges/curiosity) How did you come across these digital tools or services? Were they recommended to you, or did you actively search for them?
	Concerns (all LL)	Could you please share **any challenges or concerns related to first-hand experiences** with the changes brought about by using digital technologies in farming?	Any concerns about people's (farmers, workers) health due to digital tech in farming? Worries or challenges with changes in people's work from digital tech use? Concerns regarding interactions between farmers and their networks due to the use of digital technologies?
	Opportunities (all LL)	In your experience, what benefits or opportunities may arise for people as a result of the integration of digital technologies in farming?	
Wrap Up	(all LL)	We have finished the questions. If there is anything related to social-human changes resulting from digital technology use that I did not ask about, please feel free to share it now.	

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16.5 Time framing

During the semi-structured interviews, it is beneficial to maintain a clear focus. Our main objective is to gather narratives and insights concerning the use of digital technologies and how they change various aspects of farmers' lives, such as farm practices, farmers' health, learning, labour, networks and others. If an interviewee begins to stray from the topic, we suggest gently guiding him/her back (check prompt questions, table 1) to ensure our research remains on point and provides valuable insights. Keep in mind that the suggested time framing here below is flexible and should not lead to interrupting an interviewee who is sharing extensive insights on the subject, as each situation may vary.

Our suggestion of time framing:

- Introduction: 10 min
- Specific: 20-30 min
- Digital engagement: 10-15 min
- Wrap up: 5 min

16.6 Reporting data

Reporting data for qualitative research involves several crucial steps. Firstly, meticulously audio-record all interviews then ensure accurate transcription of spoken words. Next, undertake the essential task of translation into English.

Interviews for qualitative research can also be conducted via phone or Zoom, and it's crucial to ensure they are fully recorded for accurate data capture

Once the transcription and translation are complete, it is imperative to maintain data integrity and confidentiality. Finally, as part of the research process, consider sending by **30th May** the transcribed and translated data (in separate documents) to INRAE, for comprehensive analysis.

16.7 Analysing data

Analysing data is a pivotal phase of our research, and we will use content analysis to sort narrative (Weber, 1990) data according to the framework we introduced in the previous section, while also remaining open to uncovering new topics. In this method, phrases will serve as unit of analysis, enabling us to extract meaningful insights. These units of analysis will be meticulously scrutinized and grouped to form distinct categories. Thus, using content analysis technique is expected to yield a systematic and objective understanding of the themes and patterns related to the human costs and benefits of digitalization. We will perform content analyse on NVivo software.

16.8 Ethics

The research carried out in this task T4.5 should abide by good practice guidelines as prescribed by an appropriate professional organisation.

You must ensure that you adhere to any local regulations or human research ethical guidelines that are in place at the research location. For CODECS basic good practice means that you must ensure interviews participants are always provided with:

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- An information sheet outlining the purpose of the research, describing the process of the interview and what will be done with the data. This will also confirm their right to withdraw from the research at any time and not to answer questions should they wish. [See Appendix 1]
- A consent form to confirm their agreement to take part in the research. [See Appendix 2]

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18 APPENDIX

APPENDIX A – Participant information sheet

Dear Participant,

Your participation in this study greatly contributes to our understanding of how digitalization is changing farming practices, processes, and the lives of farmers.

You are invited to join our research, part of the EU's Horizon RIA project CODECS, through an interview conducted by [Your Organization Name] on behalf of INRAE France.

Task Objective:

We aim to comprehend how digitalization transforms farming practices, processes, and the lives of farmers.

Voluntary Participation:

Participation is voluntary with no obligations or adverse consequences. You may withdraw at any time without any negative consequences.

Data Privacy:

Data will be anonymized to protect your identity and treated with the utmost confidentiality.

Personal Data Collection:

We may collect personal data to contact you for research updates, which will be kept strictly confidential by [Your organization Name] and not used in the research results.

For questions or participation, contact:

[LL coordinator's/contact Name]

[LL coordinator's/contact Email Address]

[LL coordinator's/contact Phone Number]

Thank you for considering our research.

Sincerely,

[Your Name]

[Your Organization - CODECS]

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APPENDIX B – Sample consent form

Project name Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems (CODECS)

Project acronym CODECS

Horizon Europe Call HORIZON-CL6-2021-GOVERNANCE-01

Horizon Europe Topic HORIZON-CL6-2021-GOVERNANCE-01-22

Your written consent is essential to verify your participation in this research. By signing this form, you indicate your agreement to be a part of the study; however, it does not restrict your right to reconsider your involvement at any point in the future.

I confirm that I have read and understood the study information sheet for "evaluating digitalization's changes on farms and farmers." I had the opportunity to ask questions, and they have been satisfactorily answered.

I understand that:

- ☐ My participation is entirely voluntary, and I can withdraw at any time without providing a reason.
- ☐ I consent to the audio recording of the interview session for research purposes, with the assurance of strict confidentiality
- ☐ I consent to the use of anonymized quotes from the interviews in related publications. These quotes will not contain personally identifiable information.

By signing this form, I voluntarily agree to participate in the study, including the interviews recording and the use of anonymized quotes in publications.

Participant's Name: _____

Participant's Signature: _____

Date: _____

Thank you for your participation, which contributes to our understanding of digitalization's changes on farms and farmers.

Sincerely,

[Your Name]

[Your Organization - CODECS]

[Date]

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APPENDIX C – Interview Checklist

Before interview

- ☐ Select participants / Farmers
  - With digital technology in use and adoption process
  - Involved in farm decision making or use of digital technology
- ☐ Send out invitations
- ☐ Agree on date, time and location for the interview (preferably face to face but online possible)
- ☐ Prepare information sheet and consent form
- ☐ Prepare tests
  - Be aware of interviews goal (capture farmers experiences on using digital technologies and its brought changes on human aspects)
  - Be aware on reflective questioning techniques (see exemples here below)
- ☐ Send a reminder to the participant one week and one day before
- ☐ Check recording equipment
  - Batteries fully charged

Interview day

- ☐ Arrive early;
- ☐ Explain the purposes of the interview, within the context of CODECS / FAS
- ☐ Explain the consent form and make it sign
- ☐ Turn on recording equipment
- ☐ Introduction to the topic, by talking on general /changes/experiences on digital technologies
- ☐ Smiles, makes eye contact
- ☐ Following up on subject responses
- ☐ Allow the conversation to flow naturally without diverting it too soon. Give space for discussion on various points, and when appropriate, circle back to previous topics to explore them further
- ☐ Feel free to inquire for additional details to enhance your understanding
- ☐ Close the interview, verify if the farmer has some pending questions
- ☐ Turn off the record.

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Examples of reflective questioning:

Ex.1:

- Interviewer: “Tell me about your experience with implementing sustainable farming practices on your farm.”
- farmer: “Well, I've been using cover crops and crop rotation to improve soil health and reduce the need for synthetic fertilizers. It has made a noticeable difference in the quality of the soil.”
- Interviewer: “So, it sounds like implementing cover crops and crop rotation has had a positive impact on your soil health. Can you provide some specific examples of how you've seen the soil quality improve?

Or

EX 2:

- Interviewer: “Tell me about your experience with implementing sustainable farming practices on your farm.”
- Farmer: “Well, I've been using cover crops and crop rotation to improve soil health and reduce the need for synthetic fertilizers. It has made a noticeable difference in the quality of the soil.”
- Interviewer: “…using cover crops and crop rotation to improve soil health?”

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APPENDIX D – Interview Report

This short report will help to contextualize the transcription of the interview. Please fill-in the table and send it together with the translated transcriptions.

LIVING LAB NAME		
Living Lab coordinator		
Interviewer		
Focal Action Situation		*Copy paste the LL FAS*
Level of digitalization of the farm	☐ Digitalized (since _____) ☐ Digitalizing (since _____)	
General information about the Farm		
Name/ID of the farm	*LLName_FARM_01*	
Location of the farm	*City, Region, Country*	*the degree of precision of the location is at the discretion of the farmer*
Type of farm	☐ Crop Farm ☐ Livestock Farm ☐ Mixed Farm (Combination of crops and livestock) ☐ Other (please specify): _____	*Comments can be added to detail the type of productions*
Main production		
Farm size (in Ha)		
Involved individuals in farm operations	☐ Owner & Family : _____ ☐ Permanent employees : _____ ☐ Occasional workforce: _____	
Annual revenue of the farm		
Level of digitalization of the farm	☐ Digitalized (since _____) ☐ Digitalizing (since _____)	
What digital technologies are implemented in the farm ?		
Additional information or comments about the farm or the interview session (key findings and impressions)		

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