



# REPORT ON DIGITAL ECOSYSTEMS FINAL M36

30 SEPTEMBER 2025

CYNTHIA GIAGNOCAVO (UAL), ROSA MARIA HEREDIA HORTIGÜELA (UAL), LUCAS OLMEDO OSUNA (UAL), ANDREA KNIERIM (UHOH), BEATRIZ HERRERA (UHOH), ALESSIO FERRARI (CNR), CHIARA MANNARI (CNR), MANLIO BACCO (CNR)

DOI: [10.5281/zenodo.17235792](https://doi.org/10.5281/zenodo.17235792)

Status: submitted draft not yet approved by the EC



Funded by  
the European Union

CODECS has received funding from the European Union's Horizon Europe research and innovation Programme under Grant Agreement n. 101060179. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). The granting authorities cannot be held responsible for them.





## D3.2 REPORT ON DIGITAL ECOSYSTEMS FINAL M36

---

<b>Project name</b>	<b>Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems</b>
<b>Project acronym</b>	CODECS
<b>Horizon Europe Topic ID</b>	HORIZON-CL6-2021-GOVERNANCE-01-22
<b>Project ID</b>	101060179
<b>Website</b>	<a href="http://www.horizoncodecs.eu">www.horizoncodecs.eu</a>
<b>Document Type</b>	Deliverable
<b>File Name</b>	D3.1 Analysis of Digital Ecosystems
<b>Status</b>	Final
<b>Dissemination level</b>	Public
<b>Date of creation</b>	30.09.2025
<b>Keywords</b>	Digital Ecosystems, Living Labs, Socio ecological system, Ostrom´s framework, resources, capabilities, digitalisation, conduciveness, process modelling, Agricultural and Innovation system.
<b>Authors</b>	Cynthia Giagnocavo (UAL), Rosa Maria Heredia Hortigüela (UAL), Lucas Olmedo Osuna (UAL), Andrea Knierim (UHOH), Beatriz Herrera (UHOH), Alessio Ferrari (CNR), Chiara Mannari (CNR), Manlio Bacco (CNR)
<b>Reviewers</b>	Gianluca Brunori and Costas Iliopoulos.
<b>Version n.</b>	2
<b>Following updates</b>	
<b>Work package</b>	WP3 –Analysis of Digital Ecosystems
<b>Task number and title</b>	T 3.2 Mapping the socio-ecological context T 3.3 Farm Socio-technical Process Modelling of Use Cases
<b>Work Package Leader</b>	WP3 – Cynthia Giagnocavo
<b>Contributors</b>	Alina Silvi, Goran Kitic, Vincenzo Verrastro, Rafal Serafin, Leanne Townsend, Mel White, Reinout Godaert, Jorge Sánchez, Simona Stojanova, Argene superina, Zuzana Palkova, Romain Piovan, Emils Kilis, Alexia Gobrecht, Penny Zafiraki, Pavel Simek, Eva Kánská, Joanna Tamar Storie, Anna Wilczynska, Mario Petkovski, András Ver
<b>Project Coordinator</b>	University of Pisa

---



**Funded by  
the European Union**

CODECS has received funding from the European Union's Horizon Europe research and innovation Programme under Grant Agreement n. 101060179. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). The granting authorities cannot be held responsible for them.



This license enables reusers to distribute, remix, adapt, and build upon the material in any medium or format, so long as attribution is given to the creator



## REPORT ON DIGITAL ECOSYSTEMS FINAL M36 – VERSION 1.0

History of changes			
Version	Date	Changes	Authors(s)
0.1	30.07.2025	First draft	Cynthia Giagnocavo (UAL), Rosa Maria Heredia Hortigüela (UAL), Lucas Olmedo Osuna (UAL), Andrea Knierim (UHOH), Beatriz Herrera (UHOH), Alessio Ferrari (CNR), Chiara Mannari (CNR), Manlio Bacco (CNR)
0.2	19.07.2025	Second draft	Cynthia Giagnocavo (UAL), Rosa Maria Heredia Hortigüela (UAL), Lucas Olmedo Osuna (UAL), Andrea Knierim (UHOH), Beatriz Herrera (UHOH), Alessio Ferrari (CNR), Chiara Mannari (CNR), Manlio Bacco (CNR)
0.3	11/09/2025	Third draft	Cynthia Giagnocavo (UAL), Rosa Maria Heredia Hortigüela (UAL), Lucas Olmedo Osuna (UAL), Andrea Knierim (UHOH), Beatriz Herrera (UHOH), Alessio Ferrari (CNR), Chiara Mannari (CNR), Manlio Bacco (CNR)
1.0	30/09/2025	Final version released	Cynthia Giagnocavo (UAL), Rosa Maria Heredia Hortigüela (UAL), Lucas Olmedo Osuna (UAL), Andrea Knierim (UHOH), Beatriz Herrera (UHOH), Alessio Ferrari (CNR), Chiara Mannari (CNR), Manlio Bacco (CNR)

## Contents

<b>Part 1: Foundations</b> .....	<b>7</b>
<b>1 Introduction</b> .....	<b>9</b>
<b>2 Theoretical framework</b> .....	<b>11</b>
2.1 Mapping of the socio-ecological context .....	11
2.1.1 Analysis of Digital Ecosystem, SESF and RCCIs - UAL .....	15
2.1.2 Agricultural knowledge and innovation systems (AKIS) - UHOH.....	16
2.2 Socio-technical process modelling of use cases - CNR.....	18
<b>3 Methodological approach</b> .....	<b>19</b>
3.1 Mapping the Socio-ecological context.....	19
3.1.1 Data collection for Mapping the socio-ecological context .....	20
3.1.2 SES subsystems analysis .....	21
3.1.3 Agricultural Knowledge and Innovation System analysis (AKIS).....	22
3.2 Farm Socio-technical process modelling of use cases .....	23
3.2.1 Socio-technical process modelling method.....	25
3.2.2 Data collection for Socio-technical process modelling.....	28
3.2.3 Development and validation of process models .....	30
3.2.4 Details on the adopted research methodology .....	32
<b>Part 2: Results</b> .....	<b>36</b>
<b>4 Description of the Digital Ecosystems in 19 Living Labs. Mapping the Socio-ecological context (T.3.2)</b> <b>36</b>	
4.1. Analysis of Digital Ecosystems, Conduciveness, SESF and RCCIs - UAL.....	36
4.1.1 Pecorino Toscano Living Lab (Italy).....	36
4.1.2 APPETIT Living Lab (Poland) .....	42
4.1.3 Orchard management and digitisation Living Lab (Czech Republic) .....	47
4.1.4 Occitanum OL VITI Living Lab (France) .....	51
4.1.5 AgDiBi Living Lab (Germany) .....	56
4.1.6 Spraying drones Living Lab (Greece) .....	59
4.1.7 Innovative Soil Scanner technology for sustainable farming Living Lab (Hungary) .....	65
4.1.8 Organic table grapes Living Lab (Italy) .....	70
4.1.9 Local beef cattle farming Living Lab (Latvia) .....	76
4.1.10 Scottish Small Farms and Digital Platforms Living Lab (Scotland) .....	81
4.1.11 Greenhouse smart sensor lab Living Lab (Serbia) .....	86

4.1.12 Almería Agroecology Living Lab (Spain).....	93
4.1.13 Cloughjordan Food Hub Living Lab (Ireland) .....	100
4.1.14 Agrifood Technology Living Lab (Belgium) .....	104
4.1.15 Artificial Irrigation Management System Living Lab (Slovakia) .....	109
4.1.16 LIT OUESTEREL Living Lab (France) .....	114
4.1.17 Grassland Management Living Lab (Estonia).....	118
4.1.18 RAMAS Living Lab (Macedonia).....	125
4.1.19 Smart villages Network Living Lab (Slovenia).....	130
4.2. Agricultural Knowledge and Innovation System (AKIS): Actors and Governance - UHOH.....	134
4.2.1 Actors and Governance in Agricultural Knowledge and Innovation System (AKIS) .....	134
4.2.1. Pecorino Toscano DOP (Italy) .....	137
4.2.2. APPETIT (Poland) .....	138
4.2.3. Automation of Orchard Management (Czech Republic) .....	139
4.2.4. Occitanum OLViticulture (France).....	140
4.2.5. AgDiBi (Germany).....	141
4.2.6. Spraying drones (Greece).....	142
4.2.7. Innovative Soil Scanner (Hungary) .....	143
4.2.8. Organic Table Grapes (Italy).....	144
4.2.9. Local Beef Cattle Farming (Latvia) .....	145
4.2.10. Scottish Small Farms and Digital Platforms (Scotland) .....	146
4.2.11. Greenhouse Smart Sensor Laboratory (Serbia) .....	147
4.2.12. Almeria Agroecology (Spain) .....	148
4.2.13. Chloughjordan Food Hub (Ireland) .....	149
4.2.14. Agrifood Technology (Belgium).....	150
4.2.15. Artificial Irrigation Management (Slovakia) .....	151
4.2.16. LIT Ouesterel (France).....	152
4.2.17. Grassland Management (Estonia) .....	153
4.2.18. RAMAS (North Macedonia) .....	154
4.2.19. Smart Villages Network (Slovenia) .....	155
<b>5. Socio-technical process modelling of use cases (T.3.3) - CNR.....</b>	<b>156</b>
5.1. Process Models.....	156
5.1.1 Pecorino Toscano Living Lab (Italy).....	157
5.1.2 APPETIT Living Lab (Poland).....	159
5.1.3 Orchard management and digitisation Living Lab (Czech Republic) .....	161
5.1.4 Occitanum Sheep (France).....	163

5.1.5 AgDiBi Living Lab (Germany) .....	164
5.1.6 Spraying drones Living Lab (Greece) .....	166
5.1.7 Innovative Soil Scanner technology for sustainable farming Living Lab (Hungary) .....	168
5.1.8 Organic table grapes Living Lab (Italy) .....	170
5.1.9 Local beef cattle farming Living Lab (Latvia) .....	172
5.1.10 Scottish Small Farms and Digital Platforms Living Lab (Scotland) .....	174
5.1.11 Greenhouse smart sensor lab Living Lab (Serbia) .....	176
5.1.12 Almería Agroecology Living Lab (Spain).....	177
5.1.13 Cloughjordan Food Hub Living Lab (Ireland) .....	179
5.1.14 Agrifood Technology Living Lab (Belgium) .....	181
5.1.15 Artificial Irrigation Management System Living Lab (Slovakia) .....	183
5.1.16 LIT OUESTEREL Living Lab (France) .....	185
5.1.17 Grassland Management Living Lab (Estonia).....	187
5.1.18 RAMAS Living Lab (Macedonia).....	188
5.1.19 Smart villages Network Living Lab (Slovenia).....	190
5.2. Feedback on models.....	192
5.2.1 Feedback from Focus groups .....	192
5.2.2 Feedback from Survey .....	195
5.3. Synergies with WP4 – Cost-Benefit Analysis.....	197
<b>6. Observations on Digital Ecosystems for sustainable digitalisation of farming .....</b>	<b>198</b>
Digital Ecosystem.....	198
Agricultural Knowledge and Innovation System.....	202
Process modelling.....	203
<b>7. Bibliography .....</b>	<b>205</b>
<b>8. Annexes .....</b>	<b>211</b>

**List of Tables**

Table 1. Overview of LLs which conducted and reported a workshop. ....20  
 Table 2. Steps followed for the analysis of AKIS around the Living Labs. ....22  
 Table 3. Research activities carried out for T3.3. ....33  
 Table 4. Categories, subcategories and description of codes in Governance Subsystem..... 136

**List of Figures**

Figure 1. Scheme of nested and combined systems impacting on the FAS. .... 12  
 Figure 2. Diagram applying Ostrom’s SES framework, showing the interactions between resource systems, governance systems, resource units, and actors, with focal action situations at the core Source: adapted from Mc Ginnis and Ostrom (2014). .... 13  
 Figure 3. Conceptual diagram integrating SES, DEs, and RCCIs approach within the FAS. The diagram illustrates how the subsystems interact through DEs for describing them. Source: UAL. .... 14  
 Figure 4. Proposed RCCIs classification for describing DEs, including collaborations and innovations (based on UAL authors’ elaboration shown in section 2.1.1) Source: UAL adapted from Navas and Guerras (2018). .... 16  
 Figure 5. Left AKIS actors (Standing Committee on Agricultural Research (SCAR) Collaborative Working Group AKIS, 2012). Right: Components of Agricultural Innovation Systems (FAO, 2022). .... 17  
 Figure 6. Four-step methodology proposed for mapping the socio-ecological context of DEs. UAL authors’ own. . 19  
 Figure 7. Infographic describing the methodology to develop process models. ....24  
 Figure 8. UML class diagram. ....26  
 Figure 9. iStar goal diagram. ....27  
 Figure 10. Overlap of two BPMN diagrams. ....28  
 Figure 11. Overview of Check, Formalisation, and Agreement, including substeps and corresponding input and output. ....31  
 Figure 12. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Pecorino LL. ....40  
 Figure 13. Main enablers-hindrances of Pecorino Toscano LL. ....42  
 Figure 14. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Appetit LL. ....45  
 Figure 15. Main enablers-hindrances for Appetit LL. ....46  
 Figure 16. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL. ....49  
 Figure 17. Main enablers-hindrances of Automation of orchard management LL. ....50  
 Figure 18. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL. ....54  
 Figure 19. Main enablers-hindrances of Occitanum OL VITI LL. ....55  
 Figure 20. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in AgDiBi LL. ....58  
 Figure 21. Main enablers-hindrances of AgDiBi LL. ....59  
 Figure 22. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Spraying drones LL. ....63  
 Figure 23. Main enablers-hindrances of Spraying drones LL. ....64  
 Figure 24. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Innovative Soil Scanner LL. ....68  
 Figure 25. Main enablers-hindrances of Innovative Soil Scanner LL. ....69  
 Figure 26. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Organic Table grapes LL. ....74  
 Figure 27. Main enablers-hindrances of Organic Table Grapes LL. ....76  
 Figure 28. Interrelations between systems’ elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Local beef cattle farming LL. ....79  
 Figure 29. Main enablers-hindrances for Local beef cattle farming Platforms LL. ....81



Figure 30. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Scottish Small Farms and Digital Platforms LL.....	84
Figure 31. Main enablers-hindrances for Scottish Small Farms and Digital Platforms LL.....	85
Figure 32. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in the Greenhouse Smart Sensor Laboratory LL.....	91
Figure 33. Main enablers-hindrances of Greenhouse Smart Sensor LL.....	92
Figure 34. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Almería Agroecology LL.....	98
Figure 35. Main enablers-hindrances of Almería Agroecology LL.....	99
Figure 36. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Cloughjordan Food Hub LL.....	102
Figure 37. Main enablers-hindrances of Cloughjordan Food Hub LL.....	103
Figure 38. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Agrifood Technology LL.....	107
Figure 39. Main enablers-hindrances of Agrifood Technology LL.....	108
Figure 40. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Artificial Irrigation Management System LL.....	112
Figure 41. Main enablers-hindrances of Artificial Irrigation Management System LL.....	113
Figure 42. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in LIT OUESTEREL LL.....	116
Figure 43. Main enablers-hindrances of LIT OUESTEREL LL.....	117
Figure 44. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Grassland Management LL.....	123
Figure 45. Main enablers-hindrances of Grassland Management LL.....	124
Figure 46. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in RAMAS LL.....	128
Figure 47. Main enablers-hindrances of RAMAS LL.....	129
Figure 48. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Smart villages Network LL.....	132
Figure 49. Main enablers-hindrances of Smart Villages Network LL.....	133
Figure 50. Actors and governance mechanisms mentioned in Pecorino Toscano DOP LL.....	138
Figure 51. Actors and governance mechanisms mentioned in APPETIT LL.....	139
Figure 52. Actors and governance mechanisms mentioned in Automation of Orchard Management LL.....	140
Figure 53. Actors and governance mechanisms mentioned Occitanum OLViticulture LL.....	141
Figure 54. Actors and governance mechanisms mentioned AgDiBi LL.....	142
Figure 55. Actors and governance mechanisms mentioned Spraying drones LL.....	143
Figure 56. Actors and governance mechanisms mentioned Innovative Soil Scanner LL.....	144
Figure 57. Actors and governance mechanisms mentioned Organic Table Grapes LL.....	145
Figure 58. Actors and governance mechanisms mentioned Local Beef Cattle Farming LL.....	146
Figure 59. Actors and governance mechanisms mentioned Scottish Small Farms and Digital Platforms LL.....	147
Figure 60. Actors and governance mechanisms mentioned Greenhouse Smart Sensor Laboratory LL.....	148
Figure 61. Actors and governance mechanisms mentioned Almeria Agroecology LL.....	149
Figure 62. Actors and governance mechanisms mentioned Chloughjordan Food Hub LL.....	150
Figure 63. Actors and governance mechanisms mentioned Agrifood Technology LL.....	151
Figure 64. Actors and governance mechanisms mentioned Artificial Irrigation Management LL.....	152
Figure 65. Actors and governance mechanisms mentioned LIT Ouesterel LL.....	153
Figure 66. Actors and governance mechanisms mentioned Grassland Management LL.....	154
Figure 67. Actors and governance mechanisms mentioned RAMAS LL.....	155
Figure 68. Actors and governance mechanisms mentioned Smart Villages Network LL.....	156
Figure 69. Process transformation diagram for Living Lab Pecorino Toscano.....	158
Figure 70. Process transformation diagram for Living Lab APPETIT.....	160
Figure 71. Process transformation diagram for Living Lab Orchard management and digitisation.....	162

Figure 72. Process transformation diagram for Living Lab Occitanum sheep..... 163

Figure 73. Process transformation diagram for Living Lab AgDiBi..... 165

Figure 74. Process transformation diagram for Living Lab Spraying drones..... 167

Figure 75. Process transformation diagram for Living Lab Innovative Soil Scanner technology for sustainable farming..... 169

Figure 76. Process transformation diagram for Living Lab Organic table grapes. .... 171

Figure 77. Process transformation diagram for Local beef cattle farming. .... 173

Figure 78. Process transformation diagram for Living Lab Scottish Small Farms and Digital Platforms..... 175

Figure 79. Process transformation diagram for Living Lab Greenhouse smart sensor lab. .... 176

Figure 80. Process transformation diagram for Living Lab Almería Agroecology. .... 178

Figure 81. Process transformation diagram for Living Lab CloughJordan Food Hub..... 180

Figure 82. Process transformation diagram for Living Lab Agrifood Technology..... 182

Figure 83. Process transformation diagram for Living Lab Artificial Irrigation Management System. .... 184

Figure 84. Process transformation diagram for Living Lab LIT OUESTEREL..... 186

Figure 85. Process transformation diagram for Living Lab Grassland Management. .... 188

Figure 86. Process transformation diagram for Living Lab RAMAS..... 189

Figure 87. Process transformation diagram for Living Lab Smart Villages Network. .... 191

Figure 88. Feedback on process modelling from focus group participants. .... 197

Figure 89. Guidelines for the characterisation of DEs within the CODECS project. It includes three phases: preparation, interaction with LL for data collection, and analysis. The methodology involves participatory mapping and socio-technical process modelling.....211

Figure 90. Timeline of key WP3 activities (meetings, workshops, training, and deadlines) from Jan. 2024 to Dec. 2025.....212

Figure 91. CODECS General Assembly WP3, December 12-14, 2022 .....212

Figure 92. *Materials prepared for the participatory mapping of DEs and LLs workshops include a) Guidelines; b) Training sessions presentations and c) PowerPoint for LLs workshops and reporting templates for gathering data to support*.....213

Figure 93. General Assembly materials and results from the "4 corners of SES and DES conduciveness" workshop held on December 13, 2023 .....214

Figure 94. Material prepared for Socio-technical process modelling including Guidelines, Training material for LL coordinators and, Report template for collection of data .....214

# Executive summary

This Deliverable 3.1 provides an in-depth analysis of Digital Ecosystems (DEs) across 19 Living Labs (LLs) established under the CODECS project. It constitutes a central output of Work Package 3 (WP3), which examines how socio-ecological conditions shape agricultural digitalisation processes. The document builds upon the initial version of D3.1 delivered at M24, extending it with a more detailed and validated description of the DEs. As such, it lays the foundations for the forthcoming Deliverable 3.2 (Comparative Assessment of Digital Ecosystems, due at M44), where a typology of DEs and a comparative evaluation of farm digital readiness, scaling readiness and digital ecosystem conduciveness across Europe will be developed. The findings presented here also contribute directly to Policy Brief 2 (“Digital ecosystems for sustainable digitalisation of farming”) and Policy Brief 3 (“The role of AKIS in digital ecosystems”).

A Digital Ecosystem is defined in CODECS as a dynamic system where digital, socio-economic, organisational, knowledge and physical components converge to support the production, storage, communication and use of digital technologies and data. The analysis of DEs is relevant because digitalisation in agriculture does not occur in isolation but within complex environments shaped by resources, actors, governance systems and infrastructures. Given that CODECS aims to enhance the capacity and motivation of European farmers to adopt digital technologies as a driver of sustainable transformation, understanding the role of ecosystems is therefore essential to ensure that digitalisation is equitable, inclusive and context sensitive.

The conceptual and methodological framework of D3.1 draws on Elinor Ostrom’s Socio-Ecological Systems Framework (SESF), which provides a structured lens for exploring complex interactions between actors, governance mechanisms, resource units and resource systems. To operationalise this approach, the analysis integrates a mediating layer based on Resources, Capabilities, Collaborations and Innovations (RCCIs). This allows LLs to identify both the resources and capabilities they currently possess and those required to address their problem statements. The RCCIs approach, rooted in organisational theory, offers a bridge between socio-ecological analysis and the practical conditions needed for digitalisation.

Complementary to this, the Agricultural Knowledge and Innovation System (AKIS) perspective is employed to map knowledge flows and governance elements relevant to agricultural digitalisation. AKIS captures how formal and informal actors, ranging from advisory services and research institutions to communities and cooperatives, interact in generating, sharing and applying knowledge. The analysis situates AKIS as a sub-system within the SES, focusing here on the infrastructural perspective, namely actors and governance. Finally, socio-technical process modelling is applied to capture transformations in farm-level practices before and after the introduction of digital technologies. This participatory approach produces diagrams that illustrate how workflows, roles and responsibilities evolve, offering an accessible representation of digitalisation in practice.

The results of D3.1 are based on a participatory methodology involving workshops, interviews and co-creation sessions with the 19 Living Labs. Each LL identified its Focal Action Situation (FAS), the concrete problem statement around which actors, resources and governance systems interact, and mapped the RCCIs required to address it. Data were subsequently coded and analysed enabling a context-sensitive characterisation of DEs for each LL.

The mapping of socio-ecological contexts revealed several cross-cutting insights. With respect to resource units (RU) financial resources remain a critical enabler, but many LLs reported that traditional funding mechanisms are ill-suited to the needs of small and medium farms. Grants, subsidies and risk-sharing instruments were repeatedly identified as necessary to support the uptake of digital tools, particularly innovative ones with high upfront costs. Technological resources are widely available, but often poorly adapted to the specific needs of small and diversified farms. This lack of tailoring, compounded by the scarcity of domestic developers, undermines both affordability and localisation of solutions. Human and informational resources emerged as another key determinant: while LLs host a wealth of knowledge and experience, gaps in training and advisory services, coupled with the ageing farming population, limit digital readiness. Farmers frequently struggle not with access to data, but with the capacity to interpret and apply it effectively. Finally, infrastructural resources such as broadband connectivity and testing facilities were found to be unevenly distributed, reinforcing existing rural-urban divides.

At the level of resource systems, the analysis underscored the importance of knowledge and information transfer structures. Weak communication between farmers and IT developers hinders the design of appropriate solutions. Interoperability and standardisation remain major barriers, as closed systems and proprietary platforms restrict collaboration and data sharing. Cybersecurity and data governance were highlighted as enablers for building trust and enabling safe transactions, while at the same time representing challenges that many LLs are not yet equipped to manage. Natural resource constraints, particularly water scarcity, further condition the viability and prioritisation of digital innovations.

The actor subsystem is characterised by a strong presence of farmers, private companies (especially technology developers), researchers and advisors. Farmers not only act as end users but also as data providers and testers of digital solutions. However, their engagement is highly variable, influenced by knowledge levels, financial capacity and trust in technologies. Bridging institutions, such as advisory services, networks and cooperatives, play a decisive role in connecting actors and facilitating collaboration. Yet several gaps were noted: insufficient involvement of financial institutions, limited engagement of educational bodies and a lack of IT developers willing to co-create with farmers. These absences weaken the ecosystem's capacity to innovate and scale.

Governance subsystems revealed both enabling and constraining dynamics. On the one hand, collective organisations such as cooperatives and producer associations can anchor digitalisation through participatory governance, knowledge sharing and risk management. On the other, global market forces, certification schemes and lobbying activities often impose requirements that disproportionately affect smaller producers. Regulatory frameworks were perceived as either too fragmented or too rigid, with stakeholders emphasising the need for balance between over-regulation and regulatory gaps. In particular, participants stressed the importance of standards for interoperability, clear rules on data access and property rights, and greater transparency in public information systems.

The AKIS analysis confirmed the centrality of farmers, private companies and advisors, complemented by research institutions and innovation networks. Governance mechanisms were found to be highly polycentric, spanning local associations, national CAP strategies and European policy frameworks. Certification schemes and labelling practices emerged as critical governance instruments, shaping both market access and knowledge flows. The findings highlight AKIS as a linchpin in enabling conducive digital ecosystems yet also point to the need for stronger integration of non-formal knowledge exchange and educational institutions.

The socio-technical process modelling exercise provided a granular view of how digitalisation transforms agricultural practices. The diagrams developed for each LL illustrated shifts from manual and paper-based activities to data-driven processes mediated by digital platforms, sensors and decision-support tools. These representations revealed both efficiency gains, such as time savings and improved data accuracy, and new complexities, including additional actors, expanded roles for existing stakeholders and dependencies on digital infrastructures. While stakeholders generally found the models useful for reflection and communication, they also identified challenges in terms of readability and adaptability to dynamic farming conditions.

Overall, the analysis leads to several key findings with direct policy relevance. First, human capabilities are the main bottleneck: without substantial investment in digital skills, advisory services and training programmes, the potential of digitalisation will remain underutilised. Second, governance of data and interoperability standards is fundamental to building trust and enabling scaling. Third, current financing instruments are not well aligned with the needs of smaller farms, calling for innovative schemes that reduce risk and increase inclusivity. Fourth, infrastructural disparities in broadband and testing facilities must be addressed to ensure equal opportunities across regions. Finally, AKIS plays a pivotal role in bridging gaps between actors and ensuring that digitalisation serves the broader goals of sustainability and resilience.

In conclusion, Deliverable 3.1 confirms that digitalisation in agriculture is not determined by technologies alone, but by the conduciveness of the ecosystems in which they are embedded. By systematically analysing 19 DEs across Europe, this report provides a comprehensive foundation for comparative assessment and policy development. The results underline the necessity of context-sensitive, multi-level interventions that combine financial support, skills development, infrastructure investment and inclusive governance. As CODECS progresses towards its comparative analysis (D3.2) and policy recommendations, these findings provide evidence for designing policies that enable equitable and sustainable digitalisation of European agriculture.



# Part 1: Foundations

## 1 Introduction

The objective of this Deliverable 3.1 *Report of Digital Ecosystems (D3.1)* within WP3 *Analysis of Digital Ecosystems* is to provide a description of **Digital Ecosystems (DEs)** within the framework of the CODECS project (*Maximising the CO-benefits of agricultural Digitalisation through conducive digital ECoSystems*). This D3.1 relates to three tasks within WP3: T3.1 Development of Guidelines and training models; T3.2 Mapping the Socio-Ecological Context; and T3.3 Farm Socio-technical modelling of Use Cases. The initial version of D3.1, delivered in M24 of the CODECS project, synthesised the main elements gathered from the extensive research results gathered during the first period of CODECs from 19 **Living Labs (LLs)**. LLs analysed their problem statements using a methodology useful to explore and analyse complex and layered systems. Such a process requires a phased approach to fully reflect research findings. In this updated version of the D3.1 (M36), the report presents a more detailed description and in-depth analysis of the DE of each LL is provided. The analysis includes a validation process conducted in collaboration with the LLs, which is an important, inclusive, and participatory step in ensuring the relevance of the findings.

A **DE is defined as a dynamic system where digital, socio-economic, organisational, knowledge, and physical components converge to support the production, storage, communication, and utilisation of digital technologies and data.** The data collected and work underpinning this D3.1 are an important output of CODECS Work package 3 (WP3), in which we build the base to describe and explore the DEs of a broad range of LLs within the context of the socio-ecological systems framework utilised herein. This base, updated and further analysed in this version (M36), as well as the work in WP3, serves as the foundation for D3.2 *Comparative assessment of Digital Ecosystems* (due M44). Building on the individual analyses of the 19 Living Labs presented here, D3.2 will draw on the indicators derived from that analysis to construct a typology of Digital Ecosystems. This typology will allow for a comparative assessment across Europe, focusing on dimensions such as farm digital readiness, scaling readiness and digital ecosystem conduciveness. Specifically, this Deliverable 3.1 (M36) aims to describe the DEs of 19 LLs which have been set up within the CODECS project, all centred around the digitalisation of agriculture and the specific challenges identified by each LL. **A LL is understood as a network of farmers, knowledge intermediaries, stakeholders, policymakers, technology providers, and other concerned actors, constituted around an emerging problem within a given application scenario, and willing to develop solutions through collaboration.**

To achieve the project objectives and those of this D3.1, the analysis of LL DEs is described through **Mapping the socio-ecological context (Section 4.1), along with defining Agricultural Knowledge and Innovation Systems (AKIS) (Section 4.2) and modelling the socio-technical process of use cases (Section 5)**. These activities have been carried out under Tasks 3.2 and 3.3 of WP3. We explain below in Section 2 how these related activities fit together within the socio-ecological systems framework.

To this end, we draw from Elinor Ostrom's **Socio-Ecological System Framework (SESF)** (McGinnis and Ostrom, 2014; Ostrom, 2009; supplemented by Ostrom, 1990; and Hess and Ostrom, 2007) to analyse the DEs. This framework serves as a “scaffolding” for the assessment of the context or overall complex environment in which digitalisation takes place. The **SESF** is a conceptual tool to analyse complex interactions between ecological and social systems. Following McGinnis and Ostrom (2014), we **divide ecosystems into four subsystems: Actors, Governance systems, Resource units, and Resource systems. Additionally, a “mediating” layer based on Resources, Capabilities, Collaborations, and Innovations (RCCIs) is utilised so that LLs can identify and explore the influence of the SESF on their Focal Action Situation (FAS), defined as a scenario where subsystems interact to provide an outcome to the problem statement. The analysis of AKIS as a “layered over” related system sheds light on knowledge flows between actors within the DE.** (All terms and concepts in this paragraph are further described and explained in “Theoretical Framework” Section 2 below).

Section 4.1, Mapping of the socio-ecological context, describes how DEs are structured through the four subsystems of SESF. To facilitate the LLs in their exploration of DE and SESF, data gathering was organised around the identification of RCCIs in each LL. We explore how the SESF subsystems enable the provision of RCCIs necessary for the LLs to carry out their digitalisation initiatives and to address their problem situation. By focusing on the RCCIs in the initial analysis of LL and the FAS, the LLs are able to make more concrete the concepts of DE and SESF, facilitating meaningful data collection and linking SES and DE to their digitalisation processes and FAS. As well, by using RCCIs within our SESF analysis, we will be able to understand “the role of context in relation to whether, and for whom, digitalisation can support the development of capabilities, as well as the role of digitalisation in shaping context” (CODECS proposal 1.2.2 Beyond the cost benefit analysis).

At the core of our theoretical and methodological approach is the intent to support and explore the overall CODECS emphasis on “capabilities” and sustainable digitalisation, more specifically, the potential of digitalisation as an enabler of a transition at individual, socio-economic, technical, institutional, and governmental levels. Rather than just focusing on “means” (financial assets, digital technologies, and other goods, for example), we reframe our research on sustainable digitalisation to also include the “ends”. What this means simply in the context of CODECS is that the digital technologies, in and of themselves, do not determine or provide the opportunity to achieve sustainable and equitable digitalisation of agriculture.

“Sustainability implies that digitalisation should help maintain or, better, increase, the capacity of socio-ecological systems to respond to external threats (e.g., climate change), and support the livelihood, wellbeing and resilience of individuals, groups and rural communities situated in various contexts across the EU.” (CODECS Proposal)

These framework and concepts have been used to pursue our aim of analysing how the four subsystems of the SESF enable and set the conditions for RCCIs that the LLs need to address their problem statement (thus allowing exploration and definition ultimately of conducive digital ecosystems).

The methodology established for mapping the socio-ecological context (Task 3.2) begins with each LL identifying a clear problem statement within the FAS. In Step 1, LLs focus on their immediate digitalisation contexts and identify their current (what they have) and necessary (what they need) RCCIs to address the FAS problem statement. The RCCIs approach can be considered as an analysis that connects the SESF subsystems with the DEs and the FAS. When LLs identify RCCIs related to each subsystem, they are exploring the SES (including AKIS), but also the DE in relation to the FAS. Step 2 involves describing how the four SESF subsystems enable, foster, or set conditions for the RCCIs needed to solve the FAS. The identification of RCCIs will allow the assessment of digital ecosystem conduciveness and farmer digital readiness. In doing so, we will be able to analyse the relationships between subsystems within the SESF and their complexity, and how the SES supports digitalisation processes. Although LLs’ or farmers’ RCCIs may be unique to each farming context.

**Digital ecosystem conduciveness refers to the extent to which the environment supports the growth, success, and adoption of digital activities**, such as the development of new technologies, the creation of new businesses, and the adoption of digital solutions (UNCTAD, 2019; European Commission, 2018; World Bank, 2016). The **Digital readiness of farmers is understood as the individual or organisation’s ability to adapt and effectively utilise digital technologies and tools in order to achieve their goals and objectives.**

**[For consideration of sustainable and equitable digitalisation, see above]**

Within Task 3.2, the AKIS will be analysed as a subadjacent system within the SESF framework. AKIS assesses agricultural knowledge flows and how agricultural knowledge and innovations are produced, disseminated, and utilised in the agricultural sector, which supports farmers and other actors in implementing digital technologies and which fosters an environment conducive to digital transformation in agriculture. Within D3.1, the scope of the AKIS analysis is limited to Actors and the Governance subsystems, linking the DE and the FAS. An “infrastructural” AKIS approach will be used herein (see section 2.1.2 for description). This analysis can be situated between the actors (those who are located in the LL’s and FAS’ environment) and governance, meaning that at the governance level, AKIS is considered as the interplay of much knowledge and innovation-related corporate actors as well as governing institutions and structures. Resource units and resource systems are not considered in the infrastructural analysis of AKIS. All subsystems of SESF in this D3.1 feed into the SES, RCCIs, and DE.

Complementary to the DE analysis, a process modelling methodology is applied (Task 3.3 *Farm Socio-technical Process Modelling of Use Cases*). This focuses on the analysis of the transformation occurring to business processes after the introduction of digital solutions in the context of the problem statements within FASs addressed by the LLs. The processes of “before and after” of the introduction of digital technologies envisioned by each LL are studied, and the expected outcome consists of easy-to-read graphical representations of such before and after processes. To provide an overview of the process relevant to the definition of the social-ecological system, processes are mapped over the entities and relationships of Ostrom’s SES framework, thus considering the information required by the SESF methodology on subsystems and process modelling specifically, e.g., Actors, Resource units, Inputs, Inclusion, and participation relationships. To ensure completeness, a set of standard notations for graphical representation has been identified, and three types of diagrams will be developed by each LL focusing on three complementary dimensions: structure of the process, actors’ goals and strategic relationships, and process flow.

These two lenses of analysis, Mapping of the socio-ecological context (Task 3.2) and Farm Socio-technical Process Modelling (Task 3.3), are complementary and mutually reinforcing. The systemic-level mapping provides a broad and structural understanding of the enabling and constraining conditions, actors, and contextual factors that influence the digitalisation process. In parallel, the process-level modelling at the farm scale allows us to zoom in on specific transformations and practical implementations of digital solutions. Together, these perspectives provide an integrated and holistic understanding of the agricultural systems under study, helping to uncover how digitalisation unfolds across different levels of analysis.

This deliverable will contribute to Policy Briefs 2 and 3, namely *Policy Brief 2: Digital ecosystems for sustainable digitalisation of farming*, *Policy Brief 3: The role of AKIS in digital ecosystems*.

## 2 Theoretical framework

### 2.1 Mapping of the socio-ecological context

Overall, the purpose of CODECS is to enhance the motivation and capacity of European farmers to adopt digitalisation as a catalyst for sustainable change. An important consideration in such transition is the ecosystems in which these processes take place and how ecosystems may serve to strengthen the capacities of farmers, farm businesses, farm advisors, and other AKIS actors in the field of digital technologies and digital systems. To this end, D3.1 contributes to CODECS goals by analysing and understanding the implications of the role of different contexts in the generation of costs and benefits (in the wide sense of these terms) of digitalisation through the analysis of DEs. This evaluation places the DE within the SESF and its four subsystems.

This D3.1 evaluates and analyses DEs across 19 LLs in order to explore and assess how a wide range of DEs in different contexts enable or hinder digitalisation and the integration of digital tools and processes. Herein, we provide a summary description and analysis of these 19 DEs. As mentioned above, for the purposes of this project, **Digital Ecosystems (DEs)** are defined as **dynamic systems where digital, socio-economic, organisational, knowledge, and physical components converge to support the production, storage, communication, and utilisation of digital technologies and data**. The term ‘ecosystem’ was first introduced by Arthur Roy Clapham in the 1930s to highlight the material transfers between organisms and their environment (Willis, 1997). Today, it refers to complex, interconnected systems used in various fields such as software development, innovation, and business strategies (Wolfert et al., 2021). This dynamic nature of ecosystems means they are not static but constantly evolving. This concept is significant in the context of CODECS for understanding processes of change, cost-benefit analysis, lifecycle analysis, and process modelling, all of which focus on before-and-after scenarios, transitions, or process evolutions, as well as dynamic interactions.

According to the literature, we have found that DEs may be considered socio-technical systems that emphasise the interplay between software, stakeholders, and their relationships (Falcão, 2023). They bridge social science, computer science, and natural science (Amritesh, 2010) and are enabled by the convergence of ICT, social, and knowledge networks (EU, 2007). Additionally, DEs are described as ecosystems where digital technologies mediate

and affect the relationships among entities to perform a vast array of functionalities (Metta, 2018). As well, DEs may be seen as a social system which needs to deal with heterogeneity and variations in actors' abilities and resources (Rajagopalan, 2008).

With respect to constraints, costs, and benefits, DEs have been found to involve interconnected and intra-dependant digital platforms that help break down barriers to both horizontal and vertical knowledge sharing (Sarkar, 2007). In the context of knowledge transfer, Amrithesh, (2010) views a DE as a socio-technical system which supports knowledge creation, diffusion, absorption, and exchanges of social innovation dynamics related to digital technologies. These “digital” ecosystems cover four key disciplines: social, economic, engineering/computer, and natural sciences (Koch, 2022) and include informal institutional or organisational elements like unwritten rules that influence social interactions and trust (Wolfert, 2023).

To locate this WP3 in the CODECS project, it is useful to note the multi-layered analytical framework that has been used throughout the CODECS project to understand and upgrade the digitalisation of agricultural systems. In WP3, the socio-ecological systems are represented in Figure 2 below and are comprised of 4 subsystems. The incorporation of socio-ecological considerations ensures that digital solutions are not only technically effective but also socially acceptable and environmentally sustainable. Figure 1 illustrates the three interconnected levels of analysis: Focal Action Situation (FAS), Digital Ecosystem (DE), and Socio-Ecological Systems (SES), as well as the subjacent AKIS. The FAS is at the core of the framework and represents the situation where components of a SES interact to provide an outcome, that is, the specific, localised challenges and opportunities faced by farmers and stakeholders in their immediate agricultural environment. This level focuses on practical, actionable aspects such as resource management, decision-making processes, and day-to-day operations within farms. This is where process modelling (T3.3) is closely studied. The outermost layer is the SES, which provides the overarching context in which DEs and FAS operate (T3.2). This level considers the broader socio-economic, cultural, environmental, and institutional factors that influence agricultural systems. The AKIS represents a part within the SES that partly overlaps with the DE and influences the FAS.

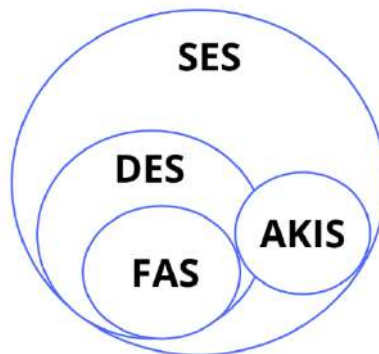


Figure 1. Scheme of nested and combined systems impacting on the FAS.

The general concepts above are further conceptualised and operationalised by resorting to the SESF (Figure 2), where **FAS are the LL situations where subsystems of the SES (actors), resource units, resource systems, and governance systems) interact to provide an outcome**, understanding the outcome as a solution for the LL problem statement. In CODECS and in this deliverable, Ostrom's SESF is fundamental for mapping, modelling, and evaluating the context in which digitalisation takes place. This framework's importance lies in its multidisciplinary applicability, encompassing diverse academic fields and multiple actors and roles. It provides a common language to compare LLs and develop theories across cases (LLs) (Ostrom, 2009). The SESF, derived from institutional analysis and Ostrom's original framework (Ostrom, 2009, and supplemented by McGinnis and Ostrom, 2014; 1990; and Hess and Ostrom, 2007), enables the analysis of multi-tier, complex phenomena by disentangling legal, economic, technological, political, social, and psychological factors. For the purpose of D3.1, the use of the SESF helps identify relevant variables for studying DE, FASs, and AKIS. While it has been proven effective in understanding systems related to common-pool resources and traditionally used for natural resources, its application to other systems has been common, including specifically to knowledge in a digital form as a common pool or shared

resource (Hess and Ostrom, eds. 2007). We extend the SESF to understand the digitalisation of agriculture and the characteristics of DEs.

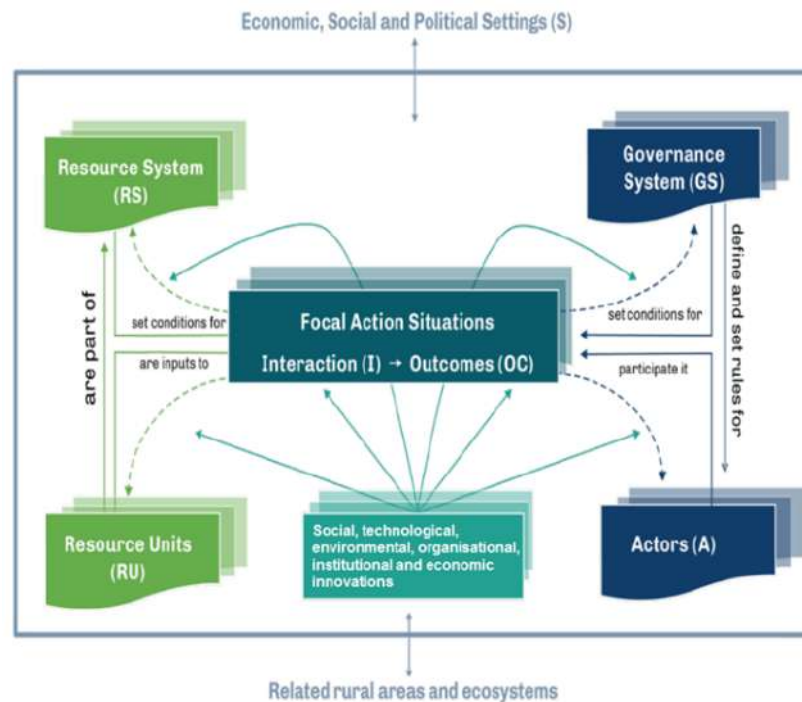


Figure 2. Diagram applying Ostrom's SES framework, showing the interactions between resource systems, governance systems, resource units, and actors, with focal action situations at the core Source: adapted from Mc Ginnis and Ostrom (2014).

The concept of knowledge as a common and a common pool resource is evident in our analysis of resource units and resource subsystems, as well as governance subsystems, and its implications for actors in the SES, including AKIS. Briefly, the role of knowledge and information as part of complex systems has been researched using systems analysis. Knowledge and information can be analysed within the SESF because it considers both knowledge and information as a commons and a common-pool resource. The study of knowledge flows (both in AKIS and in the SES in general) could be analysed as systemic interaction among a set of actors that have common, complementary, or conflicting interests which can be studied as social dilemmas (Hess and Ostrom, 2007). In Hess' words, "The complexity of the issues is enormous for many reasons: the vast number of players, multiple conflicting interests, rapid changes of technology, the general lack of understanding of digital technologies, local versus global arenas, and a chronic lack of precision about the information resource at hand" (Hess and Ostrom 2003). Using the SESF described herein, the nature of knowledge and information flows in complex systems will be explored. It is important to recognise that digitalisation introduces a fundamental change in the governance of knowledge, resources, property, etc. The physical and virtual characteristics of distributed digital information have created a completely new type of resources, which have implications for resource systems and governance. Hess and Ostrom (2003 and 2007) write that property rights play an important role in the rules for access, extraction, management, exclusion, and alienation of resource units and resource systems. Such developments imply significant changes for the SES, DEs, and implicitly for AKIS, given the way different types of knowledge, data, and information are integrated.

In addition, the SESF offers shared concepts and variables that facilitate comparisons and knowledge gathering across various situations, use cases, and LLs. Initially, the SESF breaks down systems into subsystems: resource systems, resource units, governance systems, and actors (as seen in Figure 2). It also involves interactions, outcomes, and innovations (social, technical, organisational, economic, and environmental). Inside the **Actors**

**Subsystem**, both individual and collective actors operate within the FAS with distinct interests, ambitions, capabilities, resource access, knowledge levels, and beliefs, using resource units for their processes. The **Resource units** represent the assets accessible to actors within the agricultural ecosystem, beyond just the LL. Assets may be tangible or intangible, material, financial, human, or non-human (as set out in Figure 4 below—the RCCIs classification). The resource units are encompassed by **Resource Subsystems** that outline the management and organisational conditions of these resource units, including social, economic, technological, knowledge/information, and environmental aspects. For the purposes of CODECs, data and digital information/knowledge management systems are also relevant. In turn, activities are regulated by rules and norms generated by governance systems. The **Governance Subsystem** comprises formal and informal interactions, rules, and self-governance mechanisms, focusing on decision-making processes and their implementation, reform, and reinforcement. Using the Ostrom framework, the analysis of DEs includes various components such as digital resources, which can be exemplified by data, application systems, devices, databases, software, and digital resource systems, such as platforms, infrastructures, clouds, networks, blockchain systems, etc. Additionally, it examines digital governance and resource systems, like data and information/knowledge sharing, regulation mechanisms, cybersecurity policies, and the actors involved in digitalisation.

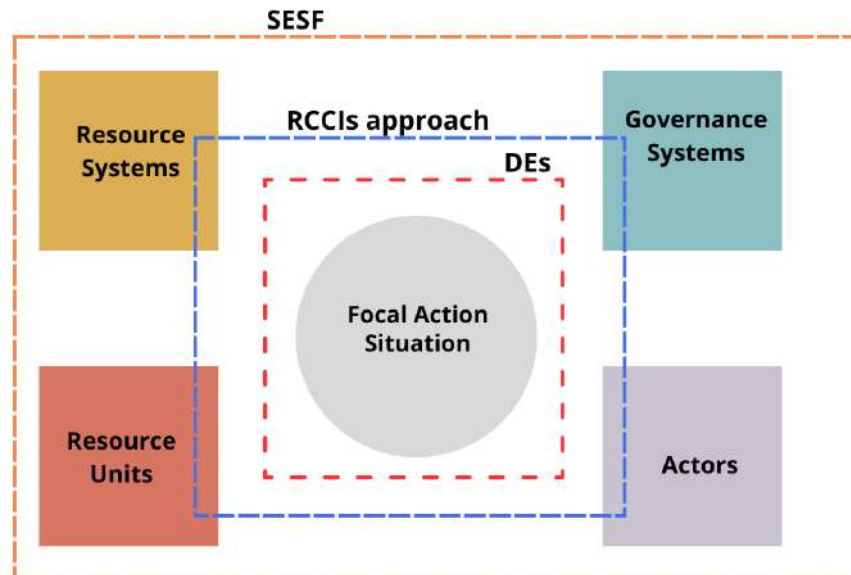


Figure 3. Conceptual diagram integrating SESF, DEs, and RCCIs approach within the FAS. The diagram illustrates how the subsystems interact through DEs for describing them. Source: UAL.

To gain a deeper understanding of the SESF dynamics and its interaction with the DE and FAS (Figure 3) and to facilitate the collection of data from LLs, the identification of resources and capabilities, including collaborations and innovations (RCCIs) has been introduced, relying on resources and capabilities analysis found in business organisation, social sciences and innovation literature (see section 2.1). This analysis helps to understand how actors respond to dynamic and changing environments and how RCCIs within the conditions provided or set by the subsystems influence or can be leveraged or acquired to transition to sustainable digitalisation in agriculture.

### 2.1.1 Analysis of Digital Ecosystem, SESF and RCCIs - UAL

In order to bridge the SES and the FAS, in the identification of the RCCIs, an important branch of organisational theory based on resources and capabilities, (including innovations and collaborations) has been used, encompassing the resource-based view of the firm (Barney 2001), dynamic capabilities (Teece, Pisano, & Shuen, 1997; Helfat and Peteraf, 2009), the knowledge-based view, (Kogut & Zander, 1992) and the relational view (Dyer & Singh, 1998). The RCCIs approach, compatible with SESF, allows us to better understand the context within the SES and its four core subsystems that interact in the FAS, as well as how organisations that carry out agricultural activity respond to change and digitalisation processes. As in Figure 3 above, the RCCIs approach is “layered over” or used to explore SESF subsystems at play in DEs, LL, and their FASs. It is a novel use of both institutional and organisational approaches.

The DEs and the RCCIs available in the digitalisation of agriculture are shaped by the SESF subsystems. For example, a resource subsystem might provide standards for interoperability, thereby enhancing the digital ecosystem for a farmer who uses multiple digital tools on their farm. Another example related to resource systems such as widespread internet in rural areas may contribute to foster the access to specific knowledge, the use of innovative tools, or certain adaptive capabilities. Another example would be knowledge (as a Resource) where knowledge is managed or organised in a system (Resource subsystem) so as to foster innovation capabilities in farmers, technology providers and producer organisations. **The RCCIs approach is used to mediate the analysis of the core SESF subsystems as perceived from FAS level’s perspective in LLs (Figure 3).**

Definitions of resources vary, and for D3.1 we have adopted the most widely agreed-upon approach, defining **resources** as: **tangible and intangible assets owned, controlled, or accessed by an entity (e.g., farm enterprise, LL, organisation, etc.), which may be utilised in order to create value, achieve an objective, or solve a problem.** Tangible resources may refer to land, buildings, equipment, and financing, while intangible resources encompass knowledge, motivation, collaborations, etc. (adapted from Barney 1991, Fernández et al. 2000, Galbreath 2005). Intangible resources can be human-dependent (human capital) or independent (non-human), and they are categorised into organisational and technological resources, such as software and AI (Hall, 1993; Fernández et al., 2000). A digital tool, such as a sensor, would be considered a tangible resource because it is material. Tangible resources include those factors related to financial and physical/material assets (Grant, 1991; Galbreath, 2005) (Figure 4. Proposed RCCIs classification for describing DEs, including collaborations and innovations (based on UAL authors’ elaboration shown in section 2.1.1). Source: UAL adapted from Navas and Guerras (2018). In the case of collaborations, resources may include valuable networks and strategic agreements, and in the case of innovation, involve novel technologies or organisational arrangements. It should be noted that the capability to innovate, and having the resources to do so (assets, access to knowledge, enabling institutions, etc.), is included within the RCCIs approach. For example, a capability to innovate can be measured within the subsystem of Actors.

Meanwhile, **capabilities** are defined as the **individual/collective know-how/abilities to achieve or undertake a specific activity or intended goal, which implies a combination of resources and organisational routines or guidelines.** Subcategories of capabilities, such as internal and external, as well as functional and organisational/cultural, may be identified (Figure 4) (adapted from Penrose, 1959; Mahoney and Pandian, 1992; Winter, 2003; Grant, 2016; Navas & Guerras, 2018).

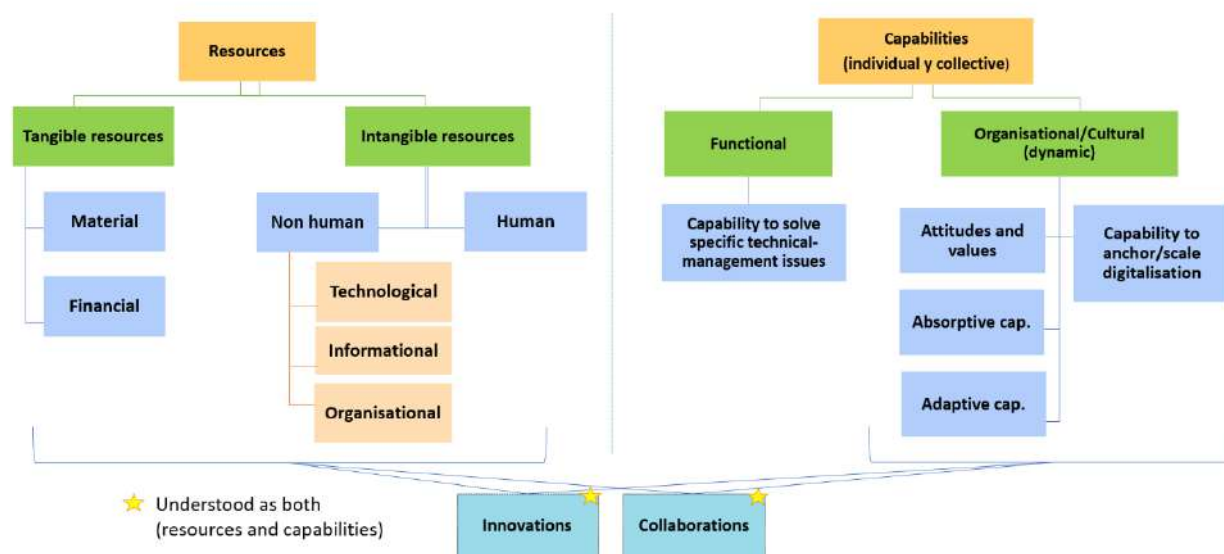


Figure 4. Proposed RCCIs classification for describing DEs, including collaborations and innovations (based on UAL authors' elaboration shown in section 2.1.1) Source: UAL adapted from Navas and Guerras (2018).

However, due to the need to tailor the analysis of capabilities to the SESF (including AKIS) and to gauge digital ecosystem conduciveness, as well as farmer digital readiness, definitions and categories of capabilities have been explored and further developed. Capabilities assist in assessing the socio-ecological context and the DE. A classic definition of capabilities starts with (Penrose, 1959; Mahoney and Pandian, 1992) wherein "Capabilities are linked to firms' technological and organisational know-how and represent ways of performing activities and using resources". Nevertheless, this definition is insufficient when we talk about capabilities within an ecosystem, in which it is necessary to consider the dynamics and the relationships between the components of which it is made. Therefore, there is a need to evaluate capabilities at both individual and collective levels. All this makes it necessary to move to a less static definition and categorisation of capabilities, giving rise to the term "dynamic capability":

In general, **dynamic capabilities** can be understood as **the ability to reorganise the assets** (resources, skills, etc.) **that an individual or collective entity possesses, controls, or has access to, not only to be able to respond to changing environments** (readiness) **but also to increase its capacity for adaptation, survival, and competitiveness** (conduciveness).

The RCCIs approach, particularly the dynamic capabilities, contributes to understanding how transitions occur and how RCCIs are utilised to respond to external factors. Nonetheless, dynamic capabilities related to change differ from operational/functional ones (Winter, 2003). Capabilities are divided into functional and cultural, involving habits, attitudes, beliefs, and values (Hall, 1993) (Figure 4).

We consider **to what extent the SESF and DEs are conducive to fostering the RCCIs that LLs need to solve their FAS problem statements**, so that the 19 DEs could be described and analysed for this D3.1

## 2.1.2 Agricultural knowledge and innovation systems (AKIS) - UHOH

Over the last decades, the study of innovations in agriculture has shifted from individual adoption models to more complex approaches where groups of stakeholders and social networks play an important role, recognising the procedural character of innovations, the multiple influencing forces, and the value of different types of knowledge and their integration. The concept of the Agricultural, Knowledge and Innovation System (AKIS) has emerged as a way to structure this complexity more systematically.

Agricultural Knowledge and Innovation Systems (AKIS) are mental constructs that relate corporate, collective, and individual actors with the aim to support voluntary, knowledge-based change and innovation processes. As social entities, they may be shaped as multi-actor networks that co-develop solutions tailored to specific contexts. The **AKIS** concept helps to analyse knowledge and innovation infrastructures in DEs, and is defined as **knowledge flows between persons, organisations and institutions who use and produce knowledge for agriculture and interrelated fields, and by linking people and institutions, AKIS promotes mutual learning and generates, shares, and utilises agriculture-related technology, knowledge, and information.**

A very specific dimension of AKIS in the European Union (EU) context is that it recently moved from being solely an academic concept used to describe actors, networks and institutions (Knierim et al., 2015) to a policy instrument, which is supposed to guide Research and Innovation policies of EU Member States (MS) (Knierim and Birke 2023; Sutherland et al. 2023). In the context of the Common Agricultural Policy (CAP), AKIS is defined as the combined organisation and knowledge flows between individuals, organisations, and institutions in agriculture (Reg 2021/2115). In this new policy perspective, the AKIS concept promotes individual, collective, and organisational generation, sharing, and utilisation of agriculture-related knowledge and technology and learning among the various actors engaged in the agricultural sector and related spheres (Knierim and Birke, 2023). The concept helps in understanding linkages, interdependencies, and interactions dedicated to knowledge and innovation spread and acquisition processes, contributing to the conduciveness of DES. The application of the AKIS concept aims at supporting targeted coordination among a broad range of actors despite national differences, ensuring effective funding mechanisms and research scopes (Moreddu and Poppe, 2013).

According to EU SCAR (2012), AKIS is a useful concept to describe a system of innovation, with emphasis on the organisations involved, the interactions between them, and the institutional infrastructure with its incentives. Some authors highlight that although extension, education, and research are key components of the concept, there are many more actors that directly influence the decision-making of farmers and their innovations (Figure 5).

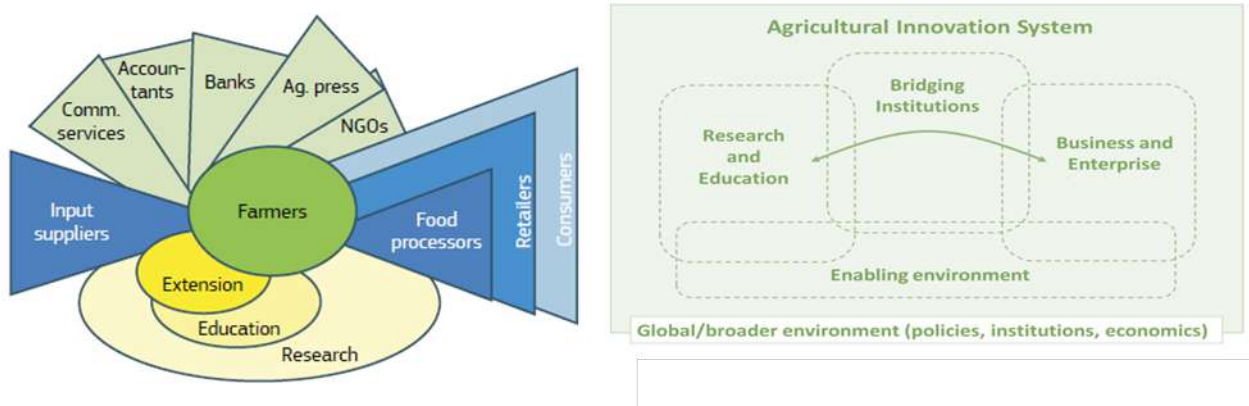


Figure 5. Left AKIS actors (Standing Committee on Agricultural Research (SCAR) Collaborative Working Group AKIS, 2012). Right: Components of Agricultural Innovation Systems (FAO, 2022).

The AKIS concept has been a transversal theme across policy instruments (e.g., CAP) and used to develop mechanisms to foster agricultural productivity and sustainability (e.g., EIP AGRI European Partnership for agricultural productivity and sustainability). The EIP-AGRI operating unit (2018) describes the AKIS as “the whole knowledge exchange system: the ways people and organisations interact within a country or a region. AKIS can include farming practice, businesses, authorities, research, etc., and can vary a lot, depending on the country or sector”.

The process of digitalisation affects, and it is affected by, knowledge flows, e.g., through the emergence of new actors (Klerkx et al, 2019) or through a shift in knowledge relationships (Ingram and Maye, 2020). Digital innovations can enable or disrupt knowledge networks, allowing new actors to enter and changing preexisting roles (Ingram and Maye, 2020). In contrast to other types of innovations in agriculture, the adoption of digital technologies requires a transition from *experiential decision-making* to *data-driven decision* processes (Eastwood 2017), causing high uncertainty and requiring support structures to facilitate learning and building trust in the implementation process (Monteiro Moretti 2023). For a digital transformation that creates value (optimise the potential and create a fair benefit for the farmer), the knowledge and skills of the actors (beyond the digital domain) need to be strengthened, in order to manage the new demands, relations, and tensions (Ingram and Maye, 2020).

There are different analytical perspectives used to study knowledge networks. In AKIS studies, infrastructural, procedural, and/or functional perspectives have been used (Klerkx et al., 2012; Knierim et al., 2015). Particularly important for policy recommendations are the infrastructural and process perspectives on AKIS across the EU, reflecting mostly AKIS strategic approaches in EU Member States (EC, 2023).

In CODECS WP3, the concept of AKIS will be used to analyse particular features of the DE, as a subjacent subsystem of the SESF. The AKIS perspective underscores the essential knowledge flows for farm digitalisation, emphasising their influence on digital transformation processes. Consequently, AKIS-related interventions can act as both enablers and hindrances to creating a conducive digital environment, aiming to enhance knowledge circulation and innovation. Summarising, the AKIS concept has the potential to further specify the actor and governance subsystems in the SESF, and to highlight knowledge exchange and learning components relevant for the interactions around the development and application of digital technologies as studied with the FAS focus (Knierim, et al. 2023).

## 2.2 Socio-technical process modelling of use cases - CNR

The Socio-technical Process Modelling method adopted in Task 3.3 stems from two main areas of the information systems field, namely business process modelling and requirements engineering.

**Business Process Modelling (BPM)** (Aguilar-Savén, 2004) is a method used to create a visual representation of an organisation's workflows and activities. This technique involves using diagrams and flowcharts, i.e., models, to map out the steps involved in various processes of the organisation. Business process models serve as a common language between stakeholders, as they enable a shared understanding among IT experts, business analysts, social scientists and economy experts, facilitating collaborative analysis, discussions, and decision-making. By modelling and reasoning on their processes, organisations can analyse their workflows to identify bottlenecks, inefficiencies, and areas for improvement. Among the visual languages used in BPM, Business Process Model and Notation (BPMN, 2010) is the most prominent one, having a large diffusion among practitioners. BPMN models are means for information exchange between engineers and business analysts (Corradini et al., 2018). The language supports advanced techniques, even AI-based, for data analysis, such as process mining (Aalst 2011) or change impact analysis (Alam, 2015).

**Requirements Engineering (RE)** (Loniewski et al.; Horkoff et al., 2019) is a field of software and systems engineering that focuses on understanding and defining what a system must accomplish. It involves capturing the expectations and needs of stakeholders, detailing them clearly, and ensuring they are realistic and achievable. The process also includes handling any changes to these requirements over time, ensuring that the system being developed aligns with user needs and business goals. To facilitate communication with stakeholders and reason on their goals, RE also involves graphical modelling activities, similar to BPM. Common visual languages used in RE are iStar (Yu et al., 2011) and KAOS (Dardenne et al., 1993). iStar focuses on representing social relationships between stakeholders that are part of a socio-technical system, i.e., a system composed of human actors and technological elements, and in representing their goals. Instead, KAOS focuses on system's objectives to be achieved, and decomposition of the objectives into lower-level requirements. Another common notation used in RE is the Unified Modelling Language (UML, 2017), which is a comprehensive software engineering language including different types of structural diagrams (e.g., class diagrams) and behavioural ones (e.g., sequence diagrams). UML is widely used in industry for requirements representation, according to the survey by Wagner et al. (2019).



### 3 Methodological approach

#### 3.1 Mapping the Socio-ecological context

Referring to **Mapping the Socio-ecological context (T3.2)**<sup>1</sup> a 4 step-methodology was set up (Figure 6<sup>2</sup>) for the LL collaboration and co-creation. This D3.1 involves Step 1 and Step 2. The initial point of the analysis of the participatory mapping of socio-ecological systems is the FAS, where each LL identify a clear problem statement, e.g., lack of interoperability among the technologies in the farm. Then:

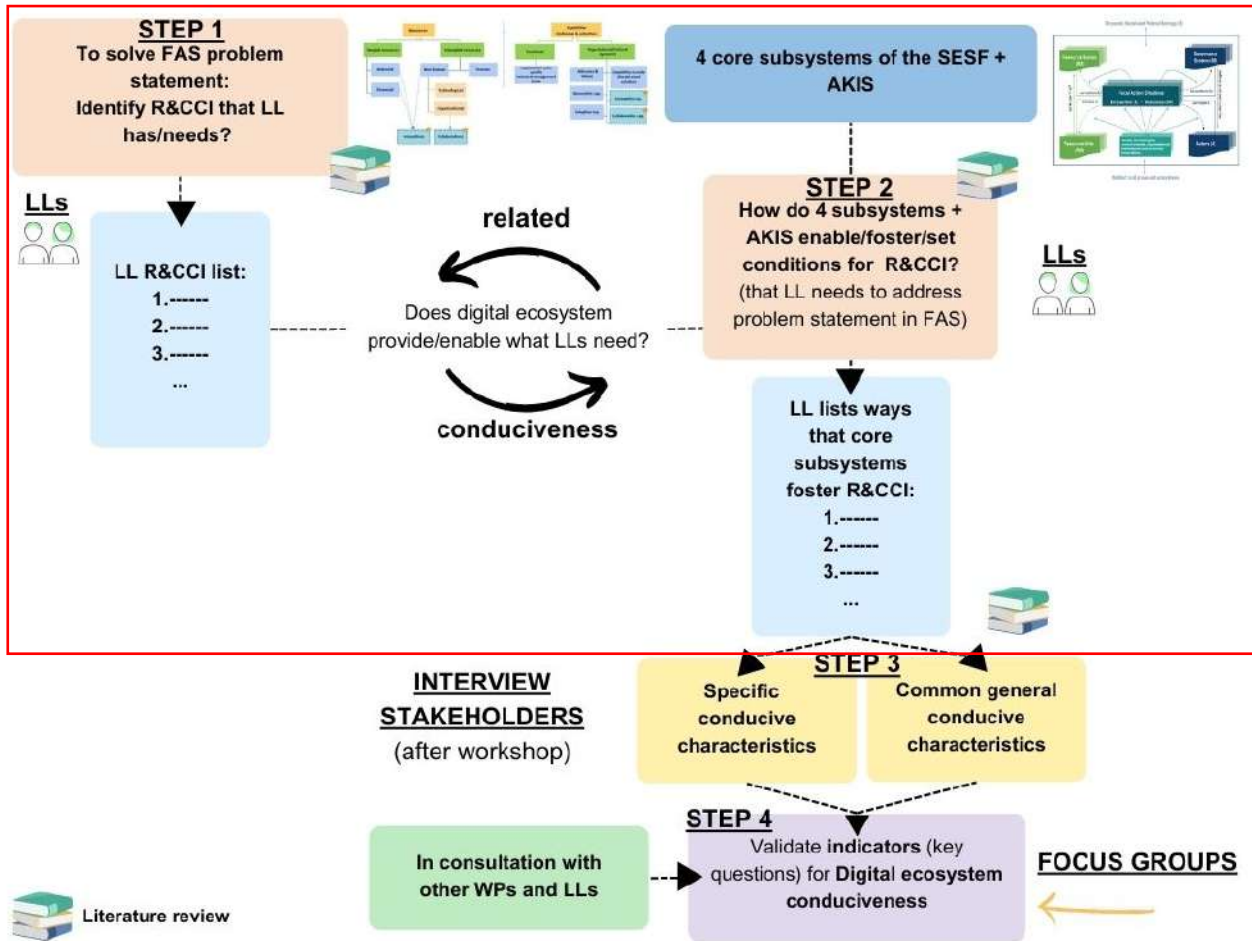


Figure 6. Four-step methodology proposed for mapping the socio-ecological context of DEs. UAL authors' own.

The **first step** involved stakeholders in the LLs **identifying their current and needed RCCIs to address their FAS problem statements**. This implied compiling a comprehensive list of RCCIs that each LL has or requires (Figure 6 - Step 1).

<sup>1</sup> For a detailed overview of the activities carried out by WP3 in the preparation of this deliverable, please see Annex A.

<sup>2</sup> It is important to note that the development of indicators (Steps 3 and 4 in Figure 6) is currently being carried out and will be further detailed in forthcoming Deliverable 3.2 (M44).. This D3.1 (M36) establishes the basis for this ongoing work by extracting observations about DEs from which indicators can be determined at a specific LL and general subsystem/SESF level.

Subsequently in the **second step**, the **four core subsystems of the SESF (actors)**, governance, resource units, and resource systems) **are analysed to determine their influence on the FAS and how they enable, foster, or set conditions for the identified RCCIs** (Figure 6 - Step 2). This helped in understanding how these SES subsystems contribute to solving the FAS problem statements<sup>3</sup>.

### 3.1.1 Data collection for Mapping the socio-ecological context

The data for mapping the socio-ecological context and AKIS analysis, was collected as part of the LLs Workshops, which were conducted between October 2023 and March 2024. The participatory workshops were designed to facilitate discussion between participants, with the objective of characterising and analysing the DEs within Ostrom's SESF and using the RCCIs approach. The following questions asked during the workshops guided the mapping of the SESF involving the four “subsystems”: actors, resource units, resource systems and governance:

- Q1. What resources, capabilities, collaborations and innovations do the LL have and need to address the LL FAS problem statement?
- Q2. What are the main actors related to the LL FAS problem statement and how do they enable or hinder the RCCI needed for addressing the LL FAS problem?
- Q3. What resource units have an influence on the LL FAS, and how do they enable or hinder the RCCI needed for addressing the LL FAS problem?
- Q4. What resource systems have an influence on the LL FAS problem and how do they enable or hinder the RCCI needed for addressing the LL FAS problem?
- Q5. Which governance mechanisms influence the LL FAS problem and how do they enable or hinder the RCCI needed for addressing the LL FAS problem?

In total, 19 LLs reported the results of the participatory workshop (Table 1).

*Table 1. Overview of LLs which conducted and reported a workshop.*

ID	Name of LL	Country	Partners
1	Pecorino Toscano DOP	Italy	UNIPI + Pec.Toscano
2	APPETIT	Poland	ISOTECH
3	Automation of orchard management	Czech Republic	CSITA + CZU
4	Occitanum OL VITI/Sheep <sup>4</sup>	France	INRAE

<sup>3</sup> During the third step, stakeholders lead the identification of specific and common general conducive and readiness characteristics (Figure 6 - Step 3). These characteristics allow to understand the conducive nature of the DEs in supporting the RCCIs and the farmer digital readiness. The fourth step involves validating the indicators of digital ecosystem conduciveness and readiness through consultations with other work packages (WPs) and LLs, focus groups, and interviews with stakeholders (Figure 6 - Step 4). This validation ensures that the identified indicators accurately reflect the conduciveness and readiness of the DEs. Throughout that process, continuous interaction with LL coordinators, literature reviews, and stakeholder interviews ensure that the methodology is co-created, validated, and refined for accurate characterisation of the DEs

<sup>4</sup> Results from Mapping Socio-ecological System (sections 4.1. and 4.2.) refers to Occitanum Viti LL. Results from Process modelling refer to Occitanum Sheep LL (section 5).

ID	Name of LL	Country	Partners
5	AgDiBi	Germany	UNI HOHENHEIM + LEL
6	Spraying drones	Greece	AUA
7	Innovative Soil Scanner	Hungary	SZE
8	Organic table grapes	Italy	CIHEAM-IAMB
9	Local beef cattle farming	Latvia	BSC + ZSA
10	Scottish Small Farms and Digital Platforms	Scotland	HUTTON
11	Greenhouse Smart Sensor Laboratory	Serbia	BIOS
12	Almería Agroecology	Spain	UAL + COEXPHAL
13	Cloughjordan Food Hub	Ireland	SUST
14	Agrifood Technology	Belgium	EV ILVO
15	Artificial irrigation Management	Slovakia	NEWEDU
16	LIT Ouesterel	France	INRAE
17	Grassland Management	Estonia	EMU
18	RAMAS	North Macedonia	AGFT
19	Smart Villages Network	Slovenia	UL

The overall results of the workshops were compiled by the coordinators of the LL, using the templates provided, and shared for further analysis.

### 3.1.2 SES subsystems analysis

The data related to the socio-ecological system mapping presented in this D3.1 is derived specifically from Steps 1 and 2 of the proposed methodology for which various materials were prepared<sup>5</sup>.

The collected data was analysed by UAL qualitatively through successive rounds of coding (Miles, Huberman and Saldaña, 2014). Data corresponding to Step 1 were coded according to the RCCIs classification. Subsequently, data from Step 2 were also coded using both the SESF subsystem categories (**Actors**, Resource Units, Resource Systems, and Governance Systems) and, where applicable, the RCCIs categories, in order to capture and visualise

<sup>5</sup> [WP3 Training](#)

the interrelations between the LL FAS and how subsystems enabled or hindered the RCCIs necessary for the LLs to solve their FAS problem situation. The qualitative analysis was carried out using the software *MAXQDA 24.5*.

This analysis was conducted to understand the SES context, and influence on, the LL and FAS and to gauge the conduciveness of the ecosystem, assessing how the elements identified by each LL facilitate their digitalisation efforts according to data from Steps 1 and 2 and the LL notes and comments. For each LL, the four subsystems have been described, integrating findings from both steps to provide a qualitative characterisation of the DE in which the LLs are situated.

The relationships between actors in the Actor subsystem and the RCCIs identified in Step 1 are detailed, focusing on how they either facilitate or hinder the acquisition of, access to, sharing of, etc. of RCCIs and the role of these actors in the digitalisation process of each LL. Likewise, the subsystems of Resource Units, Resource Systems, and Governance Systems are described in order to understand their relationship with the RCCIs and with Step 1. The extent to which each subsystem facilitates or constrains digitalisation was then described based on the LLs' input.

### 3.1.3 Agricultural Knowledge and Innovation System analysis (AKIS)

The concept of Agricultural Knowledge and Innovation System (AKIS) can be used to guide the analysis of knowledge infrastructures, processes, and functions in order to describe and compare characteristics that influence the development and adoption of innovations (e.g., digital innovations). AKIS is defined as **knowledge flows between persons, organisations, and institutions who use and produce knowledge for agriculture and interrelated fields**.

The objective of the analysis is to present the AKIS components shaping the socio-ecological context and influencing the FAS of the LLs, based on the data collected during the LL Workshops conducted in 2023 and sets out specific objectives:

1. Analyse the AKIS related results of LL workshops with respect to Actor and Governance subsystems, from an AKIS infrastructural perspective
2. Identify missing information for the characterisation of AKIS and their influence in DEs.

The analysis of AKIS focused on the infrastructural analytical perspective, which encompasses *Actors Subsystems* and *Governance Subsystems*. To guide the coding process, the following research questions were employed: (RQ1): *What are the primary actors related to the Living Lab FAS problem?* (RQ2): *Which governance mechanisms influence the Living Lab FAS problem?*

To address these research questions, Q2 and Q5 (cf. section 3.1.1) were analysed. The analysis involved three cycles of coding, which included developing a scheme of categories and subcategories to: a) identify salient ideas b) structure and compare the categories with the AKIS analytical framework, c) recategorise the answers from the LLs according to the categories found and develop diagrams by LL (Table 2).

Table 2. Steps followed for the analysis of Agricultural Knowledge and Innovation System around the Living Labs.

Step	Description	Outcome	Theoretical Reference
1	<p><b>Inductive coding</b> based on answers from the LL about actors and governance subsystem for</p> <ol style="list-style-type: none"> <li>1. For the <i>Actor Subsystem</i>, we identified and counted the types of actors mentioned classified by the Living Labs according to the closeness to the FAS.</li> <li>2. For the <i>Governance Subsystem</i>, we identified and categorized the types of rules,</li> </ol>	Codes from different Living Labs for <i>Actor Subsystem</i> and <i>Governance Subsystem</i>	Saldana, 2016



	norms, and regulations related to the definition of AKIS governance mechanisms and the coordination of AKIS components as identified by Living Labs.		
2	Review of literature, review of <b>categories and subcategories grouping the codes</b> <ol style="list-style-type: none"> <li>3. Identification of typology of actors according to the framework of agriculture knowledge and innovation system</li> <li>4. Identification of levels and governance mechanisms relevant for knowledge flows as identified by TAP and SCAR -AKIS literature</li> </ol>	Framework of categories, subcategories and codes for <i>Actor Subsystem</i> and <i>Governance Subsystem</i>	FAO 2022, SCAR-AKIS 2023 Kok et al 2023
3	Development of <b>diagrams</b> representing actors and perceived closeness to the FAS as a conceptual model of knowledge systems around the Living Labs, using the categories, subcategories and codes determined in step 2.	Living Lab diagrams	Ison, 2017

For the *Actor Subsystem*, we identified and counted the types of actors mentioned. Following the initial phase of identification, we reclassified the actors based on the characterization of actors in the AKIS literature and the concept presented in section 2.1.2. The results reflect the typology of actors as mentioned by LL members during the workshops. According to the degrees of relation stated by the workshop's participants, we separate the actors according to three grades of relation:

1. Level 1 are those actors that are actively participating in the LL
2. Level 2 are those actors which are not yet part of the LL, but could potentially be reached either to be part or to collaborate in the activities
3. Level 3 are those actors that despite having an influence in the FAS, are not considered as potential collaborations at the time of the workshop.

For the *Governance Subsystem*, we identified and categorized the types of rules, norms, and regulations related to the definition of AKIS governance mechanisms and the coordination of AKIS components based on the theoretical ground presented in section 2.1.2. The results reflect the norms, rules, and regulations related to the coordination of AKIS components.

The third stage of structuring the results consisted in revisiting the information provided by each Living Lab. We used the results described in the previous paragraphs looked from each Living Lab. The results reflect the disaggregated findings of the analysis and are presented in section 4.2.

## 3.2 Farm Socio-technical process modelling of use cases

The **Farm Socio-technical Process Modelling of Use Cases (T3.3)**<sup>6</sup> analyses the transformation occurring in the processes in the context of the FAS defined by each LL. Process Modelling is a form of **system modelling which**

<sup>6</sup> For a detailed overview of the activities carried out by WP3 in the preparation of this deliverable, please see Annex A

consists of an approach used in software engineering to represent and analyse complex systems. Process modelling involves creating abstractions of real-world processes, allowing stakeholders to gain insights into their structure, behaviour, and interactions at a very detailed level.

In CODECS, a methodology based on process modelling has been developed to carry out qualitative analysis of the process transformation envisioned by each LL by describing actors, resources (units and systems), technological innovations, and relations. The objective of the process modelling activity is to create easy-to-read diagrams of processes carried out in a farm *before* and *after* the introduction of digital solutions. The diagrams are used to qualitatively evaluate the impact of digitalisation, in terms of added or removed actors, tasks, and components.

To provide a complete overview of the processes relevant to the definition of the socio-ecological system, processes are mapped over the entities and relationships of the Ostrom's SESF, thus considering the information required by it, i.e., actors, resource units, input, inclusion, and participation relationships. A set of standard notations for graphical representation has been identified in the methodology. To ensure completeness each LL will develop three types of diagrams focusing on complementary dimensions: the structure of the process, the actors' goals and strategic relationships, and the process flow. The results will provide qualitative inputs to the cost-benefit analysis. A step-by-step procedure for carrying out the process modelling in CODECS has been applied. In the definition of the procedure, three major requirements have been considered: 1) the process modelling shall be the result of a co-creation activity by LLs and task leaders; 2) the data collection shall be performed in coordination with other tasks, and shall take into account previous project activities that already produced useful data; and 3) the number of iterations with stakeholders in terms of data collection and agreement shall be limited to avoid overburdening the participants.

The infographic in Figure 13 describes the procedure, which is articulated in subsequent phases, that has been used to generate the diagrams:



Figure 7. Infographic describing the methodology to develop process models.

**Data Collection:** this is conducted by LL coordinators through workshops, focus groups, and interviews with key informants like farmers, advisors, and technology providers, collecting diverse perspectives and insights.

- **Reporting:** following the guidelines, LL coordinators compile and report data using a provided template, ensuring accuracy and completeness, with sections for feedback on data collection challenges and suggestions.
- **Check:** task leaders review reports, seeking additional data from LL coordinators if necessary and validate collected data in plenary workshops with LL stakeholders.
- **Formalisation:** task leaders create multiple diagrams from the textual data, focusing on structure, goals, and processes.
- **Agreement:** in a workshop or focus group, LL representatives validate the diagrams, ensuring their alignment with the focal action situation, fostering a shared understanding and guiding further analysis on

the cost and benefits of the introduction of digital technology

The activities for socio-technical process modelling in Task 3.3 are the following ones. We first identified suitable graphical modelling languages for process representation (M1-M6) and defined a modelling strategy for the agricultural sector (M6-M9). A pilot study tested these languages on the Pecorino Toscano LL (M9-M15), leading to refinements in the modelling method to simplify it for stakeholders (M16-M17). Guidelines and a reporting template were developed and refined through partner meetings (M9-M17). Training was provided to LLs on using these tools (M17), followed by data collection and reporting from LL contact points (M17-M20). The reports were reviewed by task leaders (M21-24) that organised a training for LL coordinators in preparation to the second annual workshop (M24). During the workshops (M25-M26), the LLs validated the reports and complemented the initial data collection. Subsequently, the LL coordinators submitted an updated version of the report (M28). The process models were then developed and validated through dedicated focus groups (M28-M34).

In the following section, we provide detailed information on how information has been gathered from each LL.

### 3.2.1 Socio-technical process modelling method

The goal of the socio-technical process modelling (task 3.3) is to enable reasoning about the costs and benefits of digital technology within the CODECS LLs by means of a set of graphical representations called Socio-technical Process Models. These models represent different dimensions of the process transformation, namely:

- (a) the goals of the LL that trigger the introduction of a certain technology
- (b) the structure of the LL in terms of actors and resources
- (c) the process before and after the introduction of the technology

Altogether, these representations allow visualising the process transformation entailed by the introduction of a specific digital technology within the LL. In turn, this will enable reasoning about the impact of digital technology on the process, actors, and resources of the LL. These representations are operational descriptions of the farm level, which is part of the DE, with particular focus on the digital transformation of the farm, according to the FAS defined by each LL. Furthermore, the diagrammatic representations are contributing to the cost-benefit analysis (in WP4) because they support highlighting the changes to the process due to the introduction of digital technologies.

The Socio-technical Process Modelling method introduced in the context of CODECS uses a combination of notations from BPM and RE, namely: the iStar notation (Yu et al., 2011), to represent the goals of the stakeholders, and ultimately the reasons why a certain digital system is introduced; the UML class diagram notation (UML, 2017), to represent the structure of the socio-technical system in terms of actors and resources; the BPMN notation (BPMN, 2010; Corradini et al., 2018; Aalst 2011), to represent the process before and after the introduction of a digital technology. An example of these graphical notations is reported in Figures 8-10. The example refers to the Consorzio Pecorino Toscano case study. In the following, we briefly describe the context of the case study, and then we illustrate the notations “in action”.

#### **Example – Context**

Consorzio Pecorino Toscano, is an Italian LL based in Manciano, Tuscany and focused on the activity of sheep breeding and pecorino cheese production. The LL is built around the activity of the “Caseificio di Manciano” which is collecting sheep milk from several local farmers and processing it to produce pecorino cheese. Part of this cheese is certified P.D.O. The LL involves the farmers, the processors, the “Consorzio tutela Pecorino Toscano D.O.P.”, and the advisors working with the farmers of the processing plant. Local administration such as the municipality of Manciano and the Tuscany Regional Administration are also participating in some LL activities. A series of technologies aimed at supporting the work at various levels have been developed so far or are currently under development or evaluation. In the context of CODECS, the LL is developing and testing a Farm Management Information\_System (FMIS) with an app in use by farmers and advisors to monitor animals’ health status and food ratio optimisation. The FMIS aims to support the work by automating the recording and storage of farm data both through sensors and user input, and to monitor and analyse farm activities with the final objective of predicting the amount and quality of milk produced and to be processed by the cheese-making factory.

### Example – Notations

Figures 8-10 report excerpts of the different models for the Consorzio Pecorino Toscano LL.

The first model, represented in Figure 8, is the **UML class diagram**, where each box represents an entity that is part of the process, i.e., an actor or a resource, while the arrows represent an action occurring between two entities. Inside each box is a list of activities that are carried out by the entity. For example, the Agronomist (box) monitor the animals (arrow) through a Pet Scan Bluetooth (box), and exchange information with a Veterinary (box). The Pet Scan Bluetooth sends data (arrow) to an App (box), which elaborates these data (internal activity).

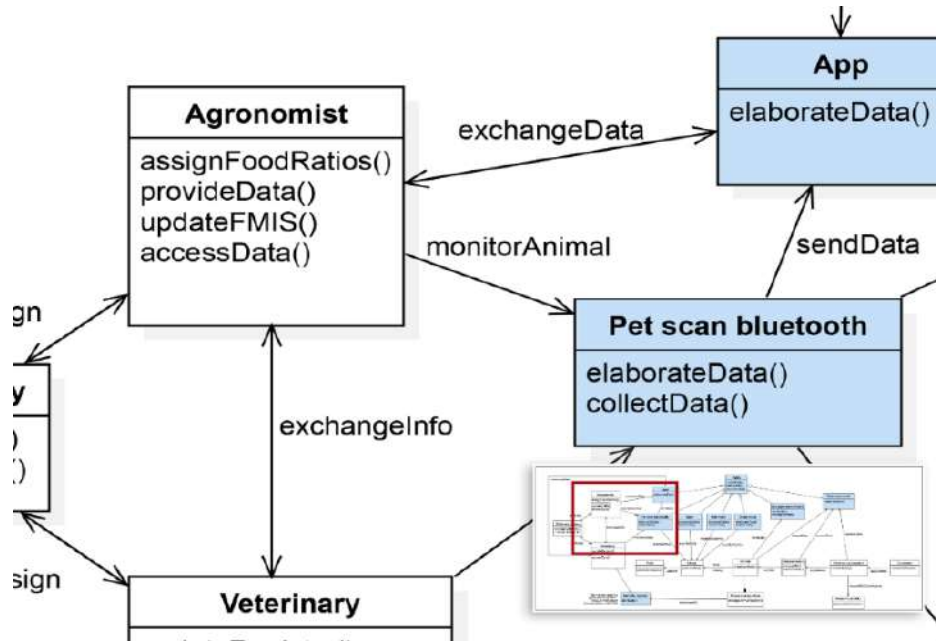


Figure 8. UML class diagram.

The second model, represented in Figure 9, is the **iStar diagram**, where we have a circled boundary for each actor involved in the process, e.g., the Agronomist in the figure. Inside the boundary, there are the goals of the specific actor (red ellipses), e.g., “increase milk quality and quantity”. These are decomposed into tasks performed to achieve the goals (blue parallelogram), e.g., “elaborate food ratio”, and into resources that support the tasks (grey rectangles), if, any, e.g., Pet Scan Bluetooth. An actor is connected to another actor if one of its goals require the involvement of the other actor. For example, the Agronomist requires the involvement of the Veterinarian to achieve the goal “assign food ratios”.

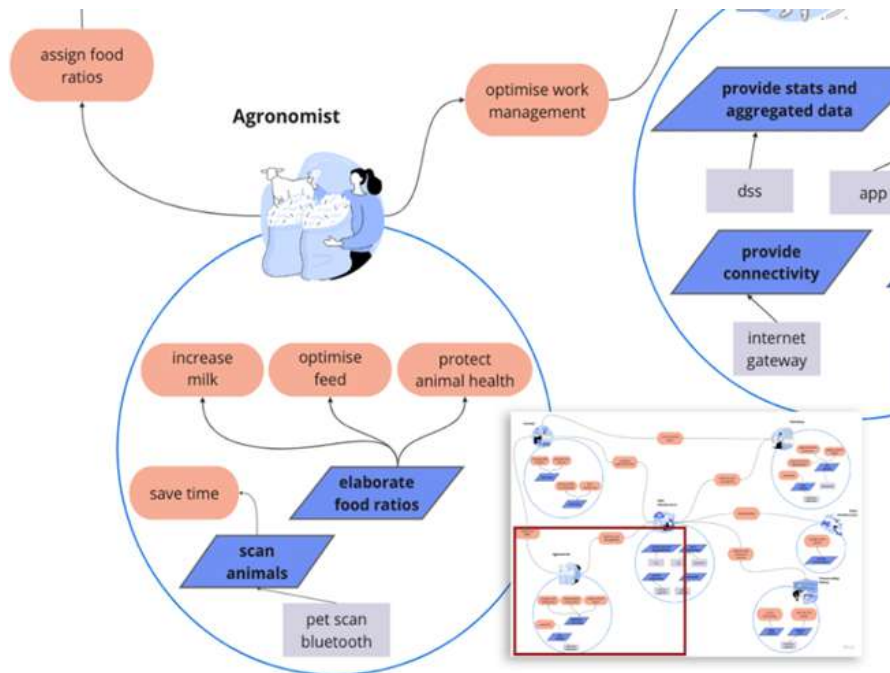


Figure 9. iStar goal diagram.

The third model, represented in Figure 10, is the **BPMN**, which consists of three different diagrams. These represent the process before the introduction of the digital technology, the process after the introduction of the digital technology, and an overlap of the two processes, respectively. For the sake of conciseness, here we report only the third diagram.

The BPMN diagram consists of a set of activities performed by actors, possibly based on some conditions. The activities are represented as boxes. When two activities are sequential, these are connected through an arrow, e.g., “visit scheduled farms” is followed by “request animals’ information”. A set of sequential activities creates a linear flow, e.g., the one that goes from “visit scheduled farms” to “update FMIS”.

Sequential flows can be performed in parallel, and this is modelled via the rhombus with the “+” symbol, which separates the different flows. Some activities or flows depend on certain conditions, and the condition is represented through the rhombus with the “x” symbol, e.g., “is day 1 of 30?”. In the overlapped diagram reported here as example, **the green elements represent those elements that do not change** in the process transformation; **the blue elements those that are introduced** due to the introduction of a digital technology; **the red elements those that are removed** after the introduction of the digital technology.

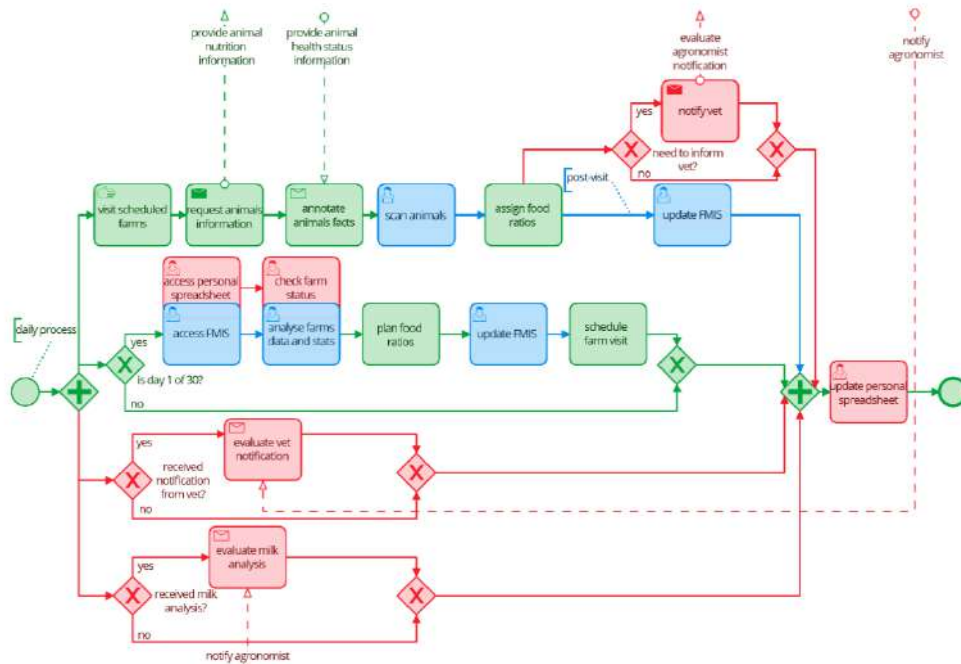


Figure 10. Overlap of two BPMN diagrams.

It should be noted that the UML and iStar diagram are based solely on the process after digitalisation, while the BPMN diagrams represent the process before and after digitalisation. This choice was driven by the prominent focus on the process of the proposed Socio-technical Process Modelling method, and the need to simplify the procedure by avoiding the proliferation of the number of diagrams.

### 3.2.2 Data collection for Socio-technical process modelling

To design the diagrams, process-relevant data need to be collected and reported by the LL contact points. To facilitate the data collection, a set of guidelines were defined together with templates for reporting. The guidelines are available in **Annex C**. In the following, we summarise the content of these documents and provide examples when appropriate.

The guidelines present three alternative procedures for data collection, with associated templates. The procedures are differentiated based on the state of digitalisation of the LL, which will be detailed in the following paragraph. Each procedure contains about 12 questions asking to describe both the process *before* and *after* the introduction of the digital solution, as well as other information to design the different models. The templates are editable documents containing the questions explained in the guidelines. Each template corresponds to a data collection procedure.

Three possible states of digitalisation have been identified, with associated data collection procedures and templates. The states are Zero Digital, Digitalising, and Digitalised:

- **Zero Digital – No digital solution in place, digital solution not identified.** This is a state in which the digital solution to solve the problem statement has not been identified yet. Starting from an evaluation of the current process in terms of assets, resources and capabilities available, the LL explores alternative solutions to solve the problem statement based on the adoption of different technologies. LLs are invited to consider that they are in a Zero Digital state also if some technologies are used in their process, but the specific digital solution they are interested in to solve the problem statement has not been identified yet.
- **Digitalising – Digital solution identified, not yet fully adopted.** In this state, a digital solution to solve the problem statement has been identified but not yet adopted. This occurs when the technology is available but not stable yet, or not fully adopted in the LL. For example, the LL could be in the process of introducing

the technology within a restricted group (e.g. a demo farm), or a prototype has been developed, and tests are being carried out. In this context, the LL is able to compare the process today (i.e., before the introduction of the digital solution) and after the introduction of the digital solution, by trying to envision the process in the future.

- **Digitalised – Digital solution adopted, to be evaluated.** In this state, a digital solution to solve the problem statement has been purchased or developed by the LL. This occurs when, after a first period of in-field testing, the technology has been adopted within the LL. In this context, the LL is able to evaluate the technology and compare the process today (i.e., after the introduction of the digital solution), and before the introduction of the digital solution, by trying to recall the process in the past.

The questions reported in the guidelines can be grouped according to the following sections, which are ordered differently depending on the state of digitalisation of the LL:

- **Introductory Questions:** questions oriented to understand the context of the LL, and in particular the core problem that will or has been addressed through a digital technology. In addition, these questions ask to reflect on the state of digitalisation and guide the LL in the selection of the most appropriate state and associated reporting template. The running example of the Pecorino Toscano LL illustrated in Section 5 can be positioned in the Digitalising case, as a technology has been selected, prototyped, but not introduced yet.
- **Description of the Digital Technology:** questions to provide a description of the digital technology, and the reasons why this has been selected. In our example, the main technology introduced is the FMIS, which aimed at facilitating the exchange of information between actors and improving the monitoring process. In the case of a Zero Digital LL, these questions enable the LL to reflect on the possible alternative digital technologies and guide the LL towards the identification of the most appropriate one for their context.
- **Process After the Digital Technology:** questions aiming to capture how the LL process appears when the digital technology is, or will be, in place. These questions are partitioned into two main groups:
  - **Goals, Actors, and Resources:** questions to identify the goals of the actors involved in the LL, and the resources used by the actors to achieve these goals. In our example, the Agronomist actor has the goal of saving time, and to this end it uses the resource of the Pet Scan Bluetooth. This information is particularly useful to design the iStar diagrams and the UML diagrams, as these are oriented to represent objectives, entities, and relations thereof.
  - **List of Actions:** questions that list the actions performed by the actors using the available resources, *after* the introduction of the digital technology. These questions ask precise lists of actions, divided by actors, and are mainly useful to design the BPMN diagram for the process that has been transformed by the digital technology. In our example, the list of actions for the Agronomist include visiting scheduled farms, requesting animal information, etc.
- **Process Before the Digital Technology:** similar to the previous set of questions, these aim to capture the LL process when the digital technology was, or is, not in place. Again, the questions are partitioned into two main groups:
  - **Actors, Resources:** questions to identify actors and resources involved in the process before its transformation. These questions aim to highlight which actors and resources were removed or added with the introduction of the digital technology. In our example, the resource App was introduced, while the sheets to trace the health status of animals were removed. These questions help in the construction of the BPMN diagram before the digitalisation.
  - **List of Actions:** questions that list the actions performed by the actors using the available resources, before the introduction of the digital technology. These questions are mainly useful to

design the BPMN diagram for the process adopted by the LL when the selected digital technology was not present. In our example, some actions such as the update of the sheet to trace the health status of animals were removed, while other actions such as the update of the FMIS were added.

**Training and Preliminary Feedback.** The guidelines and templates were released on 20th February 2024 and a two-hour training was organised with LL coordinators on 22nd February 2024. The training consisted of an introduction to the overall Socio-technical Process Modelling activity with the presentation of the case study on Pecorino Toscano LL as an example of an outcome. Then, the procedures for Zero Digital, Digitalising, and Digitalised were explained in detail.

The training was interactive reserving slots for discussion, hints for data-collection, and feedback. Hints were provided in the form of FAQs and questions were related to the management of the documentation, the timeline expected and the data collection activities to be organised. The training was coordinated with the WP4 training that was held immediately afterwards and provided more practical advice regarding interviews with farmers and practitioners. In fact, the strategy suggested to LL contact points was to collect questions for both WPs and to conduct a single interview or focus group asking multiple questions.

A survey on Mentimeter supported the training activity serving as an icebreaker for the meeting and collecting early feedback on the process modelling.

The following questions were asked to the participants in four question survey:

- Do you have previous experience with Process Modelling?
- How do you feel with respect to the Process Modelling activity in your Living Lab?
- Which state of digitalisation would you assign to your Living Lab?
- How much information do you already have?
- What kind of data collection activities do you plan to organise?
- Did this training help to clarify Process Modelling data collection?

### 3.2.3 Development and validation of process models

The development of the process models includes three phases that follow data collection and reporting: check, formalisation, and agreement. The structure and details of these phases, including their substeps as well as the associated input and output, are illustrated in Figure 11. Guidelines related to check and formalisation phases is available in **Annex D**

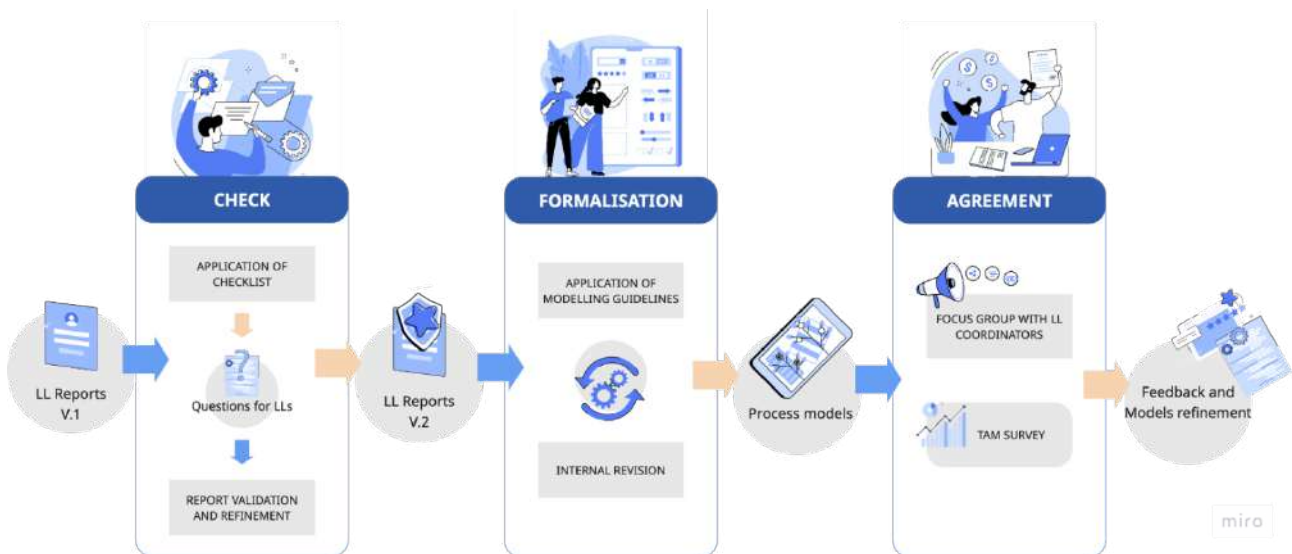


Figure 11. Overview of Check, Formalisation, and Agreement, including substeps and corresponding input and output.

The **Check** phase is carried out by the task leader, with the LL reports serving as the primary input. To ensure consistency throughout the revision process, a systematic approach is adopted using an internal **checklist document** containing specific questions linked to each section of the report. Two versions of the checklist document were prepared: one for reports describing the *digitalising* state, and another for reports describing the *digitalised* state. A checklist document for *Zero digital* has not been developed, since no LL is classified as such. Below, we provide an overview of the checklist structure.

The checklist consists of a grid with 20 yes/no questions referring to specific sections of the report. Each question aims to verify whether the answer in the report provides enough information for the purposes of process modelling, and also to identify inconsistencies or missing information. For each yes/no field, there is an additional field to formulate follow-up questions for LL coordinators. The follow-up questions are collected into a **Questions for LL** document, which includes requests for clarification to be addressed by the LL coordinators. This document is included among the materials shared with LL coordinators in preparation for the second annual workshops. Following this documentation, the LL coordinators validate the reports producing an **updated version** incorporating the feedback and clarifications received.

**Formalisation** consists of the transformation of the validated report into multiple diagrams. Also this phase is performed by the task leader following a set of **modelling guidelines**. The latter document is practice-oriented and includes guidelines to create model elements (goals, tasks, etc.) and connect them, based on the content of the LL report. To this end, the document includes specific references to the report sections. The document also includes examples, as well as an introduction to the modelling languages, recommended diagramming tools and links to template files to produce the models. To ensure formal accuracy and content robustness, the models created are subjected to **internal review**. The review is carried out by modellers with complementary expertise to those who develop the model — for example, an agronomist would create the model, and an IT expert would review it and revise the structuring of the digital technology-related aspects, or vice versa.

During the third general assembly held remotely in December 2024, a pilot study — developed following the modelling guidelines and based on the Agrifood Technology LL case — was presented to participants through an interactive session in Mentimeter. The session aimed to **evaluate the feasibility of the agreement phase and gather early feedback** on the understandability of the diagrams and the perceived usefulness of the approach from a wide range of stakeholders.

The **agreement** phase is carried out through individual **focus groups with LL coordinators** organised by the task leader individually for each LL, and a **survey** administered to all focus group participants. Prior to the focus groups, the models are shared with the LL, in order for them to have time to examine the materials, note doubts, and formulate questions for discussion. The models are accompanied by a **short guide document**. The guide aims to support LL coordinators in understanding the process models, providing an overview of the models created, i.e., goal, structure and activity models, and their purpose, and includes examples with a detailed description and a legend for each modelling notation.

The focus groups are conducted as one-hour remote meetings facilitated by the task leaders. In the first part of each session, the models—previously shared with the LL coordinators—are presented on a MIRO board. For each type of model, two main aspects are considered. The first concerns the **understandability** of the notations, focusing on how participants interact with the visual representations, the challenges they encounter, and their overall attitudes and perspectives. The second aspect involves **completeness**, with participants asked to validate the models by identifying any missing or inaccurate information. In the second part, participants evaluate the **usefulness** of each model, comparing them to one another and reflecting on the overall benefits and limitations of the process modelling approach.

After the focus group, participants are asked to complete a brief survey to finalise the feedback. The survey includes questions inspired by the Technology Acceptance Model (TAM) (Davis, 1989) and focuses on three main aspects: perceived usefulness, perceived ease of use, and intention to use. For each statement, participants are asked to indicate their level of agreement using a 5-point Likert scale (from “Strongly Disagree” to “Strongly Agree”). The survey includes questions such as:

*The models help understand how the introduction of a digital solution can transform a process.*

*The models help understand the impact of the digital solution.*

*The models have the potential to drive the analysis of costs and benefits.*

*The models are easy to read.*

*It is easy to interpret the process of transformation.*

*I would recommend the use of models to represent the process transformation.*

*I would use the models in discussing aspects related to the digital solution with different stakeholders.*

### 3.2.4 Details on the adopted research methodology

This Socio-technical Process Modelling method applied in Task 3.3 is specifically designed to represent and assess technology-driven process transformation within co-design contexts such as LLs, with a focus on the agricultural domain.

The research methodology adopted to define the method is *Design Science* (Wieringa, 2014), a research framework focused on creating and evaluating *artefacts*—such as models, systems, or methods — that solve specific, practical problems. In our case, the produced artefact is a method, i.e., the Socio-technical Process Modelling method. Design Science combines creative design with rigorous scientific approaches to develop solutions that are both innovative and effective. The goal of design science is not just to understand reality, but to actively shape it by producing artefacts that can be applied in real-world contexts, e.g., the LLs in our case. The Design Science methodology is based on multiple iterative cycles in which the artefact is incrementally refined and validated. Each cycle is composed of different steps, namely:

- **Problem Investigation:** this phase involves identifying and thoroughly understanding the problem or challenge that needs to be addressed. It includes gathering relevant information, analysing the problem's

Page | 32



context, and defining the specific objectives that the solution should meet.

- **Treatment Design:** in this phase, potential artefacts, or "treatments," are conceptualised and designed. This involves developing a framework or model that outlines how the problem will be addressed, often incorporating creative and innovative approaches to meet the defined objectives.
- **Treatment Validation:** the designed artefact is then tested to ensure that it effectively addresses the problem. Validation involves evaluating the solution against the problem's requirements and checking its feasibility, consistency, and potential effectiveness before full-scale implementation.
- **Treatment Implementation:** once validated, the solution is applied in the real-world context. This phase involves the actual deployment of the treatment, where it is integrated into the environment or system where the problem exists.
- **Treatment Evaluation:** after implementation, the solution is monitored and assessed to determine its success in solving the problem. This phase involves collecting feedback, measuring outcomes, and analysing whether the treatment achieved its intended goals, as well as identifying any areas for further improvement.

Table 32 summarises the research activities, and the artefacts that have been developed, according to the Design Science steps. In the following, we provide details on the different research activities and outcomes.

Three complete design cycles have been performed (see column #1 of Table 3). The first cycle is dedicated to the preliminary definition of the method, and its implementation and evaluation on the Pilot Study for the Pecorino Toscano LL. The second cycle is dedicated to the definition of the guidelines and templates for data collection, and their evaluation through their application on the LL, which produced the LL reports. The third cycle is focused on defining and implementing a detailed procedure for the model formalisation and agreement phases in CODECS LLs. Detailed inspection of the models could trigger possible refinement of the method and drive subsequent Design Science cycles.

Table 3. Research activities carried out for T3.3.

Cycle	Step	Activity	Outcome
1	Problem investigation	Focus group with agronomists and observation in a pilot LL	Concept of the process modelling methodology
1	Treatment design	Literature review and brainstorming focus group with software engineering experts	Improved concept Modelling languages chosen Procedure draft Requirements definition
1	Treatment validation	Focus groups and plenary presentation	Feedback on concept Requirements refinement
1	Treatment implementation	Case study "Pecorino Toscano" - set of diagrams	Set of diagrams representing the transformation of a cheese production process
1-2	Treatment evaluation / Problem investigation	Case study "Pecorino Toscano" - focus groups with LL stakeholders	Fine-tuning of the set of diagrams New requirements for the method Concept of the guidelines for data collection
2	Treatment design	Brainstorming focus group with software engineering experts	Guidelines and template draft Requirements definition

Cycle	Step	Activity	Outcome
2	Treatment validation	Validation with agronomists and the WP3 team	Feedback on guidelines and template Requirements refinement Final guidelines for data collection and template
2	Treatment implementation	Application of the guidelines in the CODECS LLs	19 LL Reports
2-3	Treatment evaluation / Problem investigation	Feedback on the guidelines and template	Fine-tuning of the guidelines New requirements for the method Concept of the check and modelling guidelines
3	Treatment design	Brainstorming focus group with software engineering experts and agronomists	Checklist document and modelling guidelines Requirements definition
3	Treatment validation	Application of modelling guidelines on a pilot case and plenary presentation of Case “Agrifood technology”	Requirements refinement Final guidelines for modelling Early feedback on process models
3	Treatment implementation	Application of the checklist and modelling guidelines in the CODECS LL	19 process modelling use cases
3	Treatment evaluation	Focus group with LL coordinators and survey	Models and feedback from focus groups Models refinement New requirements for the method

### Cycle 1 – Preliminary Method

The **Problem Investigation** started with a focus group involving the agronomists from the University of Pisa, to understand the context of the research and the needs to be addressed, namely facilitating communication with LL stakeholders and fostering reflections on the impact of digitalisation. The focus group was complemented with a visit to an existing LL, to better understand the context of the research. This phase was carried out before the CODECS proposal was submitted and triggered the definition of the initial concept of the method, with the idea of using graphical models to represent the process transformation.

The **Treatment Design** mainly consisted in identifying the modelling languages to be used, based on a survey of the literature. In this step we also provided a preliminary definition of the procedure to be followed to define and validate the models.

The **Treatment Validation** was based on a set of focus groups with agronomists from the University of Pisa, to understand whether the proposed approach was feasible and useful.

The **Treatment Implementation** consisted in the definition of the models for the Pecorino Toscano LL, based on a set of interviews, observations, and focus groups with the LL stakeholders.

The **Treatment Evaluation** consisted of acquiring feedback from the LL stakeholders about the completeness, usefulness, and understandability of the models, by means of focus groups.

### Cycle 2 – Guidelines and Templates

The **Problem Investigation** was based on the focus groups organised in the Treatment Evaluation and led to the identification of further improvements of the method. In particular, it emerged the need to better structure and systematise the procedure for collecting the data to be used to design the models, to avoid an excessive number of iterations with the stakeholders, and limit the effort required by the Task coordinators, also considering the language barriers with the stakeholders of non-English speaking LLs. This triggered the concept of the guidelines for data collection to be used by the LL contact points, which should have facilitated the systematic collection of information.

The **Treatment Design** consisted of brainstorming among the software engineering experts involved in the Task and led to the definition of a draft of the guidelines and templates.

The **Treatment Validation** involved agronomists from the University of Pisa and from the WP3 Team, which provided feedback on the guidelines and templates. These were finalised based on this feedback.

The **Treatment Implementation** consisted of applying the guidelines to the 20 CODECS LL, and the collection of the LL reports.

Finally, the **Treatment Evaluation** was included as part of the reports, in which the LL contact points were required to provide explicit feedback on the data collection method.

### Cycle 3 – Formalisation procedure and application

The **Problem Investigation** was based on the detailed inspection of the reports which triggered refinement of the method and led to the subsequent cycle focused on defining and implementing a detailed procedure for the model formalisation and agreement phases in all LLs.

The **Treatment Design** consisted of brainstorming among the software engineering experts of CNR and a team of agronomists from the University of Pisa collaborating to the formalisation phase and led to the definition of a draft of the checklist and guidelines for model creation.

The **Treatment Validation** involved agronomists from the University of Pisa and the CNR team applying the procedure on selected cases. The Belgian LL *Agrifood technology* was chosen as pilot study in this phase and the Belgian case was discussed during an interactive session organised during the general assembly.

The **Treatment Implementation** consisted of applying the checklist and modelling guidelines to the 19 CODECS LLs that submitted the report, and develop the set of models for each LL.

Finally, the **Treatment Evaluation** was carried out through focus groups with LL coordinators that were engaged in the evaluation of their respective models and were invited to provide feedback on the overall method both during the discussion and by completing a questionnaire.

## Part 2: Results

### 4 Description of the Digital Ecosystems in 19 Living Labs. Mapping the Socio-ecological context (T.3.2)

#### 4.1. Analysis of Digital Ecosystems, Conduciveness, SESF and RCCIs - UAL

In this section, we present summary results focusing on describing each LL and its corresponding DE. To analyse these ecosystems, we implemented a four-step methodology (Figure 6) designed to capture the characteristics within each LL. This D3.1, specifically includes the findings from Steps 1 and 2 found in Figure 6.

As previously discussed, Step 1 involves identifying the RCCIs necessary for each LL to address its FAS problem statement, and for understanding the socio-ecological-technical factors that enable or hinder digitalisation within the LLs. Step 2 builds upon this foundation by examining how the four core subsystems of Ostrom's SESF (actors), Resource Units, Resource Systems, and Governance Systems) influence the LL and FAS and enable or hinder the acquisition of RCCIs necessary to solve their problem situation found in the FAS.

To collect the data needed for the participatory mapping of socio-ecological contexts, a variety of materials have been developed, including guidelines, training modules, workshops, and several exercises (**Annex A**).

The focus in this Deliverable 3.1 is on the outcomes from Step 2, where we analyse how these four subsystems enable, foster or set the conditions to acquire the necessary RCCIs for the LL's digital transformation and problem-solving processes. This analysis allows for an improved understanding of how each LL's DE operates within its specific socio-ecological context.

Furthermore, while we primarily focus on the enabling and hindering factors associated with Step 2, it is important to note that the SES analysis and DE are already being expanded in D3.1 (M36) through more extensive coding of all four subsystems and the development of indicators. This ensures a better understanding and allows for comparison of the DEs across all LLs, aligning the findings with a unified framework and enhancing the clarity and cohesion of the overall analysis. The relationships between subsystems will be analysed as well as relationships with elements of process modelling and AKIS findings. Further integration of process modelling and AKIS perspectives will be carried out to give a more complete and holistic analysis of complex SES applied to the digitalisation of agriculture.

##### 4.1.1. Pecorino Toscano Living Lab (Italy)

###### **Introduction**

The LL of Pecorino Toscano DOP, located in Tuscany, Italy, focuses on extensive dairy sheep farms. The stakeholders of the Pecorino LL describe the FAS as follows:

*"Facilitate farmers in the data collection of data related to farm processes and use such data in order to improve the quality of production, the quality of work and life of farmers, the visibility of the farm and the animal health and welfare."*

To achieve this, the LL employs a Farm Management Information System (FMIS) which is currently at Technology Readiness Level 6 (TRL6).

###### **Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation**

- Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources, including facilities/buildings, e.g. shelters; ICT devices, e.g. sensors; and animal/crop for applying the technology, e.g. sheep.

Page | 36

To support digitalisation processes, these ‘basic’ material resources need to be complemented with technological and informational resources. Technological resources include databases, apps, and reliable internet connectivity, while informational resources encompass availability and diverse sources of information related to digitalisation processes. In the context of the Pecorino Toscano Living Lab, the Poderi App represents a key technological resource, designed to improve farmers' quality of life by saving time on farm management.

Sustainable digitalisation is also conditioned by the (lack of) availability of human resources. Within this type of resources, labour, e.g., specialised workers, farming workers; and knowledge, and more specifically the valorisation of traditional knowledge and targeted training for knowledge integration and to develop digital skills —such as data analysis and interpretation—have been identified as key conducive elements for sustainable digitalisation.

In addition, financial resources represent a key element for sustainable digitalisation. In this regard, rather than stressing a single financial/funding (re)source, it is the combination of farmer’s own investments (from their own profit generation), loans from private lenders/institutions, research funds, together with CAP funds and other public subsidies which have been identified as conducive for sustainable digitalisation processes.

Finally, collaborations (as a resource) among different actors such as public entities, farmers, second level organisations, research institutions/universities, technology developers and also partnerships that link local and extra-local actors, have been identified as key elements for sustainable digitalisation.

#### - Capabilities

Beyond the above-mentioned resources, different capabilities, understood as individual and/or collective know-how/abilities to undertake specific activities, which implies a combination of resources and individual actions or organisational routines, have been identified as significant conducive elements to sustainable digitalisation procedures. Within these, regarding functional capabilities, farmers and stakeholders possess clear know-how in animal health management and in production and processing techniques of the Pecorino Toscano PDO cheese. These capabilities are supported by farmers’ management and organisational skills developed through direct experience in grazing and daily routine practices. However, our analysis shows challenges for stakeholders, and especially for farmers, related to relevant capabilities for sustainable digitalisation such as data management, recording, analysis and interpretation, as well as for data access; all of these shortcomings lead to inefficient practices. Also, our analysis shows challenges in terms of efficient funds management, especially of public funds, by stakeholders and more specifically by some producer organisations and policymakers/public administrations.

Our analysis also shows how digital skills are related to the development of adaptive capabilities, or dynamic capabilities, which refers to the adaptation in view of a changing external environment. Other dynamic capabilities key for sustainable digitalisation refer to values related to a strong link of farmers with nature, empathy among stakeholders, awareness of the added value of the products and of the relevance of recording and sharing data, but also attitudes related to willingness to change and innovate. Closely related to these attitudes and values are two fundamental capabilities for sustainable digitalisation; the capability to start, develop and maintain collaborations and the exchange and integration of different forms of knowledge, for example traditional know-how with digital techniques (innovation).

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the (sub)systems which participate in the digitalisation processes. These elements of the (socio-ecological) systems set the conditions, contributing to enabling and/or hindering the resources and capabilities identified by the LL for sustainable digitalisation.

Agricultural/farming system (**resource systems**) in Pecorino Toscano PDO cheese is a complex multi-stakeholders’ system which includes diverse actors such as farmers and farm workers, cooperatives, farmers’ associations, producers’ organisations, associations of producers, certification bodies, the PDO consortium, advisors, inputs suppliers, retailers, tech developers, researchers, public entities-policymakers, among others; these stakeholders coordinate and manage digital initiatives across the sector. The agricultural system is entangled with specific natural environments (**resource systems**) which influence the material resources available, for example the animal (and

crops) in which the technologies are applied, in the specific case of this LL the sheep, and their interactions with other natural resources, e.g. rivers, mountains, and other animals, e.g. predators.

Furthermore, the agricultural/farming system is also entangled with regulations (**governance system**) which set governance conditions related to animal/crop production, health and safety, (human, animal, plant) wellbeing, natural resources and environmental management-pollution (water, soil, pesticides, waste, energy, carbon), but also related to data management, collection, storage, usage, ownership in sustainable digitalisation processes. A significant regulation for any EU farming system is CAP policy, stakeholders from Pecorino LL have stressed the high complexity of CAP procedures that hinders access to resources, and the need to simplify CAP complex procedures related to data record and management for enhancing digital ecosystem conduciveness to sustainable digitalisation. Moreover, CAP funding, especially Pillar 1, is perceived as not always going towards the interests of the farmers, as it does not support active farmers. Beyond CAP funding, other regulations such as those related to financial, tax and fiscal rules set up the conditions for sustainable digitalisation processes especially in accessing the financial and material resources needed for these processes. In this regard, stakeholders stress the importance of the availability of loans/credits (**resource units**). The access to these financial resources for digitalisation is partially influenced by a long-term collaboration, and therefore trust, which has developed a strong link between local banks and farmers (**resource systems**).

Within agricultural/farming systems, farmers and their farms are central actors not only for their economic/productive activities but also because of their roles in land management, environmental stewardship and their social function in rural areas. Our analysis shows how social rules (**governance system**) such as negative public opinion towards (certain) farmers related to their contributions to environmental pollution is a relevant element hindering sustainable digitalisation processes. Furthermore, conservative thinking and lack of collaboration among farmers are also noted by stakeholders as social norms/rules blocking innovation (digitalisation) (**governance system**), as these hinder previously mentioned capabilities related to exchange and integration of knowledge, willingness to change, collaborations and access to resources, e.g., financial and informational resources.

The culture and mindset of the actors affect the successful implementation of digitalisation. Actors in the Living Lab are perceived as open-minded and motivated to change mindsets in order to change the way the system currently works and take advantage of digital technologies. A collaborative attitude strengthens networks of people (**resource unit**) that foster the exchange of information and data, which benefits the implementation of digitalisation in the sector and alleviates the perception of pending collaborations with actors who are not yet involved. The actors involved in the Living Lab exhibit a clear desire for change. This motivation is deeply rooted in mutual trust (social capital) (**resource unit**) which has been pointed out as essential for building, developing and maintaining collaborations and for enhancing innovation and change that leads to sustainable digitalisation. Trust among stakeholders not only fosters a willingness to embrace innovation (digitalisation) but also creates the conditions necessary to overcome challenges and implement sustainable solutions. Furthermore, farmers are aware of the value of their production, but they are unable to increase their economic benefits. In this regard, collaborations with advisors and researchers (**actors**) and digitalisation play an essential role, as for instance, is the failure of farmers to record data which leads to inefficient management.

Collaborations among stakeholders (**resource unit**) play a key role as an intermediate layer that facilitates access to other above-mentioned resources, such as finances, information, and knowledge. In this line, our analysis points towards the essential role of Second Level Organisations (including PDO consortium, farmers associations, producers' organisations) as structured/organised networks that act as intermediaries (**actors**) between farmers and other relevant stakeholders (policymakers, regulators, markets) for sustainable digitalisation processes. As stressed by the participants of this LL, second-level organisations often act as keepers of data, collecting and storing information relevant to their activities and stakeholders, thus they are critical within a high complex environment in terms of regulations, including data regulations, health and safety, production, CAP, certification, supporting other actors' capabilities and access to resources. The trust of farmers on these second level organisations is critical for digitalisation processes, which implies innovation, change, and investment. In this regard, these second level organisations (should) act as actors that on the one hand, are close to the ground and know the needs and demands of farmers related to digitalisation; but also link these local demands with external knowledge and policy frameworks that transcend local issues, therefore channelling resources and opportunities bidirectionally (bottom-up and top-down) for sustainable digitalisation. However, some second level organisations, namely producer organisations, are



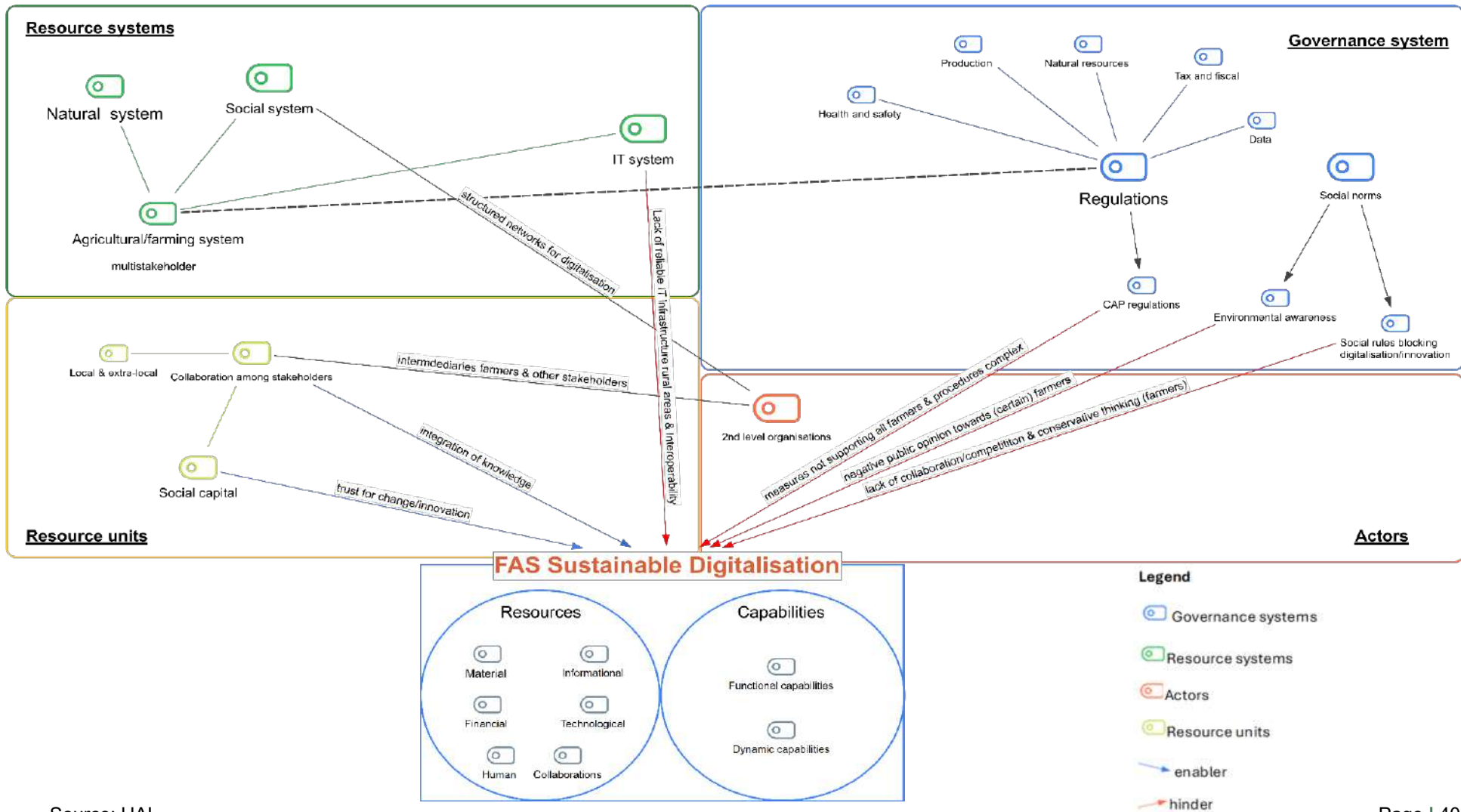
criticised for inefficiently managing some public funds (financial resources) related to sustainable digitalisation. In the same line, policymakers, who (should) act as facilitators by providing the necessary information to access and apply for public funds, are also criticised for their lack of skills to manage financial resources. This often leads to inefficiencies, resulting in funds being underutilised or failing to reach the intended beneficiaries.

Finally, a key element for sustainable digitalisation is the IT system (**resource system**). In this regard, stakeholders have stressed the need of developing reliable infrastructure related to broadband in rural areas and of data interoperability as these remain significant challenges for accessing and properly implementing technological resources for sustainable digitalisation. The lack of system integration and general interoperability hinders the use and development of digital resources and technologies, as well as unstable or inefficient broadband infrastructure creates problems in the application of digital technologies in sheep farms.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Pecorino LL.



Figure 12. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Pecorino LL.



Source: UAL



Funded by the European Union

CODECS has received funding from the European Union's Horizon Europe research and innovation Programme under Grant Agreement n. 101060179. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). The granting authorities cannot be held responsible for them.

## **Conclusions and summary**

The Pecorino Toscano LL in Italy illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below). In terms of enablers, a well-established network of stakeholders, including farmers, cooperatives, farmers associations, PDO consortium, consumers, traders, input suppliers, technicians, researchers-university, public institutions-policymakers, creates a strong collaborative environment that supports the acquisition of resources (material, financial, informational, technological, social capital-trust) and the presence of a wide range of functional and dynamic capabilities needed for the sustainability of the digital ecosystem, including the integration of different forms of knowledge, for example, traditional know-how with digital techniques (innovation).

The system of structured collaborations/networks among these diverse sets of actors enable resource sharing and knowledge exchange throughout the food-value chain, which in turn, support the conduciveness of the digital ecosystem of Pecorino LL. Within these actors, the farmers are central as they are in charge of implementing the technology, and making investments for digitalisation, but they also have a role in environmental stewardship. An enabling factor is represented by farmers', and other stakeholders, willingness to change (innovate). Furthermore, second level organisations (including PDO consortium, farmers associations, producers' organisations) enables a sustainable digital ecosystem by acting as intermediaries between farmers and other stakeholders, and by being delegated roles related to complex tasks and regulations such as those regarding data management. Trust on these organisations, and among stakeholders of the LL, have been identified as a key enabler for change (innovation) towards digitalisation.

Finally, the CAP, and especially the (public) funds associated with it, is presented as a key enabler in promoting the adoption of digital initiatives across the LL. These funds from the CAP are necessary but not sufficient as they need to be coupled with other revenue streams such as farmer's own investments, loans from private lenders/institutions, and research funds.

In terms of hindrances, the Pecorino LL stakeholders stressed the rigidity of the political framework, particularly regarding regulatory issues tied to CAP funds. While CAP funds are supportive, stakeholders perceive the CAP rules as complex and not always aligned with their needs, especially when it comes to active farmers, hence, this challenges the access to these resources. In a similar line, data (management) regulations have also been stressed as overly complex, thus hindering digitalisation processes.

Besides the above-mentioned formal regulations, social norms/rules (governance) are a barrier to digitalisation, especially those related to conservative thinking and lack of collaboration among (some) farmers, who view each other as competitors rather than collaborators. Furthermore, difficult/weak collaborations between public entities and the farming sector, for example in terms of data access, represent a hindering factor for a conducive digital ecosystem.

The IT infrastructure needed for sustainable digitalisation also presents a challenge as some rural areas still present inadequate broadband connectivity and especially due to a lack of interoperability/integration of data that impedes data exchange and the use of digital tools across the farm and at the various stages of the food-value chain.

Despite the presence of a wide range of digital skills within the LL, the need of enhancing digital skills through specialised training, especially of farmers and workers of the farms that can implement the technologies developed, is important.

In conclusion, the digital ecosystem of the Pecorino Toscano LL shows enablers and hindrances (see Figure below); in terms of enablers a structured collaborative networks, farmers and stakeholders' motivation to change-innovate, the presence of second level organisations acting as intermediaries and availability of a wide range of resources and capabilities. However, it also faces hindrances such as regulatory complexity, some social norms acting as barriers to digitalisation, poor/lack of collaboration in some respects, inadequate IT infrastructure (broadband connectivity and especially data interoperability) and digital skills and training.

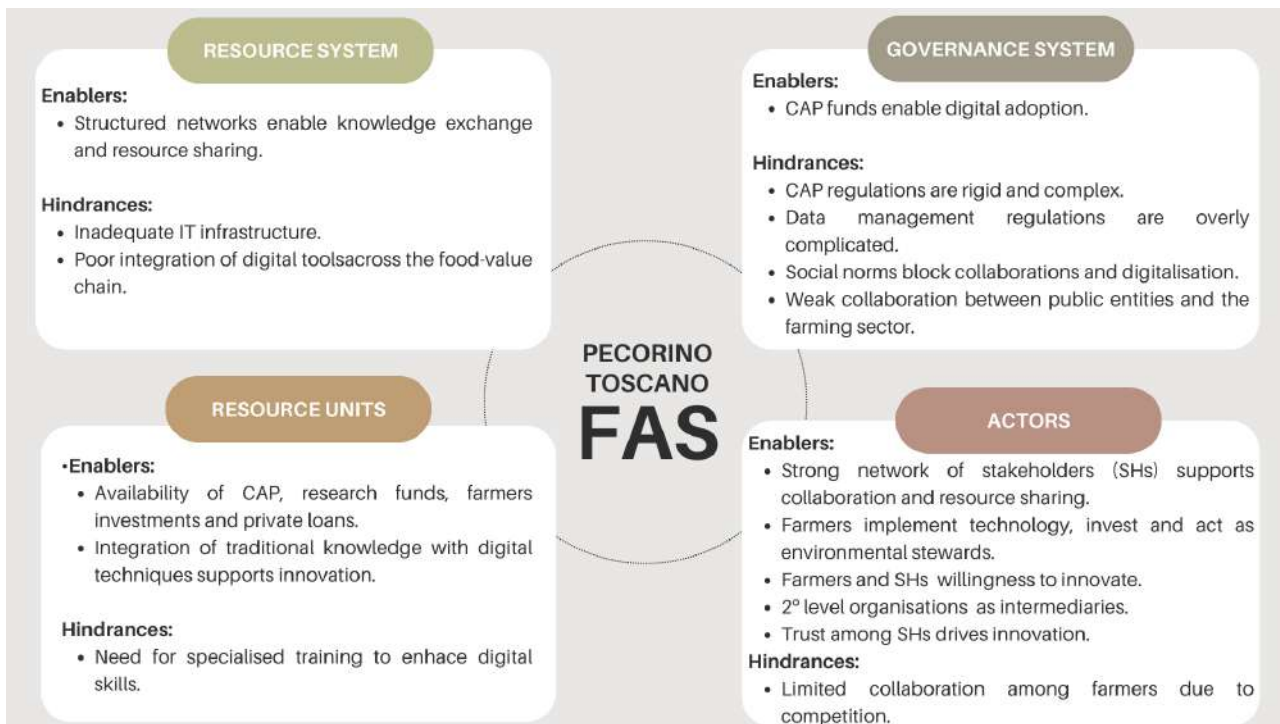


Figure 13. Main enablers-hindrances of Pecorino Toscano LL.

Source: UAL

#### 4.1.2. APPETIT Living Lab (Poland)

##### Introduction

The LL of Appetit, located in four localities around Poland, focuses on growing local markets for locally produced food. The stakeholders of the APPETIT LL describe the focal action situation (FAS) as follows:

*"To build collaborative arrangements for IT-enabled sharing economy functionalities for strengthening, replicating and growing local food markets to solve the problem related to engaging small-scale food producers, consumers and rural development stakeholders in growing local markets for locally produced food".*

To achieve this, the LL employs a digital platform for collaborative organisation which is currently at Technology Readiness Level 4 (TRL4).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources, including facilities, e.g. logistic centres, equipment and products with great value which form the base of the local food markets. To support digitalisation processes, these 'basic' material resources needed to be complemented with technological resources, in this case the development of a digital platform hosting local markets for locally produced food (virtual marketplace), and which included the organisation of collection points, e-commerce and with the potential for automating intermediary services.

Sustainable digitalisation is also conditioned by human resources. Within this type of resources, local leaders were stressed as a key component for the LL, these included a core group of small farmers (some working within the informal economy) and proactive consumers willing to engage, provide feedback, and experiment.

In addition, financial resources represent a key element for sustainable digitalisation. In this regard, grants and subsidies were highlighted as the main sources for the LL, these were especially important as start-up funding but

also mentioned for growing (scaling) and technology development. Stakeholders also identified as a challenge limited access to start-up, operating and investment funding for collective arrangements that enable joined up solutions beyond individual-oriented solutions.

Finally, collaborations (as a resource) among farmers, with consumers, with public entities and Local Action Groups (LAGs) were also identified as relevant resources.

- Capabilities

Besides the above-mentioned resources, different capabilities were identified as significant conducive elements to sustainable digitalisation. Within these, regarding functional capabilities, abilities related to leadership (e.g. for initiating joined up solutions/innovations – collective leadership), fundraising (e.g. grant preparation, relations with investors) and organisational skills related to developing distribution channels and business models were stressed as essential for sustainable digitalisation.

In terms of dynamic capabilities, which refers to the adaptation in view of a changing external environment, the ability to build/develop collaborations to share/transfer experience and expertise, networking and engagement with consumers, universities/research centres and advisory services, such as veterinary and sanitary services have been highlighted by stakeholders. In this regard, our analysis shows the relevance of working interactively with software developers and of recruiting farmers - especially those in the informal economy - to join in developing a producer-consumer food marketplace. Moreover, a key (dynamic) capability refers to the development of advocacy capacity by LL stakeholders in order to interpret and influence regulations/policy making. These capabilities are directly related to the capacity of stakeholders to grow (scale/ing) the digital solutions proposed for developing local food markets.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes. These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems (see Figure below).

The Appetit LL is formed by multiple stakeholders including small-scale farmers (some within the informal economy), food processors, local food market initiators (including municipalities, some farmers, NGOs, informal groups of producers and consumers), food market organisers, software developers, university/research institute and Local Action Groups (**actors**). Besides the stakeholders who form part of the LL, others stakeholders influence the LL, including industrial scale farmers (usually with contrasting interests to small-scale farmers), NGOs, farmers organisations, supermarkets, policymakers including regional and national government institutions (Ministry of Agriculture and Rural Development; Agricultural Modernisation and Restructuring Agency), advisory services (including agricultural, veterinary and sanitary services), and financial institutions-investors.

Within these **actors**, farmers have a pivotal role in the Appetit LL/FAS, influencing key areas such as collaborations by leveraging their knowledge of the marketplace and their ability to work effectively with other stakeholders. Through their collaboration and active participation, farmers encourage others, particularly those from the informal economy, to join and expand producer-consumer networks. Their leadership fosters collective innovation and accelerates the scaling of local food markets by facilitating the transition of small-scale farmers into the formal economy, a critical factor for market development. In addition, they facilitate resource mobilisation through their leadership, which translates into financial and advisory resources, such as those offered by the CAP Plan.

Other relevant **actors** to Appetit LL are advisory services such as veterinary and sanitary services which currently focus on strict enforcement acting as barriers for sustainable digitalisation; the national agricultural advisory centre supports market growth (scaling) through programmes which prioritise local food systems, and; regional advisory services which enhance accessibility to financial resources and foster the growth of local food markets through their support with subsidies and grants.

Regarding the financing/funding system (**resource system**), there is an emphasis on public funding, including grants and subsidies (**resource units**), especially focused on the initial/start-up phase and the novelty of the initiative but also due to the aim of developing a small-scale non-industrial food processing and local food markets. The



coordination of funding between different stakeholders, e.g. farmers, initiators, software developers, is also stressed. Additionally, financial services tailored to the needs and circumstances of participants of local food markets are identified as critical to ensuring accessibility and addressing financial barriers that hinder growth (scaling). In this line, stakeholders of Appetit LL acknowledge that private investments (**resource units**) are important in terms of bringing both capital and developing a mindset to articulate and communicate needs and develop opportunities related to intermediary services. However, currently this represents a hindering factor for the LL as stakeholders note limited availability of private investments and recognised that investment funding for collective arrangements in the form of local food markets remained a big challenge.

In this context, local food-market systems (**resource system**) provide a collaborative framework for diverse stakeholders, fostering a more equitable, community-centred approach to food production and distribution. They promote sustainable digital development by enhancing collaboration (**resource units**) through empathy, boosting competitiveness with strategic funding, and leveraging digital governance to build resilient and inclusive food networks.

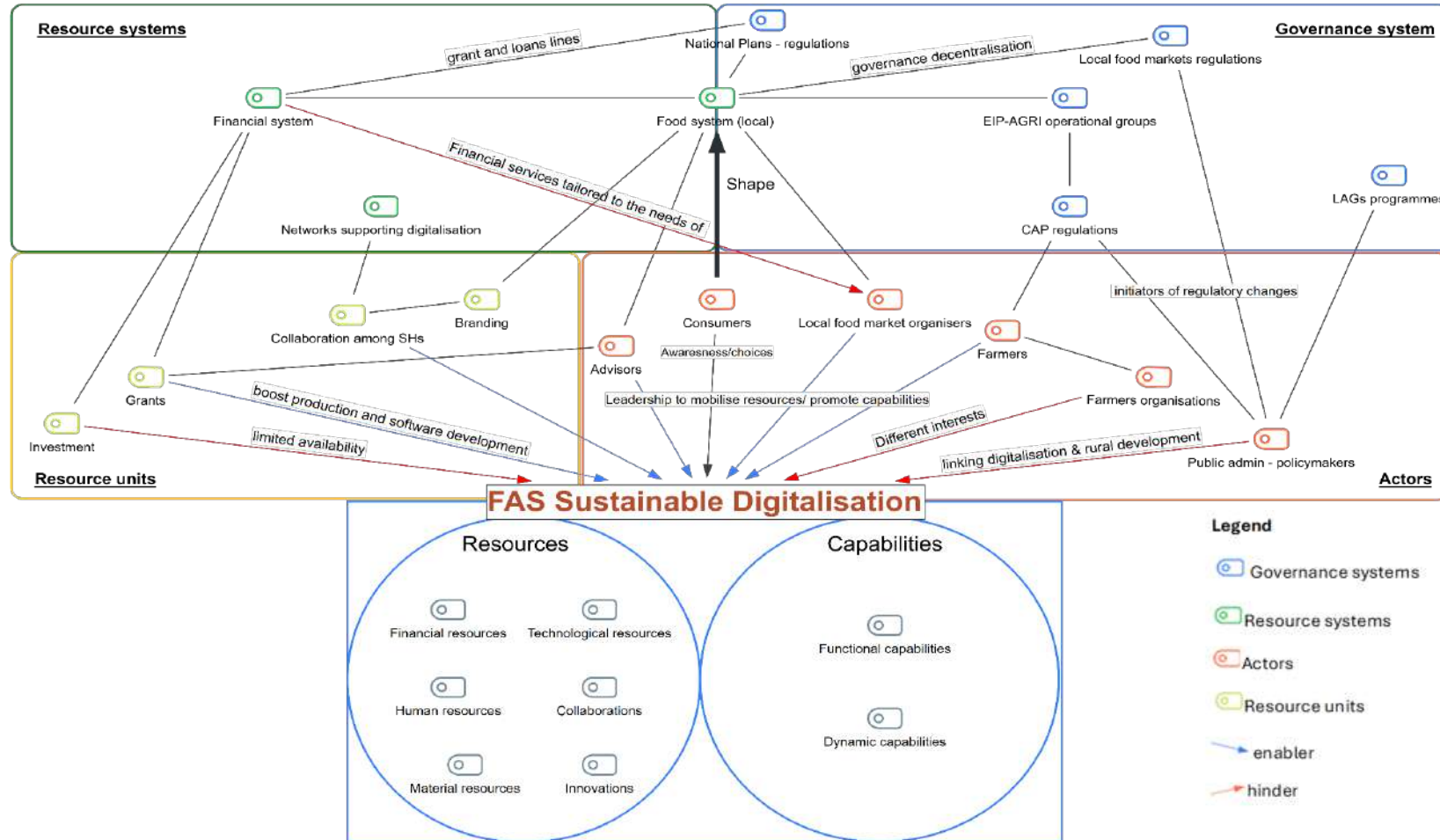
The former links with the significant role of public policy (regulations) (governance) related to sustainable digitalisation in agriculture and rural development. In this regard, stakeholders from Appetit LL perceived a change from the previous CAP which was more focused on industrial farmers and export-led agricultural sector to a shift that recognises that the small farm sector represents an opportunity, this is coupled with a National Recovery Plan (Poland) (governance) which have grant and loans lines targeting small-scale food processing, EIP-AGRI operational groups which provides opportunity for collaborative partnerships for innovation and Local Action Groups that have opted to support local food markets in their strategic plans for rural development. This perceived change in public policy/programmes' priorities links with the opportunities to get financial resources for sustainable digitalisation and with the relevance of developing collaborative and advocacy capabilities. Besides public policies related to small scale farmers and grants, stakeholders stressed the need for linking digitalisation innovation with rural development, including local food markets, by public policies/administrations.

Furthermore, regarding the different interests between small-scale and industrial farmers, the role of farmer organisations (second level organisations) (**actors**) was also highlighted, which organisations were criticised from Appetit LL stakeholders for being oriented to support and represent the interests of industrial farmers and have limited capabilities to provide advisory services (for Appetit LL). However, stakeholders recognised that there is potential for change as small farmers gain representation in Agricultural Chambers or set up their own organisations and coalitions.

In addition, in terms of governance is also important to note that the Appetit Digital Platform, besides a technological resource is conceived as a governance tool that proposes a decentralised model that replaces traditional intermediaries with shared responsibilities among stakeholders, with producers for example, handling tasks like marketing, pricing, and logistics, while consumers contribute to promotion, authentication, and distribution. The platform enables stakeholders to opt into co-providing intermediary services (such as transaction management, logistics, and reporting) without centralised control. The APPETIT platform is seen as an opportunity to devise and host a governance system that engages individuals and organisations involved in the local food system in a specific territory and with the potential capability to monitor and assess social and environmental impact.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Appetit LL.

Figure 14. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Appetit LL.



Source: UAL

**Conclusions and summary**

The digital ecosystem of the Appetit LL in Poland presents several enablers and hindrances that shape its sustainable digitalisation (see Figure below).

Concerning enablers, the availability of funding, namely in the form of grants and subsidies for start-up, and high-quality local food products are stressed. Moreover, national and regional advisory services play a key role by prioritising local food systems, facilitating access to financial resources, and fostering market start-up and growth (scaling) through targeted support. Additionally, the presence of local leaders (farmers and consumers) and collaborations between farmers and consumers, with software developers, university/research institute, public entities (namely municipalities) and Local Action Groups (LAGs) were also identified as enablers. In this regard, innovation fostered by the collaboration of these actors has been critical in developing organisational arrangements and digital solutions tailored to the needs of local food markets. Collective leadership and the ability to cooperate among stakeholders and engage small-scale farmers, some of whom operate outside of the formal economy, represented significant enablers for sustainable digitalisation. In terms of governance, the (current) CAP together with national plans, EIP-AGRI operational groups and LAGs programmes provides opportunities for developing innovations around small-scale food processing.

In relation to hindrances, limited access to start-up, operating and investment funding for collective joined up solutions rather than individual-oriented solutions. Another hindrance factor is the different interests between industrial farmers and small-scale farmers, with the former still controlling farmers organisations which represent the ‘interests’ of the sector. Regarding regulations (public policy/programme) the lack of joined up thinking of policymakers for example by not linking digitalisation and rural development policy/programmes represent a hindering factor.

In conclusion, the digital ecosystem of the LL shows enablers and hindrances (see Figure below); in terms of enablers it is driven by engaged stakeholders, especially local leaders; the Appetit platform itself, which serves as a hub for collaboration and technological innovation; grants/subsidies used as start-up funding and some favourable regulatory environment. However, the ecosystem’s progress is hindered by gaps in stakeholder representation, controversies among different industrial and small-scale farmers and limited financial support to collaborative actions.

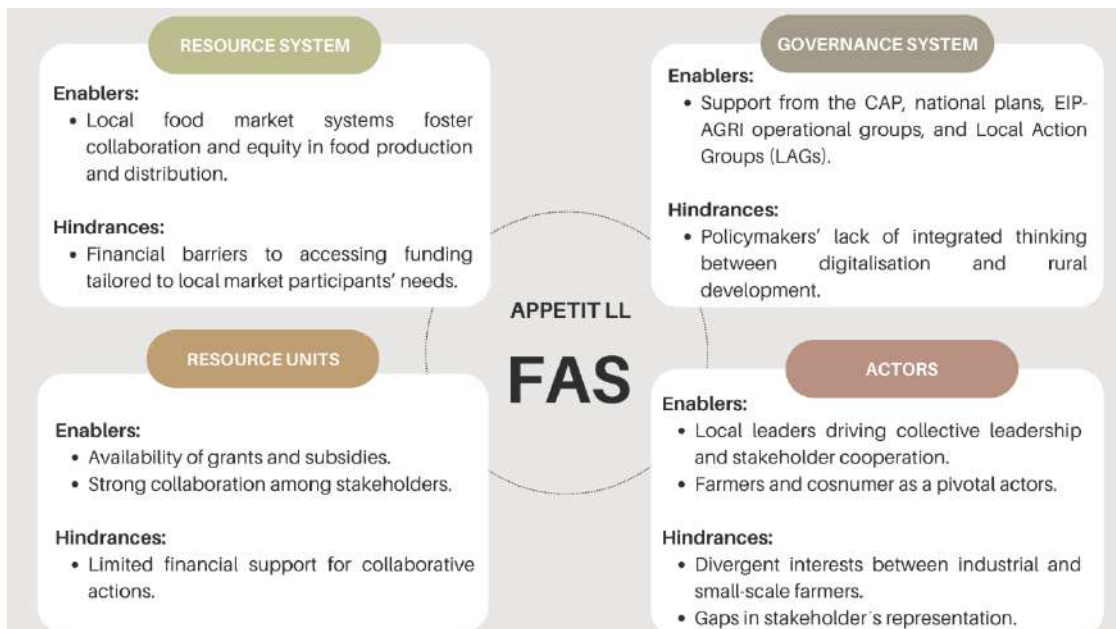


Figure 15. Main enablers-hindrances for Appetit LL.

Source: UAL

### 4.1.3 Orchard management and digitisation Living Lab (Czech Republic)

#### Introduction

The LL 'Automation of orchard management', located in the Czech Republic focuses on the use of digital technologies for orchard management to increase the volume and efficiency of fruit harvesting. It also focuses on production management overall and on facilitating reporting obligations. Farmers, members of non-profit organisations, policymakers, and agricultural advisors are working with technology suppliers and researchers to test technologies that will enable automation of irrigation and monitoring of climatic conditions in the orchard. This initiative aims to reduce water and pesticide use, mitigate the impact of adverse weather on crops, and simplify reporting obligations.

The stakeholders of 'Automation of orchard management' LL describe the focal action situation (FAS) as follows:

*"To reduce impact of adverse weather on crops, reduce water and pesticide use, automation of irrigation and facilitate reporting obligations."*

To achieve this, the LL employs a new sensor-based orchard management system for crop protection, remote control of the irrigation system, frost monitoring. The system also measures air and soil temperature and humidity. An end-user application for farmers supports decision-making and is currently at Technology Readiness Level 6 (TRL 6).

#### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

##### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material and technological resources, including irrigation systems, ICT devices, e.g. sensors; and monitoring station-system. Moreover, informational resources, in the form of orchard trees registers (databases), crops growing conditions and long-term meteorological, yield and fertiliser data represent significant available resources for the LL.

Sustainable digitalisation is also conditioned by the (lack of) availability of human resources. Stakeholders pointed towards the scarcity of workers in the orchard field(s), the need for a better trained and more stable workforce, and also a need to attract a younger generation since current workers tend to be older. Stakeholders of this LL also pointed towards the potential role of robots in substituting the scarcity of workforce.

Financial resources also represent a key element for sustainable digitalisation. In this regard, subsidies, grants and national funds were identified as critical for the LL. While private investments were mentioned, they play a secondary role. Notably, collective investments among farmers were stressed as important in order to share the high costs of technologies.

Finally, collaborations (as a resource), especially among farmers and between farmers and associations were highlighted as a relevant resource for the LL especially in terms of information sharing.

##### - Capabilities

Concerning functional capabilities our analysis outlines that know-how related to theoretical knowledge (orchards, soil, climate zone) and capacity of obtaining measurements are important for sustainable digitalisation and are available within the LL. However, other capabilities relevant for the LL such as the ability to analyse and interpret data to make data-driven decisions, and the capacity to work with complex Apps (digital skills) need to be improved.

Furthermore, in regard to dynamic capabilities, the ability to transfer, share and integrate information and knowledge was stressed as key for sustainable digitalisation. Besides the sharing of data, results, and other information, the relevance of developing the ability of integration between modern technology and standard ('traditional') technologies was noted. Last but not least, stakeholders highlighted the relevance (and need) of adapting technologies and innovations to the local context/ecosystem in order to enhance sustainable digital solutions that work in practice.

#### Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation



The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is comprised of a structured network of different stakeholders (**resource system**), including farmers, non-profit organisations, policy makers and agricultural advisors/research institutes working with technology suppliers and researchers to test technologies (**actors**).

Within these **actors** research bodies/organisations such as the Research and Breeding Institute of Pomology Holovousy Ltd is highlighted in its role as provider of independent research for farmers, building awareness, providing training and the Institute of Agricultural Economics and Information as provider of inputs to policymakers. However, more intense cooperation with research institutions is needed to transfer innovation into the practice; moreover, stakeholders outlined an overreliance on often costly foreign consultants who increase the financial expenses and limit access to context-specific advice thus hindering sustainable digitalisation. Retail chains are also identified as actors pressuring farmers on prices which results in low margins weakening farmers' ability to invest in technologies. On the other hand, second level organisations such as farmers associations and unions are perceived as a significant element for sustainable digitalisation as enablers of collaborations and sources of information which in turn facilitates knowledge/information access for farmers (**actors**).

The public administration is a significant actor for the LL. Grants, subsidies and access to information were pointed as key resources for sustainable digitalisation, in this regard public bodies act as enablers in their capacity of sharing information, which in some occasions they obtain through compulsory registration (governance) (e.g. land register, orchard register), for further development of other actors' capabilities.

According to farmers in this LL, horticulture is not seen as a priority by the Czech government (**actors**) which is demonstrated by a lack of clear/long-term vision and weak national policy support for agriculture/horticulture (governance). Furthermore, despite the relevance of the CAP and national programmes (governance) in providing funding, for example for capital investments in 'traditional' technologies; these regulations are criticised as inefficient and especially as overly complex, thus in need of simplification of procedures/bureaucracy.

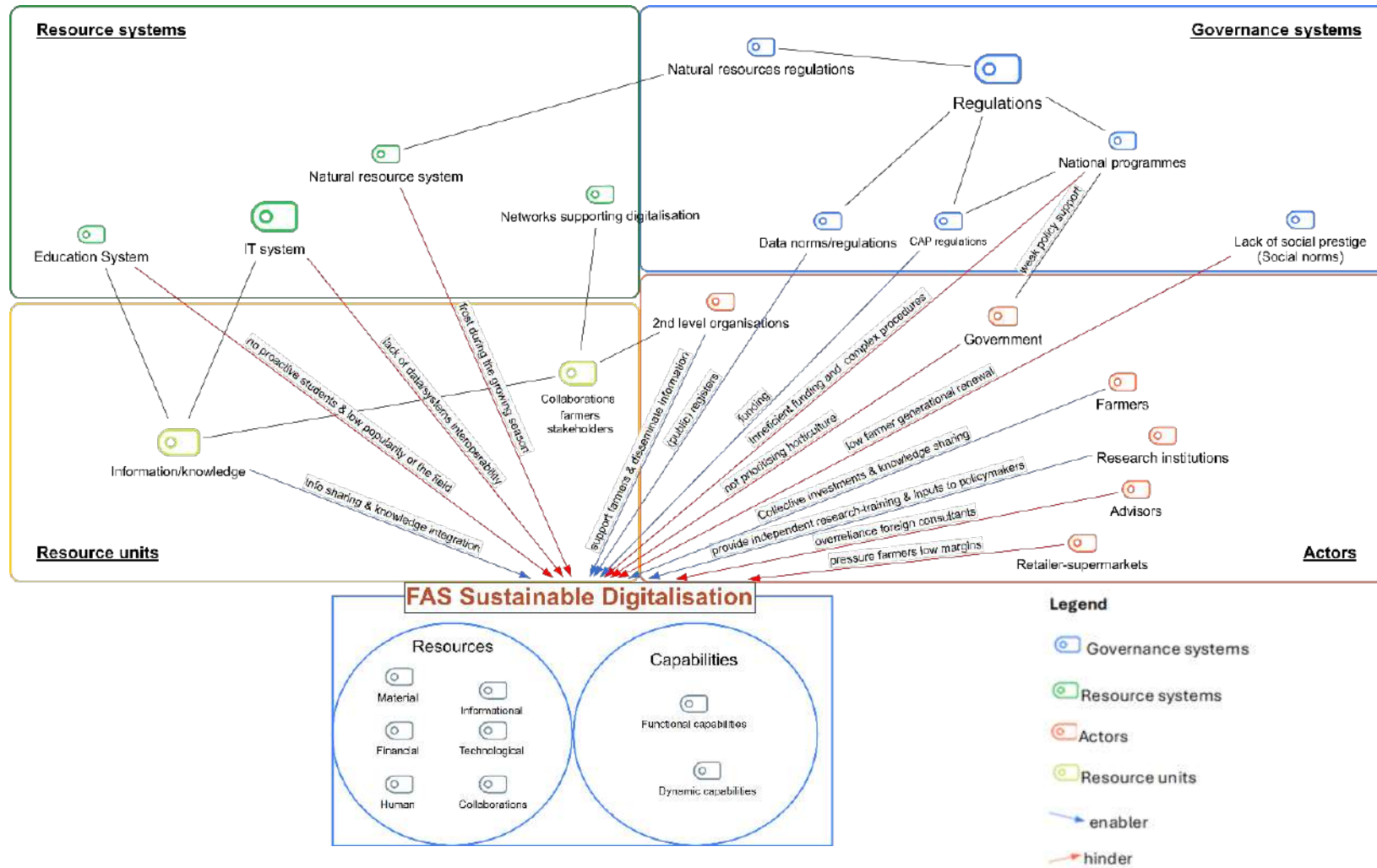
Besides the above-mentioned formal regulations, farmers mentioned social norms (governance) such as the lack of social prestige of agriculture as a relevant element hindering sustainable digitalisation for example in terms of farmers generation renewal.

Stakeholders from this LL perceive that the education system (**resource systems**), namely vocational and higher education institutions provide relevant training, nonetheless students are often not sufficiently proactive in acquiring the specialised skills required for digital (orchard) management. This reflects a broader issue: the generally low popularity of the field, which is commonly perceived as involving a large amount of manual work. As a result, a gap remains in the availability of trained human resources. This gap is further exacerbated by the aging demographic of current farmers, with limited interest from younger generations in entering the horticultural/agricultural sector. In this regard, stakeholders emphasise that collaborations, both among farmers and between farmers and other stakeholders beyond the LL (**resource units**), such as professional associations, are relevant to efficient knowledge and information sharing and access (**resource units**), strengthen networks and innovations.

Finally, two further elements are perceived as a key for sustainable digitalisation, first, the lack of interoperability and integration of data and digital technologies/platforms within IT systems (**resource systems**) which hinders the transfer and integration of data/knowledge and second, the limitations, due to scarcity of natural resources (**resource systems**) such as water. In the case of orchards, however, stakeholders highlight frost during the growing season as the main climatic challenge affecting production.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL

Figure 16. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Automation of orchard management LL in the Czech Republic illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, a **multi-stakeholder network/partnership** including farmers, members of non-profit organisations, policymakers, and agricultural advisors create collaborations which enables the acquisition of resources and a wide range of capabilities within the LL. In this line, the presence of **second level organisations** is also stressed as relevant for developing further **collaborations between farmers and other stakeholders**. The relevance of **information/knowledge sharing and integration**, and **expertise (know-how)** regarding the orchards, soil, climate is highlighted. Moreover, other enabling aspects are the presence of **research companies and institutions** providing some **training** and **evidence-based inputs, especially to policymakers**. Funding in form of **grants and subsidies** from CAP and national programmes are also enablers for sustainable digitalisation for this LL, together with **collective investments** from farmers to acquire digital technologies.

In terms of **hindrances**, this LL points to the **scarcity of workers**, and a **lack of regeneration/renewal of farmers**. Moreover, needs in terms of ability of farmers (or farm workers) to analyse and interpretate data to make data-driven decisions, and capacity to work with complex Apps (**low digital skills**) is highlighted together with the **need of adapting technologies and innovations to the local context/ecosystem**, namely as a consequence of overreliance on foreign consultants. Furthermore, the **lack of interoperability and integration of data and digital technologies/platforms (IT systems)** and natural resources, especially **water scarcity** are also identified as hindering factors for sustainable digitalisation. In terms of governance, both **CAP and national programmes are criticised for being too complex and the need for simplification** of procedures is stressed. Finally, agriculture/horticulture is not perceived as a priority for the national government which reflects **on weak policies** in the sector which hinders sustainable digitalisation.

In conclusion, the digital ecosystem of the LL shows enablers and hindrances (see Figure below), in terms of enablers a multi-stakeholder collaboration, relevant flows of information and knowledge sharing, some training options and funding from grants, subsidies and collective investments. However, it also faces hindrances such as regulatory complexity, inadequate IT infrastructure (data interoperability), digital skills, lack of adaptation of technologies to local context and unsupportive national policy environment.

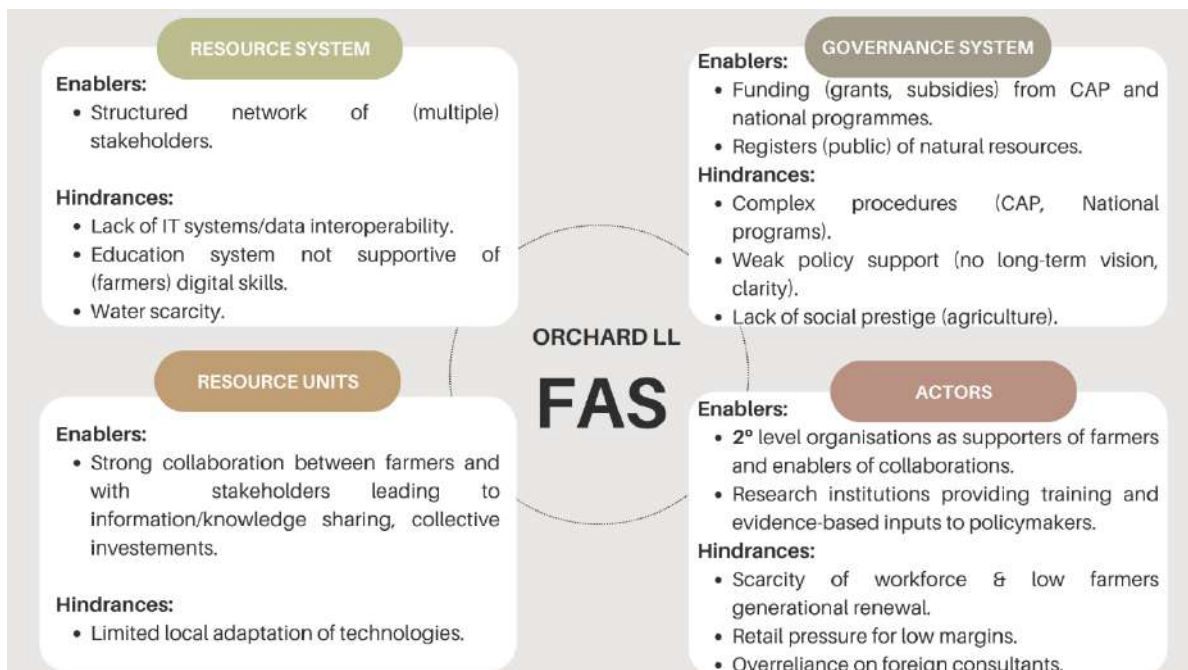


Figure 17. Main enablers-hindrances of Automation of orchard management LL.

Source: UAL

#### 4.1.4 Occitanum OL VITI Living Lab (France)

##### Introduction

The LL Occitanum OL VITI, located in France, focuses on the use of digital technologies for vineyard management in sustainable agriculture. Its goal is to optimise fertilisation strategies to preserve the varieties of wines while ensuring environmental protection. Fertilising a vineyard plot is a key stage in the growing cycle as it maintains soil balance and grape yield.

However, maintaining a sufficient availability of elements in the soil over time is a complex task given that vineyard soils are rarely homogeneous. Successful fertilisation requires a deep understanding of plot heterogeneity, historical management practices, and pedoclimatic conditions. The LL seeks to improve fertilisation management by following the principles of measure, decide, and act.

The stakeholders of the Occitanum OL VITI LL describe the focal action situation (FAS) as follows:

*"To ensure successful fertilisation by understanding vineyard soil heterogeneity, historical data, and pedoclimatic conditions, while preserving wine typicity and protecting the environment."*

To achieve this, the LL employs a system that integrates satellite images, vigour maps, and a user-friendly interface to support precise fertilisation management currently at Technology Readiness Level 7 (TRL 7).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified for the sustainable digitalisation of the Occitanum OL VITI LL include a combination of material and technological resources. The Gaillac vineyard and experimental site serve as a testing ground for implementing and validating digital solutions in viticulture. Similarly, advanced technological resources, such as satellite imagery and a variable rate application console, provide tools for precision fertilisation.

One of the main hurdles in innovation is the need to tailor technological advancements to the specific requirements of viticulture. Stakeholders emphasise that no single service provider fully meets the LL's needs. To address this, the LL follows a user-centred methodology, where stakeholders identify their needs through consultations. These insights then inform a Call for Interest to select AgTech providers capable of co-developing relevant solutions. Among the key technological advancements currently implemented in the LL are vigour maps and modulation systems.

Sustainable digitalisation is also conditioned by the availability of human resources. In this regard, the LL benefits from an existing community of practice, originating from a previous project. Moreover, farmers and technicians are actively engaged in the initiative, while an agtech company selected through the Call for Interest, contributes to the co-creation of software solutions. On the other hand, the shortage of human resources remains a challenge for the deployment of digitalisation, particularly due to the lack of agricultural labour force.

*Financial resources* also represent an essential element for sustainable digitalisation. In this regard, stakeholders highlighted a significant lack of research funds and public funding, which hampers both the finalisation/implementation of the project and the ability to compensate the farmers involved or impacted by the implementation of technologies. Also, securing financially stable startups or agtech companies remains an obstacle, as the company selected for this project is currently facing severe financial difficulties.

*Collaborations* (as a resource) are considered drivers for a successful digitalisation, especially among farmers, particularly those from the Vinnovale cooperative. These farmers maintain connections with a CUMA (Cooperative of Mutualisation of Agricultural Machinery) and technical institutions such as IFV (Institut Français de la Vigne et du Vin). However, further efforts are needed to expand farmer participation and, most importantly, to strengthen partnerships with educational institutions that can provide specialised training tailored to the region's agricultural needs.

###### - Capabilities

Concerning *functional capabilities*, the Occitanum OL VITI LL benefits from a high level of technical expertise in viticulture. Nonetheless, beyond technical know-how, stronger management and organisational capabilities are needed, particularly in assessing the reliability of AgTech companies and securing long-term partnerships. Likewise, fundraising and stakeholder engagement are recognised as important skills to attract financial resources and expand (mainly) farmer participation.

Furthermore, in regard to *dynamic capabilities*, within the Occitanum OL VITI LL a lack of interest among younger generations in agriculture is observed, raising concerns about farm succession. Despite this, the LL demonstrates a strong ability to facilitate dialogue, engagement and helping stakeholders express their needs and co-develop solutions. However, as mentioned above, difficulties remain in enhancing adaptive capabilities, particularly in tailoring digital technologies to the specific demands of viticulture and local conditions.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes. These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The Occitanum OL VITI LL is comprised of a diverse network of stakeholders. An important group of actors in the LL are the cooperatives, which facilitate farmer participation and provide access to facilities, production structures, and specialised equipment (material resources). Organisations such as CUMA (Cooperative of Mutualisation of Agricultural Machinery), Vinnovalie, and Cave de la Bastide (**actors**) play a role in ensuring that farmers have access to both technical knowledge and shared resources. Additionally, a competitiveness hub serves as an intermediary between agritech companies and end-users.

In parallel, research institutions, particularly INRAE (as coordinator of Occitanum) and IFV, serve as governance enablers, providing structural methodologies for governing the LL (**governance system**), experimental facilities, and research-based knowledge that support both innovation and collaboration. Additionally, the Institut Agro contributes to training and capacity-building of stakeholders.

Nevertheless, the LL faces a demographic challenge. While both farmers and advisors (**actors**) demonstrate a proactive attitude toward change, the ageing farming population, with an average age exceeding 55 linked often to a lack of interest of new generations, poses a serious obstacle to farming generational succession and potentially slow down the uptake of digitalisation efforts in viticulture.

Alongside these challenges, AgTech companies (**actors**) have a dual role in the LL. On the one hand, they contribute to co-developing digital solutions, providing manpower, product development capabilities, and new software applications. On the other hand, their financial instability presents a major hurdle, hindering collaboration and limiting the continuity of ongoing projects and technology implementation.

Furthermore, second-level organisations (**actors**) serve as intermediaries between technology providers and end-users. For instance, the Chamber of Agriculture enables technical knowledge transfer, facilitates stakeholder interactions, and plays an active role in animating the LL by linking farmers with emerging digital solutions. Similarly, the CRAO (Regional Chamber of Agriculture Occitanie) contributes to training and collaboration, holding an influence in shaping stakeholder engagement.

The governance methodology (**governance system**) provided by Occitanum serves as an enabler of collaboration, offering a structured framework that facilitates interaction between stakeholders. However, it is also perceived as a hindrance, as its large and complex structure often leads to rigid processes, limiting the LL's ability to quickly adapt. Another obstacle regarding governance involves financial rules and funding schemes. The rigidity of financial regulations creates barriers for certain stakeholders, making it difficult for some actors to access funding.

In addition, contractualisation poses a legal hurdle, particularly regarding the contribution of partners to digital innovation, mainly farmers. The legal complexity of defining intellectual property rights (**governance system**) creates uncertainties in recognising and compensating stakeholders (mainly farmers) for their contributions.

As part of the broader Occitanum ecosystem, which includes 13 different Living Labs, the LL gains access to knowledge-sharing and resource pooling (**resource units**). Furthermore, the DigiFermes Network further reinforces the LL by integrating it into a national network of experimental and demo farms focused on digital agriculture. The Call of Interest process also fosters collaboration and innovation by identifying the most suitable digital technologies tailored to user needs.

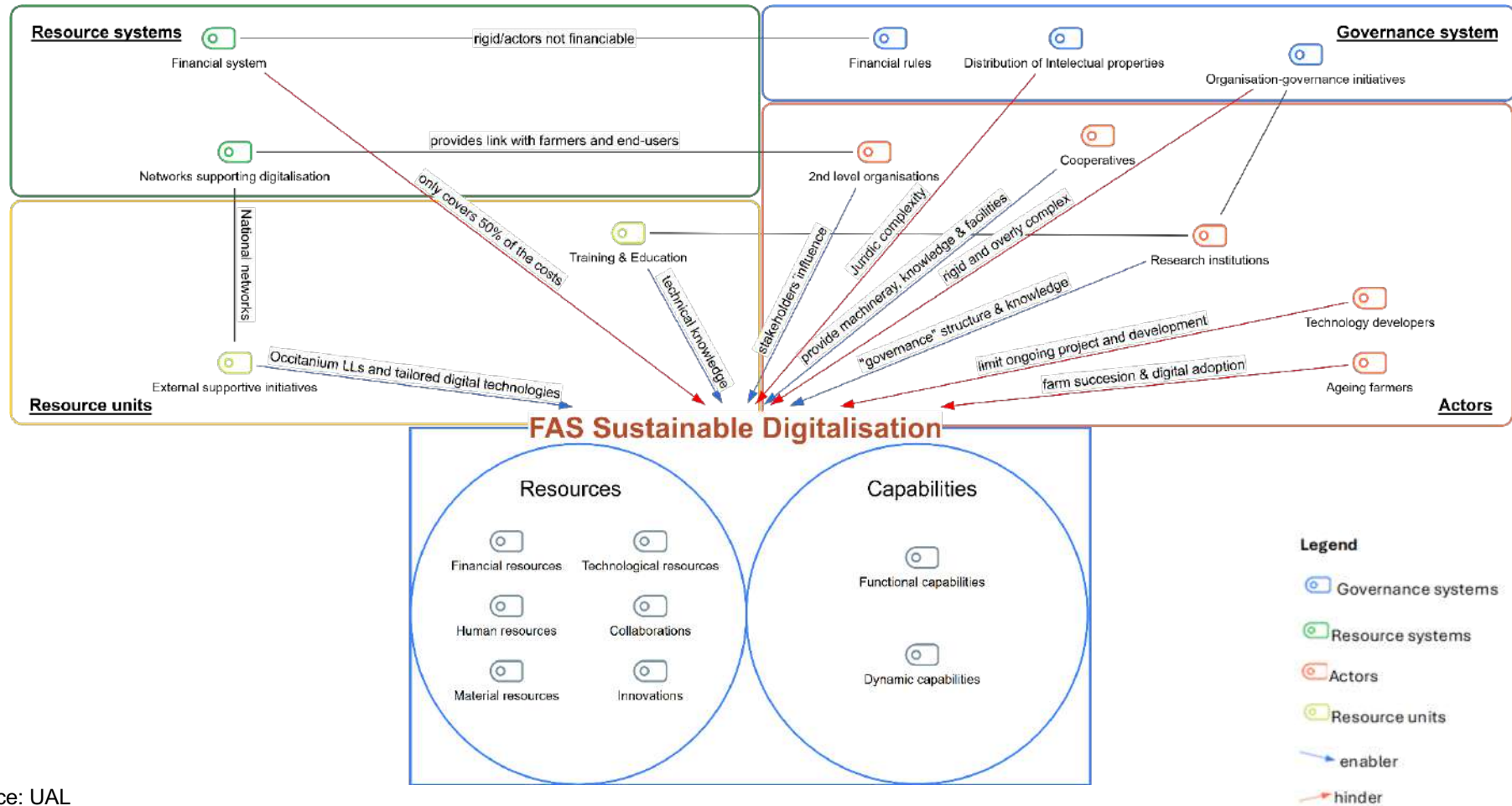
Notwithstanding, funding schemes (**resource systems**) remain a constraint. Public funds from the state and regional levels only cover 50% of project costs, restricting financial flexibility. Moreover, financial rules (**governance system**) are rigid, and some actors are not eligible for funding.

Beyond financial constraints, the LL has access to specialised training modules (**resource units**) designed to support digitalisation. Examples include, Vivea and Mobilab, training organisations (**actors**) focused on the agricultural sector which provides targeted training in digital agriculture, enhancing stakeholders' skills and capacity building.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL.



Figure 18. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Automation of orchard management LL.



Source: UAL

**Conclusions and summary**

The Occitanum OL VITI LL in France illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, the Occitanum OL VITI LL possesses its strong multi-stakeholder network, which facilitates collaboration, knowledge exchange, and resource access. Cooperatives and second-level organisations play a key role in farmer participation, access to material resources, including production structures, equipment, and technical knowledge transfer.

Research institutions contribute to scientific expertise, structured methodologies, training, and capacity-building, fostering innovation and collaboration and allowing the exploration of digital technologies aligned with stakeholders' needs. The broader Occitanum ecosystem, comprising 13 Living Labs, enhances knowledge-sharing, while DigiFermes integrates the LL into a national network of digital agriculture experimental farms. Additionally, programs provided by training organisations enhance the development of digital skills and support the transition towards precision viticulture.

In terms of **hindrances**, the LL faces demographic challenges, particularly the ageing farming population, which create uncertainty regarding generational renewal and technology adoption. As well, financial constraints remain a barrier and rigid financial rules prevent some stakeholders from accessing funds, limiting the LL's ability to implement and scale digital solutions. In terms of governance, while the Occitanum framework enables collaboration, its large and complex structure hinders agility, creating rigid processes and slow decision-making. Similarly, contractualisation (which refers to the juridic complexity to address the contribution of partners) presents legal challenges, particularly in defining intellectual property rights and recognising farmers' contributions to digital innovation.

In conclusion, the digital ecosystem of the Occitanum OL VITI LL shows enablers and hindrances (see Figure below), in terms of enablers a robust network of stakeholders and access to regional and national digital agriculture initiatives, all of which promote collaboration and capacity-building. However, financial constraints, governance complexity, and demographic challenges continue to limit the LL's ability to integrate and scale digital technologies.

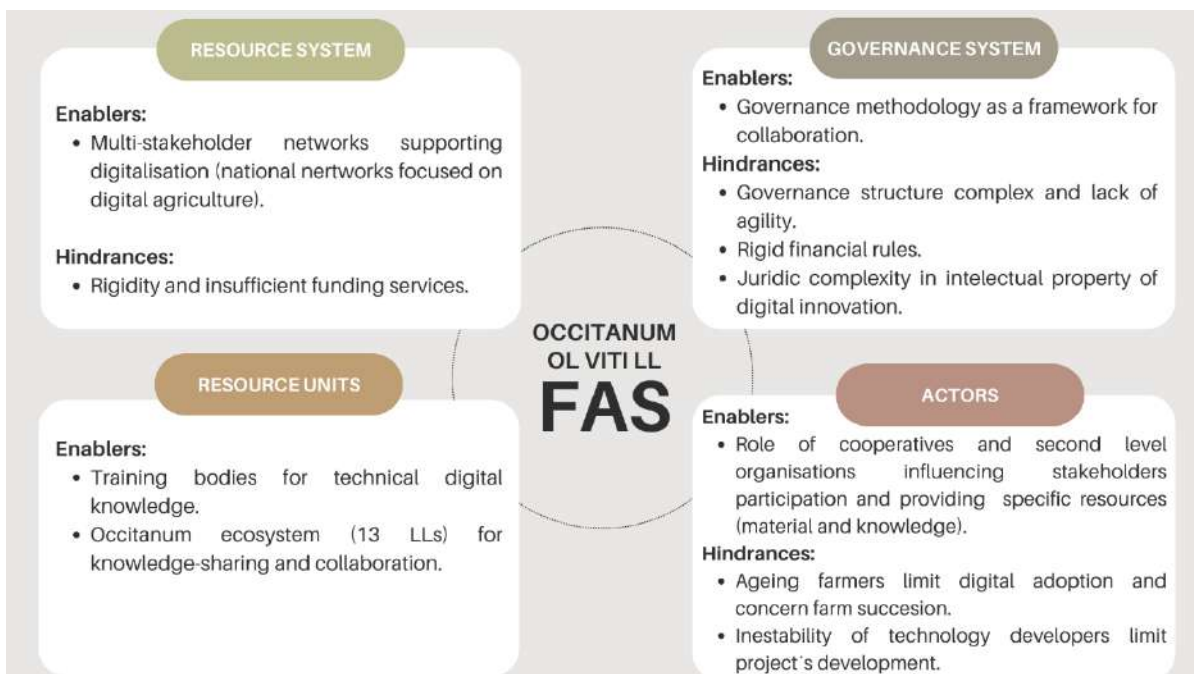


Figure 19. Main enablers-hindrances of Occitanum OL VITI LL.

Source: UAL

#### 4.1.5 AgDiBi Living Lab (Germany)

##### Introduction

The AgDiBi LL, located in Germany, focuses on knowledge transfer related to digital technologies to enhance the application of digital and precision farming technologies in crop production. Researchers, demo farms, agricultural teachers, and an agricultural state institute collaborate with students and farmers to develop an educational format centred on digital and precision farming technologies. This initiative aims to support knowledge building on digitalisation in a sustainable and long-term manner. The LL is dedicated to social and organisational innovation, working towards creating a digitally literate agricultural community

The stakeholders of the AgDiBi LL describe the focal action situation (FAS) as follows:

*"AgDiBi in Germany works on knowledge transfer on digital technologies to increase the application of digital and precision farming technologies in crop production".*

The LL's primary objective is to support knowledge building on digitalisation in vocational education for prospective farmers and agricultural educators. This is achieved through a collaborative approach that integrates the expertise of researchers, demo farms, agricultural teachers, and state institutes, ensuring that the educational format developed is both practical and sustainable in the long term.

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key resources identified for the sustainable digitalisation of the AgDiBi LL were material resources, such as digital devices and technical equipment e.g. sensors, beamer, audiosystems, but also land/fields and material infrastructure to set up a demo farm to develop the activities. Technological resources including technologies for precision in fertilisation, crop-animal production, fertilisation map development and wireless data transfer were also outlined. Within these, a planning software for fertilization and documentation, Düngung-BW, provided by the federal state was stressed as an important resource for the LL.

In terms of financial resources, stakeholders mentioned investment subsidies programmes for the development of the activities. As well, time was stressed as a relevant resource due to the limited time of teachers within their schedule to engage with the digitalisation. Along this line, teaching materials that develop the knowledge in agronomy and digitalisation for vocational education students was highlighted, including a didactical methodological approach towards teaching digitalisation.

Finally, regarding collaborations (as a resource) stakeholders described the importance of collaborations between education institutions and research, but also with the demo farm and public authorities. Stakeholders also outlined that there is a further need to develop collaborations between the LL and other actors such as technology developers, technology dealers, advisors and other vocational training farms.

###### - Capabilities

Concerning functional capabilities, stakeholders stressed that within the LL there is know-how, practical experience, in agronomy, digitalisation and didactic/education. Also, the LL the learning interest of students in digitalisation was mentioned as an important capability. On the other hand, stakeholders stressed the need to improve the capacity to analyse data especially related to georeferencing soil samples.

In regard to dynamic capabilities, stakeholders of the LL remarked the importance of integrating knowledge by bringing together theory and practice in digitalisation, being the demo farm an example of this as it provides a platform to connect teaching and research. Stakeholders pointed to the need for further development of capacities related to determining key competences on digitalisation and creating trust/confidence in digitalisation.

##### Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes of the AdDiBi LL. These elements of the systems not only set the conditions

for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is represented by a diverse range of actors, including a university (University of Hohenheim), which has a strong influence on the LL as reported by stakeholders, two vocational schools and a technical school who are in charge of the practical and theoretical training, public authorities (Landesanstalt für Landwirtschaft, Ernährung und Ländlichen Raum; and Landratsamt Böblingen) in charge of the training at country level, a demo farm (Ihinger Hof) and a collaborating research project in the demo farm (5G-PreCise). Furthermore, other actors collaborate and/or influence the LL these include the German Ministries of Agriculture and Education, which has a supervisory role, vocational training farms and technology developers and vendors.

A key element enabling the digital ecosystem of the AgDiBi LL is the education system (**resource system**) whose network of technical and vocational schools and public authorities at different levels provides a structured educational programmes-curricula (**governance system**) for vocational and technical training at school and farm level, with detailed instructions on learning contents for advanced training linked to agriculture and digitalisation. These elements are stressed as key for the development of education and training (**resource units**), enhancing trust on digitalisation (**resource unit**) and some of the resources and capabilities described in the focal action situation such as teaching/learning materials, didactic knowledge and the learning interest of students on agriculture and digitalisation. In addition, stakeholders of the LL also highlighted the relevance of training opportunities for teachers which are currently limited.

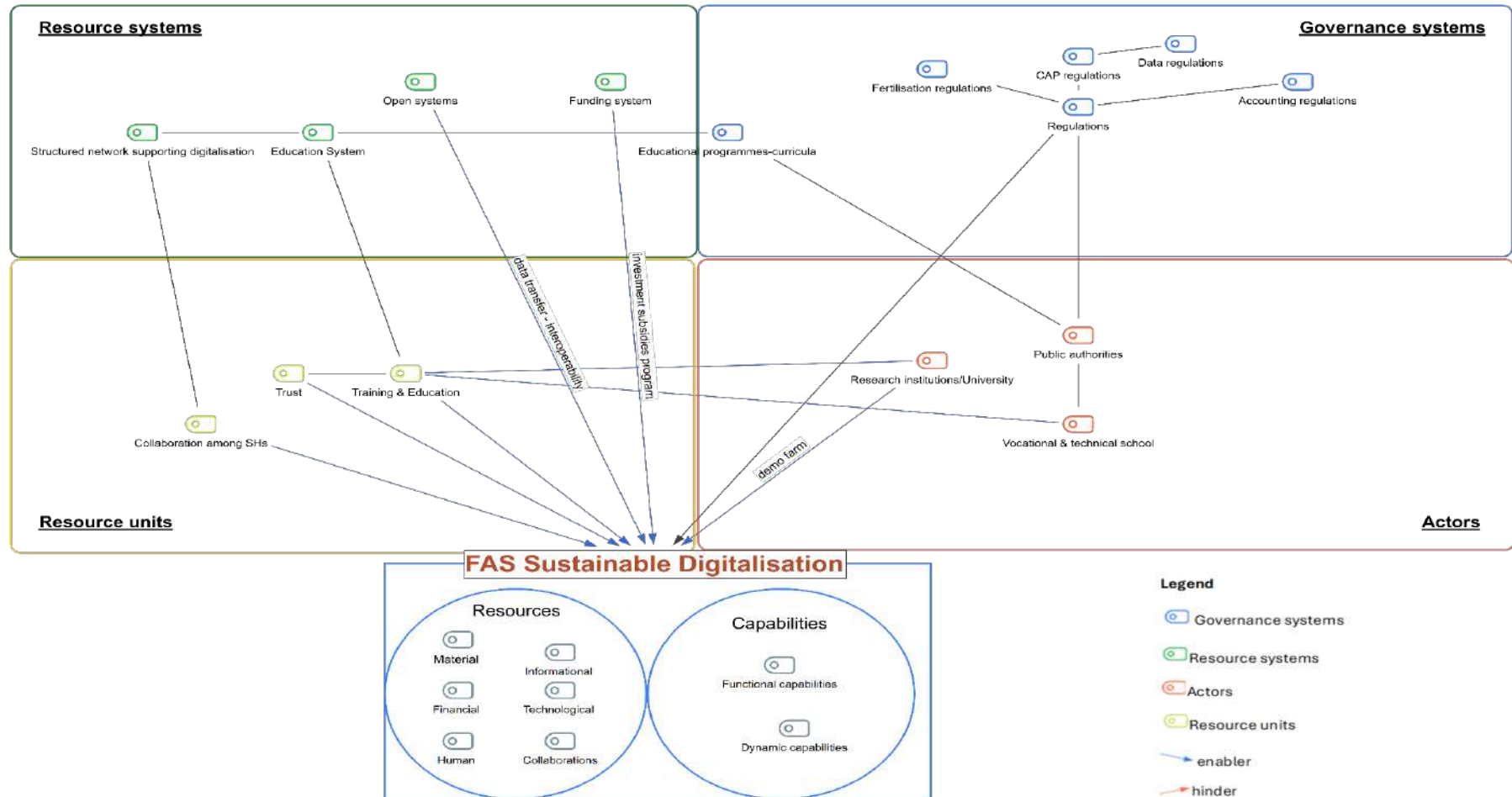
In addition, the elements compounding the education system form a structured network supporting digitalisation in agriculture (**resource system**), in this case from an educational perspective. The network also includes some research actors, thus enhancing the integration of education and research. Despite this, stakeholders highlighted the need to complement this network with greater synergies and collaborations with other stakeholders (**resource units**) such as technology providers, advisors and more vocational training farms.

Stakeholders also emphasised the relevance of the funding system (**resource system**) related to investment subsidies programs which enable investment in farming technologies, having an indirect effect on vocational training and therefore influencing the digital ecosystem of the LL. Furthermore, stakeholders of the LL mentioned the importance of wireless data transfer, which is facilitated by the availability of open systems such as LoRaWAN (**resource system**).

Finally, stakeholders highlighted key elements for the digital ecosystem such as regulations related to fertilizers application and documentation (**governance system**). Examples include fertilisation regulations that digital technologies need to comply with; accounting regulations for enterprises that farms must follow; and data regulations, for example guidelines to fill out information and data about land use for CAP (FIONA regulations).

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in AgDiBi LL

Figure 20. interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in AgDiBi LL.



Source: UAL

**Conclusions and summary**

The AgDiBi LL in Germany presents several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below). In terms of **enablers**, the educational system supports a structured programme on vocational and technical training on agriculture and digitalisation. Within the system a structured network of institutions also acts as an enabler. Moreover, at LL level the collaboration between educational, research, and public administration entities act as enablers. These actors, collaborations and networks enable education and training and trust on digitalisation, integrating education and research for the development and transfer of knowledge and know-how. The funding system which contains an investment subsidies programme also constitutes an enabling element as well as, the availability of open systems and reliable IT infrastructure.

In terms of **hindrances**, despite collaborations between some stakeholders there is a need to improve the engagement-collaborations with technology providers, advisors and vocational training farms. Time and more training opportunities for teachers have also been outlined as hindering elements.

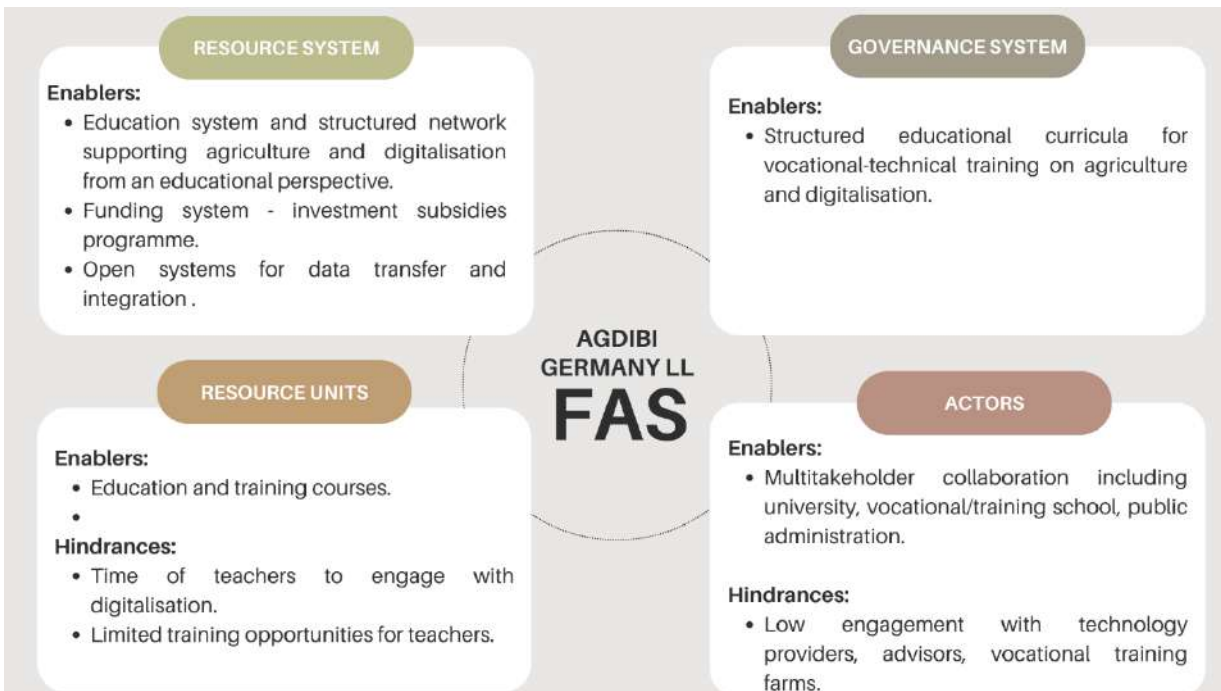


Figure 21. Main enablers-hindrances of AgDiBi LL.

Source: UAL

**4.1.6 Spraying drones Living Lab (Greece)**

**Introduction**

The Spraying drones LL, located in Greece, focuses on vineyard spraying and crop protection, leveraging advanced digital technologies to enhance the productivity, profitability, and sustainability of agriculture. It aims to assess and analyse the best drone spraying configurations for field use, comparing them with conventional spraying machinery like terrestrial boom and mist sprayers to evaluate their spraying quality

The stakeholders of the Innovative Soil Scanner LL describe the focal action situation (FAS) as follows:

*"The Greek LL is working on vineyard spraying and crop protection, utilising advanced digital technologies to enhance the productivity, profitability, and sustainability of European agriculture compared with conventional techniques".*

To achieve this, the LL employs spraying UAVs (drones), GIS, sensors, IoT stations, LiDAR for altitude adjustment, and vision systems, which are currently at Technology Readiness Level 9 (TRL 9).

### **Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation**

#### - Resources

Key resources identified for the sustainable digitalisation of the Spraying drones LL include material resources, such as land to develop demonstrations and advanced equipment including spraying machinery to ensure a well-equipped environment for experimentation and innovation. Similarly, technological resources including sensor technologies, software and open data for improving efficiency of the spraying were also highlighted by stakeholders as essential resources for digitalisation.

In terms of financial resources, grants and subsidies have been stressed as needed to maintain continued financial support for the LL. In addition, stakeholders from the LL pointed that financial constraints may limit the ability to invest in expensive technology, and the LL faces challenges in securing funding for research and development. In order to partially address the risk of investing in expensive technologies, stakeholders described the importance of insurance services as a way of compensation for investment risk, particularly in light of climate change.

Knowledge was also highlighted as a key resource for the LL; especially technical knowledge related to spraying techniques and appropriate dosage levels which should be considered while considering environmental aspects. In this regard, stakeholders mentioned that limited technical knowledge can make it difficult to adopt and adapt to new technologies, which can hinder the successful implementation of innovative spraying practices. In terms of information, stakeholders stressed the relevance of having communication strategies and activities to disseminate research results, this being an aspect to improve within the LL.

Finally, collaborations (as a resource) with cooperatives, producers, universities/research institutes, and the private sector have been emphasised. However, stakeholders described that until now, there has been no collaboration with other LL to promote an interconnected network of collaborative efforts and that it would be helpful to engage with and utilise the collective expertise of other LL, sharing insights, methodologies and innovative approaches.

#### - Capabilities

Concerning functional capabilities, the Spraying drones LL stakeholders mentioned that practical experience fosters a deep understanding of the challenges and opportunities in the LL and that expertise and know-how in industry best practices represent a driver for innovation and problem-solving ability. Stakeholders also remarked on the relevance of organisational innovation, meaning systematically sharing information, communicating data smoothly, and strategically disseminating information to help promote and guide specific action initiatives. Complementary, digital skills were mentioned not only in terms of managing the technology of drones for spraying but also to be able to access, manage, analyse and to interpret data.

Furthermore, in regard to dynamic capabilities, attitudes towards change and innovation were stressed, according to stakeholders this is influenced by factors such as education, technical knowledge and financial security, such as compensation for risk investment. Moreover, stakeholders outlined the relevance of being able to transfer-disseminating knowledge and information and more specifically of communicating in an efficient manner research results into practical applications/solutions for farmers, the lack of this capacity currently constitutes a hindering element for the LL. The ability of testing solutions in controlled and real-world environments to evaluate the effectiveness of new technologies and practices, such as for example in demo farms, was also reinforced. Finally, the advocacy capacity of farmers to actively participate in decision-making and legislation, expressing their concerns and helping to develop regulations that address practical challenges on the ground, was also mentioned as a relevant capability for conducive digital ecosystems.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes of the Spraying drones LL. These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is represented by a diverse range of actors, including farmers, research institutions, and companies providing technology equipment and services. Furthermore, other actors collaborate and/or influence the LL, these include consulting companies, agricultural supply stores, other technological companies, certification bodies, the Hellenic Crop Protection Association and legislative authorities.

Within the LL farmers were mentioned as key actors in their role of providing valuable feedback to the technologies but also as protectors of the environment. Research institutions/universities (**actors**) were stressed by their role in analysing data and the procedures facilitating the demonstrations for testing the technologies. Regarding technological companies (**actors**), these play a crucial role in supplying resources such as advanced equipment and services aimed at improving spraying efficiency, including spraying machinery and sensor technologies (**resource units**). In this line, agricultural supply stores (**actors**) were noted in their role as providers of inputs and tools available in the market to enhance spraying efficiency, thus enabling the acquisition of cutting-edge technologies and products (**resource units**).

Advisors from the public and private sector were also described as relevant actors for the LL, however, stakeholders mentioned that consultancy in Greece is still weak. One of the actors providing advice to the LL is a national second level organisation, Hellenic Crop Protection Association, which as a representative body for crop protection provides industry experience and advice on best practices and developments in crop protection technologies. In addition, the association also plays a role in providing regulatory insights and it helps the LL to coordinate its operations with industry standards and compliance with regulatory requirements (**governance system**). Also, in relation to standards compliance certification bodies (**actors**) have been highlighted as relevant to ensure that the spraying techniques and technologies used in the Living Lab meet strict guidelines for effectiveness, safety and environmental impact. Finally legislative authorities (**actors**) were recognised for their role of filling a regulatory gap regarding spraying (**governance system**).

In terms of governance, the absence of a specific legislation covering drone spraying and an appropriate regulatory framework is perceived by stakeholders as a hindering element as they stressed that guidelines and standards should be established to promote collaboration, encourage investment, and facilitate the integration of innovative technologies into farming practice. Stakeholders reinforced the relevance of compliance with public legislation but also to private certification standards (**governance system**) which enhances the credibility of the LL initiatives, fosters trust among stakeholders (**resource units**), and promotes the wider adoption of innovative solutions. A final relevant element in terms of governance identified by stakeholders of the LL is the participation of farmers (**actors**) in influencing legislation, so they are heard and can express their concerns and help to develop regulations that address practical challenges on the ground. According to stakeholders this inclusion of farmers' views strengthens cooperation, encourages innovation and ensures that regulations meet the needs of the farming community (**governance system**). In this regard, access to instant information on CAP legislation, particularly in areas such as crop protection, enables the LL to align its activities with regulatory requirements. Conversely, delays or non-compliance may arise if immediate legislative information is not accessible, hindering the implementation of new solutions.

As mentioned above, stakeholders of the LL highlighted the relevance of access to information and knowledge (**resource units**) as a key element for digital ecosystems conduciveness. Within this, in regard to data access, stakeholders remarked the importance of data transparency and accessibility through the adoption of an open data approach within open IT systems (**resource systems**). Furthermore, stakeholders outlined the relevance of efficient data storage and processing systems (**resource systems**) to facilitate the collection, analysis and interpretation of data. In this context, inefficient systems for dissemination of research and educational material limit stakeholder awareness and understanding of innovative spraying solutions.

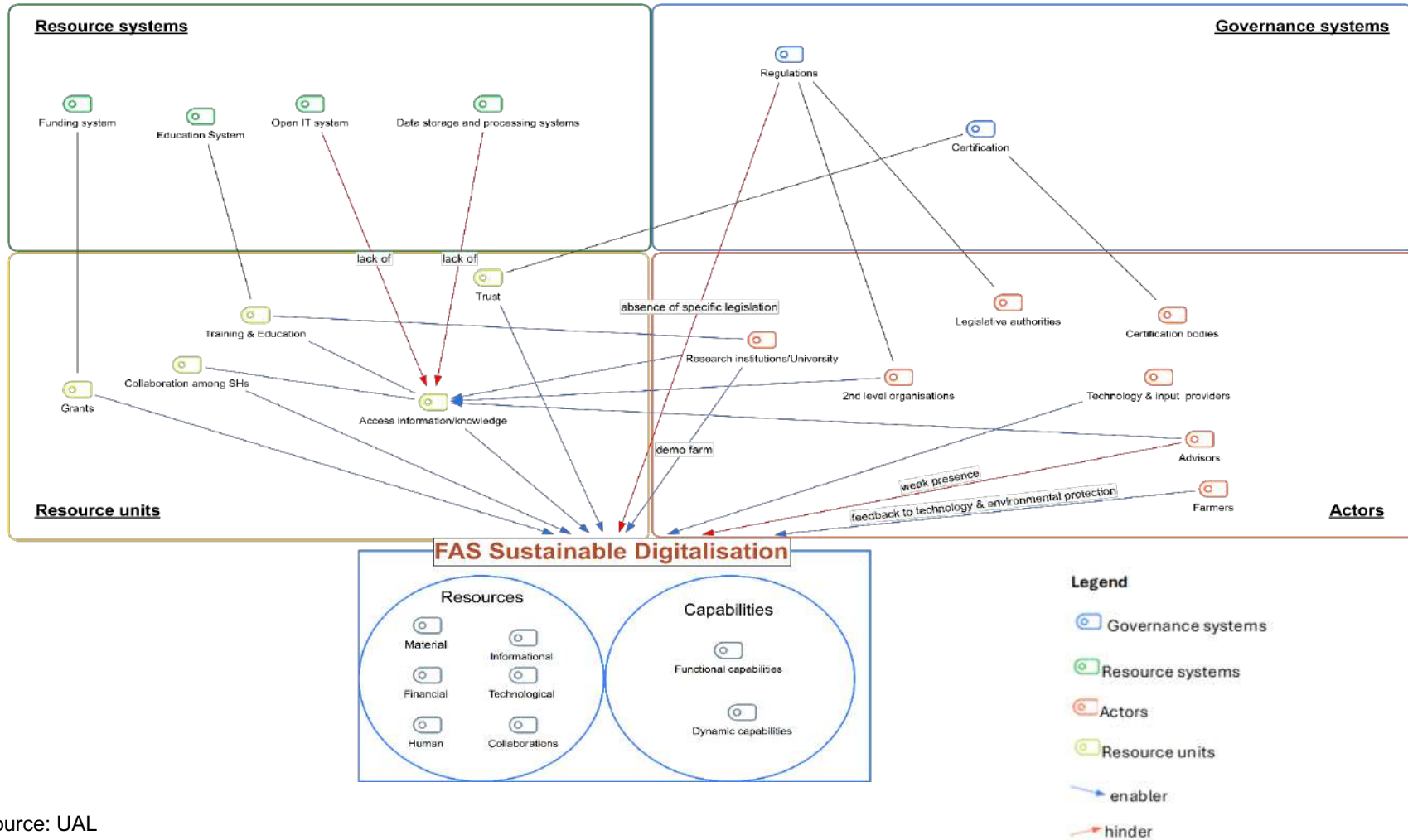
The funding system (**resource systems**), and especially grants (**resource units**) were also outlined as key elements providing funding to acquire necessary resources, technology, and expertise, supporting research and development activities. Education and training (**resource units**) were also relevant elements highlighted by stakeholders of the LL. In this sense, the LL engages with the education system (**resource system**) to provide clear and structured learning experiences, training programmes and educational resources for a range of stakeholders. Limited education makes it harder for people to accept change or understand complex technology and it possesses challenges for the adoption of new spraying solutions. Finally, collaboration among stakeholders of the LL and



beyond it (**resource units**) were mentioned as an enabling element for developing resources and capabilities needed for digital ecosystems conduciveness.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Spraying drones LL.

Figure 22. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Spraying drones LL.



Source: UAL

**Conclusions and summary**

The Spraying drones LL in Greece presents several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation. In terms of **enablers**, The LL benefits from the availability of material and technological resources including a demo farm, drones, sensor technologies and access to some data. Also, despite financial constraints some grants are also available for the development of the LL. Moreover, a well-established network of actors, including farmers, research institutions/university, technology companies and collaborations with other stakeholders which also contribute to enabling material, technological, and knowledge resources. Within these collaborations, a national second level organisation is key in providing industry experience and advice on best practices as well as regulatory insights for compliance. Clarity from certification bodies is also an enabling element as certification, in turn, creates trust among stakeholders. The advocacy capacity of farmers and education and training through structured learning experiences, training programmes and educational resources are also enabling elements for sustainable digitalisation.

In terms of **hindrances**, the absence of a specific legislation covering drone spraying and an appropriate regulatory framework is perceived by stakeholders as a hindering element, also lack of communication strategies to establish a clear dissemination of research results and its application for farmers. In this regard, challenges in accessing information and knowledge, and especially open access to data has also been pointed as a hindering factor, partially due to a lack of open IT systems that could enable it and to the need of efficient data storage and processing systems. Finally, limited presence of advisors and limited technical knowledge from farmers is seen as linked to risk aversion and blocking their willingness to innovate.

In conclusion, the digital ecosystem of the Spraying drones LL presents both enablers and hindrances (see Figure below). The digital ecosystem of the Spraying drones LL is characterised by strong enablers in the form of actor involvement, collaborations, and material and technological resources availability, which support the implementation and testing of digital technologies. However, hindrances such as limited technical knowledge, data accessibility issues, and regulatory gaps represent hindrances to the digital ecosystem's conduciveness.

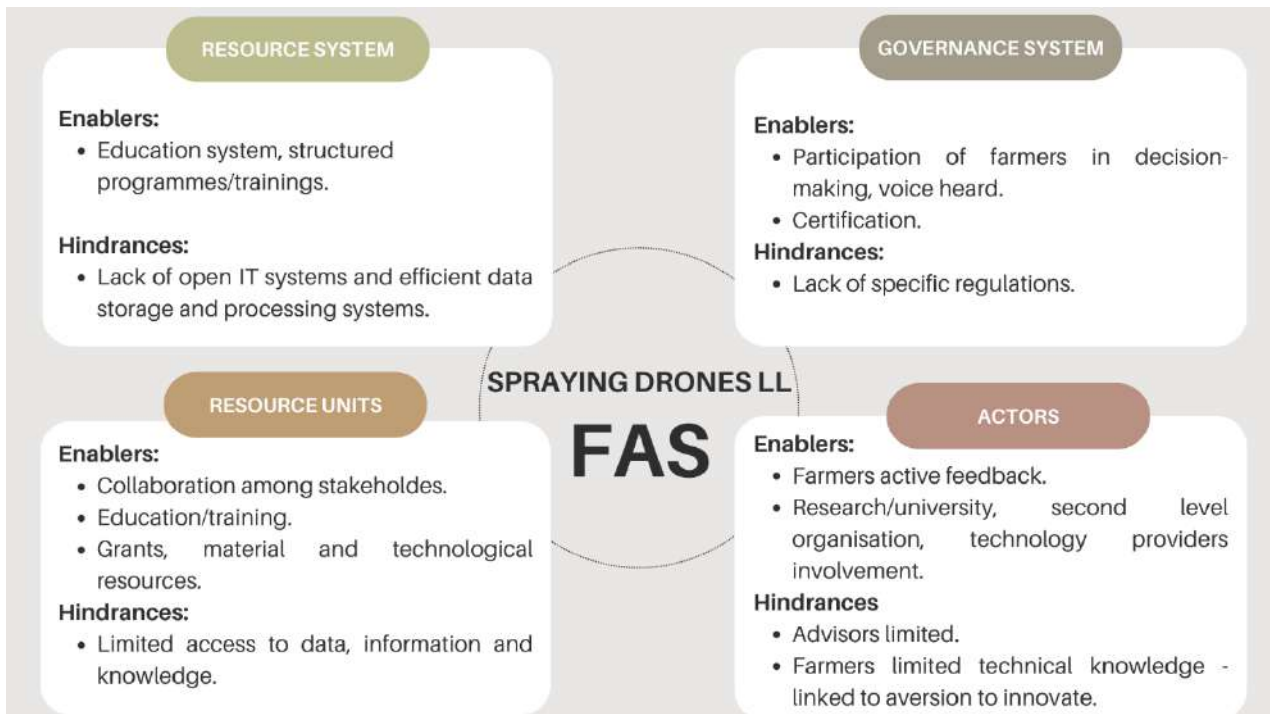


Figure 23. Main enablers-hindrances of Spraying drones LL.

Source: UAL



#### 4.1.7 Innovative Soil Scanner technology for sustainable farming Living Lab (Hungary)

##### Introduction

The Innovative Soil Scanner LL, located in Hungary, focuses on the use of digital technologies for optimising fertilisation in arable crops. Its goal is to reduce environmental impact and improve fertiliser efficiency through site-specific application, ensuring better nutrient distribution while minimising economic damages for farmers.

Traditional, non-site-specific fertiliser application leads to environmental stress, uneven nutrient distribution, and financial inefficiencies. Additionally, older generations of farmers often resist adopting new technologies, maintaining a 'we've always done it this way' approach to soil management.

The stakeholders of the Innovative Soil Scanner LL describe the focal action situation (FAS) as follows:

*"To mitigate environmental stress, nutrient imbalance, and economic losses caused by non-site-specific fertilisation, while addressing farmers' resistance to new technologies through an easy-to-use soil scanner system."*

To achieve this, the LL employs an innovative soil scanner with sensors and cloud-based data storage currently at Technology Readiness Level 9 (TRL 9).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified for the sustainable digitalisation of the Innovative Soil Scanner LL include a combination of resources. Material resources, such as land for testing, provide an opportunity for adaptation studies, ensuring that the soil scanner technology is tailored to the environment. Additionally, the LL benefits from a university farm, which provides the necessary infrastructure for organising demonstrations

Technological resources also influence the LL structure, particularly through its cloud-based database and its digital platform that allows members to better understand each other's needs while strengthening community creation through empathy and tolerance.

Sustainable digitalisation is also reinforced by human resources. A dedicated advisory support team provides guidance on nutrient optimisation and the use of digital tools, increasing the technical knowledge already available in the LL. Furthermore, the LL has an established professional network (community of practice), which accelerates trust-building and knowledge exchange although emphasis needs to be placed on cooperation. Similarly, the feasibility and ease of integration of the soil scanner system in the farms enable adoption by farmers.

###### - Capabilities

Concerning functional capabilities, the Innovative Soil Scanner LL balances stakeholders' interests through a common platform, where members with diverse perspectives collaborate and define shared goals through a participatory approach. Additionally, networks and community engagement support data collection and analysis, enhancing decision-making. However, beyond technical expertise, the LL needs stronger management and organisational capabilities, particularly in developing problem-solving skills among both individual farmers and the broader community.

Furthermore, in regard to dynamic capabilities, the Innovative Soil Scanner LL demonstrates a strong ability to communicate stakeholders' needs, supported by a high level of community awareness and peer support within the LL. A key strength of the LL is its high level of interactivity, that combined with a participatory approach (also considered part of the innovation), ensures that stakeholders engage in decision-making. Moreover, the LL has the capacity to generate results and test them (very important for farmers), creating transferable information and knowledge flows. However, improving knowledge transfer remains a key challenge, requiring efforts to reduce information overload and developing effective communication strategies to ensure a better translation of research results into farmers' language for more effective application in practice.

Additionally, strengthening lobbying power is stressed as an important ability to be developed, as stakeholders pointed out that a community with strong advocacy capacity is better able to express its needs and priorities in decision-making processes, ensuring that its voice is heard in political and economic discussions.

## Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation

The resources and capabilities above mentioned are enabled and/or hindered by elements of the systems which participate in the digitalisation processes of the Innovative Soil Scanner LL. These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is represented by a diverse range of stakeholders with a high level of interaction and cooperation, the common platform (resource) allows a participatory approach (**governance system**) where stakeholders understand each other and the needs of their community, which help in building trust and corporations. The Digital Academy of Agriculture as a disseminator (**actors**) have been identified as facilitator of the LL's communication strategy, stressed by stakeholders for enhancing the visibility of its products and informing consumers, thus raising awareness and transferring knowledge.

In this context, other actors such as advisors and their collaboration networks (**resource units**) have emerged as the primary channels for knowledge transfer. These advisors work alongside research institutions, which through demo-farm networks, ensure that scientific advancements are translated into practical applications within the agricultural sector and provide the evidence through testing an important aspect for stakeholders, and especially for farmers.

Farmers (**actors**) are declared as proactive in collaborating and showing a clear need for digital innovation. They act as leaders and local decision-makers, being able to provide tailored responses to the local needs. Nonetheless, pioneering actors in this domain can have both positive and negative influences, as for example, groups radically committed to a specific technology, such as zero tillage can be harmful.

In addition, technology developers (**actors**) as Agrocares have been recognised with an undeniably fundamental role in the LL, they provide technological tools such as software and real-time digital monitoring solutions, which make digitalisation feasible. Moreover, technology providers also contribute to the process through training, improving the ability to manage digital solutions and this way promoting the willingness to innovate and change.

Similarly, certification bodies (**actors**) were pointed out as indispensable in licensing procedures. Meanwhile, public administration is seen as an element that shapes the environment for agricultural development and sustainable practices through its ability to influence regulatory frameworks (**governance system**). However, a lack of communication and collaboration of public institutions with the LL has been identified as an obstacle to the scalability of digitalisation in the context of the Hungarian LL. An improvement of the relations of the LL with public institutions, e.g., Hungarian Chamber of Agriculture or the Ministry of Agriculture, would make regulatory systems more farmer centred.

Building on this, an ill-conceived legal framework (**governance system**) further hinders the efficient use of natural resources such as land. In many cases, farmers are thus forced to farm under different conditions, making it difficult for digitalisation to take hold and work efficiently. The way land is organised (**resource systems**) impacts the implementation of digitalisation in agriculture, and as mentioned above, land provides an opportunity for further adaptation studies. In many cases, industrialisation encroaches on valuable farmland, limiting the space available for agricultural production and technological integration. Conversely, a well-structured farm system fosters the development of sustainable practices communities (**resource units**). Beyond legal constraints, the lack of data-driven precision farming negatively impacts the entire agricultural sector (**resource systems**) and it highlights a gap in data collection but also in its interpretation and analysis. Additionally, it is declared that even social norms related to environmental awareness (**governance system**) when taken to an extreme, can hinder the adoption of digital solutions.

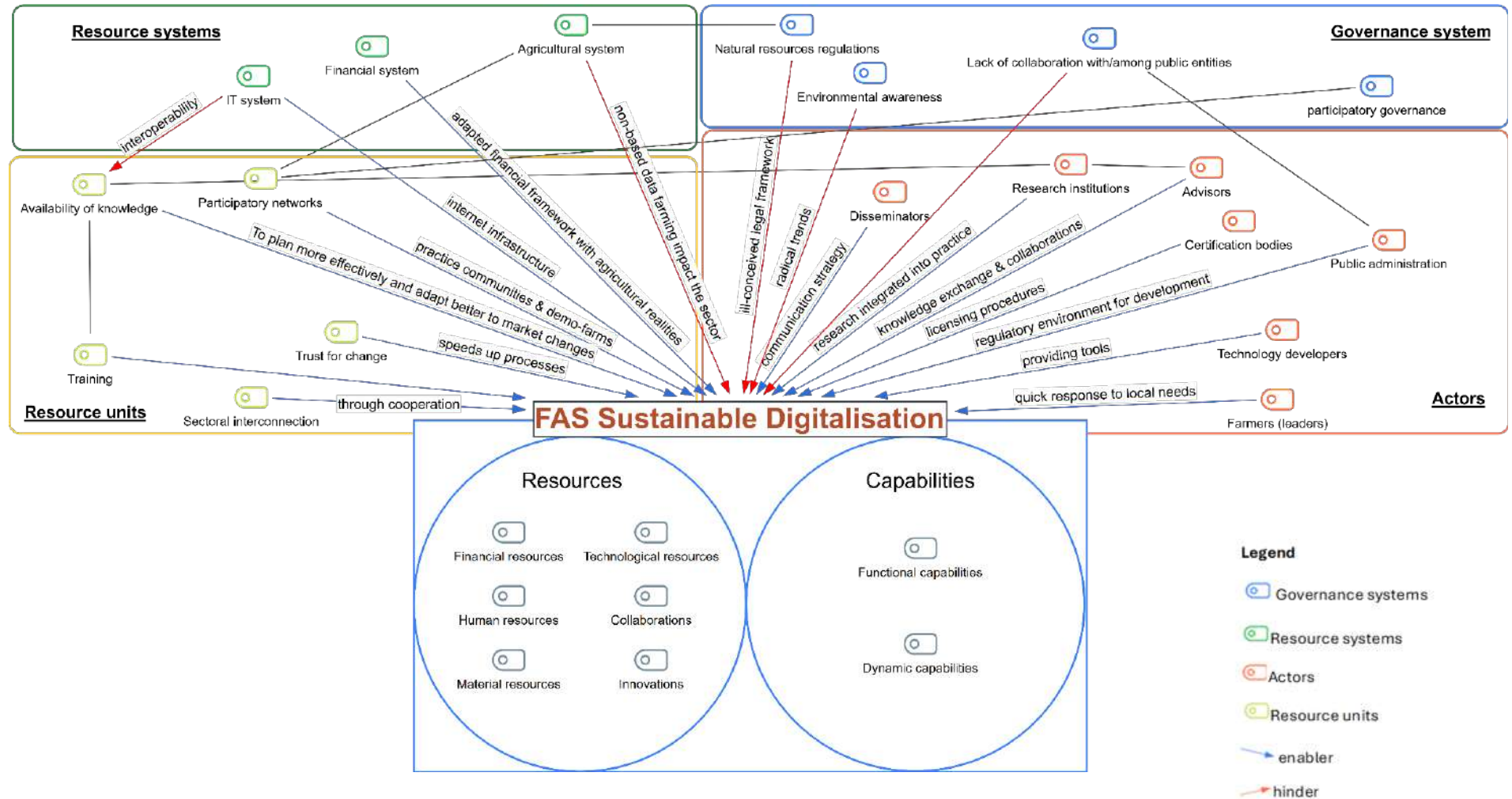
Another factor shaping digitalisation in agriculture is the financial system (**resource systems**). A well-adapted financial framework that aligns industrial economic models with agricultural realities boost the efficiency in production systems. Furthermore, IT infrastructure (**resource systems**) is a fundamental enabler of continuous digital work on farms. Reliable connectivity (**resource units**) allows for real-time monitoring, data-driven decision-making, and automation. In parallel, open IT systems (**resource systems**) would facilitate data access (e.g., to geoinformatics databases), interoperability and compatibility.

Likewise, access to market information (**resource unit**), including product demand, pricing trends, and other key market dynamics empowers farmers and agricultural stakeholders to plan more effectively and adapt to market fluctuations. However, access to information alone is not enough. Trust (**resource unit**) within professional networks plays a key role in accelerating digitalisation. Strong professional relationships streamline processes, foster credibility, and create a community of practice where knowledge exchange and peer support take place, e.g., through a common platform where people with different interests understand each other foster empathy and community awareness. Most importantly, training initiatives (**resource unit**) not only enhance digital skill levels but also increase the willingness to engage in digital solutions. As well as the sectoral linkages offer broader cross-sector benefits of digitalisation.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Innovative Soil Scanner LL.



Figure 24. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Innovative Soil Scanner LL.



Source: UAL

**Conclusions and summary**

The Innovative Soil Scanner in Hungary illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, The LL benefits from a diverse multi-stakeholder network, facilitating collaboration, knowledge transfer, and access to resources. Disseminators, advisors, and research institutions play a key role in communication strategies, ensuring that research findings are effectively translated into practical knowledge for farmers. The LL counts with a demo farm network that brings the benefits of digitalisation and information technology to the agricultural sector. Additionally, advisory networks act as primary channels for knowledge exchange. Farmers actively contribute to the digitalisation of the LL. They act as leaders in responding to local agricultural needs. In addition, a good internet infrastructure allows the continued work in the fields.

Moreover, the existing information flows provide market information that allow better planning and adaptation to changes. The LL counts with a professional networking that speeds up processes and contributes to the trust of stakeholders. In this line, the members of the LL are diverse, the participatory approach allowed by the common platform is considered as a facilitator for better reflecting the needs of the community and for the building of community awareness, commitment and cooperation. Also, a well-adapted financial system aligned with agricultural needs improves efficiency in farming and training new generations, raises skills and increases the willingness to engage in digitalisation initiatives.

In terms of **hindrances**, the LL faces regulatory gaps and a lack of communication within public institutions which limits the scalability of digital solutions. An ineffective legal framework and industrialisation further complicates land use for agriculture and farm technology integration. Non-data-driven precision farming practices negatively impact agricultural efficiency, which point out the lack of data collection, interpretation, and analysis. Environmental awareness is essential, nonetheless, taken to the extreme hinders digital adoption. Additionally, the lack of open systems affects data interoperability and access as for instance to global geoinformatics databases.

In conclusion, the digital ecosystem of the Innovative Soil Scanner LL presents both enablers and hindrances (see Figure below). In terms of enablers, the LL benefits from multi-stakeholder collaboration, advisory and research networks, access to demo farms, and a well-supported communication strategy. However, the LL also faces hindrances such as regulatory limitations, limited coordination with public institutions, land use inefficiencies and absence of open and accessible systems.

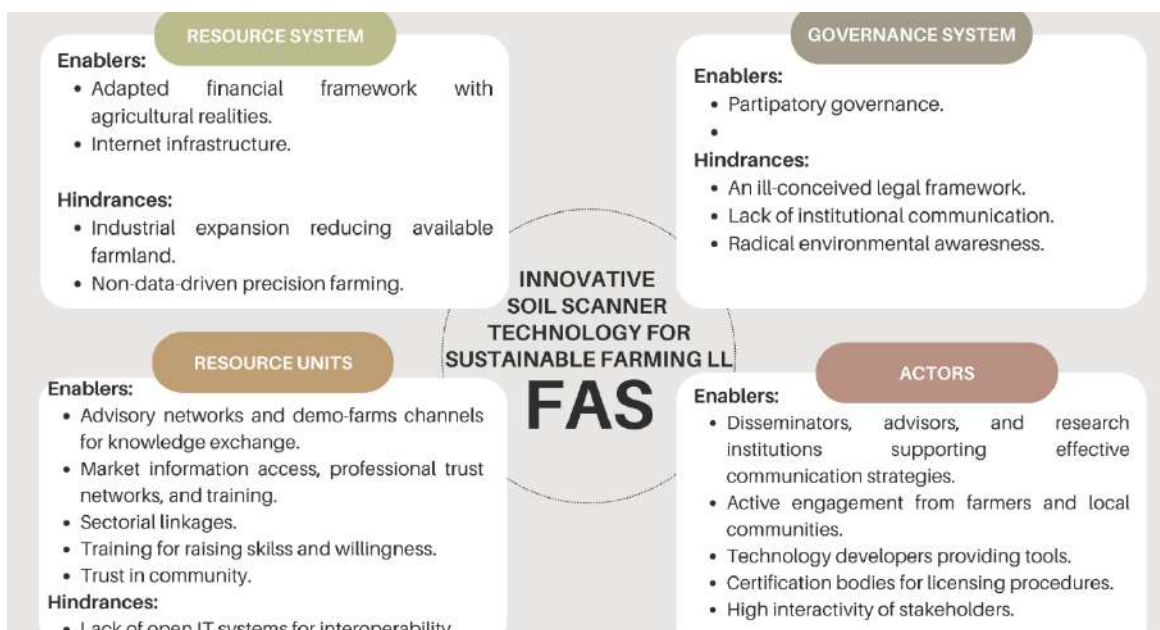


Figure 25. Main enablers-hindrances of Innovative Soil Scanner LL.

Source: UAL

#### 4.1.8 Organic table grapes Living Lab (Italy)

##### Introduction

The Organic Table Grapes LL, located in Puglia, Italy, focuses on the use of digital technologies to optimise organic table grape production. Its primary goal is to improve irrigation management, fertilisation patterns, and pest and disease control.

The stakeholders of the Organic Table Grapes LL define the focal action situation (FAS) as follows:

*"How can we increase the quality and quantity of organic table grape production by reducing the qualitative and quantitative pressure on soil and water resources?"*

To achieve this, the LL employs interconnected sensors at the field level (monitoring soil, environmental, and crop conditions) which are linked to a Decision Support System (DSS) at Technology Readiness Level 8 (TRL 8).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key resources identified by the Organic Table Grapes LL encompass material, technological, human, informational, financial, and organisational elements for sustainable digitalisation.

With respect to material and technological resources the participants of the LL named the integration of weather stations and sensors for data collection with a Decision Support System (DSS), which is central to addressing the FAS problem. They also stressed the need for a virtual physical facility to store all knowledge available, along with low-cost hardware solutions connected to the cloud. Additionally, computer forecasting models and monitoring instrumentation/App were recognised for the optimisation of agricultural practices and for solving the problems they encounter. The BlueLeaf is the digital agricultural platform they use as a support system, and it serves as a key tool for data-driven decision-making. Nonetheless, stakeholders pointed out the need for an easy-to-use App for a smoother implementation of the FAS technology; specifically, they mentioned the need for an application for farmers and advisors that it is not complicated to manage and that keeps people informed about the crop in all the aspects (health, soil, irrigation, etc.).

Sustainable digitalisation is also conditioned by human resources, stakeholders of the Organic Table LL remarked the relevance in particular of agricultural entrepreneurs who, on the one hand, demonstrate a strong openness to digital innovation but who, on the other hand, need training for being up to date and also need technical preparation.

In addition, stakeholders highlighted the lack of time as a common obstacle to raising awareness, communicating and promoting digital innovations. Regarding their awareness and communication activities, the LL maintains relations with the distribution system, research institutions (institute for organic research and historical valorisation-IAMB, the Council for Agricultural Research and Analysis of Agricultural Economics-CREA, University of Bari Aldo Moro-UNIBA), and industry players. One key aspect of those collaborations (research-company actors) is the sharing experiences, data and knowledge.

In regard to information resources, the LL was characterised by presenting and having good data availability, but it suffers from a poor dissemination of the available knowledge. The latter underscores the need for innovations in ways of disseminating new knowledge, technologies and its application. Innovations in the Organic Table Grapes LL are explored from different perspectives (social, technological, informational), and they arise from the need to solve problems through the union of human and technological knowledge. Some other innovations include reduction of plastics guaranteeing the same quality, new varieties strategically oriented to the fruit-growing territorial context, and monitoring systems minimising the need for physical control units in vineyards.

Finally, stakeholders described that financial resources remain a challenge, especially in terms of adequate funding to support technological adoption and research activities. While some private investments are present, additional mixed funding for viticulture research and innovation transfer is required.

###### - Capabilities

Concerning functional capabilities, the LL benefits from a strong technical knowledge base and know-how, grounded in scientific expertise on organic viticulture, irrigation strategies, phytosanitary management and experiences and professionalism developed and matured over years of work, research and field tests. This accumulated knowledge enhances the interaction between individual information/expertise and technological knowledge as an important element for the use and awareness of digital solutions in farms. For example, the ability to monitor and apply forecasting models or even the need for training in data interpretation/analysis and precision agriculture has been highlighted as a key area for improvement of the LL. On the other hand, stakeholders emphasise that there are many data sources available, as for instance, databases, but technicians often lack the ability to discern which ones can actually be useful for applying precision agriculture techniques. So, the tool is available and often has lots of data but there is little critical capacity to understand if that data is useful and how to use it.

Furthermore, regarding dynamic capabilities, stakeholders of the LL mentioned the importance of the ability to listen to diverse stakeholders' needs and adapt accordingly, which is linked to the adaptation of the technologies to the local context. Additionally, the LL emphasised the relevance of peer support and the ability of building a network that integrates diverse experiences and skills. However, stakeholders underlined the need to increase awareness of the value and benefits of data recording and improve their capacity for knowledge transfer. While there have been attempts to establish platforms for knowledge exchange, none have proven to be long-lasting or fully effective.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

Actors such as laboratories companies, e.g. AGROLAB or CLORYSIS were identified as elements to help farmers to carry out their own monitoring by fostering individual capacity to collect data in real time, as well as being key actors that enable the implementation of a user-friendly app that keeps farmers and advisors informed, as they have experience in the use of this type of application and provide training in it (**resource units**).

Regarding farmers (**actors**), their cooperation (**resource units**) was recognised as a way to stimulate the adoption of digital solutions. At the local level, collaboration between farmers, consultants, and agribusinesses was seen as promoting shared approaches to problem-solving and decision-making. However, stakeholders highlighted the need for stronger cooperation across the supply chain, particularly in information exchange, branding strategies, and market positioning. At the same time, digitalisation redefines the role of the farmer in society, i.e. in the mindset of people (**governance system**).

Advisors (**actors**), such as business consultants, were declared as a support for farms in improving quality in products (**resource units**). Their agronomic expertise and farm consultancy services are needed resources and therefore, networks of technicians (structured system of competences of technicians and consultants) (**resource system**) provide adequate information and consultancy (**resource units**).

Research institutions (**actors**) were identified as being actively present in the LL, with key players such as IAMB (an institute for organic research and historical valorisation), CREA, and UNIBA. Collaborations (**resource units**) with research institutions were mentioned as an enabler in understanding agricultural transformations and improving knowledge transfer in a way that is understandable to farms and businesses. However, a lack of research directly applicable to agricultural enterprises and weak connections with real-world farming realities hinder the adaptation of digital solutions to local needs. Moreover, stakeholders claimed that ensuring that research projects and their results remain independent of sponsor or lobby influences is essential for maintaining credibility and fostering unbiased innovation within the LL.

In line with the latter, stakeholders pointed out the need for a greater alignment between scientific research and large-scale distribution (**actors**), specifically regarding phytosanitary issues and residue limits. As mentioned by LL participants, a realistic scientific confrontation with large retailers would help to ensure that regulations (**governance system**) and standards are based on scientific research rather than solely market-driven criteria. Large retailers have decision-making power that often operates independently of producers' needs, impacting product quality and

production practices in accordance with good agricultural practices. They impose economic and market-driven guidelines instead (**resource system**).

Given this scenario, second-level organisations (**actors**) were distinguished for their role in balancing market power (**governance system**). However, stakeholders highlighted a lack of strong producer organisations capable of imposing influence, leaving most control in the hands of private traders or false producers' organisations (**governance system**). Conversely, the existence of other organisations such as AGROFARMA was seen as an enabler for generating innovation in the system and organisations, such as cooperatives with organic product lines or better specialised in organic grapes which allow the use of digital innovation or even the shared use of instrumentation.

Other actors in the food supply chain, such as those mentioned above, distribution lobbies, seed companies, large producers of technical means, were selected to have also a role in governance in directing choices, influencing and regulating the market (**governance system**). In addition, a lack of information exchange across the supply chain was seen as hampering digitalisation, actors need to share information and tools to improve the supply chain.

In terms of public administration (**actors**) more interaction was recognised as a need between organisations, regions, ministries and the European Commission (**governance system**). Furthermore, regarding data availability (**resource units**) the national statistical system (**resource system**) was pointed out for not providing accurate real knowledge of the areas by variety, age and management system, which would help farmers.

Entrepreneurs (**actors**) were proclaimed as a relevant type of actor in the LL ecosystem, their ability to listen and innovate, together with their ability to listen to the needs of stakeholders is a great help in adapting technologies to the needs of stakeholders and local conditions. Additionally, the ability to develop and customise software solutions was remarked as a facilitator for tailored forecasting models suited to organic viticulture.

As previously mentioned, the stakeholders highlighted that large retailers influence the implementation of EU policies, so it is essential that European policymakers become more aware of their impact on the agri-food chain and the sustainability of the sector (**governance system**). Other aspects that were identified and would enable better digitalisation include access to credit, European organic regulations, and intellectual property control with regard to royalties and the rights of varieties to be used.

Collaborations and in particular networks that support digitalisation (**resource system**) were announced as fundamental in terms of sharing knowledge and even resources. In this sense, increased relationships between sector operators (**resource units**) were noted as an enabler of digitalisation. The LL as manifested, already benefits from established partnerships, including collaborations (as resources) with distribution systems, scientific institutions (IAMB, CREA, UNIBA), and other supply chain actors. Noteworthy collaborations included CNR-IBE, which provided meteorological and satellite data, and Nexas, a company specialising in sensor automation and hardware development. Moreover, interactions between research and business were fostered within the LL, ensuring that scientific advancements were translated into practical agricultural applications. These collaborations were classified as facilitators for knowledge transfer, data exchange, and commercial partnerships, while the LL's participation in international symposia and research conferences enhanced global knowledge-sharing.

The management of natural resources (**resource system**) was also considered as an aspect aimed to make digitalisation sustainable at different levels. In the case of LL, according to LL participants, the technology promotes environmental sustainability, since digital knowledge improves all systems of application in the environment and culture (**governance system**). Similarly, considering the management consortium, many farms operate under water allocation schedules that limit their flexibility. As noted by stakeholders, improved autonomous water management systems would provide greater resilience and efficiency (**resource system**).

With respect to financial resources (**resource units**) the need for adequate funding resources that can supplement research in viticulture and for the necessary training of stakeholders was recognised. While some funding mechanisms were declared as existing, they are often inaccessible or not received. To address this, collaboration (as resource) among agricultural enterprises was raised as a helper to sustain innovation financing, aligning economic services with the realities of the agricultural sector (**resource system**).

On the other hand, production was seen as negatively influenced by the lack of data and their poor sharing, which is why stakeholders shared that the implementation of an integrated computerised system for recording production data and vegetation status could improve traceability and efficiency. Open systems such as the open-source Decision Support System (DDS) were indicated to facilitate innovation by providing better access to databases and improving supply chain transparency. In this area, interoperability (**resource system**) is crucial, as expressed, in Organic Table Grapes LL technology and data are present but there is no standard (**resource units**) that can be used in different contexts, moreover, standardised technical solutions do not provide operational certainties.

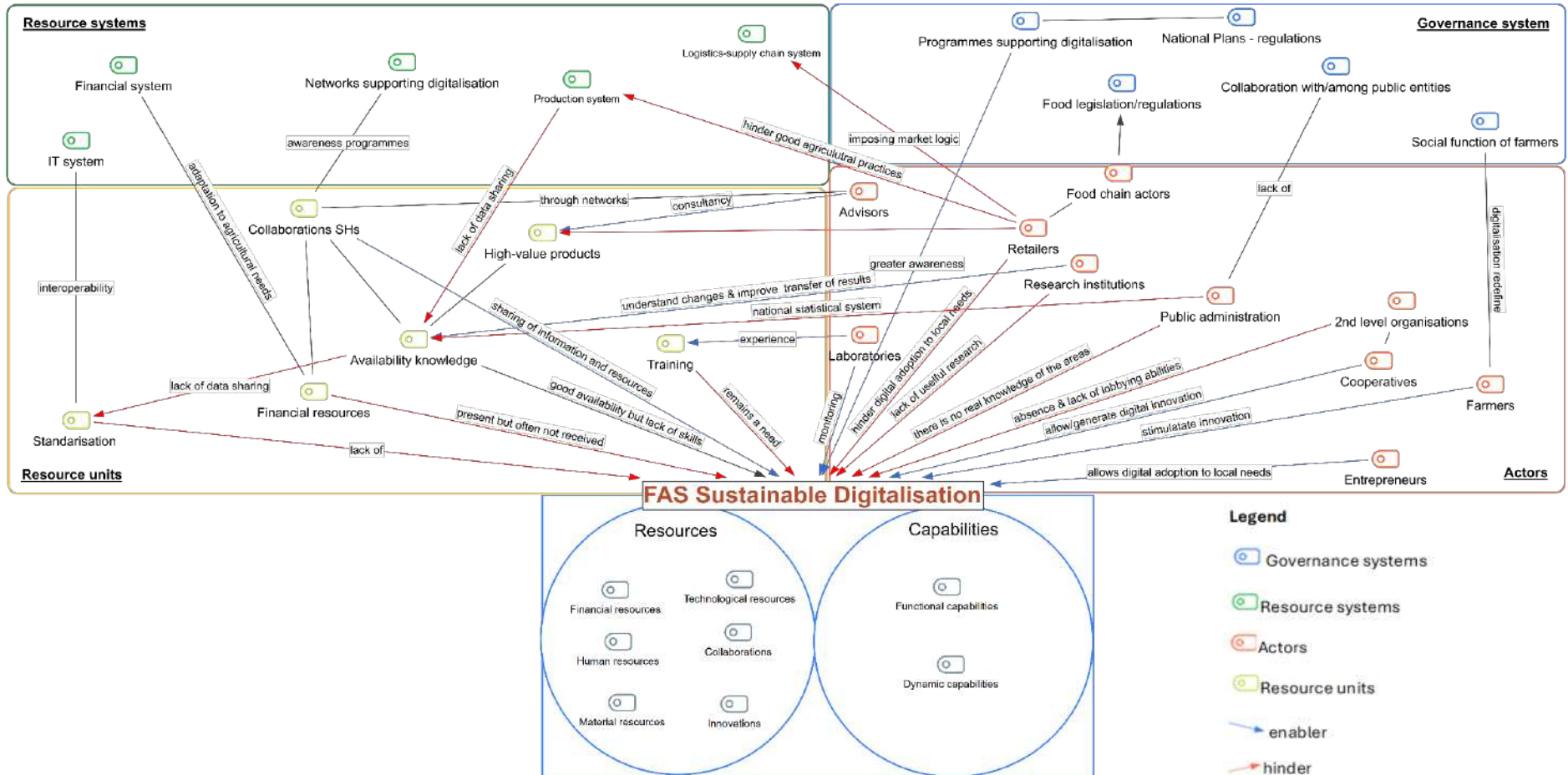
Despite the LL's good availability of data (**resource units**) through databases, collaborations, and synergies, the stakeholders indicated that many technicians struggle to identify which data sources are truly valuable for applying precision agriculture techniques.

There was also a clear need noted by LL participants to enhance skills in regional irrigation management, organic viticulture, and precision irrigation, particularly in relation to phytosanitary and nutrient management. As previously mentioned, entrepreneurs and stakeholders require further training (**resource units**) in data analysis and DDS usage. The stakeholders reported that while digital technologies exist, the LL must continue investing in operator training to ensure effective adoption of monitoring techniques.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Organic Table grapes LL.



Figure 26. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Organic Table grapes LL.



Source: UAL

### **Conclusions and summary of digital ecosystem of the LL**

The Organic Table Grapes LL in Italy illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, the LL benefits from a multi-stakeholder network that includes farmers, research institutions, business consultants among others, fostering collaboration, knowledge exchange, and digitalisation adoption. Research institutions actively contribute to knowledge transfer, capacity-building through training, and the development of scientific advancements. Advisors and agronomic experts provide farm consultancy services, supporting quality improvement, and facilitating the adoption of digital solutions.

Digital technologies, such as weather stations, sensors, and Decision Support System (DSS), enable data-driven decision-making and precision agriculture. Open-source DSS and digital platforms enhance data interoperability and accessibility, supporting traceability and transparency within the supply chain.

Furthermore, financial and policy frameworks, including EU regulations, access to credit, and research funding, provide some support for digitalisation efforts, although improvements are needed. The LL's participation in international symposia and research conferences further strengthens global knowledge-sharing and promotes innovation.

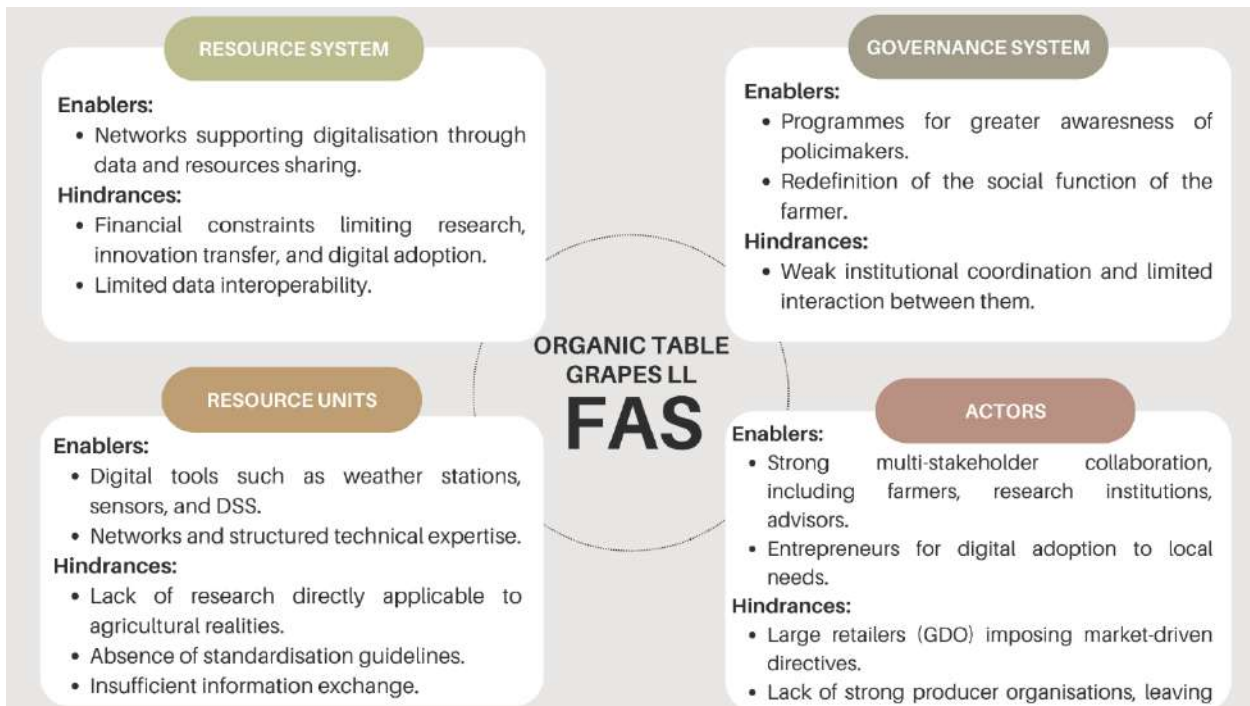
In terms of **hindrances**, the LL faces a lack of coordination within the supply chain which restricts information exchange, branding strategies, and market positioning. Weak connections between research institutions and agricultural enterprises hinder the practical application of scientific advancements in farming operations.

The limited presence of strong producer organisations leaves market influence in the hands of private traders, making it difficult for farmers to leverage digital innovations. Large retailers hold significant decision-making power, often imposing market-driven directives that do not align with producers' needs, restricting local adaptation of solutions.

Financial constraints remain a major barrier, as many funding mechanisms are either inaccessible or not received, slowing down innovation and digital adoption. Data-related challenges, including the lack of interoperability hampering supply chain transparency, integration, and standardisation, prevent the efficient use of agricultural data for precision farming. Additionally, limited digital skills and technical training among stakeholders hinder the adoption of monitoring technologies and digital decision-support tools.

In conclusion, the digital ecosystem of the Organic Table Grapes LL presents both enablers and hindrances (see Figure below). The LL benefits from multi-stakeholder collaboration, research and advisory networks, access to digital technologies, and the integration of open systems that enhance traceability and decision-making. However, challenges remain, including weak institutional coordination, restrictive market dynamics, financial constraints, and limited digital skills, all of which hinder the scalability of digital solutions and the broader transition toward sustainable digitalisation.





Source: UAL

Figure 27. Main enablers-hindrances of Organic Table Grapes LL.

#### 4.1.9 Local beef cattle farming Living Lab (Latvia)

##### Introduction

The Local beef cattle farming LL focuses on enhancing the market position of farmers. The aim of the LL is to test digital marketing solutions to provide an effective and easy-to-use marketing tool for farmers who produce products from semi-natural grasslands characterised by high biodiversity (special focus on beef, as cattle are used to graze grasslands and maintain their biodiversity).

The stakeholders in Local Beef cattle farming LL describe the focal action situation (FAS) i as follows:

*"To provide an effective and easy-to-use marketing tool for farmers to inform consumers about their farms and the characteristics of their products, thus strengthening their market position."*

To achieve this, the LL is currently exploring the potential of various tools and applications relevant to digital marketing.

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

- Resources

Key elements identified by stakeholders for sustainable digitalisation relate to technological resources such as the digital platform that farmers of LL use to promote and sell their products through short food supply chains, but also decentralised product delivery platforms with whom the LL collaborates to make the products arrive to consumers. Despite the existence of diverse digital platforms useful for the purpose of the LL, stakeholders stressed the lack of an online tool that would help to bring together specific actors such as the owners of semi-natural grasslands and the semi-natural grasslands producer/farmer, as this tool could promote the production process of products from semi-natural grasslands. Stakeholders also outline the relevance of other technological resources such as websites, social media, Apps and AI for product promotion and sales.

Sustainable digitalisation is also conditioned by human resources. In this regard, a shortage of specialised workers was described, and more specifically a shortage of farm advisors. Advisors are very important for farmers, and this

shortage means that farmers often have to wait for consultations/visits for a long time, even a few months, which constitute a hindering factor. Time has also been identified as a relevant resource which is currently not available, especially for farmers to learn digital skills such as digital marketing for example.

In addition, financial resources represent a key element for sustainable digitalisation. In this regard, stakeholders from the LL stressed the relevance of available public funding support for developing activities such as new product development, cooperation activities, and web page development. On the other hand, the need of this public funding was stressed for other activities such as maintenance and modernizations of the websites, exchange of experiences about the development of new cooperatives and support for producer organizations in certification and brand development. Regarding informational resources a better labelling for enhancing traceability of the products was also outlined, together with concerns about misinformation through false news and stories which can hinder the capacity to attract consumers.

Finally, collaborations among farmers in the LL with other stakeholders such as slaughterhouses, and between producers and web developers were also stressed.

#### - Capabilities

Besides the above-mentioned resources, different capabilities have been identified as significant conducive elements to sustainable digitalisation. Within these, regarding functional capabilities, the specific skills, know-how of farmers to produce products from semi-natural grasslands and the relevance of effectively planning work and time in the farm were outlined. Furthermore, abilities related to digital skills were stressed; within these, data recording, the capacity of farmers to efficiently use digital platforms and tools to sell their products, and especially digital marketing skills related for example to promotion of product sales and storytelling of products were described as a need for being improved. Interestingly, stakeholders also highlighted the relevance of digital skills from the consumers side, for example, to place orders of products. Moreover, the need for skills related to web page maintenance and modernization was highlighted.

In terms of dynamic capabilities, the ability to develop collaborations has been highlighted especially linked to other dynamic capabilities such as the transfer of information, knowledge and skills between farmers and with other stakeholders. Also, it stressed the need to adapt digital technologies to local conditions, in this case for example developing IT solutions tailored to the needs and skills of the farmers producing beef in semi-natural grasslands.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes. These elements of the systems not only set the conditions for the resources and capabilities of the LL, but the interrelation among some of them are also significant for the conduciveness of digital ecosystems (see Figure below).

The LL is formed primarily by small and medium scale farmers who produce products from semi-natural grasslands, and non-governmental associations, such as Latvian Fund for Nature and Zemnieku saeima (association/organisation of agricultural producers) (**actors**). Besides the stakeholders who formally constitute the LL, other actors also collaborate in activities associated with it. These include consultants and farm advisors (e.g. Latvian Rural Advisory and Training Centre), farmers' cooperatives (e.g. Latvijas Liellops), public institutions (e.g. Agricultural Data Centre, Food and Veterinary Service), research institutions and universities (e.g. Latvia University of Life Sciences and Technologies), other NGOs, and influencers in the areas of food and beef consumption. In regard to farmers, despite the fact that they are the main actors of the LL and present significant skills related to know-how, for example in terms of production methods, the ageing of farmers coupled with time constraints are stressed as obstacles linked to low digital skills and adoption of technological innovations.

The role of farm advisors (**actors**) both from the public sector and private consultants has also been highlighted as crucial. Their roles are diverse, including the development of the abovementioned marketing digital platform for local farmers to promote and sell their products through short food supply chains, share information about various support tools and funding at different scales and even supporting farmers to complete the data reports required by the public administration. Stakeholders also underlined the importance of non-governmental organisations (NGOs) (**actors**), especially in its capacity of lobbying. NGOs can lobby either in favour of the aims of the LL, for example advocating

for the grassland product label and protection of semi-natural grassland habitats; or against the LL as those focused on no meat consumption. Besides their advocacy role, NGOs and other organisations such as cooperatives (**actors**), are acknowledged as relevant actors for enhancing cooperation and collaborations between farmers and with other stakeholders (**resource units**), especially for information and knowledge sharing/transfer; but also for supporting farmers in aspects related to education campaigns, applying for certification and new product and brand development.

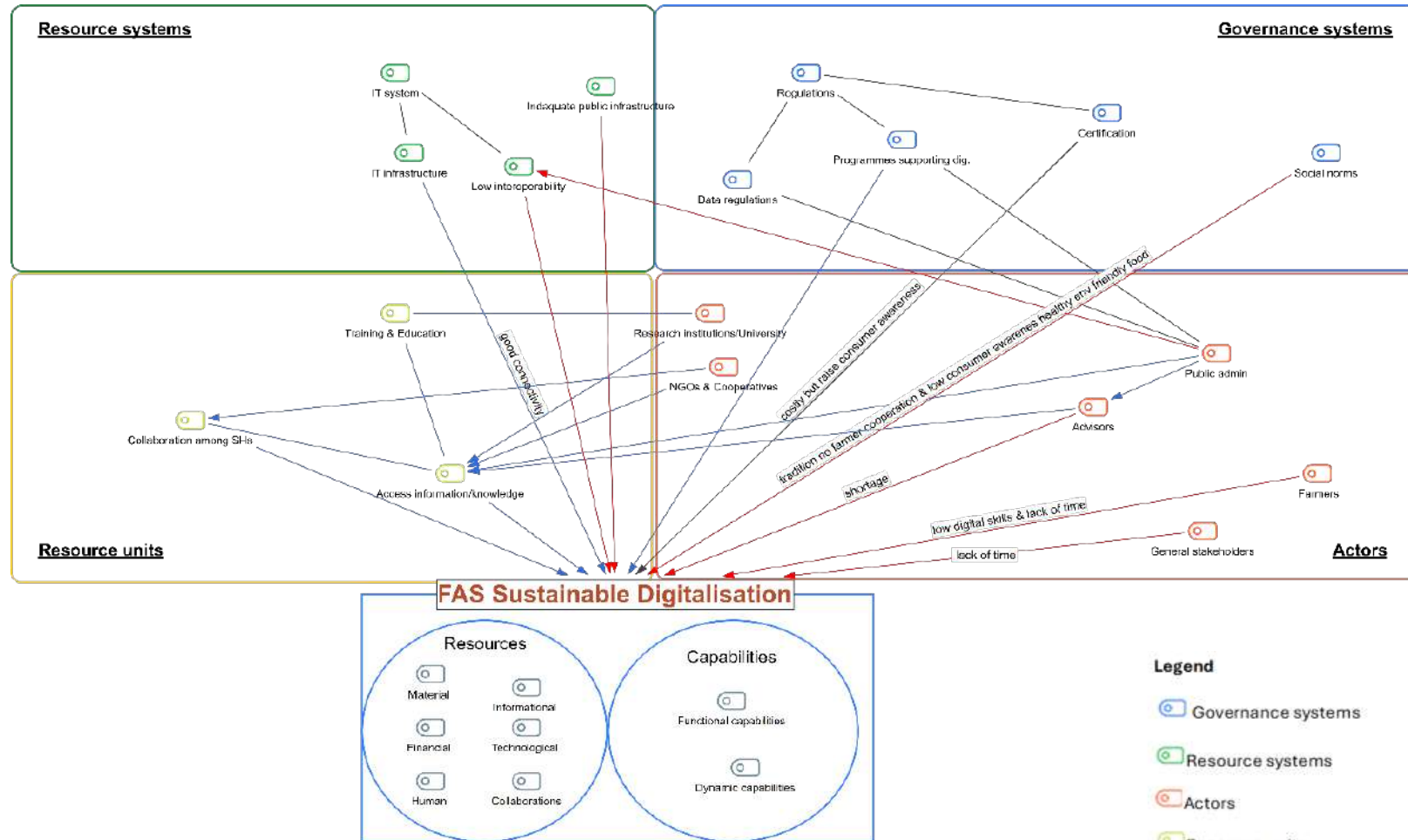
Stakeholders also stressed the importance of the need of creating/developing awareness among consumers (**actors**) bringing the topic of healthy and environmentally friendly food in the consumers' agenda. In this regard, influencers, public educational campaigns and labelling with clear traceability were mentioned as means to inform consumers. Public administration/institutions (**actors**) are emphasised as key actors for sustainable digitalisation with various roles, on the one hand, supporting the LL by providing funding, e.g. website development, digital marketing tool, business incubators, and also providing advice and relevant information (**resource units**). However, regarding data procedures and regulations (**governance system**) related to data recording, management and access, the collaboration with the public sector operates more as a burden due to the complicated forms to be filled in and the issue that some public organisations are internally closed and unresponsive.

Concerning the last point, stakeholders pointed as a hindrance that farmers have to provide data to different public institutions and that it would be a useful move to synchronise this process and make data open to different institutions, hence enhancing a governance framework of more collaboration-synergies between public institutions. This issue links with an essential element for sustainable digitalisation as it is enhancing a system of data interoperability (**resource system**); making this data compatible and transferable between institutions would facilitate the process of data entry for farmers but also would enable the accessibility to information and knowledge for stakeholders (**resource units**). Complementary to a system for data interoperability, stakeholders highlighted the relevance of a data security system for safe online financial transactions-payments and also the relevance of IT infrastructure and especially of good internet coverage which in the case of this LL is not an issue as they country has in general terms good IT infrastructure (**resource system**).

On the other hand, stakeholders from the LL stressed that a better public infrastructure system (**resource system**) in rural regions is needed as due to the lack of infrastructure, the price for products is higher and delivery takes longer. This points to the relevance of the logistics (product supply chains) system (**resource system**) for sustainable digitalisation to happen also in rural remote areas. Moreover, in relation to the education system (**resource system**), despite the fact that some actors such as Latvia University of Life Sciences and Technologies are mentioned as key for providing education and training in digital skills and nutrition science, stakeholders pointed that due to a lack of specific school programmes/courses (**resource units**) there is a shortage of practical skills to cut the meat which hinders the development of LL FAS. This shows the relevance of combining digital skills with other 'practical' know-how for sustainable digitalisation.

In relation to governance, the aforementioned lack of collaboration between public institutions but also the lack of tradition of cooperating (in cooperatives) among farmers in their community, who work more as competitors, represent social norms hindering the conduciveness towards sustainable digital ecosystems. Other social norms (**governance system**) such as low consumer habits and appreciation for good quality food as for example meat that has been farmed extensively while preserving biodiversity, which meant to be ready to pay a premium for it and; social norms related to environmentalism which is very focused on reducing climate change emissions but less so in enhancing biodiversity is identified by stakeholders as elements hindering sustainable digitalisation processes in the LL. In terms of certification and product regulation, (**governance system**) while positive for strengthening awareness of consumers, stakeholders pointed out that certifications are costly for farmers who cannot always pay for these and that there are already too many certification systems and consumers can be confused by them. Finally in terms of regulations (**governance system**), stakeholders highlighted the relevance of programmes supporting digitalisation-innovation, such as the Rural Support programme and other national and regional programmes which have meant essential for providing access to funding and information and knowledge (**resource units**).

Figure 28. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Local beef cattle farming LL.



Source: UAL

## **Conclusions and summary**

The Local beef cattle farming LL in Latvia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

Concerning **enablers**, the availability of a digital platform for farmers to sell their products through short food supply chains, and other technological resources (e.g. websites, social media) are considered enabling factors. Other supporting factors relate to the collaborations of farmers with other stakeholders and to the presence of advisors who support farmers in various ways (development of digital platform, information, data recording). Another enabling element is the presence of NGOs which lobby for the aim of the LL and also with cooperatives enhance cooperation-collaborations among stakeholders and access-transfer of information and knowledge. Public institutions, especially through programmes supporting digitalisation which provide funding for digitalisation, but also in their role as providers of advice and information are also considered enablers for sustainable digitalisation. Certification schemes are also an enabling element as they raise the awareness of consumers regarding healthy and environmentally friendly food. Finally, having a good IT infrastructure in terms of internet coverage across the country also enables sustainable digitalisation.

In relation to **hindrances**, the shortage of specialised workers, and more specifically of farm advisors, and low digital skills of farmers related to their age and time constraints for learning these new skills are considered hindering factors. Misinformation for consumers and those entities lobbying against LL, can reinforce the low awareness of consumers towards healthy and environmentally friendly food. In terms of data procedures and regulations for public registers they represent a burden due to the complicated forms to be filled in and due to the closed and nonresponsive attitude of some public organisations. Also in this regard, the low collaboration among public entities for data sharing and low data adaptability-interoperability represent a hindering element for sustainable digitalisation. The lack of tradition of cooperation among farmers in their communities is also a hindering factor. Despite the fact that certifications can be an enabling element, they are considered at the same time hindering as these are costly for farmers and may cause confusion amongst consumers. Finally, inadequate public infrastructure in rural areas and lack of specific educational programmes with specific practical skills needed for developing the LL aims are also considered hindering factors.

In conclusion, the digital ecosystem of the Local beef cattle farming LL shows enablers and hindrances (see Figure below); in terms of enablers these include the presence of a digital platform useful for farmers, the support of diverse actors such as advisors, NGOs, cooperatives and public institutions who provide key funding and advice for the development of the technological resources. However, lack of appropriate digital skills by farmers and shortage of specialised workers, together with lack of collaboration among public institutions, inadequate public infrastructure in rural areas and the absence of a data interoperability system hinders the LL digital ecosystem conduciveness.



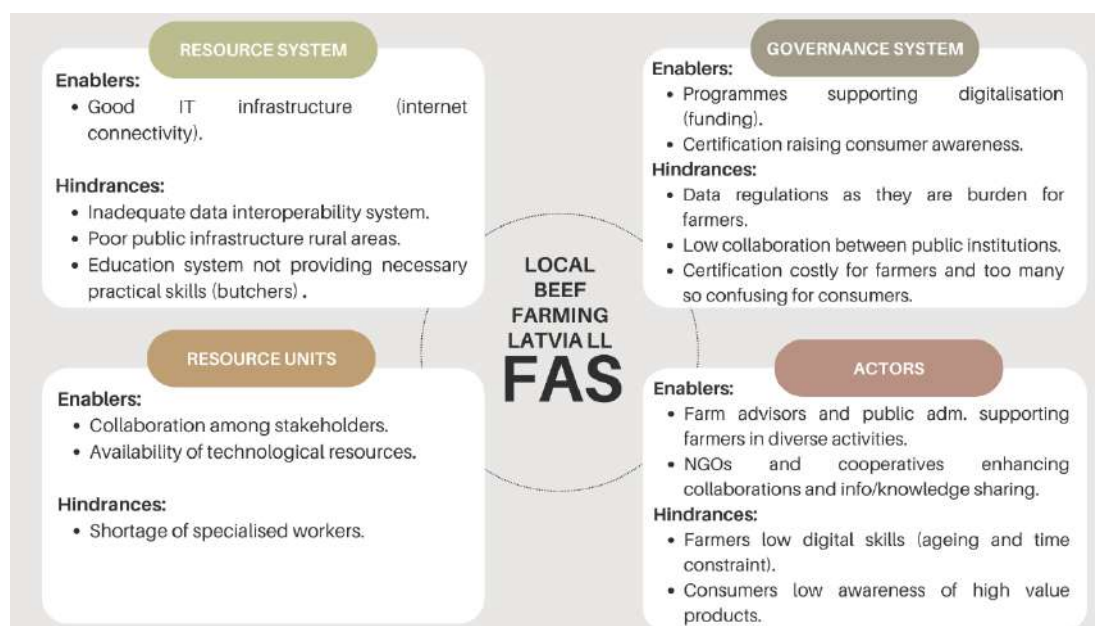


Figure 29. Main enablers-hindrances for Local beef cattle farming Platforms LL.

Source: UAL

#### 4.1.10 Scottish Small Farms and Digital Platforms Living Lab (Scotland)

##### Introduction

The Small Farms and Digital Platforms LL focuses on enhancing the economic activities and resilience of small farmers and crofters (farmers) situated in rural and remote settings of Scotland. These farmers face numerous challenges, including distance to markets, issues with digital connectivity, access to digital skills support, and the first impacts of climate change, such as extreme weather events.

The stakeholders of the Scottish LL describe the focal action situation (FAS) as follows:

*"To harness the power of digital tools and platforms to support and improve sustainable agricultural practices and problems related to rural and remote settings; distance to markets, issues with digital connectivity, access to digital skills support, impacts of climate change, etc."*

To achieve this, the technological setup includes a digital platform for training and collaboration, online social media, QR coding, 360-degree cameras, and virtual reality demonstrations, currently at Technology Readiness Level 3 (TRL 3).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

- Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources, including machinery, facilities (e.g. storage) and ICT devices such as sensors and digital thermometers. Complementary, diverse technological resources were mentioned by stakeholders, including social media, alert/monitoring systems, digital platforms, software and Apps, for example related to selling excess of production locally, and providing product information and traceability.

Sustainable digitalisation is also conditioned by human resources, in this regard, the lack of human resources to manage data on the farm was stressed and the idea of establishing a cooperative and/or to cooperate to share human resources, for example a digital marketing person among different farmers/organisations, was suggested.

Time was also a resource stressed by stakeholders as important for digitalisation and was seen as constituting a hindering factor due to low time capacity on the farm.

In addition, financial resources represent a key element for sustainable digitalisation. Capital funding was highlighted as key for setting up some additional/diversification of business activities; moreover, grants and funding schemes from the Scottish Agricultural Organisation Society (second level organisation) were also mentioned.

Finally, collaborations among farmers, as well as with other stakeholders such as community initiatives and consumers were also identified as relevant resources.

- Capabilities

Besides the above-mentioned resources, different capabilities have been identified as significant conducive elements to sustainable digitalisation. With respect to functional capabilities, abilities related to leadership, engagement, fundraising (e.g. grant writing skills) were stressed as relevant for sustainable digitalisation. Furthermore, stakeholders in the LL referred to digital skills related to use of digital platforms, digital marketing, and digital content creation, together with data recording/gathering, management and analysis for adopting data driven decisions. They gave as an example the ability to simplify data, thus producing reports that make sense and are useful for the farmers. Also in this line, the relevance of technical support for software and building cybersecurity capacity to protect from being hacked, was noted.

In terms of dynamic capabilities, which refers to the adaptation in view of a changing external environment, the ability to develop collaborations for peer support and to share information have been highlighted by stakeholders. Closely related to financial resources, stakeholders of the LL stressed the relevance of developing capabilities linked to income diversification for example by creating videos on permaculture which attract attention and raise awareness internationally, providing an extra source of income. Furthermore, digital resilience was mentioned in relation to the ability to adapt to changing environments. Also linked to adaptive capabilities, stakeholders highlighted the relevance of being able to adapt digital technologies to local conditions and to small-size farms, which is not common, since the target market for technologies often seem to have big/large scale farms in mind.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes. These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems (see Figure 1).

The Scottish Small Farms and Digital Platforms LL is formed mainly by small-scale farmers, the Hutton Institute (research institution) and by neighbours and peers from the local community (**actors**). Besides the stakeholders who form part of the LL, other actors also collaborate and influence the LL, including the local government (e.g. Planning and Environmental departments, and Farm Advisory Service), second level organisations and associations (e.g. Women in Agriculture, Community Supported Agriculture Network UK), advisors, technology providers-suppliers and research institutions (e.g. Aberdeen University, Scotland's Rural College-SRUC). Stakeholders from the LL stressed the relevance of support from family, and of peer support from neighbours and the local community, but also from second level organisations, including associations, and from advisory services provided by the local government. On the other hand, local government officials can also represent a hindering factor as they can be restrictive and lacking flexibility, requiring a lot of administrative procedures.

Within the above-mentioned actors, farmers represent the backbone of the LL. Stakeholders of the LL expressed that ageing and lack of generational renewal of farmers represent a hindering factor as older farmers are more unwilling to engage or adopt digital technologies. Other relevant actors are second level organisations such as associations, which are considered important as enablers of collaborations and networks (**resource units**) at regional and national levels but also due to their support to farmers for example in relation to certification (Soil Association), to developing diversification activities (Scottish Agrotourism), to enhance the role of women in farming (Women in Agriculture), and to advise on animal health (Goat Veterinary Association). With regard to research institutions, in addition to conducting research for advancing knowledge in fields such as agroforestry, they also provide education/training for farmers. Moreover, technological providers such as software suppliers are often on

hand and can provide some support to farmers with digital technologies. However, stakeholders from the LL also expressed their concerns about the need for more technological support from software companies which are usually more focused on large-scale farmers rather than small farmers.

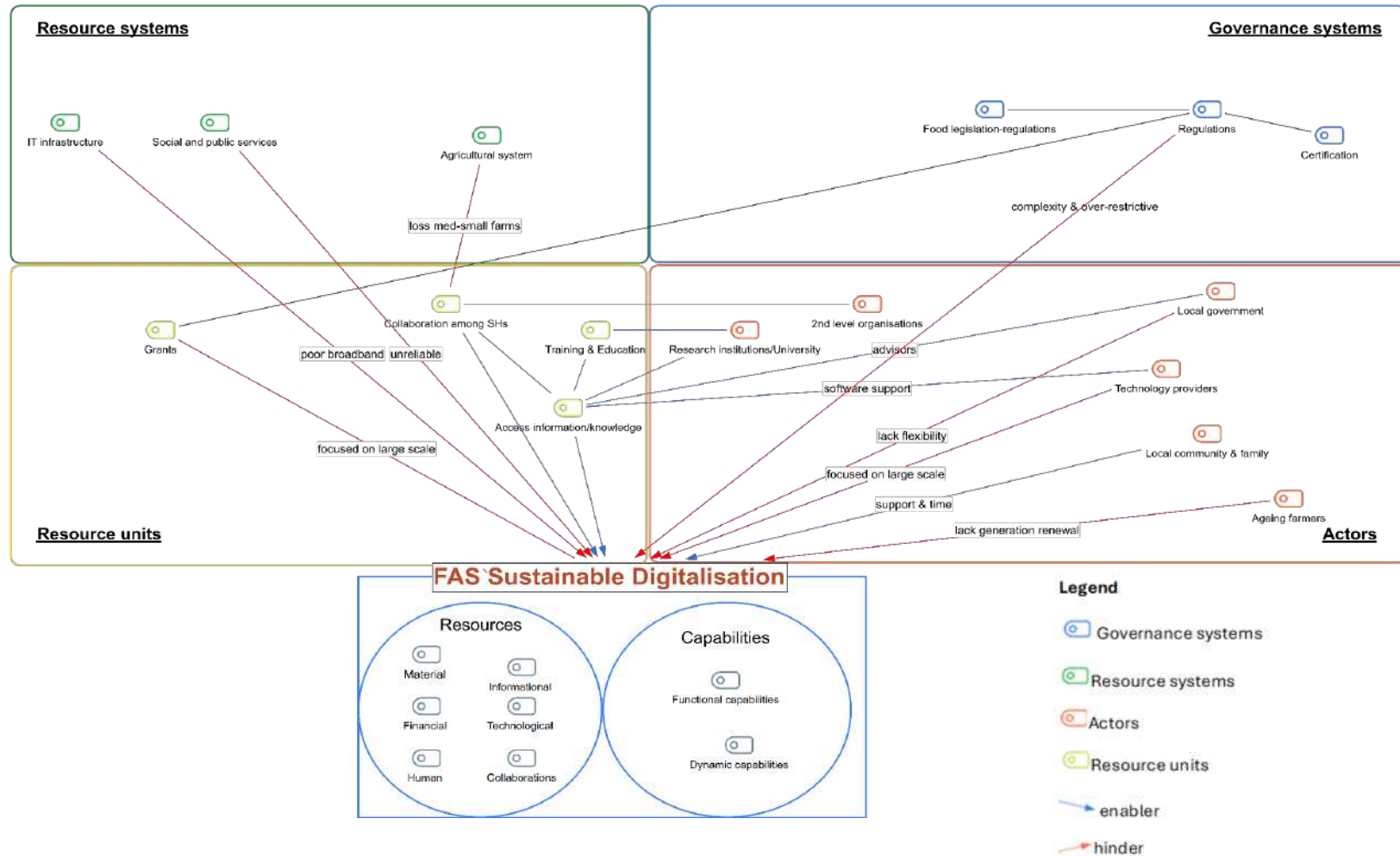
Challenges for small-scale farmers compared to large-scale farmers also were mentioned in relation to the availability of grants for digitalisation (**resource units**), which according to stakeholders are mostly geared to large farms. Stakeholders also pointed to the system of social and public services and infrastructure (**resource system**), for example roads, mail, childcare, as a relevant element of sustainable digitalisation. In this regard, stakeholders from the LL pointed to the lack of reliable services-infrastructure which hinders their capacity to spend time and resources on digitalisation. Collaboration among stakeholders (within the local community but also at regional, national and international level) (**resource units**) have also been mentioned as a key element for digitalisation as these enhance accessibility to knowledge and information sharing but also peer support and consumer engagement. Interestingly stakeholders stressed that structural changes in the agricultural system (**resource system**) linked to loss of medium size farms have meant less opportunities for collaborations with other farms. Regarding the IT-infrastructure system (**resource system**) still many farmers struggle with broadband connectivity which is a significant hindering element for sustainable digitalisation. Stakeholders mentioned that there are some alternatives-workarounds to broadband connectivity, such as Starlink, but that these are too expensive for a small-scale farm to justify.

Finally, in relation to governance, stakeholders pointed to the complexity of regulations and more specifically outlined food legislation and labelling, also certification, as restrictive, with a need for one stop online source with updated information. The LL stakeholders also stressed the relevance of governance related to initiatives such as food markets which needs strong leadership to be developed and maintained.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Scottish Small Farms and Digital Platforms LL



Figure 30. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Scottish Small Farms and Digital Platforms LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The digital ecosystem of the Scottish Small Farms and Digital Platforms LL presents several enablers and hindrances that shape its sustainable digitalisation (see Figure below).

Concerning enablers, the availability and use by stakeholders of technological resources such as social media, alert systems, digital platforms, software, and Apps, represent an enabling element, as they further allow resources to be captured, for example, in terms of income diversification for raising financial resources. The LL is formed by a multistakeholder network that provides mutual support, sharing knowledge and information. The presence of other actors that influence the LL, including the local community, second level organisations, research institutions, technology developers and advisors from the local government, also enables resources and capabilities of the LL, providing advice, training-education and support to farmers with digital technologies. Collaborations are developed between LL stakeholders and other actors within the local community but also at regional, national and international levels which further enables the accessibility to knowledge and information, and raises awareness of the focal action situation of the LL.

In relation to hindrances, the lack of human resources with appropriate digital skills to manage data on the farm, linked to lack of time to develop these skills and the ageing of farmers and lack of generational renewal were mentioned as relevant hindering factors for sustainable digitalisation. Moreover, the focus on large scale farms rather than small farmers for example in terms of grants for digitalisation and support from technological providers also represent a hindering element for the LL. Structural challenges related to agricultural restructuring which have meant the loss of small-medium farms and, as a consequence, less opportunities to collaborate; an inadequate IT infrastructure with poor broadband connectivity and unreliable social-public services also represent hindrances to sustainable digitalisation. Finally, complexity in regulations and access to information related to food legislation and restrictions related to food labelling, certification was also pointed out as hindrances for sustainable digitalisation of the LL.

In conclusion, the digital ecosystem of the LL shows enablers and hindrances (see Figure below); in terms of enablers, it is driven by mutual support and collaborations between farmers and a wide range of actors both within the community and external to it. However, structural challenges linked to demographic decline and ageing, agricultural restructuring towards larger scale farming, inadequate broadband and social-public services in remote areas represent challenges to the sustainable digitalisation in the LL.

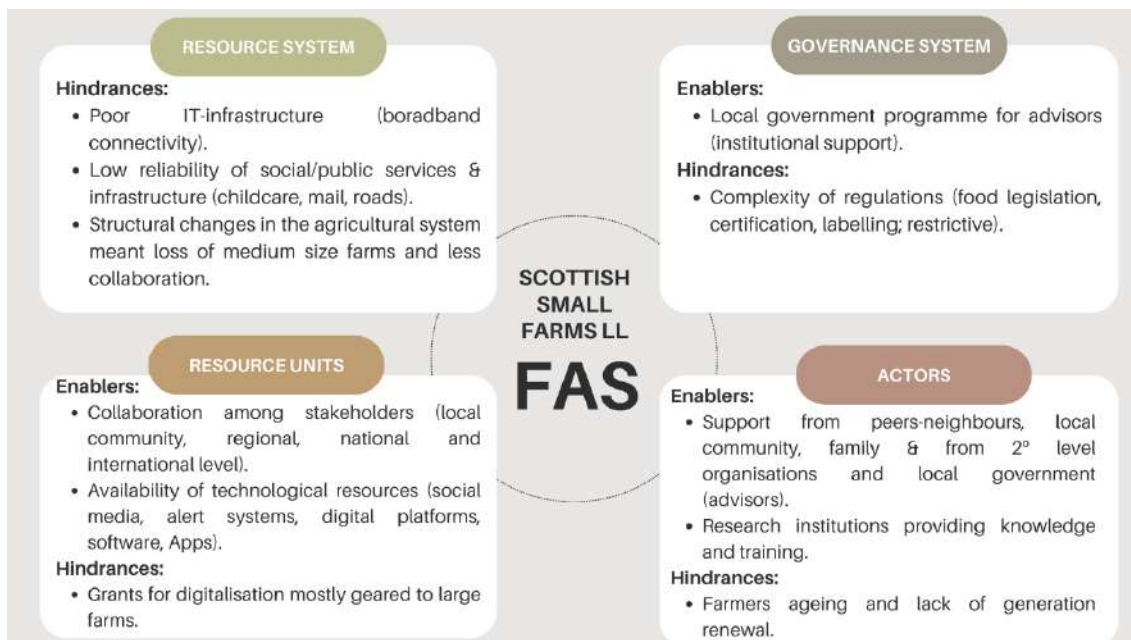


Figure 31. Main enablers-hindrances for Scottish Small Farms and Digital Platforms LL.

Source: UAL

#### 4.1.11 Greenhouse smart sensor lab Living Lab (Serbia)

##### Introduction

The Greenhouse Smart Sensor Laboratory, located in Serbia, is still at a low level regarding digitally related solutions. The farmers still rely on traditional methods and their experience in making decisions related to agricultural production. This often results in high consumption of inputs, lower profits and a lack of farmers' time and welfare. Introduction of digitally related solutions aims to achieve optimal, efficient and sustainable agricultural production.

The stakeholders of the Greenhouse Smart Sensor Laboratory LL describe the focal action situation (FAS) as follows:

*"To transition from traditional farming practices toward digitally related solutions that enable optimal, efficient, and sustainable greenhouse production."*

To achieve this, the LL employs a range of IoT sensor nodes to monitor the conditions in the greenhouse and that are connected to a web platform accessible via PC, tablet, or smartphone, allowing farmers to make informed decisions. The technology currently operates at Technology Readiness Level 7 (TRL 7).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

The Greenhouse Smart Sensor LL in Serbia benefits from a broad array of resources that support its digitalisation. Among the key elements identified by stakeholders for sustainable digitalisation are material resources, for example, the demonstration farm, which is equipped with a greenhouse structure, water wells, and has sufficient land available to test and implement the technology. In terms of equipment, stakeholders recognised that most of the necessary hardware for the smart sensor system is already available within the LL. However, they also pointed out that probably certain hardware components are still missing to complete the system (e.g., specific sensors not currently available in Serbia, such as those designed to analyse the inner structure for premium product classification).

Technological resources were also highlighted by LL stakeholders. For instance, the need for a software platform capable of integrating all stakeholders was emphasised. Although the AgroSense app exists at the national level, it does not currently include all the relevant actors required for this Living Lab's activities. Similarly, stakeholders underlined the importance of developing a decision support system, which would be built upon the data collected and standardised through the implementation of smart sensor technologies.

Sustainable digitalisation also depends on the availability and quality of human resources. According to stakeholders, the LL benefits from a team with a broad range of expertise and professional backgrounds, including hardware and software engineers providing the technological knowledge required for the implementation of smart systems. Several participants identified human resources as the most valuable asset of the LL, emphasising the diversity and experience of the individuals involved. Additionally, it was noted that there is an available workforce to carry out the necessary operations at the farm. One of the key contributions from human resources was the recognition that sensor measurement data should be enhanced with proper interpretation.

Regarding informational resources, one key issue raised by stakeholders is the difficulty in distinguishing real knowledge from quasi-knowledge. In the era of the internet and agricultural TV shows, self-proclaimed experts often disseminate misleading advice, which can ultimately hinder the implementation of new technologies. In this context, evidence of digital solutions plays an essential role in adoption. Stakeholders highlighted that the LL is more aware of digitalisation opportunities and benefits compared to other agricultural sectors, such as arable farming. Furthermore, the LL has been positioned as a good example for other farmers to follow. Despite this awareness, participants acknowledged a lack of data on the use of smart sensor technologies and limited documentation of farmers past experiences. To address this gap, stakeholders proposed the organisation of the demo farm as a standardised demonstration site where one greenhouse operates with the proposed digital solution and another follows traditional methods.

Financial resources also represent a key element for sustainable digitalisation. According to LL participants, the current financial support is sufficient to initiate the implementation of the smart sensor technology. However, stakeholders emphasised the need for continued funding to ensure long-term adoption.

In terms of collaborations, LL participants recognised the current cooperation with BioSense Institute, already involved in the LL. However, stakeholders have also pointed out a lack of relation with reseller and export companies, which could be valuable for marketing and distributing the products made at the farm. Likewise, the LL misses collaboration with experts in areas such as climate change and carbon footprint. Furthermore, stakeholders have noted that more collaboration with different farmers is needed, particularly with farms in the region that have similar production systems and share the goal of digitalising their processes.

Finally, as described by the LL participants, the proposed solution and sensor node that is offered is an innovation per se. Stakeholders acknowledged that the system is still emerging, but there was a clear tendency toward further development and implementation. Moreover, the potential development of sensors or combinations of sensors capable of detecting plant infections at an early stage was noted as a valuable advancement. In addition, stakeholders recognised the importance of monitoring and understanding the correlation between key ecological factors such as temperature, soil moisture, air humidity, and lighting. Ultimately, the development of systems capable of not only monitoring but also actively controlling these ecological factors was seen as a forward-looking innovation.

#### - Capabilities

Concerning functional capabilities, stakeholders have identified the need for the ability to optimise operations and increase efficiency through clearly defined KPIs, particularly regarding financial savings, labour reduction, and the use of inputs such as water and fertilisers. In addition, the ease of digital technologies has been perceived as a significant factor. This challenge may be mitigated through collaboration with experts who help simplify the technology, making it more accessible and practical for farmers.

Moreover, LL participants have also emphasised a strong capacity for stakeholder engagement, having successfully attracted relevant actors through established networks. The presence of agronomic expertise within the demo farm has been appreciated as the base for the technical know-how.

However, while a basic level of managerial competence has been noted, stakeholders have acknowledged that management and organisational skills remain underdeveloped and require further improvement. On a positive note, the LL has pointed out the ability to leverage financial opportunities, accessing national and EU-level programmes to support innovation and boost production.

Furthermore, in regard to dynamic capabilities, the LL underlined the stakeholders' openness and willingness to adopt innovations. As declared by LL participants, all stakeholders are very open to hosting and/or taking part in innovation processes. In this line, attitudes regarding education about innovations, such as readiness to go to listening seminars, conferences and workshops about new methods to improve the production process were also raised. Similarly, according to stakeholders, LL members are open to sharing their knowledge and resources, and there is openness for cooperation. In general, as reported by the LL, all the relevant stakeholders that are involved are willing to cooperate.

Participants have also acknowledged the importance of adapting digital technologies to local conditions. For instance, developing models that combine sensor data and agronomic expertise enables context-specific applications. However, it has been noted that the broader agricultural sector in Serbia still faces challenges in fostering confidence in technology, particularly among older generations.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL, but the interrelation among some of them is also significant for the conduciveness of digital ecosystems.

At the core of the LL are the farmers (**actors**), who, according to stakeholders, show openness for learning, developing collaborations, and testing available technologies. LL members recognised farmers as an important part



of the LL, as technology will be installed at their farms where innovations will be/are tested to see what their benefits and costs are. Nonetheless, the technical ability of the farmers in general has been reported as limited, and they are described as reluctant to adopt new technologies. It is said that the majority of farmers are not ready to accept new technologies.

Research and academic institutions (**actors**) have been identified by LL participants as fundamental enabling actors in the digitalisation process. Stakeholders have referred to them as the primary source of reliable knowledge (**resource units**), which will help to ensure the use and interpretation of sensor data. Among these, the BioSense Institute (**actors**) has been particularly emphasised, as it was the organisation that initiated the LL and brought stakeholders together to address the FAS challenge. Likewise, faculties of agriculture, especially from the Universities of Belgrade and Novi Sad (**actors**), were recognised for their openness to collaboration and were acknowledged for bringing in skilled personnel, specialised knowledge and experience into the LL activities.

In addition, the Institute for Crops and Vegetables (Novi Sad) (**actors**) was mentioned as a potential valuable contributor, given its expertise in vegetable production and its role in developing new plant varieties. Similarly, the Institute for Vegetables in S. Palanka (**actors**), although not yet involved in the LL, was considered by participants as a potential future partner, due to its focus on developing new vegetable varieties. Furthermore, the Institute for Weather Forecast (**actors**) was highlighted for its ability to support production planning and plant protection. Stakeholders recognised that its forecasts could help reduce production inputs and minimise risks in greenhouse management practices.

Advisors (**actors**) have been acknowledged by LL participants as key actors in supporting the adoption of digital innovations. Stakeholders reported that the experimental farm already has a cooperation (**resource units**) with a team of advisors with different backgrounds who provide guidance in areas such as plant protection, marketing, and technology. Moreover, agricultural and advisory professional services were recognised for their ability to help farmers adopt innovations more quickly. LL members emphasised that these services not only provide technical advice but also support decision-making and influence the direction of development. In this regard, stakeholders highlighted the importance of the state-owned Advisory Service in Serbia (**actors**), which offers support, usually free of charge, to farm owners. According to participants, some of the country's top agricultural advisors are part of this service. Finally, the need to integrate advisory knowledge (**resource units**) with sensor data was underscored. As noted, the sensor measurements are fine, but knowledge from advisors should be added to them in order to have proper models for farmers.

Public administration (**actors**) was recognised by LL participants for shaping the structural conditions of the digital ecosystem, particularly through their regulatory, strategic, and financial roles. The Ministry of Science, Innovation and Technological Development was identified as directly responsible for both the strategy and financing (**resource system**) that supports the application of science in the agricultural sector. In this regard, stakeholders suggested that the ministry could further improve knowledge transfer by promoting conferences and outreach events (**resource units**) for farmers. Similarly, the Ministry of Finance (**actors**) was described by stakeholders as the authority in charge of approving agricultural measures and issuing project calls (**governance system**).

The Ministry of Education (**actors**), on the other hand, was seen as responsible for shaping the education system (**resource system**) and for updating and improving educational programmes (**governance system**) to better prepare future agronomists and farmers in the use of digital technologies. The Ministry of Agriculture (**actors**) was also emphasised as a key actor, with stakeholders acknowledging its dual role in both governance (i.e. setting regulations and strategies for agriculture) and in administering financial support programmes (**governance system**). However, LL participants expressed concerns about the lack of consistency in the ministry's regulatory measures (**governance system**), which makes it difficult for farmers to make reliable long-term plans. Furthermore, the Ministry of Trade (**actors**) was identified for its influence on the ease and profitability of trade through its legislative framework (**governance system**). The cooperation among ministries (**governance system**) was raised as agriculture is covered by four ministries, and they need to cooperate to work on the challenges agriculture is facing today.

Food chain stakeholders and large companies (**actors**), such as exporters and national distributive chains, have been identified by LL participants for dictating market trends and demands, selling price and farmers' focus on their decision making. On the other hand, the LL members highlighted the lack of a commercialisation partner for the



proposed digital solution. In addition, the absence of reliable retailers (**actors**) and procurement networks (**resource units**) was seen as a hindrance.

Similarly, other food chain actors, such as processing companies, were recognised for their influence in determining the profitability of cultivating specific vegetable crops, affecting both volume and market appeal. Stakeholders also underlined the importance of agricultural retailers (e.g. buyers) (**actors**) both as enablers and hindrances, due to their stability providing a secure source of income and funding (**resource units**) for farmers. Influencers (**actors**) were mentioned as individuals who shape trends, impacting consumer preferences and, consequently, influencing producers and the entire agricultural value chain. In this line, consumers (**actors**) themselves were recognised as actors whose preferences and purchasing habits, embedded as social norms (**governance system**), determine which products become popular, their pricing, and which producers or sellers they support.

Cooperatives (**actors**) were suggested by LL participants as potential enablers. It was noted that, unlike in many EU countries, cooperative systems are not widely adopted in Serbia, but their inclusion could prevent farmers from working in isolation and strengthen their market position.

Accredited laboratories were also reported as important actors in the system, with LL stakeholders noting that their certifications and standards (**governance system**) (e.g., HACCP, IFS) define the procedures and quality of agricultural products (**resource units**). As mentioned by LL members, standards as part of the governance system regulate the market and provide clear guidelines for buyers and producers.

From a financial perspective, participants pointed to collaborations (**resource units**) with banks (**actors**) for securing investment resources, especially for advancing technological implementation within the LL.

Concerning technological development, participants recognised a gap in the availability of local technology developers (**actors**) considered vital to supply the necessary technology (**resource units**). According to stakeholders, Serbia currently relies heavily on imported sensors, which constitute a barrier to the affordability and sustainability of technologies.

In relation to the administration of natural resources, the Administration for Agricultural Land (actor) constitutes the resource system for obtaining more land (**resource units**). In this sense, the organisation of the land (**resource system**) is under the state regulation on how agricultural land can be used, traded, and protected (**governance system**). Likewise, the law on water management (governance systems) was mentioned, state regulations on how water can be used in agriculture and protected as a common good (**resource systems**).

In terms of supporting programmes (**governance system**), LL members acknowledged the existence of governance instruments such as the Development Fund of the Autonomous Province of Vojvodina, which provides a range of incentives (**resource units**) to support farmers. However, a gap was identified in the digital system (**resource systems**) for evaluating governance measures, stakeholders noted that the absence of such a system makes it difficult to assess whether implemented initiatives are successful or not, limiting evidence-based decision-making at the policy level.

Regarding agricultural subsidies, participants referred to the law on subsidies in agriculture (**governance system**), which defines the eligibility criteria and usage conditions. At the local level, the Provincial Secretary of Agriculture in Vojvodina (**actors**) was recognised as the entity responsible for agricultural strategies and regulations where the demo farm is located.

Furthermore, LL participants emphasised the importance of patent protection (**governance system**) to secure intellectual property for the proposed sensor-based solutions. Food and agricultural regulations were also raised, while clear and consistent regulations facilitate the adoption of new technologies, stakeholders warned that inconsistent or outdated frameworks may act as barriers.

Based on stakeholder insights, one of the key enablers identified is the digital infrastructure (**resource system**) for implementing the proposed sensor-based solution. The LL location has been reported to benefit from a stable cable internet connection, further supported by low-power Wi-Fi access. These systems, according to participants, enable sensors to be interconnected (**resource system**) and ensure smooth communication with the monitoring application. Furthermore, LL members noted that a national mobile network provider (**actors**) has opened LoRa communication channels (**resource system**), which are used by the proposed solution. Internet providers (**actors**) and stable



telecommunications infrastructure (**resource system**) were consistently recognised as necessary conditions for successful implementation.

In parallel, the stable electric power supply system (**resource system**) in Serbia has been described as reliable, well-organised, and affordable, with stakeholders noting its importance for the actuation (irrigation, automatic opening...) in greenhouses, which will be based on sensor data. Road infrastructure (**resource system**) was also positively remarked.

On the natural resources side, LL participants reported that the experimental farm already has access to sufficient water sources for irrigation, along with an adequate amount of land (**resource units**). However, related to the acquisition and organisation of the land (**resource system**) they also recognised that additional land can be rented if necessary. It was also mentioned that research institutes have the possibility of acquiring up to 1000 hectares for experimentation purposes.

Regarding resource systems for production management, the app developed by BioSense Institute was highlighted as a tool to provide management and information (**resource units**) to all actors in agriculture, especially for farm owners.

Data storage systems (**resource systems**) were described as easily accessible and capable of handling large volumes of sensor data. However, stakeholders raised concerns about the accessibility (**resource systems**) of certain types of data and knowledge (**resource units**), which are often protected by private companies. The strategy of knowledge transfer (**resource systems**) was identified as missing, and LL participants remarked that the absence of a structured approach to sharing information has hindered technology adoption. Although stakeholders expressed willingness to collaborate, the lack of official institutional cooperation (**resource systems**) has been viewed as a limitation.

In terms of financial systems, LL members recognised that several funding programmes are available through public ministries and EU channels (governance systems). Some of those possibly can be used for financing technology purchase, training, and data standardisation. However, stakeholders highlighted the lack of a national financial framework to support experimentation and technology uptake.

The need for long-term funding and risk-compensation mechanisms (**resource systems**) was particularly emphasised. Banks (**actors**) were mentioned as providers of dedicated loans (**resource units**) for farmers, yet concerns were raised that, with increasing climate-related risks, securing loans might become more difficult in the future.

Participants also raised concerns about the lack of adequate educational resources (**resource units**). It was underlined that there are not enough programs or materials to properly educate farmers about the benefits and use of technologies. On the other hand, the AgroSense platform (**resource units**), for instance, was mentioned as a valuable tool to educate farmers about new technologies and emphasise benefits. Data standardisation was also flagged as a critical factor (**resource unit**) still underdeveloped in Serbia.

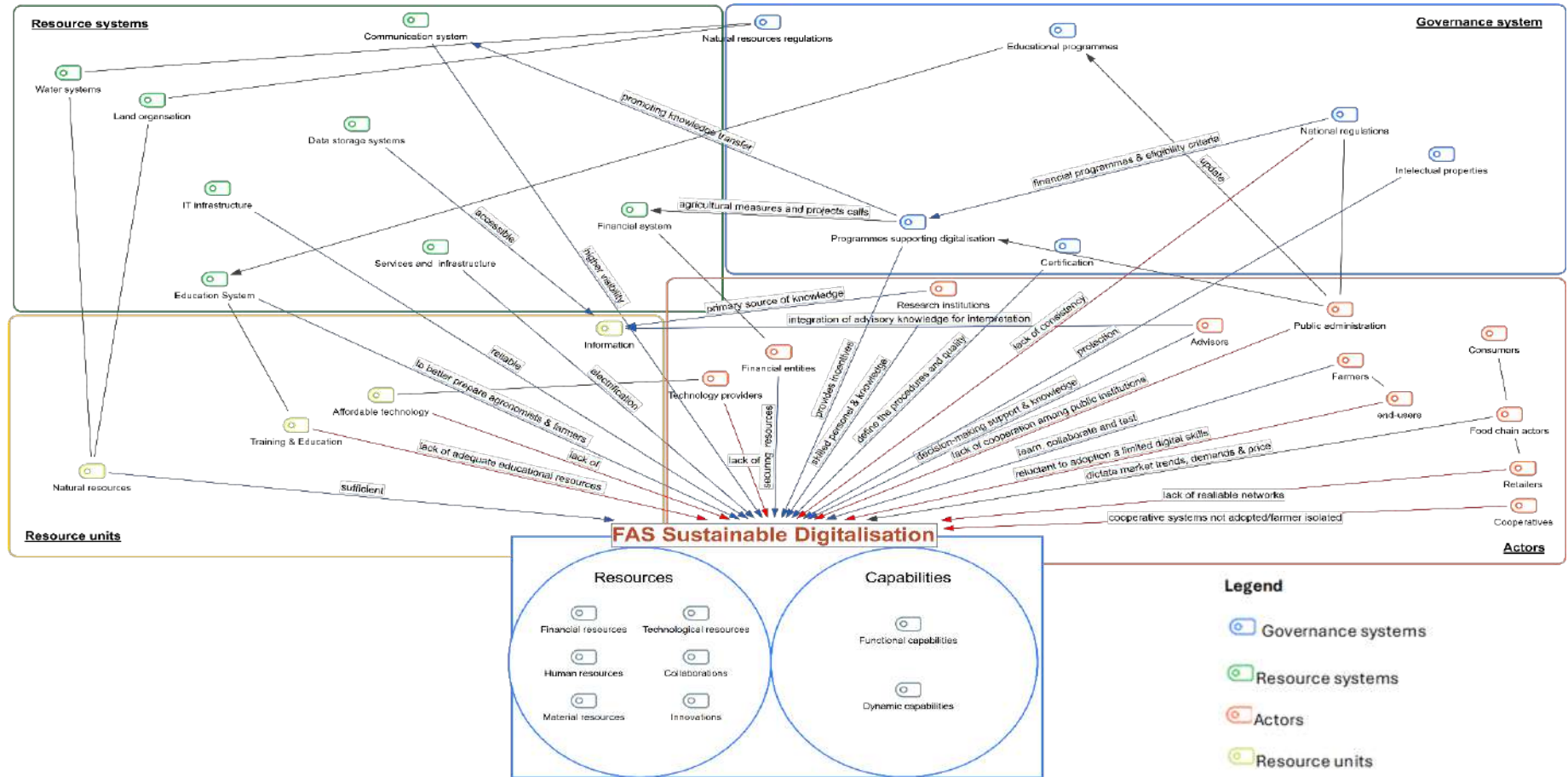
Cost was another major concern. Stakeholders recognised that some of the technologies required for smart sensor systems remain prohibitively expensive for most Serbian farmers, pointing to a clear need for more affordable technology (**resource units**).

On the market side, LL participants declared that Serbia currently lacks an official classification for premium agricultural products (**resource units**), which limits the potential for producers to access more profitable markets.

Finally, issues of visibility and communication were highlighted. Stakeholders called for greater dissemination and promotion (**resource systems**) of the Living Lab's activities, especially through media channels. They also proposed that the results of the demo farm should be more openly shared with the wider community and other stakeholders.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in the Greenhouse Smart Sensor Laboratory LL.

Figure 32. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in the Greenhouse Smart Sensor Laboratory LL.



Source: UAL

### Conclusions and summary of the digital ecosystem of the LL

The Greenhouse Smart Sensor LL in Serbia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers** identified by stakeholders is the presence of robust digital and physical infrastructures, including stable internet, LoRa communication channels, and reliable electricity and road systems. The availability of technical and agronomic expertise within research institutes and faculties has also been recognised as a driver for technological adaptation. Moreover, support from advisory services and openness among farmers to explore new tools were reported as strengths. Financial incentives and digital platforms such as AgroSense, along with accessible land and water for production, were also noted as significant contributions to digital implementation.

In terms of **hindrances**, stakeholders have raised concerns about the limited technical skills of farmers, reluctance to adopt digital innovations, and the absence of affordable technologies. The lack of institutional cooperation, a missing strategy for knowledge transfer, and weak educational support hinder technology uptake. Regulatory inconsistencies and the absence of commercial partners were also reported. Furthermore, gaps in data standardisation, lack of a premium product classification system, and underdeveloped dissemination channels reduce the visibility and impact of the LL.

In conclusion, the digital ecosystem of the Greenhouse Smart Sensor LL in Serbia shows enablers and hindrances (see Figure below). Regarding enablers, conditions such as well-established infrastructure, scientific collaboration, technical advisory services, and initial financial support are in place. However, digitalisation is hindered by fragmented governance, limited institutional coordination, low farmer digital capacity, and missing systems for data standardisation, education, and commercial scalability.

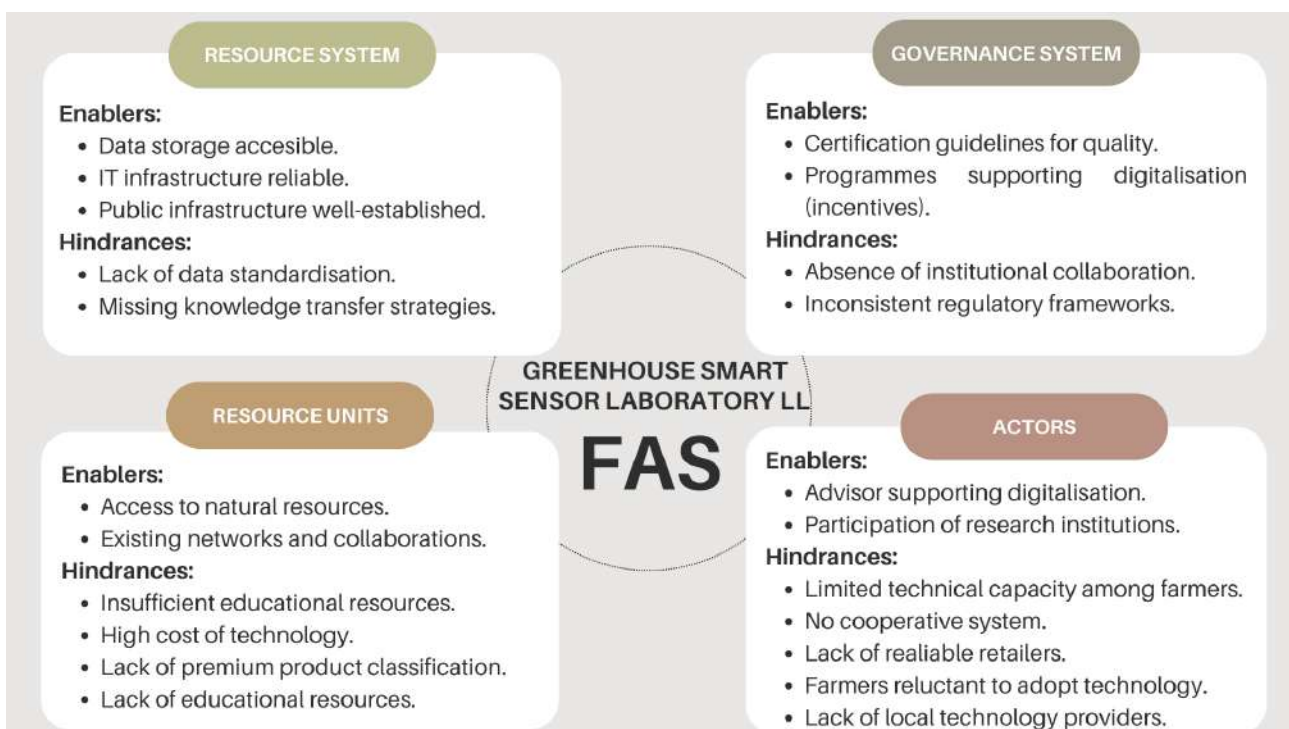


Figure 33. Main enablers-hindrances of Greenhouse Smart Sensor LL.

Source: UAL

#### 4.1.12 Almería Agroecology Living Lab (Spain)

##### Introduction

The Almería Agroecology Living Lab, located in the south-east of Spain, focuses on digitalisation in vegetable greenhouse production to optimise resource management.

The stakeholders of the Almería Agroecology LL describe the focal action situation (FAS) as follows:

*"To overcome the lack of interoperability among heterogeneous data sources and address the difficulty in managing and optimising resources for sustainable greenhouse production."*

To achieve this, the Living Lab employs a digital platform that centralises data and it is currently at Technology Readiness Level 5 (TLR 5).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources are the availability of an experimental farm, such as technified greenhouses for demonstrations in the field as a core activity of the LL for dissemination of more success case studies. In this sense, inputs as electricity was recognised as a key aspect for digitalisation as it determines the possibility of being able to implement the technologies in field. Similarly, conventional agricultural equipment and devices for measuring, monitoring and visualising data (sensors, actuators and weather stations already presented in the LL) were also highlighted by LL participants as important elements for a favourable implementation of technologies.

On the financial side, LL members acknowledged funds for competitive research and start-up fundings as necessary for initiating and supporting the implementation of digital solutions. At the same time, it was noted by stakeholders that broader public and private investments are needed to facilitate digital adoption among end-users and the industry.

In terms of technological resources, LL participants have declared as necessary the use of Artificial Intelligence for the development of ETL (extraction, transformation and loading) systems in a simple and autonomous way. They have also mentioned the need for software tools such as the EERR system to support decision-making, along with monitoring and modelling systems to ensure traceability and data collection, as well as reliable internet connection. On the other hand, stakeholders have recognised that the LL already benefits from data integration platforms and a user-oriented app.

Sustainable digitalisation is also conditioned by the availability of human resources. The presence of experienced facilitators, advisors, technicians, and farmers already engaged in the LL was noted by LL members. Nonetheless, participants have highlighted the need for more specialised staff with specific-technical knowledge, including IT technicians and data analysts, to support data interpretation. In this regard, knowledge of cost-benefit analysis has been identified as an enabler for the adoption of digital solutions.

Informational resources have been also recognised by stakeholders as key to fostering digital adoption. Communication strategies, outreach campaigns, and online networks like Agroconnect have supported knowledge sharing and mindset change. Word-of-mouth and visible success stories have been particularly effective locally. Stakeholders also stressed the importance of data traceability and transparency to build trust in a traditionally cautious sector.

Moreover, regarding collaborations, stakeholders have pointed to strong relationships with farmer associations, cooperatives, technology providers, and research centres. Nonetheless, LL participants have emphasised the need for broader value chain representation, noting that engagement with public administration, retailers, and other market actors is still necessary.

Finally, innovations described in the LL by members include the trialling of new technologies, especially those involving artificial intelligence, and the optimisation of production processes. According to them, the LL has also engaged in intellectual property registration and economic studies aimed at strengthening the viability of the



proposed solutions. Stakeholders mentioned the importance of designing tools and communication frameworks and standards that unify language across users, regulators, and technology providers.

- Capabilities

Concerning functional capabilities, stakeholders have recognised the LL's ability to carry out data integration and analysis, including the monitoring of key parameters to optimise resources and processes. Additionally, LL participants have highlighted its skills to identify hotspots, address topics of general interest, and balance conflicts of interest among stakeholders. However, additional functional capabilities have been identified as necessary for technology deployment, such as cybersecurity, particularly in relation to data, and the digital skills to manage it to build trust. LL participants also stressed the need to simplify technology use to enable wider adoption and improve market access.

The wider adoption of digital technologies is influenced by several key dynamic capabilities, particularly stakeholder attitudes. Confidence has been highlighted by LL members as essential when dealing with technology, and the LL has been recognised for its ability to foster environments of trust. Likewise, ambition to improve and willingness to innovate and change have also been acknowledged. However, stakeholders have noted the need for a more proactive attitude, as digitalisation requires transformation across the entire value chain, not just in the production stage. In this regard, community awareness and shared values and goals were declared as crucial for shifting the sector's mindset.

Regarding knowledge and information, its creation and transfer have been as well identified by LL participants for its importance in the adoption of digital solutions. Even so, better transfer skills and common assimilation of knowledge is still necessary.

In terms of adaptive capabilities, stakeholders have reported the LL's ability to update technologies and carry out trials of new ones. However, they have also highlighted the need to strengthen overall technification skills to support farm modernisation. Furthermore, better adaptation to farmers' needs and the local environment has been stressed. Finally, a cooperative attitude has been seen as essential to foster integration and identify synergies.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

Farmers (**actors**) have been identified by stakeholders as actors whose proactivity directly influences the success of digitalisation. As end-users, they decide which technologies to implement at the farm level, they are in charge of data collection, and they are responsible for its veracity, fostering trust (**resource units**) and building evidence on digital solutions. According to LL participants, their role as enablers also includes the dissemination of benefits and costs through word-of-mouth. Additionally, LL members have recognised that farmers' feedback can influence technology developers and suppliers to better meet on-farm needs, as their experience could help shape practical and relevant standards (**resource units**). Their demand for transparency in data management also impacts the development of data regulations (**governance system**).

Research centres and universities (**actors**) have been mentioned for enabling affordable technologies (**resource units**) through their data analysis and knowledge creation skills. They constitute a source of information, increasing evidence on technologies and supporting informed decision-making, particularly for farmers.

Technology providers (**actors**) have been highlighted by stakeholders for supplying the devices needed for deploying digital solutions. They have also been acknowledged as contributors to the development of standards and protocols (**governance system**), which support wider technology adoption and interoperability (**resource system**). Additionally, they were also stressed for their influence in technology affordability by setting prices (**resource units**). Likewise, LL participants have mentioned they may handle data storage (**resource system**). Technology developers (**actors**), in turn, have been noted for ensuring the simplicity and user-friendliness of digital tools.

Advisors and consulting companies have been described by LL participants for their role in building stakeholder confidence/trust (**resource units**) and enhancing digital skills through technical support. Similarly, advisors have been declared as important knowledge channels and sources, contributing both to the dissemination and creation of information.

Second-level organisations such as cooperatives (**actors**) have been especially highlighted for their role in fostering sectoral interconnection (**resource unit**), particularly at the local level. According to LL members, cooperatives maintain direct communication with farmers, acting as intermediaries that facilitate training (**resource units**) through educational programmes (**governance system**) and offering recommendations to ensure members are familiar with and proficient in digital technologies. In the same way, some cooperative members may serve as beta testers, helping to generate evidence and build trust in digitalisation (**resource unit**). Their collaborative decision-making and participatory governance structures (**governance system**), shared also by producers' organisations, was identified for promoting equitable access to information. Additionally, producers' organisations have been noted for their potential to support technological progress and adoption through the use of operational funds.

The visibility of the LL has been recognised as a key factor in advancing digitalisation. In this line, disseminators (**actors**), vocational trainers (**actors**), and the creation of start-ups have been highlighted for their role in facilitating knowledge transfer.

Stakeholders have recognised food chain actors, such as the auxiliary industry, for their role in regulating the supply of digital solutions and identifying new market opportunities. Retailers and marketers have been mentioned as key to ensure that the added value of digitalisation is reflected throughout the entire value chain. LL members have also identified private companies (**actors**) as drivers capable of accelerating the adoption of technologies. These actors have been reported to lead the development of their own data standards (**governance system**). Moreover, stakeholders have noted that private companies, particularly those operating in data-driven environments, shape governance by building business models around data collection, processing, and analysis. Their ethical practices and accountability in handling data have been seen as crucial for fostering user trust (**resource unit**).

LL participants have recognised that within the value chain, consumers (**actors**) claim the veracity of data and the traceability of a product, having a significant impact on sectoral decisions, e.g., in the adoption and scalability of digitalisation. Likewise, stakeholders have mentioned that certifiers contribute to ensuring good practices and trust (**resource units**). Certifiers have also been acknowledged for opening new markets and bringing economic and social benefits (status).

LL members have identified financial entities (**actors**) as relevant partners for providing adequate and sufficient financial resources, for supporting experimentation and the broader adoption of digital solutions.

The public administration (**actors**) has been mentioned for its relations with regulations (**governance system**) that pertain to digitalisation, such as data norms (**governance system**), making it difficult or not to adopt them in legislative matters. Data protection laws have been recognised for establishing access and ownership rights for individuals and organisations, which directly impacts how data is shared and to its interoperability (**resource system**). Stakeholders have also identified its role in shaping standardisation (**governance system**) and funding facilitators. In this regard, LL participants have mentioned that financial incentives (**resource units**) help overcome economic barriers and stimulate investment in interoperable solutions within the agricultural sector. With respect to standards (**governance system**), they specify how data should be structured, stored, and transmitted. They can be used as common rules, helping to build an interoperable environment that ensures data protection and user trust. In the Almería LL, tools like data models and communication protocols have been developed to support standardisation and traceability. Furthermore, LL members have highlighted that ownership structure can either facilitate or restrict collaboration, as private companies may create incompatible solutions due to proprietary interests, thereby hindering interoperability. Therefore, securing intellectual property (**governance system**) has been seen as a way to move forward in digitalisation. In this sense, good user accessibility to their data and good traceability has been recognised as essential to generate the necessary trust (**resource units**) and change of mindset. As a conservative thinking (**governance system**) predominates.

Markets (**governance system**) have been acknowledged for their ability to incentivise the use of common standards and practices for data integration. Stakeholders have highlighted that the demand for interoperable digital solutions would promote alignment across the value chain.

State programmes (**governance system**) which support digitalisation have been remarked for its importance, and stakeholders have reported that those programmes could be created and spread through recommendations. Recommendations may seek harmonization of policies and regulations related to data management and sharing including guidelines and best practices for data governance and interoperability.

In this sense, the education system (**resource system**) has a key role, for instance, the Agricultural and Knowledge Integration System (AKIS) supports the transfer of knowledge. Stakeholders have recognised that the existence of communication channels favours interoperability and technology adoption as interoperability in agriculture often involves adapting technologies to specific local contexts, through knowledge flows that promote understanding of specific needs and allow technologies to be adapted to be interoperable with local practices and resources. Moreover, the access to knowledge (**resource units**) allows informed decisions regarding the adoption, usefulness, and use of these technologies and the possibility and management of their integration. At the same time, they have pointed out that training (**resource units**) and capacity-building activities for farmers are included enhancing interoperability by teaching end-users how to use the technologies.

When dealing with systems, market is an important one. LL participants identified that the existence of a monopoly (**resource systems**) (in term of technology provision) hinders the interoperability of technologies. There is less incentive to adopt standards that facilitate interaction and data sharing between technologies and other providers because there is a tendency to create a closed ecosystem where product and service options are limited for actors. In the contrary, open systems (**resource systems**) and open access to resources, e.g., digital platform for data integration allows the standardisation of protocols and facilitate decision support. Data format (**resource units**) was highlighted by stakeholders for its influence in improving interoperability, in this sense, a data model affects the way information is organized and stored. European and international standards promote interoperability in a wider context and often they include safety and reliability requirements. Data security systems (**resource systems**) were also mentioned for the development of trust on the part of users and companies that share their information between systems.

LL participants have recognised that local and general connectivity-infrastructure (**resource systems**), as well as network coverage, define the possibility of implementing technologies. They have also identified that internet infrastructure influences the security of data interoperability, as encryption and firewalls are essential to protect the integrity and confidentiality of data during transfer. In addition, they have mentioned that internet infrastructure (**resource systems**) includes services for storage, processing, and data access, which facilitate interoperability by allowing different systems to share and access information.

Reliable storage systems (**resource systems**), such as data models and integration platforms, have been reported for facilitating data sharing and promoting standardisation if the data storage follows accepted practices (in terms of control and security).

Accessible and affordable technologies (**resource units**) were remarked as relevant conditions for digitalisation. For example, having a common platform allows to use data from different sources, similar to LL's iVEG interoperability software, with an app, all the data is queried. Furthermore, affordable (economically) and reliable technologies direct influence on the scalability and expansion of their use. Therefore, maintaining a competitive market is key to keeping prices reasonable.

In addition, financial systems (**resource systems**) have been pointed out as enablers, particularly through subsidies and grants that improve accessibility to digital technologies for small-scale farmers and cooperatives. As reported by stakeholders, having access to them by the ecosystem (**resource units**) is not only an element that increases the conduciveness of the environment but at the same time allows for pooling more resources, both material, human, technological and capacity building, necessary for the interoperability, implementing workshops, disseminating knowledge, etc.

Participants have also recognised that natural resource infrastructure (**resource systems**) (such as access to water and land) influences where and how technologies can be implemented, and interoperability may be affected if these

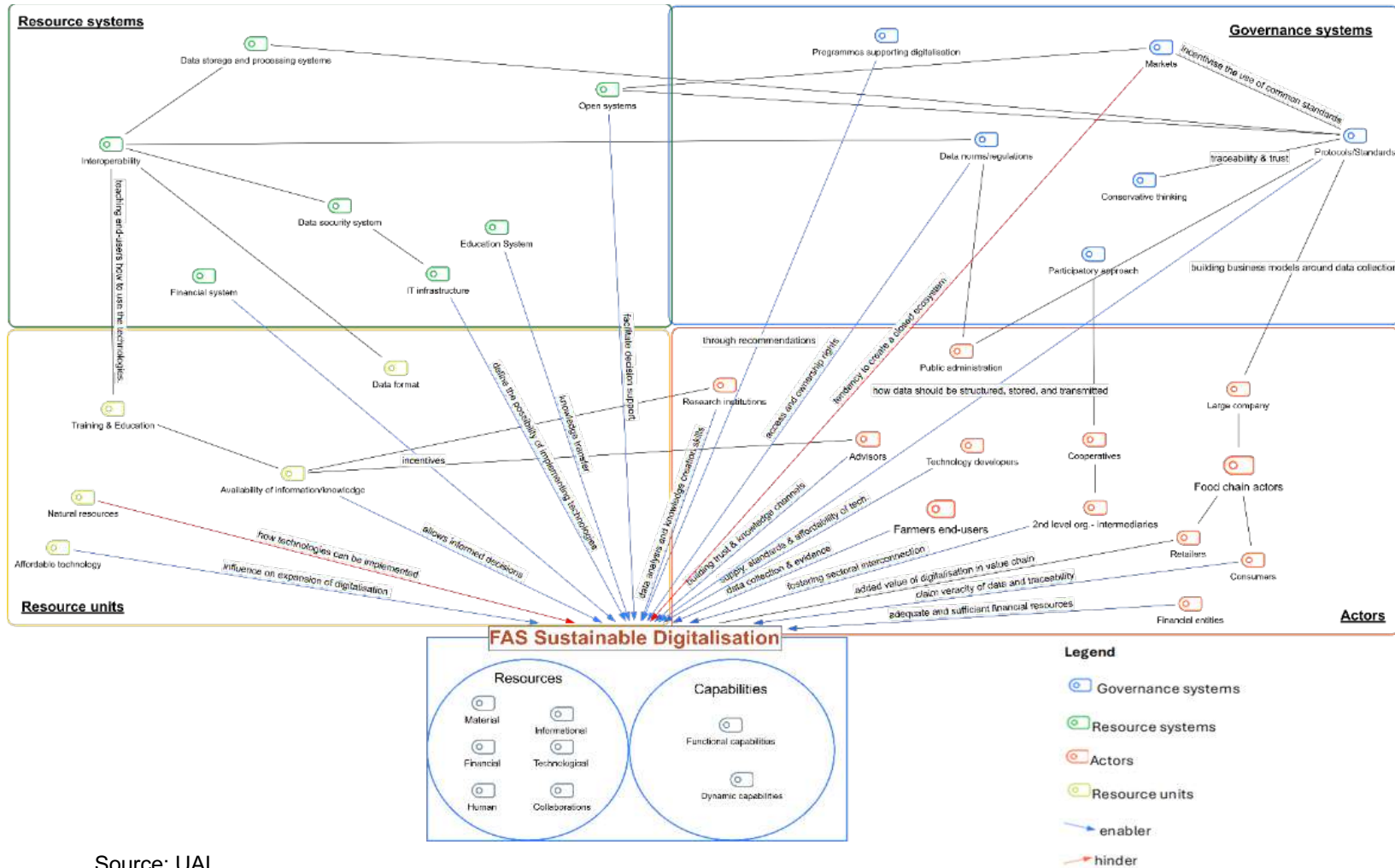


geographical locations make it difficult to connect to other infrastructures or systems. For instance, some technologies rely on specific raw materials (**resource units**) that may be limited in nature. In addition, a farm (land) provides a place to test and test the usefulness of the digital solutions and technologies that you want to integrate.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Almería Agroecology LL.



Figure 34. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Almería Agroecology LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Almería Agroecology LL in Spain illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, stakeholders identify the presence of an experimental farm, the availability of diverse material and technological resources (e.g., sensors, actuators, weather stations), and initial infrastructure for data integration. Human capital, including experienced facilitators, advisors and technicians, also stands out as a strong asset. Likewise, data integration platforms, a user-oriented app, and the use of protocols and standardised tools play a role in current digital innovations. Similarly, collaborations act as a significant driver, promoting training, knowledge sharing, and trust-building.

Public institutions and funding systems support this enabling environment through regulation, financial incentives, and standardisation. Markets, certifiers, and consumers reinforce the system by generating demand for traceability, transparency, and evidence-based technologies. The education system and AKIS also support knowledge transfer and local adaptation.

In terms of **hindrances**, the LL still lacks private investment. Stakeholders note the need to simplify tools for easier adoption by smallholders. Digital skills gaps also limit progress, along with insufficient capabilities to adjust technologies to different farm contexts. At the system level, monopolistic practices and proprietary standards reduce interoperability and scalability. LL participants underline the importance of better internet infrastructure, stronger data security, and open, standardised platforms.

In conclusion, the digital ecosystems of the Almería Agroecology LL show enablers and hindrances (see Figure below); in terms of enablers a strong material and technological resources, committed human capital, and collaborative networks. Institutional backing, financial incentives, and demand from markets and consumers further reinforce its potential. However, key challenges remain, including limited investment, digital skills gaps, and barriers to interoperability caused by monopolistic practices and non-standardised systems.

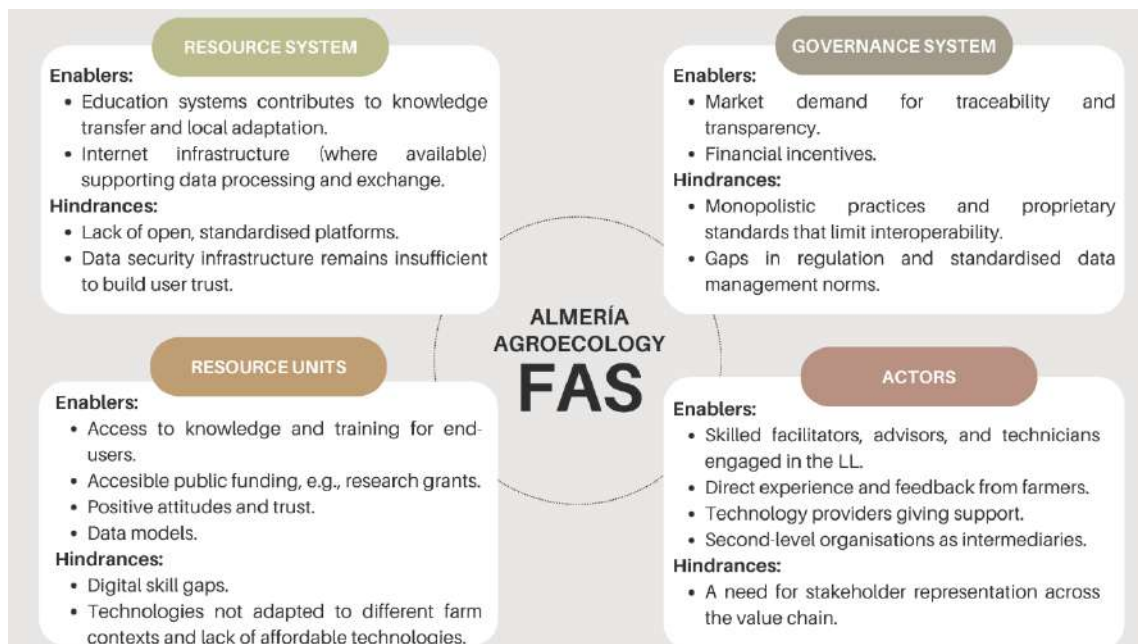


Figure 35. Main enablers-hindrances of Almería Agroecology LL.

Source: UAL

### 4.1.13 Cloughjordan Food Hub Living Lab (Ireland)

#### Introduction

The Cloughjordan Food Hub LL, located in Ireland focuses on enhancing local food systems through digitalisation. This LL focuses on local communities and small farmers, with the goal of shortening supply chains and creating a food system controlled by producers, consumers, and local businesses. The LL aims to develop an online marketplace that allows small-scale food producers in rural areas to access local markets, thereby supporting local economies.

The stakeholders of Cloughjordan Food Hub LL describe the focal action situation (FAS) as follows:

*“How can local farmers and suppliers get paid a fair price and ensure that people have the option of better, fairer ways to source their food directly from the producers?”*

To achieve this, the Cloughjordan Food Hub employs an Open-Source digital platform which is currently at Technology Readiness Level 7 (TRL7).

#### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

##### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources including digital devices (laptop, smartphones) as well as equipment and facilities for storage, packaging and a physical space for local farmers and artisans to drop off their produce and for customers to collect. Complementary technological resources, including software, internet connectivity and especially the digital platform (Open Food Network Platform) which is at the centre of the LL.

Sustainable digitalisation is also conditioned by the availability of human resources, stakeholders described the human resources of the LL, including farmers, volunteers, local artisans and some facilitators and coordinators. However, there is a need for more specialised labour, such as IT staff for troubleshooting and support for platform users, as well as more disseminators and trainers to increase outreach and upskilling. Stakeholders of the LL stressed the relevance of knowledge, including technical knowledge, communication strategies/activities and skilled support providers for changing direction (e.g. from primary production to diversified).

Financial resources also represent a key element for sustainable digitalisation., Stakeholders emphasised the importance of private and public investments to maintain platforms, apps etc. as well as to pay salaries. Due to the nature of community supported agriculture as the focus of the LL, stakeholders highlighted the recurring subscriptions from consumers as a key financial resource to secure/enhance reliable finances for farmers.

Finally, stakeholders of the LL described collaborations with farmers, consumers and networks such as Open Food Network, ARC and Feeding Ourselves. On the other hand, stakeholders stressed the need to improve collaborations with technology providers and experienced and knowledgeable facilitators to increase the number of people being trained and accessing the digital marketplace.

##### - Capabilities

Concerning functional capabilities, stakeholders of the LL described know-how related to experience and abilities to solve especially technical issues of the digital platform as a key aspect. Stakeholders also stressed the importance of enhancing digital skills for losing fear of usage of the technologies by farmers and consumers. This links with the need for simplification of the technology to make it as user-friendly as possible. According to stakeholders, this would increase technology adoption and consumers and farmers' engagement and enhance the provision of valuable data to the farmers through consumers' purchase behaviour as well as possibly increase the number of users through recommendations.

Furthermore, regarding dynamic capabilities, stakeholders outlined the relevance of transfer and integration of knowledge related to feedback integration in the digital platform, to broaden, expand and re-fit knowledge. Moreover, stakeholders also stressed adaptive capabilities related to being able to update technologies and made data-driven decisions. Regarding attitudes and values, stakeholders identified optimism and cooperative attitude as important

positive values within the LL. On the other hand, confidence and willingness to adopt digital technologies and community awareness are identified as attitudes that the LL needs to enhance the conduciveness of the digital ecosystem.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is mainly formed by farmers (**actors**). Furthermore, other actors collaborate and/or influence the LL. These include public and private advisors, consumers which enable the digital market to operate and are as crucial as the farmers, a researcher and a climate activist. The use and feedback of farmers and consumers of the digital platform can enhance the simplification and usability of the digital platform, a key aspect for enhancing short food supply chains. If they lack the digital skills or confidence to access the digital platform it'll hinder the idea for a local digital market.

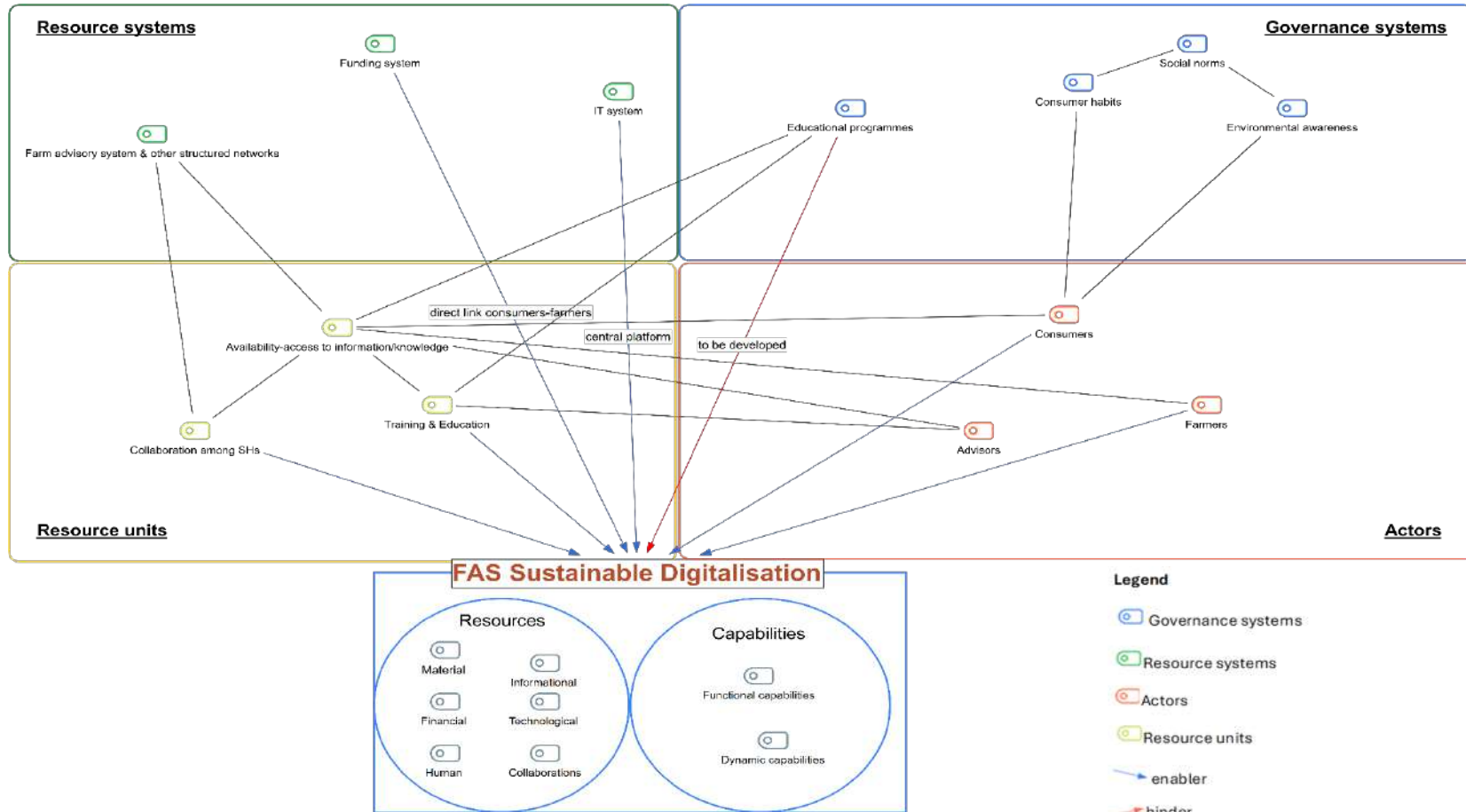
Stakeholders stressed the importance of establishing collaborations among stakeholders (**resource units**). These collaborations refer to the cooperation between the community supported agriculture farm and the wider ecovillage of Cloughjordan where it is situated; but also, of collaborations with other external stakeholders such as ARC, Open Food Network, and other food hubs for exploring possibilities for trading between these. Moreover, these collaborations with external stakeholders are important to enhance the availability and access to information and knowledge (**resource units**) as well as for education and training (**resource units**).

The availability of information is also related to having a platform as a centralised hub (**resource systems**) that enables the LL to shorten the supply chain addressing the LL FAS problem statement. Also, other resource systems supporting the conduciveness of the LL digital ecosystem relate to logistics/distribution, a financing system that straightforward and directly link producers and consumers, and knowledge systems of networks supporting digitalisation, namely formed systems of advisors and second level networks, that supports providers-farmers for changing direction (e.g. from primary production to diversified).

Finally, in relation to governance system, stakeholders of the LL pointed towards the importance of social norms related to consumer habits and environmental awareness, for example, in terms of overcoming eco fatigue and saturation of micro food enterprises and cultural barriers to engaging with ecovillage entities. Also, in terms of governance systems, stakeholders stressed the relevance of developing structured training programmes (**resource units**) that enable stakeholders to reach their full potential and anchoring the digital approach into their daily routine.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Cloughjordan Food Hub LL.

Figure 36. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Cloughjordan Food Hub LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Cloughjordan Food Hub LL in Ireland illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation. In terms of enablers the LL presents material, technological, financial and human resources, including equipment, devices, farms, a digital platform, knowledge and some available funding. Also, as enablers the LL has established collaboration among different stakeholders. Attitudes such as optimism and cooperation are also enablers. Having a platform as a centralised hub for information access and exchange and linking consumers and farmers is an important enabler. Moreover, support systems from networks, advisors’ systems and the possibility of establishing an alternative and direct financing system from producers to consumers also represent enabling elements for digital ecosystem conduciveness.

In terms of hindrances there is a need for more specialised labour, especially IT staff and facilitators. Despite the established collaboration the LL needs to improve collaborations especially with technology providers. Moreover, there is a need for simplification of technology and enhancing digital skills through education and training, including the development of structured training programmes, for wider technology adoption. Some social norms related to ecological fatigue and cultural barriers to engage with ecovillage also represent hindrances for sustainable digitalisation.

In conclusion the digital ecosystem of the Cloughjordan Food Hub LL presents both enablers and hindrances (see Figure below). The digital ecosystem of the LL is characterised by collaborations between different stakeholders that brings resources and capabilities and attitudes for sustainable digitalisation, and by a digital platform that allows for direct exchanges between farmers and consumers. On the other hand, the need for more specialised staff and collaborations with IT developers, a more user-friendly platform, structured training programmes and some social/cultural barriers hinders the digital ecosystem conduciveness towards sustainable digitalisation.

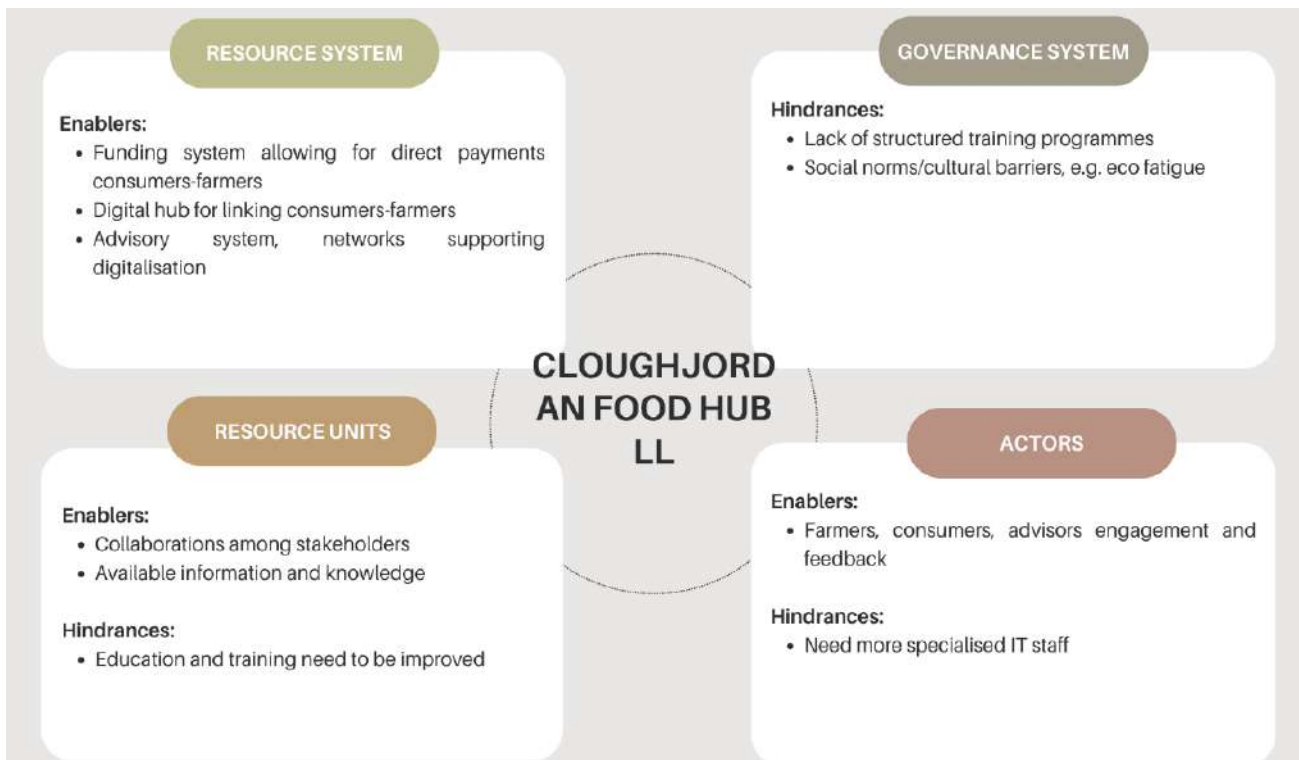


Figure 37. Main enablers-hindrances of Cloughjordan Food Hub LL.

Source: UAL

#### 4.1.14 Agrifood Technology Living Lab (Belgium)

The Agrifood Technology Living Lab, located in Belgium, focuses on digital technologies to enhance sustainability in arable crop production. The primary goal of this LL is to reduce the use of crop protection products through site-specific spraying, optimizing the application of pesticides and herbicides.

The stakeholders of Agrifood Technology LL describe the focal action situation (FAS) as follows:

*"To reduce the use of crop protection products through site-specific spraying while enhancing weed, disease, and pest detection in commercial arable farms"*

To achieve this, the LL tests ultra-high resolution RGB cameras on drones, AI-based models, task map generation, and label tools for weeds. The LL is currently operating at Technology Readiness Level (TRL) 7.

#### **Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation**

##### - Resources

Key resources identified in the Agrifood Technology LL include material and technological resources. These include for example experimental fields to test the technology and obtain evidence, a key aspect for a conducive digital ecosystem. Moreover, the LL relies on machines equipped with site-specific application, ultra-high resolution on drones, AI models, and label tools to improve weed, disease, and pest detection. The RTKRTK GPS system ensures centimetre-accurate precision for site-specific applications, while robust AI detection models and computing power are necessary for producing real-time task maps. From an informational perspective, the availability of reliable weather forecasting tools is also a challenge, as according to stakeholders Belgium's forecasts are not always accurate.

Sustainable digitalisation is also conditioned by the lack of availability of human resources. LL's participants recognised a need for a trained workforce capable of managing innovations and data. Additionally, attracting young, interested farmers was also mentioned, as many farmers currently prefer traditional farming methods over digitalisation. Stakeholders emphasised the value of the knowledge on economic benefit, and in general, cost-benefits considering economic, social and environmental impacts of technology.

Financial resources also represent a key element for sustainable digitalisation. Stakeholders emphasised the need for grants and economic incentives to support the early adoption of technology, cover learning challenges and promote confidence in digital solutions. However, a key concern remains regarding liability for prediction models, as farmers currently bear the full risk.

Certain collaborations were also identified as beneficial for the Agrifood Technology LL, particularly those that bring together farmers, technology providers, drone pilots, and experimental centres.

Regarding the innovations, the LL is focused on disease and pest detection technology, as well as site-specific spraying. One of the main innovations that participants identified as necessary is improving disease detection models, making them more robust and incorporating risk factors.

##### - Capabilities

In terms of functional capabilities, the Agrifood Technology LL recognised the ability to improve detection models, supported by an increased digital skill. Moreover, the digital divide in digital skills is widening between top and bottom. There is a need for a better ability of the farming sector to analyse drone data which, according to stakeholders, has to be carried out on a larger scale with smaller turnaround time, requiring a high level of skills to interpret and process data effectively.

Concerning dynamic capabilities, the Agrifood Technology LL highlighted uncertainty regarding the potential to increase economic margins and achieve cost savings through the use of drone images for site-specific spraying, as the low price of crop protection products reduces the economic incentive for farmers to adopt precision spraying techniques. At the same time, the LL declared there is a need for skills to process drone images into task maps. However, the turnaround time from ordering a drone flight to receiving actionable results remains too long.

#### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**



The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

Farmers (**actors**) were mentioned for their role in testing new technologies in practice, yet their willingness to invest in digital tools remains a challenge due to cost concerns. As well, stakeholders pointed out technology providers (**actors**) as contributors by supplying drone technologies but currently they lack the capability to offer end-to-end solutions tailored for farmers. Similarly, technology developers (**actors**) deliver machine manufacturers which allow integration of data (e.g., John Deere) and facilitate data-driven farming practices. However, limited platform interoperability restricts full technological integration (**resource system**). Accordingly, the lack of standards (**resource units**) for multiple machine manufacturers (e.g. Agrirouter) is remarked as a hindrance, as noted by LL participants, currently, almost every machine manufacturer uses different standards.

Research institutions (**actors**), including ILVO and universities, provide fundamental research and drive innovation through spin-off companies, but their focus remains more theoretical than practical, therefore there is a need to translate research results into practical solutions. In addition, with innovative software and hardware, researchers can find new ways to save on the usage of plant protection products. Regarding second-level organisations (**actors**), Boerenbond, a farmer association, wereas distinguished for its lack of active site-specific recommendations. With respect to advisory support, Bayersupply companies and other advisor services are not independent advisors, which may influence recommendations based on crop protection manufacturers interests.

Additionally, stakeholders described that retailers and distribution networks (**actors**) are currently not incentivised to take an active role in supporting digital agriculture, even though they could help coordinate pricing and market alignment. Consumers (**actors**) also were noted by stakeholders for their impact on social norms (**governance system**) such as their habits, choices, and appreciation of products produced with the help of digitalisation. Their willingness to pay more for products produced with technology is an important element as currently, all costs are for the farmers.

Large agricultural companies (**actors**), particularly contractors, were identified as contributing to the LL by offering large-scale services (**resource units**). Their ability to invest in new technology, combined with their larger scale and possibility to provide education on innovations, would enhance digital adoption. However, the availability of contractors willing and able to apply site-specific solutions remains limited. Additionally, foreign companies supply predictive models through licensing fees, increasing costs and limiting adaptability to local farming conditions.

In the public landscape, the LL recognised the need for a closer collaboration with the government to introduce digitalisation in practice to bring digitalisation to farmers (**governance system**).

Regarding the governance system, drone and spray legislation were identified as restrictive in the use of drones for site-specific spraying, adding an administrative burden that complicates technology adoption. At the EU level, stakeholders recognised that regulations (**governance system**) on permitted plant protection products under the Green Deal impose strict limitations on the quantity and type of substances that can be used. And there are no local recommendations and limitations regarding manure and fertilizer. Furthermore, the Ministry of Health (FAVV) (**governance system**) was identified by its influence on the products that farmers produce and the production conditions (**resource system**).

Additionally, LL participants declared that data ownership regulations (GDPR) pose another challenge. The strict rules on data collection and usage create obstacles for drone flights and data analysis (**governance system**).

In terms of funding, subsidies and grants (**resource units**) have been identified as overly generic and administratively complex (**governance system**), making them difficult to access (**resource system**). Belgium's "Area Declaration" policy further adds to administrative requirements, obliging farmers to declare all plots every three years, adding complexity to regulatory compliance. Nonetheless, despite these challenges, digitalisation presents an opportunity to improve some social norms and perceptions (**governance system**), such as the image of farmers by reducing excessive pesticide use.

A major hurdle highlighted by stakeholders for the Agrifood Technology LL is the lack of universal standards for data platforms and machinery (**resource units**), which hinders seamless integration and adoption of digital solutions. In this context, the availability of open-source models (**resource system**) without licensing fees could significantly facilitate technology adoption and interoperability. Additionally, enhancing connectivity and data integration across platforms (**resource system**) is seen as a key enabler for digitalisation. Equally important is the connectivity infrastructure (**resource system**) to prevent time delays in obtaining results, as timing in these areas is crucial.

The lack of rewards (**resource units**) for farmers adopting digital innovations hinders widespread implementation of drones in the field. Stakeholders recognised the need for incentives and compensation funds for risks, for instance, grants to support initial learning phases (**resource units**). There are no direct incentives and rewards mechanisms (**governance system**) are currently limited to investment support, rather than compensating farmers for the actual use of digital tools like drones or precision spraying. Additionally, larger-scale test facilities backed by guarantees (**resource units**) when yield or quality is affected could increase confidence through concrete proof-of-concept in digital solutions and promote their uptake.

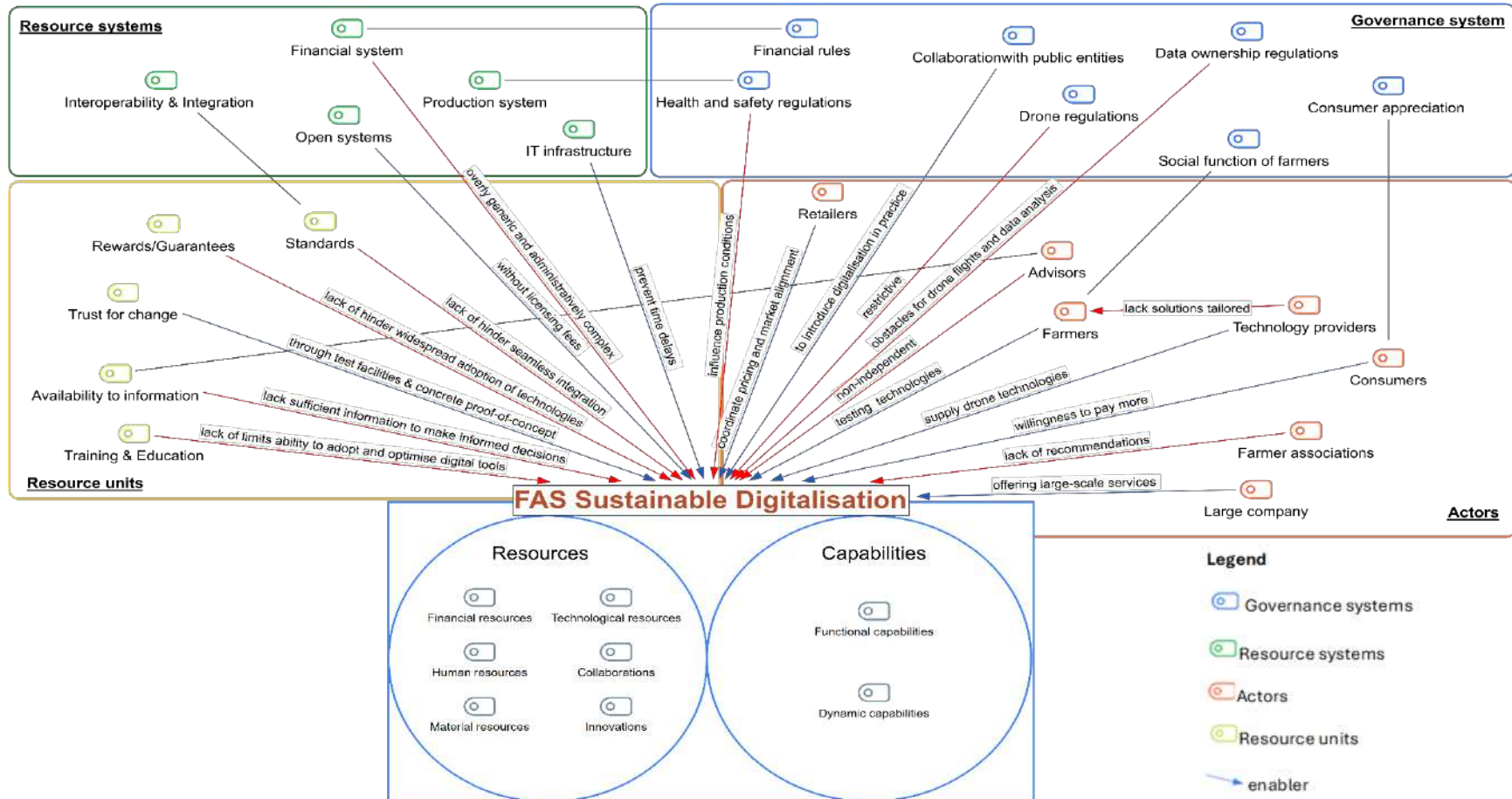
Educational systems and training resources (**resource unit**) were also pointed out for their influence in digitalisation. The lack of exposure to new technologies among new farmers, combined with insufficient training programs, limits their ability to adopt and optimise digital tools. Furthermore, data availability (**resource unit**) remains a concern, as farmers lack sufficient information to make informed decisions, reinforcing the need for data integration and sharing through platforms (**resource systems**) like DjustConnect.

Finally, water availability and resistant crop varieties (**resource units**) are key within the natural resource system (**resource systems**) that could influence digitalisation efforts. The adoption of more resilient crops could help reduce dependence on plant protection products, aligning with sustainability objectives.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Agrifood Technology LL.



Figure 38. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Agrifood Technology LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Agrifood Technology LL in Belgium illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of enablers technology providers and research institutions supply drone technologies and develop innovative models that contribute to data-driven farming. Moreover, the availability of open-source models and improved platform connectivity enhances interoperability and reduces licensing costs, making technological adoption more accessible. Large agricultural companies and contractors contribute by offering large-scale services, investing in new technologies, and providing educational resources to farmers. Retailers and consumers further influence market demand, with potential willingness to pay more for products produced through digital solutions. Financial support, such as subsidies and grants, helps farmers cover initial investment costs, mitigating some of the risks associated with new technology. Furthermore, education and training programs are essential enablers, particularly for new farmers and stakeholders who require enhanced digital skills to optimise the use of technology.

In terms of hindrances, high costs remain a major obstacle, as farmers bear the financial burden of adopting new technologies, with limited financial incentives or direct rewards for implementing drones or precision spraying. Another challenge is the lack of standardisation, as there are no universal standards for data platforms or agricultural machinery, which restricts interoperability and slows technological integration. Furthermore, regulatory constraints and administrative burdens such as complex subsidy applications pose additional barriers, including restrictive drone and spray legislation, GDPR data ownership regulations, and strict EU Green Deal limitations on plant protection products. The lack of engagement from retailers and the weak advisory systems further limits opportunities and informed decisions for farmers. Similarly, issues related to data availability, integration and a general lack of trust in technology also hinder digital deployment.

In conclusion, the digital ecosystem of the Agrifood Technology LL shows enablers and hindrances (see Figure below). Enablers include innovative drone technologies, open-source models, improved connectivity, financial support, and large-scale services from agricultural companies. However, challenges persist, such as high costs for farmers, lack of financial incentives, limited standardisation, regulatory barriers, weak advisory systems, and data integration issues.

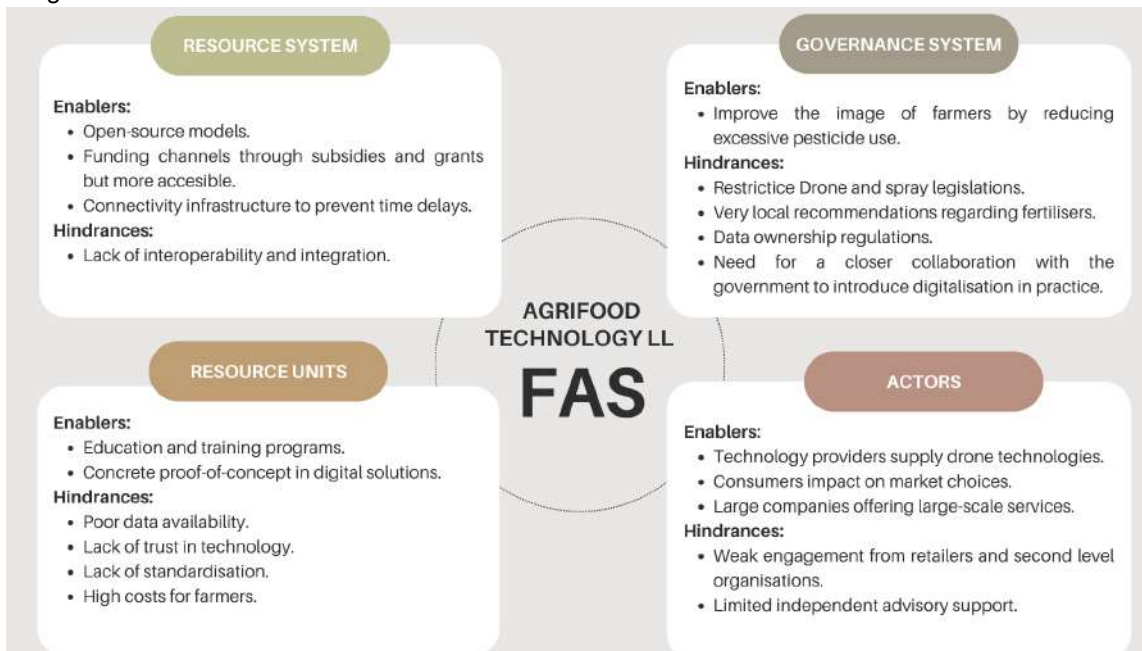


Figure 39. Main enablers-hindrances of Agrifood Technology LL.

Source: UAL

#### 4.1.15 Artificial Irrigation Management System Living Lab (Slovakia)

##### Introduction

The Artificial Irrigation Management System LL, located in Slovakia, is focused on a critical aspect of sustainable agriculture: optimising irrigation to enhance crop production while conserving water. This endeavour, especially in the context of climate change and the need for precision agriculture, is pivotal. The goal of the Slovak Living Lab is to create, evaluate and test an application for agronomists that will enable the automatic determination of the irrigation dose.

The stakeholders of the Artificial Irrigation Management System LL describe the focal action situation (FAS) as follows:

*"To provide irrigation doses tailored to plant phenophases, soil water reserves, and environmental conditions, ensuring sustainable water use and optimal crop growth."*

To achieve this goal, the LL will start from a combination of data obtained from measurements from sensors, irrigation systems, from databases of the physiological need for individual irrigation doses for a specific plant, data on environmental factors that are on the company's server, and available scientific knowledge. The LL employs a mobile application currently at Technology Readiness Level 7 (TRL 7).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation in the Artificial Irrigation Management System LL relate to a diverse range of material resources to optimise irrigation practices in production, including soil moisture sensors and other measurement devices, necessary for collecting real-time data. These sensors collect data on soil moisture levels, temperature, humidity, and other environmental factors affecting crop water needs. In relation to technological resources, stakeholders noted that the state and advancement of technological tools for data collection and analysis determine the efficiency and effectiveness of the solutions provided by the LL.

In addition, stakeholders declared the LL benefits from the availability of a broad array of data sources, including sensor measurements, irrigation system data, plant physiological needs databases and meteorological data. These resources are instrumental for developing a holistic understanding of the irrigation needs, accurate irrigation models and decision-support tools.

Sustainable digitalisation is also conditioned by the availability of human resources and their knowledge and expertise. According to LL participants, there is a strong base of scientific knowledge and technical expertise within the team, crucial for analysing data and developing algorithms.

Financial resources also were mentioned as a key element for sustainable digitalisation, particularly in terms of public funding through CAP financing, subsidies, and grants.

Similarly, collaborations have been identified as digital enablers. Stakeholders recognised benefits from strong partnerships with academic and research institutions, which provide access to research insights, innovative approaches, and additional expertise. Moreover, The LL cooperates with technology companies specialising in agricultural technologies. At the end, the need for an increase in collaborations with stakeholders across the agricultural value chain, including farmers, agritech companies, and policy makers, to ensure the solutions are scalable and meet the users' needs was raised by LL participants.

Finally, as described by the LL a significant innovation is the reduction of the reliance on subjective decision-making and potentially improving water use efficiency. The integration of various data sources into a coherent algorithmic solution to predict and apply the optimal irrigation dose is an innovative approach in precision agriculture. Additionally, the LL highlighted the exploration of artificial intelligence and machine learning to refine predictive irrigation models for the analysis of complex datasets and generate accurate irrigation schedules.

###### - Capabilities

The Artificial Irrigation Management System LL mentioned several functional capabilities for precision irrigation. For instance, in terms of data accessibility, the LL declared having access to data including global climate models or regional weather data that allows analyses of the vast amounts of data collected from sensors, irrigation systems, and external databases. Participants classified this capability of analysing data as essential for developing accurate algorithms for irrigation management as advanced algorithms that can predict irrigation needs require the integration of diverse data types, including soil moisture levels, plant physiology, and environmental factors. Moreover, the LL highlighted its expertise in deploying and utilising soil moisture sensors and environmental monitoring devices for collecting real-time data on temperature, humidity, and crop water requirements.

Furthermore, in regard to dynamic capabilities as mentioned above, the LL leverages collaborations to enhance the scalability of digital innovations, ensuring that technological solutions align with users' needs. Besides, the LL remarked adaptive capabilities in relation to data-driven decision-making with respect to water use.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the RCCIs of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

Farmers and agronomists were identified as central actors in the LL, as they are the primary end-users of the LL digital innovations (irrigation application). Their role was mentioned as fundamental in providing practical insights into the system's usability and effectiveness under real-world agricultural conditions. Their feedback helps to refine the application and impact the abilities to make data-driven decisions for irrigation efficiency.

Accordingly, stakeholders remarked on the role of research and academic institutions (**actors**) as contributors to scientific knowledge, information access and research capabilities, helping to refine algorithms and models as well as fostering collaborations and innovations. As noted, the National Agricultural and Food Research Centre provides informational resources in research results format (**resource units**) including scientific data on plant moisture needs and environmental factors. Independent research helps in building awareness among stakeholders but mainly between farmers. In addition, stakeholders of the LL mentioned the Agricultural Knowledge and Innovation Institute for providing a broad portfolio of services mainly in the area of continuing vocational lifelong education and training (**resource units**) and certification of agricultural advisors. It compiles a specialised library collection which ensures effective and efficient access to information and information resources (**resource units**) through services and technology (**resource system**).

On top of that, the LL recognised a second level organisation (**actors**), the Rural Parliament in Slovakia, as an enabler of collaborations among stakeholders (**resource units**) through information-sharing and dissemination (**resource system**), enhancing the LL ability of transferring and integrating knowledge.

Similarly, technology partners (**actors**), such as IT companies and developers, were stressed for their role in providing technological and material resources, including advanced sensors, data analytics tools, and digital platforms which enable real-time data collection and analysis. Likewise, LL participants named retail companies (**actors**) also as contributors to resource availability and the strengthening of capabilities.

Stakeholders of the LL also recognised educational institutions (**actors**), including vocational and higher education institutions, as potential contributors that could reinforce digital capabilities within the LL. However, stakeholders pointed out that the educational system (**resource system**) and its educational courses and training (**resource units**) do not adequately prepare individuals with the skills required for digital agriculture, hindering the development of a skilled workforce prepared for implementing sustainable and advanced agricultural technologies. Additionally, agricultural public advisors (**actors**) were mentioned as lacking relevant knowledge about the LL background.

The European Commission and the national government (**actors**) were identified as an obstacle for digitalisation efforts. As stakeholders highlighted, the complexity of subsidy and grant conditions (**governance system**) creates administrative burdens and slows down technology adoption. Nonetheless, government regulations (**governance system**) influence systems related to subsidies, water and agricultural management (**resource system**) and sustainability.

In this line, the Common Agricultural Policy (CAP) is perceived positively as it provides funding opportunities for farmers, although bureaucratic challenges can negatively impact its accessibility and effectiveness (**governance system**). Similarly, according to stakeholders of the LL, the second pillar of CAP (governance systems), which funds rural development and supports innovation and knowledge transfer, faces hurdles due to limited access to information (**resource units**) and bureaucratic processes (**governance system**).

Furthermore, regulatory policies surrounding water use and agricultural practices can either promote the adoption of innovative irrigation technologies or act as barriers to their implementation (**governance system**). As mentioned by stakeholders, overly restrictive regulations or lack of supportive policies for sustainable irrigation practices impede the development and adoption of digital innovations. As well as inconsistencies or conflicts between local, regional, and national regulations create confusion and make it difficult for stakeholders to invest in or commit to digitalisation (**governance system**).

Another key element highlighted by the LL includes the state and advancements of technological resources (**resource units**), which determines the efficiency of irrigation solutions through data collection, analysis, and application. The lack of access to modern technology or high costs associated with advanced technological (**resource units**) solutions limit the adoption of innovations, particularly in regions with limited financial resources or in smallholder farming contexts. As seen, the availability and correct allocation of financial resources (**resource units**) were identified as directly impacting digital adoption. However, the interoperability and integration of data (**resource system**) was another aspect raised by the LL, as for the use of the digital technology proposed the integration of various data sources into an algorithmic solution is required.

In addition, according to stakeholders, knowledge and information sharing (**resource system**) are the key for farmers and facilitate collaborations (**resource units**) and technological integration. Additionally, LL participants emphasised that the availability and quality of water resources (**resource units**) affect the application of irrigation strategies. In this case, sustainable water management practices (**resource system**) are necessary to ensure long-term viability. At the system level, inadequate or outdated water management infrastructure (**resource system**) limit the effectiveness of innovations by restricting the availability of water for irrigation or making it difficult to implement advanced irrigation techniques.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Artificial Irrigation Management System LL.



**Conclusions and summary of digital ecosystem of the LL**

The Artificial Irrigation Management System LL in Slovakia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, the LL benefits from the involvement of key stakeholders, where research institutions contribute to knowledge generation by conducting independent research, validating information sources, and providing vocational education and training programs. In addition, second-level organisations have a role in knowledge dissemination. Technology providers support the LL by supplying digital tools and strengthening the LL’s analytical capabilities. Furthermore, the availability and proper management of natural resources, such as water, enable the implementation of sustainable agricultural practices. The LL also benefits from financial mechanisms such as CAP funding and other public grants, which support rural development and investment in innovation. Information-sharing networks further facilitate collaboration, improving the LL’s ability to integrate digital solutions.

In terms of **hindrances** bureaucratic complexities in subsidy access, grant conditions and regulations create administrative burdens. In addition, the lack of interoperability between data platforms and limited access to modern and affordable technology pose challenges, particularly for small-scale farmers. At the same time, outdated water management infrastructure remains a bottleneck, restricting the effectiveness of advanced irrigation techniques. Additionally, the education system does not provide adequate vocational education and training related to digital skills development in agriculture.

In conclusion, the digital ecosystem of the Artificial Irrigation Management System LL presents both enablers and hindrances (see Figure below). The LL benefits from diverse stakeholder collaboration, research and tech support, information availability and sharing, and financial mechanisms among others. However, challenges such as regulatory barriers, limited technological interoperability, financial constraints, and skill gaps hinder the scalability and full implementation of digital irrigation solutions.

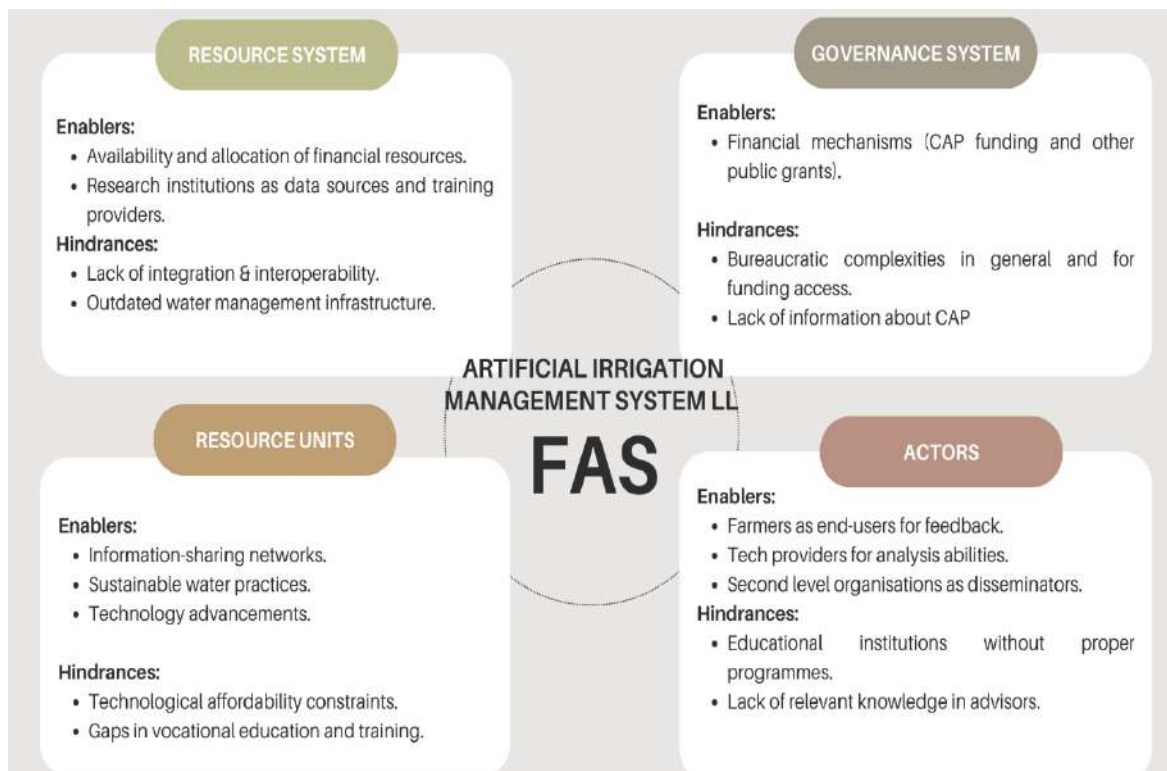


Figure 41. Main enablers-hindrances of Artificial Irrigation Management System LL.

Source: UAL

#### 4.1.16 LIT OUESTEREL Living Lab (France)

##### Introduction

The LIT OUESTEREL Living Lab, located in the Grand Ouest region of France, focuses on pig meat production and explores how digital technologies enhance pig welfare and working conditions throughout the production chain. The LL is combining technological, organisational and social innovation.

The stakeholders of the LIT OUESTEREL LL describe the focal action situation (FAS) as follows:

*"To use non-invasive digital technologies to improve pig welfare and workers' conditions across production stages, while enabling data interoperability to facilitate farm management and food traceability."*

To achieve this, the LL brings together farmers, veterinarians, advisors, data and technology providers, and researchers. They test a digital platform that links farm and equipment data to facilitate interoperability and data sharing between machines and management software. This platform is expected to simplify farm operations and improve traceability and food safety from farm to consumer. The technology currently operates at Technology Readiness Level 6 (TRL 6).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources available, such as a demo farm (IFIP experimental farm) where the digital platform is tested. Financial resources also represent a key element for sustainable digitalisation. As reported by LL participants, in the form of research funds, e.g., the LL has received a project grant ("Data for Food"), and in the form of financial support for equipment manufacturers.

Technological resources have also been highlighted by stakeholders, the LL is supported by servers, databases (which constitutes a source of information), cloud system and the platform itself is recognised as an innovation.

Sustainable digitalisation is also conditioned by human resources. According to LL participants the LL counts with specialised workers personnel such as platform developers, web designers, and engineers with expertise in both technical and economic farm data. Notably, the project was led by individuals who, according to stakeholders, had no commercial interest.

Moreover, collaborations were highlighted, the LL also benefits according to stakeholders from already established contact networks that help to ease the diffusion and from the pre-existence of the LIT OUESTEREL living lab initiative. Besides, stakeholders pointed out the "Living Lab way of working" as a key organisational resource.

Finally, from an innovation perspective, the platform itself was described as an innovation. In addition, IoT systems and the development of a new business model were mentioned aimed at becoming a standard in the sector.

###### - Capabilities

Concerning functional capabilities, stakeholders identified limited access to markets. In terms of data collection, it was acknowledged the ability to reduce the double capture of data by the farmers and the automatic data entry of advising services.

Furthermore, in regard to dynamic capabilities, benchmarking was seen as an important strategy to foster progress. Stakeholders also recognised some lobbying and advocacy capabilities. For instance, the sales force needs to be used to convince farmers to use the platform, so they would convince the equipment manufacturers. As above mentioned, the LL possesses the abilities to test technologies in demo farms. Finally, a willingness to embrace change and engage in innovation search was also considered, especially for identifying and integrating new equipment and tools.

##### Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the

conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

Farmers (**actors**) are at the heart of the LL as end-users of the digital platform. Their engagement is, according to stakeholders, quite relevant as they both enable or hinder the digital transition depending on their willingness to adopt and use the digital platform. Similarly, cooperatives and manufacturers (**actors**) play a role, they act as bottlenecks if they are resistant or disengaged from using the digital solution. Research institutes (**actors**) were acknowledged for their contribution to both the development and diffusion of the platform.

In terms of technical development, the LL members identified dashboard editors (**actors**) as facilitators of the use of the platform and ISAGRI an IT company (**actors**) who gives advisory services of the platform. At the same time, technology providers (**actors**) such as Google or Microsoft enable the ability of data storage and in terms of infrastructure, Internet providers (**actors**) have a clear enabling, depending on whether there is sufficient internet coverage.

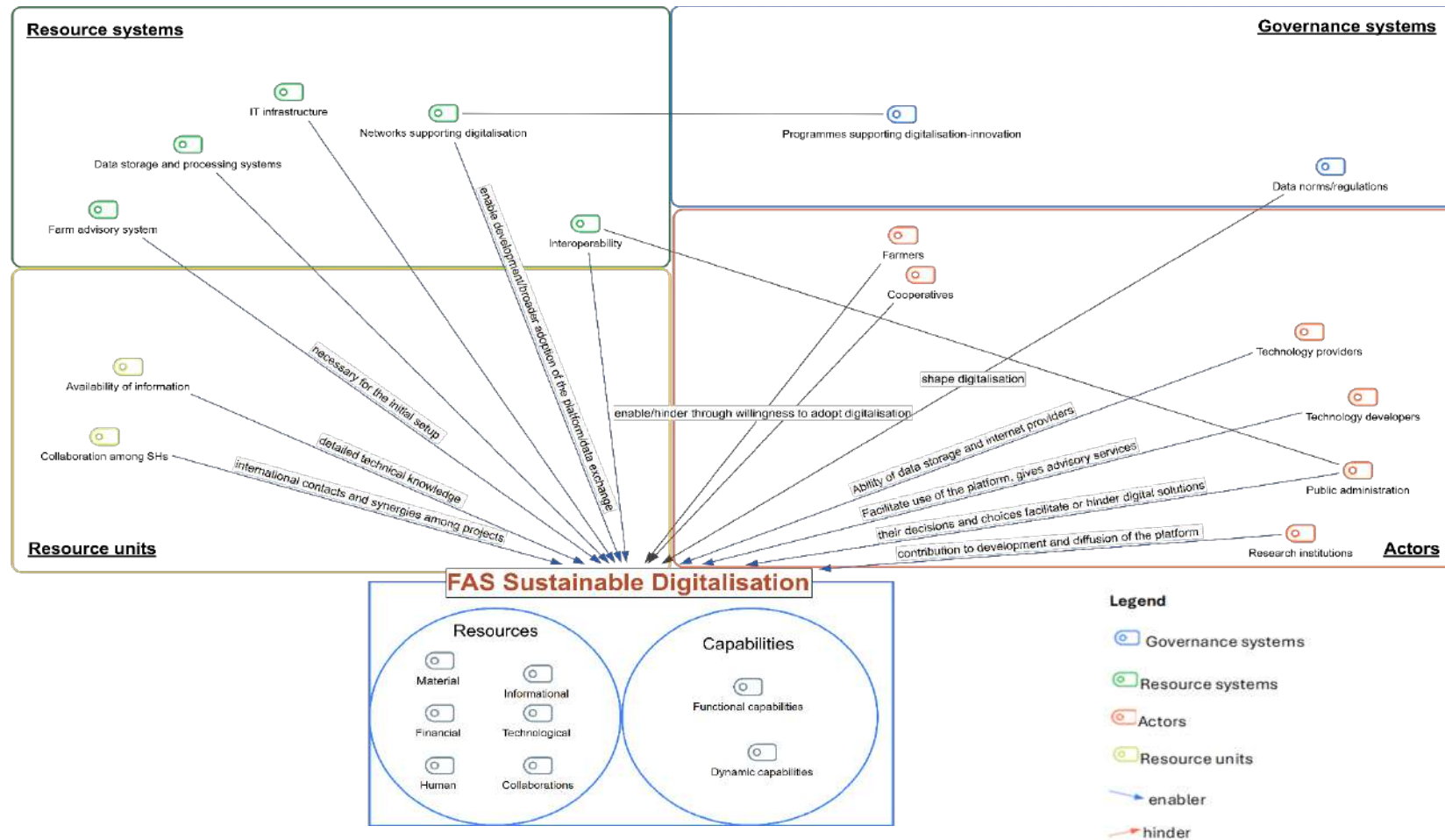
Furthermore, the involvement of policymakers and, more broadly, public administration (**actors**) had been emphasised by stakeholders as a factor influencing the LL's digitalisation processes. It was noted that their decisions and choices could either facilitate or hinder the implementation of digital solutions. In this regard, political support had been identified as an enabler, particularly in promoting the adoption of the platform and ensuring data compatibility and interoperability across systems (**resource system**).

In parallel, stakeholders had also pointed to the role of data norms and regulations (**governance system**) in shaping digitalisation. Additionally, the existence of national programmes supporting digital agriculture such as the French Development Plan for Agriculture (**governance system**) have been acknowledged as another supportive factor. Complementing this, networks that promote and facilitate digitalisation (**resource system**), such as the PigLink community or the European networks, were recognised for enabling the development and broader adoption of the platform and for data exchange. In particular, platforms like BDPORC, BNO or PigConnect were identified as complementary interfaces (**resource units**) enabling dematerialised data exchanges within pig farming systems (**resource system**). Data storage and management systems (**resource system**) as well as a cloud system for equipment were referred to as a supporting element for the implementation of the digital platform. In line with this, stakeholders emphasised the need to ensure internet connection and infrastructure (**resource system**) in each building of the farm in order to enable the platform usage. This also relates to the technical backing of farms (**resource system**) which was considered necessary for the initial setup and for demonstrating how to use the platform correctly.

Knowledge access (**resource units**) was recognised by LL members as relevant, particularly the detailed technical knowledge required to describe the structure of the farm and its buildings. Additionally, experience in data standard in farms was also highlighted and, in this sense, the platform AG Porc (**resource units**) was reported for supporting data normalisation and establishing standard definitions. Regarding collaborations (**resource units**), international collaborations, for instance, international contacts using similar platforms and collaboration between project leaders were other facilitator elements highlighted.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in LIT OUESTEREL LL.

Figure 42. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in LIT OUESTEREL LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The LIT OUESTEREL LL in France illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, stakeholders recognised farmers as key end-users and research institutes as drivers for platform development and dissemination. Technical actors like dashboard editors and IT firms facilitated usability through advisory services. Cloud systems, internet providers, and global tech companies enabled data storage and management, depending on infrastructure availability. Political support and public administration involvement were identified as important enablers. Networks and European data exchange systems, along with platforms supported interoperability. The presence of a demo farm, financial support for equipment manufacturers, and skilled human resources (engineers, developers, and data experts) were seen as relevant resources. Knowledge access and experience in data standardisation were highlighted, as were collaborations at both national and international levels for sharing practices.

In terms of **hindrances**, stakeholders mentioned that the engagement of farmers, cooperatives, and manufacturers is not guaranteed, and their reluctance to adopt the digital platform could slow down the deployment of the digital solution. Furthermore, the platform was noted to be less adapted to outdoor systems, and the lack of internet access in certain farm buildings presents a practical barrier to its implementation. Technical support is still needed on-site to ensure correct installation and use of the platform. Additionally, the insufficient data standardisation limits digitalisation.

In conclusion, the digital ecosystems of the LIT OUESTEREL LL shows enablers and hindrances (see Figure below); in terms of enablers the LL benefits from engaged research institutions, technical support actors, digital infrastructure and data exchange networks. However, challenges remain, including technical limitations, lack of internet connectivity, and insufficient data standardisation.

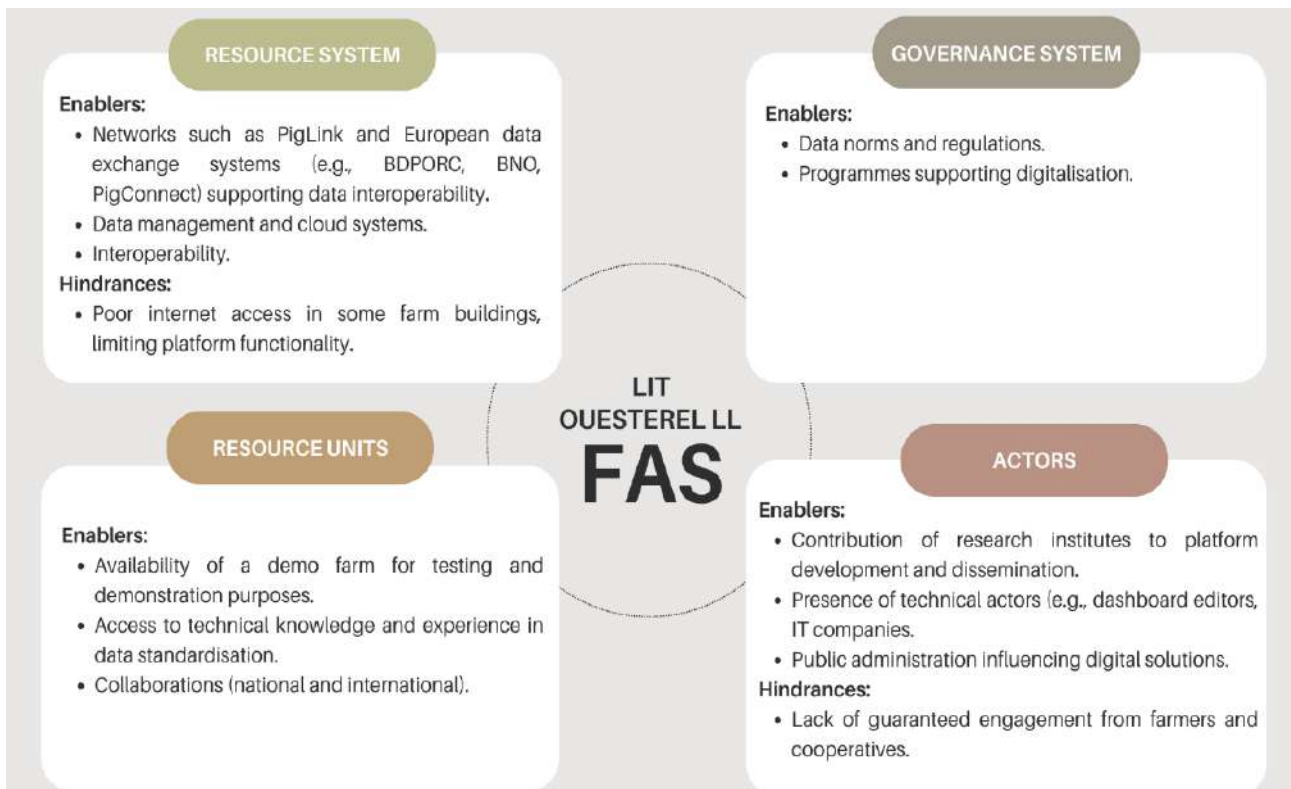


Figure 43. Main enablers-hindrances of LIT OUESTEREL LL.

Source: UAL

#### 4.1.17 Grassland Management Living Lab (Estonia)

##### Introduction

The Grassland Management LL, located in Estonia and Latvia, focuses on digital technologies to enhance grassland management, conservation and semi-natural grassland restoration planning. The primary goal of this LL is to co-design a drone-based remote sensing service suited for animal husbandry and agriculture within complex ecosystems while supporting farmers operating in nature protection zones and managing rural heritage landscapes. Latvian organic beef producers and drone operators from the Estonian University of Life Sciences are testing drone technologies, including hardware, various sensors for mapping farmlands, and photogrammetry software while also developing customised vegetation indices. The main goal is to look into how these multilayered geo-packages can be used in animal husbandry and farm infrastructure management, keeping track of land history, and helping farmers to record their semi-natural grassland restoration efforts. These precise, farm-specific maps enhance farmers' communication with public actors, consultants, and grassland specialists, plus the interactive and visual character of geo-packages can enable peer-to-peer learning processes.

The stakeholders of the Grassland Management LL describe the focal action situation (FAS) as follows:

*"To improve the monitoring and maintenance regimes to manage grassland through drone-based observations."*

The LL is currently operating at Technology Readiness Level (TRL) 3.

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key resources identified in the Grassland Management LL include technological resources: a drone-based remote sensing system (drone tech).

The system includes commercial DJI drones equipped with RGB video and image cameras that can monitor landscapes in real time and be sent on missions to capture sequences of aerial photographs for subsequent use in creating orthophoto maps and 3D models. To provide a mapping service for grassland farmers drone operators also use more advantageous drone tech, which is needed for professional environmental monitoring and natural resource surveys. These are fixed-wing eBee X mapping drones equipped with interchangeable rigs: dual RGB/thermal mapping camera or multispectral sensor (able to detect green, red, red edge, and near-infrared (NIR) spectral bands).

Next, geo-packages, or digital maps including 3D modelling, are created from aerial image sequences using commercial (Pix4D) and/or open-source photogrammetry software. Depending on whether the farmer owns a drone and their farm's computational power, as well as the farmer's knowledge and experience, collecting aerial data via drone flight and creating maps can be done independently or by subcontracting drone operators. DJI drones on some farms by farmer, are used to assess farmland in real time and for tasks such as locating cattle; also, it can be used to create compelling visual communication materials about the farm. It is possible for farmers to make limited maps/3D models for recording and planning infrastructure management using commercial drones.

Furthermore, to advance innovation, LL investigates professional drone tech application in planning EU-valued semi-natural grassland management. There are semi-automated vegetation indexes being created employing machine learning, for which specialised remote sensing knowledge is required and more advanced computational power than what's available on homesteads; therefore, drone operators from the Estonian University of Life Sciences execute this task as a service for farmers.

LL's farms, once mapped, use this comprehensive and multilayered geo-package (accessible through open-source software QGIS) in addition with satellite geospatial data available from National Geographic Information System (GIS) to manage farm infrastructure (for example, plan paddock system for grazing, manure storage/collection facilities, strategize how to mitigate wildlife damage to the hydrology system (beaver dams) or damage to hay meadow infrastructure (wild boar digs) etc.) and monitor semi-natural grassland restoration progress as well as plan conservation (biodiversity monitoring in relation to different grazing and hay mowing patterns, devising tree and shrub cutting for wooded meadow conservation and restoration, protected tree canopy tracking and in general, to

record grassland development to document farm landscape history). Sustainable digitalisation is also influenced by the availability of human resources.

LL's target stakeholder group consists of the grassland-managing community, which includes livestock farmers, grassland specialists, and NGOs as farm advisors. LL's farmers have generations-long experience in animal husbandry, working on challenging landscapes like river floodplain meadows and highly biodiverse but low-biomass grasslands. They also have a keen interest in and knowledge of managing farming businesses, so they adhere to nature and landscape conservation restrictions. The grassland-managing community, knowledge institutions, and researchers have co-created the Grassland Habitat Management Guidelines for Latvia. Guidelines for the protection and conservation of habitats of EU importance were issued in 2017 by the Nature Conservation Agency Republic of Latvia. The main idea behind using drone technology as a key innovation in grassland management was to enhance farmers' GIS workspaces by incorporating digital map layers obtained from drone-based remote sensing. The primary goal was to collaboratively develop a remote sensing service that utilises farmers' practical knowledge to support grassland management planning following these guidelines.

At the centre of the digital solution's co-development is a demo farm. This farm has extensive social resources, and besides the organic beef business, the farmer runs seminars for other farmers interested in grassland management and habitat restoration; geospatial data derived from drones is used to create communication materials. The LL's grassland-managing community is active in the peer-to-peer learning process, supporting other farmers and grassland enthusiasts using face-to-face communications facilitated by the seminar facilities available at Demofarm and other means of digital communications, such as social media. For instance, the Ziedu Pļavas (Blooming Meadows) network, which connects 76 small-scale farmers via WhatsApp, facilitates knowledge exchange and peer support in mapping grasslands.

To effectively augment drone tech applications in managing complex ecosystems like biodiverse grassland habitats, farmers' knowledge is crucial. In the LL community, farmers assist in identifying ground control points that are necessary for training algorithms to create semi-automated indexes. Farmers also determine which farm structures need to be mapped, and the right timing based on the farming calendar to ensure that remote sensing data meets the specific needs and is meaningful in devising management plans.

Financial resources also represent a key element for sustainable digitalisation. Public funding has been recognised by LL stakeholders as the primary support, mainly through subsidies and grants tied to regenerative agriculture and eco-friendly farming practices.

The full digitisation of LL's farms and the adaptation of drone technology necessitate significant computational power; a factor closely associated with financial resources. However, if needed, it is possible to create a service that provides drone-based mapping and farm-tailored indexing. The service would offer a multilayered geo-package that farmers can access using open-source GIS software like QGIS. In both cases, whether farmers use drone tech independently or subcontract mapping might not be a priority for investing large amounts, as the priority is animal welfare and the productivity of grasslands to feed livestock for organic farming. Drone tech can be used to create and communicate additional value for organic meat production, which is the byproduct of such a business focused on biodiverse habitat conservation: organic honeys, herbal teas, and recreational value for the grassland landscapes for ecotourism, and other non-monetary values such as preservation of agricultural heritage and providing other ecosystem services such as supporting diverse flora and fauna. This also includes providing farmland for natural sciences to conduct research aimed at understanding grassland ecosystems.

Stakeholders highlighted the need for a more effective communication strategy, in particular, educational information that should be disseminated to the public to enhance understanding the role of animal husbandry in grassland habitat and biodiversity conservation, also rural heritage landscape preservation. p. LL participants raised the point that an increase in the public awareness could also put pressure on civil servants and policymakers to develop better policies and support mechanisms to support medium-size and small farm digitalisation. Also recognise a need for financial support for conservation agriculture and a link between drone-based remote sensing and monitoring biodiversity as well as other environmental factors to assist farmers willing to work towards nature .

Nevertheless, beyond specific technological solutions, it is crucial that innovations account for changing weather conditions. For example, as noted by stakeholders, the current year has been particularly dry, leading to the



predominance of certain habitats, whereas a wetter year could alter the landscape. Meadow maintenance is not like industrialised agriculture where spot weeding/fertilising is needed and is only looking at short-term inputs. Biodiversity management is a long-term practice.

- Capabilities

In terms of functional capabilities, the Grassland Management LL has reported strengths in data collection. For example, university drone operators work on what can be measured by developing algorithms to identify particular expansive species, particularly in detecting expansive and unpalatable species such as cow parsley (*Anthriscus sylvestris*), which negatively impacts hay quality. Thus, the LL has emphasised its ability to enhance efficiency and optimise field tasks. This capability is particularly valuable for comparing year-to-year changes through natural management principles and relevant for subsidy eligibility and conservation planning. However, data interpretation remains a challenge.

Furthermore, in terms of dynamic capabilities, particularly regarding attitudes and values, the LL has acknowledged a strong connection between farmers and the environment. In addition, stakeholders have demonstrated the ability to generate tangible outcomes, such as mapping efforts carried out through collaborations within grassland-managing community via farmer-led seminars and social media. In spite of this, farms face challenges, including limited ability to increase economic margins and a lack of influence over regulatory frameworks.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The Grassland LL has listed a diverse range of actors contributing to sustainable digitalisation. Among them, beef farmers were seen as crucial for their role focusing on organic meat production within biodiverse wooded meadows. Their agricultural practices align with conservation efforts, in this LL, environmental awareness is deeply embedded as a social norm (**governance system**), shaping decision-making and fostering practices that prioritise biodiversity preservation. Stakeholders distinguished that farmers not only possess extensive ecological knowledge but also adhere to EU and Latvian protected habitat and landscape management guidelines (governance systems). LL participants made the traditional knowledge of farmers evident when they mentioned that farmers cite grassland habitat numbers by heart.

As previously seen, awareness through education (**resource units**) is a hotspot in this LL. The LL members declared the need for a better dissemination strategy of educational information, in this sense, an ecological teacher (**actors**) uses a beef farm as a demonstration site to showcase nature-friendly farming practices.

The public administration (**actors**) also plays a significant role in shaping the LL's landscape, particularly Lauku Atbalsta Dienests (LAD, Rural Support Service of Latvia), which administers subsidies for farmers (**resource system**). However, several concerns have been raised by LL participants regarding LAD's approach. Stakeholders pointed out that discrepancies perceived by them (LAD) are punishable by fines and frequently used, showing a lack of flexibility in governance practices (**governance system**). On top of that, there is apprehension that future compliance metrics used by LAD may be enforced too rigidly (**governance system**), without considering seasonal variations or the impact of wildlife damage on farming practices. The hierarchical nature of the LAD has led to a lack of trust (**resource units**) as reported by stakeholders.

In this context, governance is a particular issue, mainly the lack of collaboration (**resource units**) with public institutions. In the case of LAD (**actors**), the organisation is often accused by LL members of taking away subsidies unnecessarily and not working with small farmers. There is the feeling that they favour large farms. As mentioned, stakeholders declared the need for a better collaboration with the government and other stakeholders (**resource units**), and farmers would want governmental support in the form of subsidies, so the work to preserve habitats is not interrupted (wooded meadows especially).

Beyond LAD, other actors were recognised as influencing the LL's digital operations. LL participants named the Latvian State Forests (Latvijas Valsts Meži - LVM) for their work with some farmers to provide land for the re-



establishment of wooded meadows. However, environmental concerns were remarked on, particularly in relation to the construction of a wind farm in the vicinity, which could impact local eagle and stork populations, an issue of importance to those developing nature-friendly farming practices within the production system (**resource system**).

Another key aspect identified regarding the governance of the LL was the role of the Nature Protection Agency (Latvijas Dabas Fonds and Latvijas Dabas Aizsardzības Pārvalde) (**governance system**). A significant concern raised by stakeholders was the need for participatory governance (**governance system**), specifically in scheduling meetings to ensure farmers' participation without disrupting agricultural activities. Additionally, support programs (**governance system**) like the Countryside Development Programme were criticised by the LL for lacking a results-driven approach. Although, the Blooming Meadows Project (Grasslife) was highlighted as an exception, as it requires results to be shown.

Stakeholders also praised a system of networks supporting digitalisation and innovation (**resource system**). The Blooming Meadows group serves as a support network for landowners managing biodiverse meadows. Additionally, *Zaļā brīvība* (Green Freedom), a conservation group primarily focused on forests, has been suggested as a potential partner in challenging regulatory decisions affecting grasslands, such as those made by LAD.

The LL is embedded in a broader social and environmental resource system. According to stakeholders, tourism for boating, fishing, and sightseeing in biodiverse areas have unintended negative consequences, including illegal fishing. It is specified that farmers have reported instances where high-resolution maps provided to the public increased awareness of prime fishing spots, exacerbating the issue.

Moreover, a key component identified for influencing digital adoption is the agricultural subsidy system (**resource system**) and its administration (**governance system**). For example, LL members claimed that subsidies are only payable if legume cover (particularly red clover) exceeds 50%. In addition, the Latvian State Forest's auction system and lease agreements (**resource system**) have an impact in the land management.

From a technological perspective, open systems (**resource systems**), such as aerial monitoring systems were cited to contribute to natural resource monitoring by generating geo-spatial data sets, which may or not be publicly available. In addition, geo-spatial data sets serve as a source of information (**resource units**) and it was seen as an enabler as it reduces the time required for visual surveying.

On the other hand, stakeholders acknowledged that challenges remain regarding internet infrastructure (**resource system**), as connectivity varies across regions. While some areas benefit from strong internet access, others experience weak signals, limiting the LL's ability to utilise cloud storage for data management.

Education and training (**resource units**) were recognised as essential elements in awareness-raising, helping to put pressure on the civil servants and politicians to create good policies and support mechanisms to protect these farms and understand the value of conservation practices (**governance system**).

Furthermore, data format (**resource units**), as well pointed out, is an important element. Stakeholders stressed the importance of delivering information in an understandable format or improving farmer education (**resource system**) to enhance data interpretation. In this sense, LL participants noted that digitalisation efforts tend to be tailored and focused on large farms, whereas semi-natural grasslands with diverse habitats are typically smaller.

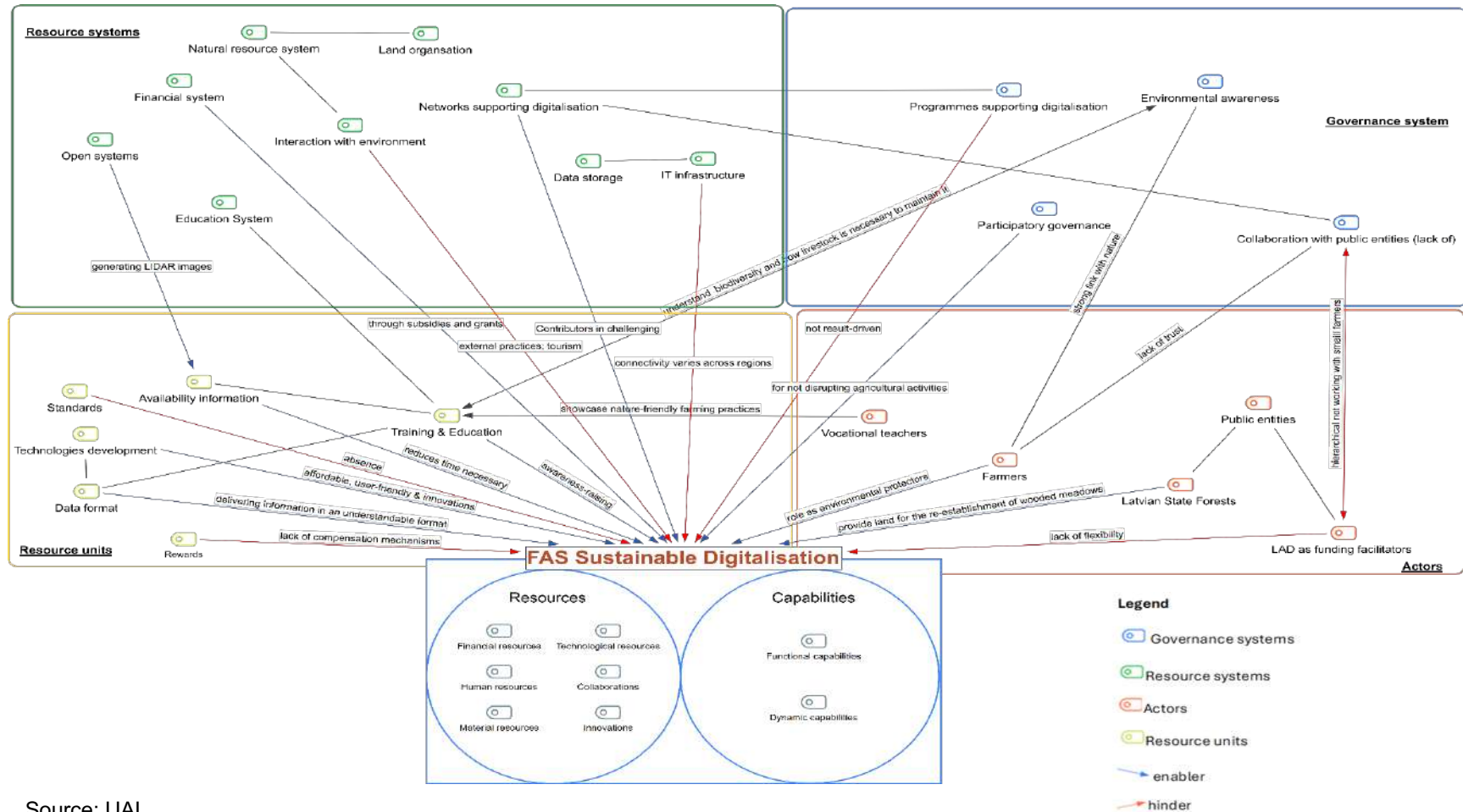
As a result, technological development (**resource units**) is considered a determinant for the success of the digital deployment. Stakeholders recognised the need for affordable, user-friendly drone training methods (**resource units**) or alternative tools to register landscape damage correctly. For example, wild boar digging, which is highly irregular and detrimental, could be systematically recorded and used as the basis for a compensation mechanism (**resource units**). Besides, high-resolution photographs were seen as necessary to assess landscapes, such as beaver holes, wild boar damage, and flood-prone areas. These images as differentiated by LL members facilitate planning, communication with contractors, and engagement with authorities to implement remedial actions. Despite this, stakeholders declared that no support system/networks or compensation mechanisms are currently in place (**resource system**). For example, stakeholders remarked that sometimes LAD come at difficult times of the year and suggest that the land no longer qualifies for subsidies i.e. flooded meadow, but the photos could be used as proof that at other times of the year, they are productive meadows that are being maintained properly.

Further and continuing with technological development (**resource units**), thermal maps were mentioned as an aid to conservation efforts, but according to stakeholders' drones are unable to provide thermal data in winter due to battery limitations. Unlike satellites, which are restricted to pre-scheduled flyovers, drones offer greater flexibility, allowing flights at different times of the day depending on weather conditions. This flexibility was seen as beneficial for farmers. Provision of a drone service would also require minimal time investment, enabling them to focus on other agricultural tasks but maybe too expensive. Finally, the reported absence of clear management guidelines (**resource units**) also affects digitalisation as they vary by EU country.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Grassland Management LL.



Figure 44. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Grassland Management LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Grassland Management LL in Estonia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of enablers, environmental awareness is deeply embedded as a social norm, guiding farmers toward biodiversity-friendly practices. Likewise, the LL benefits from supporting networks for landowners in managing biodiverse meadows. Besides, education and training initiatives with demonstration sites have a role in boosting digitalisation in this LL. Technological advancements such as spaceborne LIDAR systems facilitate landscape monitoring. There are also opportunities for digitalisation through improved data presentation, ensuring that farmers can interpret and utilise digital tools.

In terms of hindrances, governance challenges remain a barrier, particularly rigid compliance metrics enforced by Lauku Atbalsta Dienests (LAD), leading to a lack of trust among stakeholders. Limited collaboration with public institutions has created disparities in subsidy distribution, with farmers perceiving that financial support is skewed in favour of large-scale farms. The lack of data-driven programmes imposes hurdles as well. Digitalisation efforts are further hindered by poor internet infrastructure, restricting cloud storage capabilities for managing large datasets. The adoption of digital solutions remains challenging due to the absence of affordable and user-friendly drone training, along with a lack of compensation mechanisms for damage. Lastly, the lack of standardisation across the EU, with varying conservation guidelines, further complicates the scalability of digital solutions in grassland management.

In conclusion, the digital ecosystem of the Grassland Management LL in Estonia presents enablers such as strong environmental awareness, supporting networks, education initiatives, and technological advancements (see Figure below). However, governance barriers, limited institutional collaboration, poor internet infrastructure, and the lack of standardisation and compensation mechanisms hinder digital adoption and scalability in grassland management.

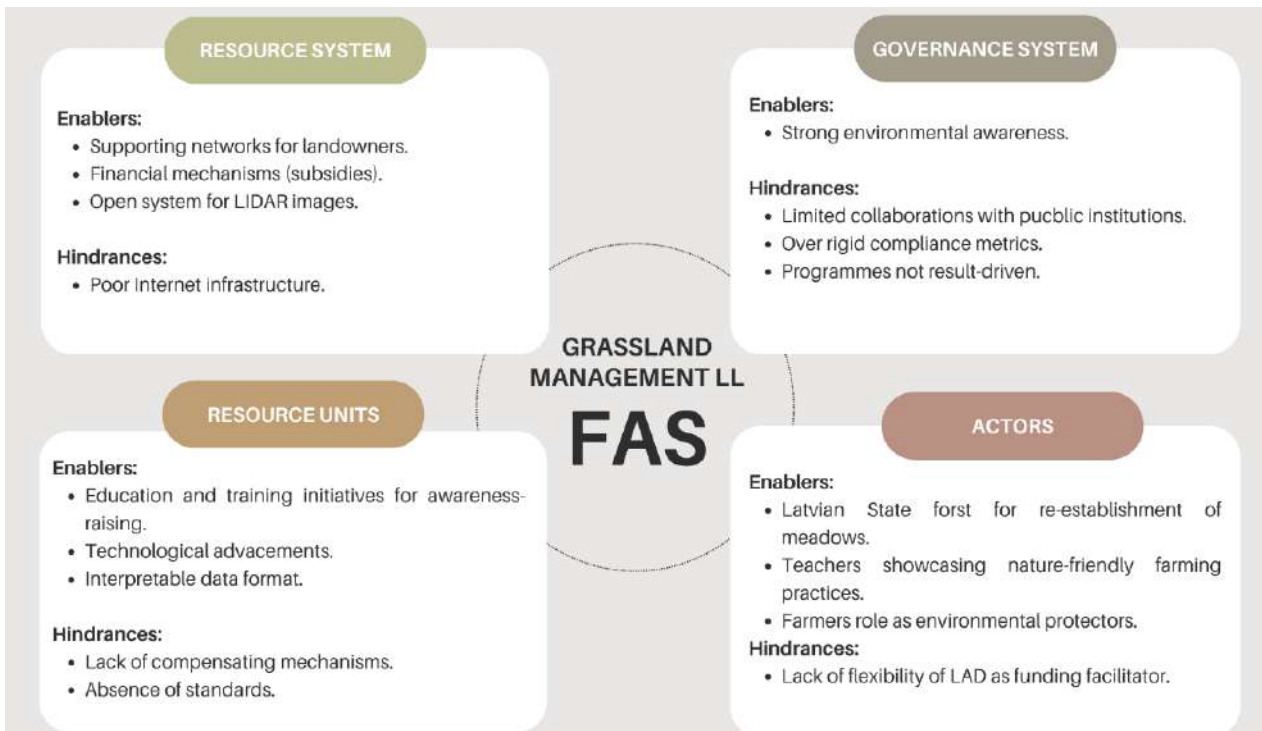


Figure 45. Main enablers-hindrances of Grassland Management LL.

Source: UAL



#### 4.1.18 RAMAS Living Lab (Macedonia)

##### Introduction

The RAMAS LL, located in Macedonia focuses on enhancing decision-making processes in agricultural production through communication between farmers and advisors, supporting data-driven decision-making, and promoting efficiency in farm management, particularly by reducing the use of agrochemicals.

The stakeholders of RAMAS LL describe the focal action situation (FAS) as follows:

*“Establishing decision-making processes in agricultural production by providing advisory services in extensive, real-time field data gathered at every stage of the agricultural process”*

To achieve this, the LL employs the Remote Agricultural Monitoring and Advisory System (TRL 5) to optimise agricultural inputs and processes.

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources such as machinery, equipment, including digital devices such as sensors, drones, thermal cameras, which are combined with mechanical tools for taking soil samples or pheromone traps for pest control. Complementary technological resources, including a website, software, monitoring-management systems, GPS and GIS, digital platforms, satellite technology, internet connectivity, databases and a data centre were identified. Databases and the data centre were stressed as two key resources to store, manage and analyse data. Despite the great availability of technological resources, stakeholders mentioned that there is a need to develop a mobile phone App from the website to enhance a more user-friendly technology.

Sustainable digitalisation is also conditioned by the availability of human resources. RAMAS LL stakeholders explained that a team of experts (agronomists, economists) prepare activities related to collecting and analysing the data, giving advice, and being available for the farmers. However, they recognised that more educated agronomists and advisors who are able to use digital technologies and possess more applicative knowledge are also needed. Stakeholders also stressed the need of developing educational resources for enhancing education/training in digital technologies and marketing/promotional resources to create awareness and highlight the value of the farm management system developed by the LL.

Financial resources also represent a key element for sustainable digitalisation, stakeholders outlined the importance of CAP funds, including direct payments and rural development funds, together with other national subsidies as these can significantly boost farm operations and sustainable practices. Moreover, other funding sources such as donors and funds are also mentioned to enhance financial sustainability of the activities of the LL.

Finally, stakeholders of the LL described extensive collaborations in scientific research projects, with IT and software providers/companies, laboratories, public institutions and between agronomists and farmers. On the other hand, stakeholders stressed that more collaborations are needed with some national agencies, other advisory services to broaden the scope of expertise and with associations working to preserve indigenous breeds within the country.

###### - Capabilities

Concerning functional capabilities stakeholders of the RAMAS LL highlighted the relevance of efficiency and optimisation of processes/operations to save time and reduce costs of farmers as the main pursued outcome from the application of the digital technologies developed in the LL. To do so, stakeholders stressed the importance of capacities related to data collection, access, management and analysis, and especially the capacity for gathering and monitoring data at real time for making informed and data driven decisions. Complementary stakeholders pointed to the expertise and know-how available within the LL to be able to apply the technology and make sense of the data to inform and take data driven decisions. In this regard, some of the abovementioned collaborations are important to leverage the expertise for example of agronomists. However, stakeholders also stressed the need for

enhancing digital skills, including digital-technology literacy, of farmers to ensure that they have the necessary skills to effectively navigate and leverage the farm management system, maximizing its benefits for efficient and informed decision-making.

Furthermore, in regard to dynamic capabilities, stakeholders outlined the relevance of transfer and integration of data and knowledge to raise awareness, convince the older generations about the benefits of using the technology developed and, in turn, enhance the wide adoption of the technology. In addition, stakeholders stressed the abilities related to sharing resources and collective action for enhancing the farm management system of the LL. According to stakeholders in the LL, these dynamic capabilities further reinforce/enhance the previously mentioned efficiency/optimisation, but also adaptive capabilities related to resilience, adaptation of technologies to local and farm level conditions and independent data driven decision making.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is represented by a diverse range of actors, including agronomists, farmers, agricultural cooperatives, an accredited laboratory, a research institute for agriculture, IT companies, data analyst, the Administration for hydro-meteorological affairs and the Ministry of Agriculture, Forestry and Water Economy of Macedonia. Furthermore, other actors collaborate and/or influence the LL, these include public institutions such as the Agency for Financial support of agriculture and rural development, National Extension Agency, Food and Veterinary Agency, Ministry of Environment and Physical Planning, Civil Aviation Agency, Agency for Real estate cadastre. Also, private actors such as suppliers of equipment and materials, funds and donors; and higher educational institutions (faculty, academies).

Stakeholders stressed the importance of establishing collaborations and coordination among stakeholders (**resource units**), and the strength of the LL in these collaborations. In this regard, stakeholders described the collaborations and coordination with different public institutions (**actors**) as relevant especially for complying with regulations in different aspects such as environmental, fertilisation, health and safety and drones' regulations, both at national and European level (**governance system**). These collaborations-coordination with public institutions enable access to information and knowledge (**resource units**) which enhance previously mentioned resources and capabilities such as transfer of knowledge. Regarding public institutions at the local level, stakeholders stressed that engaging with local government (**actor**) fosters community-level collaboration to ensure better conditions for further development of agricultural production.

Moreover, public institutions (**actors**) provide access to funding resources, especially grants and subsidies (**resource units**) from CAP and national programmes (governance systems), for the development of the technologies and innovations. Despite the relevance of the access to these funds from policy programmes stakeholders described that funding support from the agency of agriculture and rural development follows a complicated application processes and sometimes delays in fund disbursement which may hinder timely implementation of planned activities (**governance system**). Also, in terms of access to finance, stakeholders outlined the role of private foundations and donors (**actors**) who serve as an external financing mechanism (**resource unit**) for specific agricultural projects enhancing financial sustainability. In this line, stakeholders stressed that planning capacity for predicting production factors necessitates ongoing investment (**resource unit**) in research and technology.

Regarding farmers (**actors**), they are final users of the technology of the LL. Stakeholders described that active engagement with farmers ensures the farm management system remains user-centric, addressing practical needs and fostering widespread adoption. However, stakeholders also mentioned that there is a need to establish a stronger connection with farmers which involves active engagement and feedback mechanisms. Interestingly, stakeholders of the LL highlighted that engaging with actors such as agricultural cooperatives, producer organisations and the National Federation of Farmers strengthens community-based approaches and fosters collective action. This engagement and collaborations among stakeholders (**resource units**) also enhances

resource sharing and strengthens advocacy and representation, ensuring the farm management system aligns with the collective needs and interests of the farming community.

In regard to universities and research institutions, stakeholders highlighted the important role of these actors in terms of knowledge and innovation development but also in transferring and integrating knowledge and data, thus making knowledge available to stakeholders (resources units). Stakeholders also stressed that the engagement of the LL with advisors (**actors**) is important for incorporating diverse perspectives, specialized knowledge and specially know-how into the LL. Furthermore, the collaboration with an accredited laboratory ensures the reliability of analytical data, maintaining the integrity of soil and crop assessments within the farm management system.

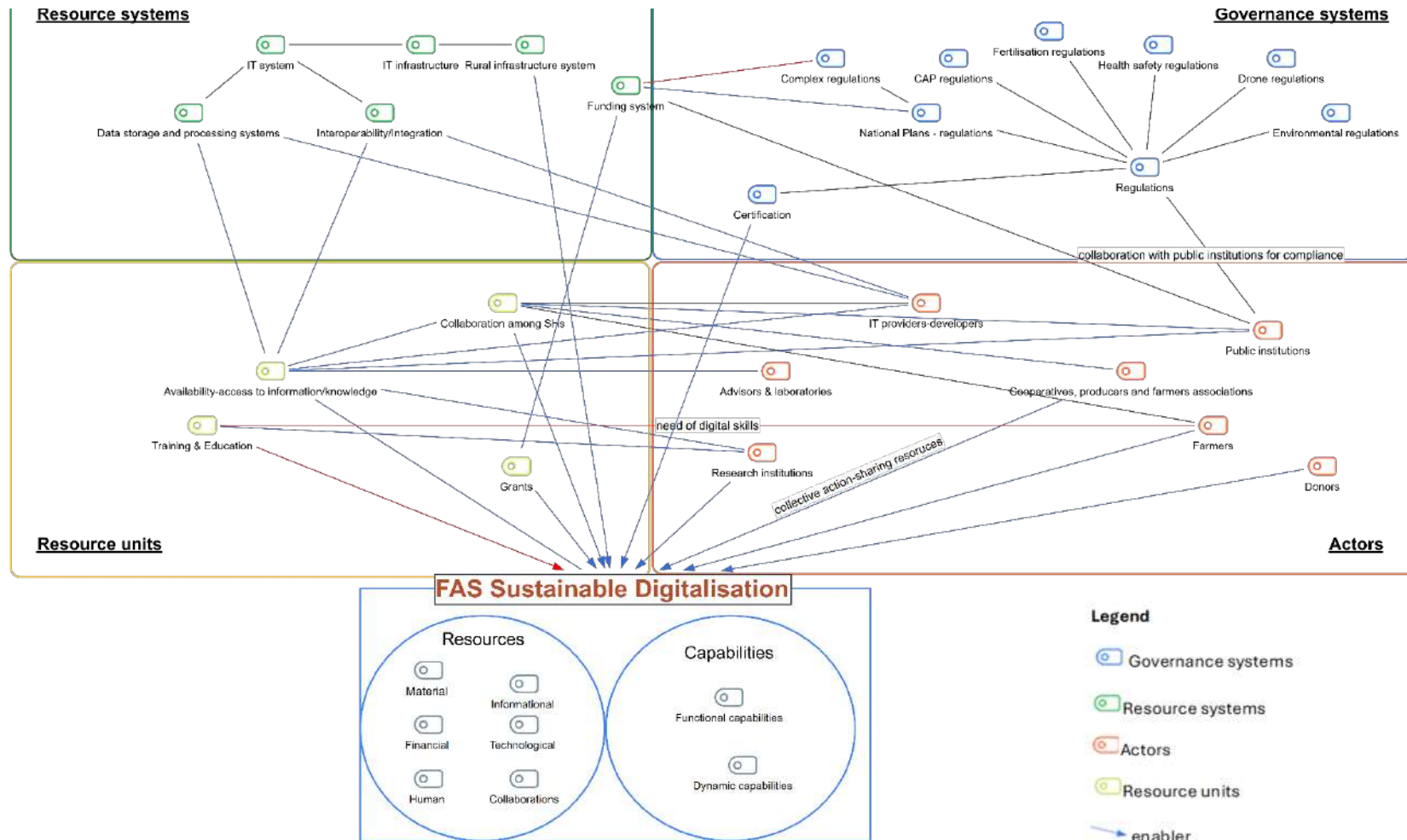
The collaboration of the LL (**resource units**) with IT developers and providers (**actors**) is stressed as a key aspect for ensuring technological advancement and system updates, thus, to access technological resources, enhancing real-time data collection and analysis. These actors in turn, enhance the access and availability of information and knowledge (**resource units**) for the LL. Moreover, they are important in terms of developing data storage and processing systems (**resource systems**) for efficient record-keeping which facilitates data-driven decision-making, enhancing the overall organization and management of the farm. These collaborations with IT providers enhance the integration and interoperability of technologies within the IT system (**resource systems**), fostering real-time data collection and analysis for a more comprehensive and effective farm management system.

Stakeholders of the LL also highlighted the relevance of education and training courses (**resource units**), especially for farmers to foster a culture of lifelong learning and empowering farmers with the knowledge and skills needed to maximize the benefits of the farm management system; the lack of these courses represent a barrier for the LL. According to stakeholders, education and training can also overcome social and demographic barriers related to the implementation of the farm management system. In addition, stakeholders of the LL pointed to the relevance of infrastructure system in rural areas (**resource systems**), such as roads and connectivity, which have improved and facilitate the transport of goods and services, contributing to efficient farm operations.

Finally, in relation to governance system, besides the relevance of the above-mentioned regulations, programmes, policies and collaborations with public institutions, stakeholders of the LL mentioned certification schemes (governance systems) and its corresponding national and international certification bodies (**actors**) as key for ensuring adherence to quality and safety standards (governance systems), enhancing the marketability of farm products and promoting sustainable practices. More specifically, organic certification and GAP principles were mentioned as important to incorporate into the farm management system to ensure compliance with recognized standards for sustainable and ethical agricultural production. In this line, stakeholders also mentioned the European Green Deal and the United Nations Sustainable Development Goals as concepts that provide a framework (governance systems) for addressing global challenges, promoting sustainable practices and climate resilience in agriculture.

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in RAMAS LL.

Figure 46. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in RAMAS LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The RAMAS LL in Macedonia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation. In terms of **enablers** a wide range of stakeholders, including public and private actors are involved in the LL and collaborate in the development and implementation of the RAMAS. This strong collaboration among stakeholders enhances availability, transfer and integration of knowledge and information, resource sharing, access to funding, data collection, management and analysis, technological development and compliance with different regulations and certification schemes. This wide range of actors also brings diverse resources including material, technological and human resources; and capabilities, including know-how, collective actions and capacity to transfer and integrate different data and knowledge. The availability of some funding schemes from CAP and national programmes and the complementary funding from donors also represent enabling factors. Also, in relation to governance, certification schemes represent enabling factors for digital ecosystem conduciveness towards sustainable digitalisation.

In terms of **hindrances** there is a need for enhancing digital skills of farmers, including digital-technology literacy. Also, in relation to farmers, there is a need for establishing a stronger connection with farmers which involves active engagement and feedback mechanisms. Finally, the complexity in accessing some funds and delays in disbursement and the need for long-term investment in technology and research represent hindering factors.

In conclusion the digital ecosystem of the RAMAS LL presents both enablers and hindrances (see Figure below). The digital ecosystem of the LL is characterised by strong collaborations between public and private actors and the availability of relevant material and technological resources. On the other hand, education and training concerning digital skills and technological literacy of farmers and long-term investments need to be addressed for enhancing the digital ecosystem conduciveness towards sustainable digitalisation.

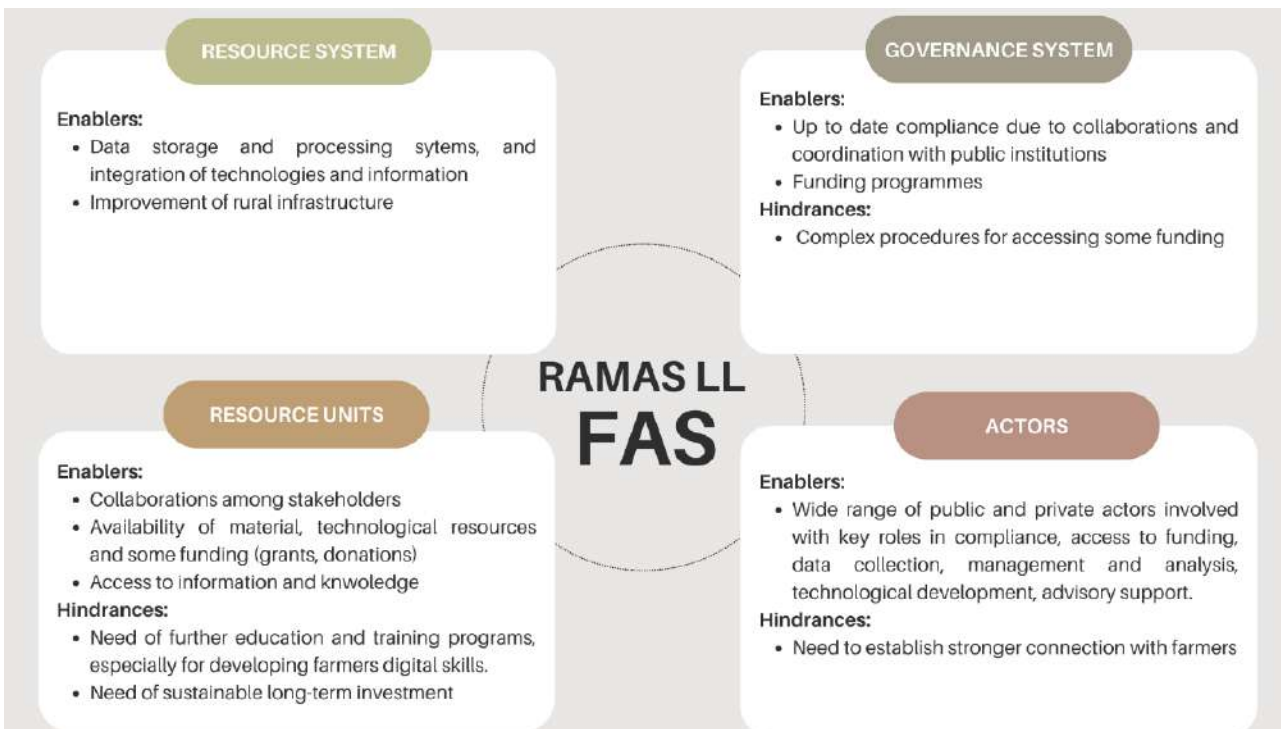


Figure 47. Main enablers-hindrances of RAMAS LL.

Source: UAL

#### 4.1.19 Smart villages Network Living Lab (Slovenia)

##### Introduction

The Smart Villages Network LL, located in Slovenia focuses on leveraging digital technologies in viticulture and honey production, striving to enhance sustainability across environmental, economic, and social dimensions, ensuring a holistic impact on agricultural practices.

The stakeholders of Smart villages Network LL describe the focal action situation (FAS) as follows:

*"How to use digital technology in viticulture and for bee protection, in order to affect the environmental, economic, and social aspects of sustainability".*

To achieve this, the LL employs IoT and LoRaWAN technology for a resilient infrastructure addressing connectivity issues, rugged terrain, and diverse microclimates in the same vineyard. Deploying microclimate, soil moisture, rain, and leaf wetness sensors the system transmits data to a dashboard, ensuring continuous availability and informed decision-making (TRL 7).

##### Resources, Capabilities, Collaborations and Innovations for Sustainable Digitalisation

###### - Resources

Key elements identified by stakeholders for sustainable digitalisation relate to material resources, including land, facilities to sell local products, machinery, equipment, ICT devices (e.g. sensors, sprayers). Complementary stakeholders pointed to the relevance for the LL of technological resources such as modular IoT infrastructure (temperature, humidity, soil and leaf wetness), sensor technology, automatization, and Apps. Stakeholders also mentioned other technological resources such as remote-controlled lawnmower or farm management information systems as important but still not available in the LL.

Sustainable digitalisation is also conditioned by the availability of human resources; stakeholders stressed the relevance of professional staff (highly skilled) for information sharing and use of new technologies. Moreover, stakeholders mentioned that there is a shortage of labour force, especially at peak season and the use of robots, for example in soil tillage, as an alternative that decreases human resources needs. In terms of knowledge, stakeholders highlighted the need for more knowledge related to new technological innovations, and also the relevance of traditional-family knowledge complemented with advisory support.

Financial resources also represent a key element for sustainable digitalisation, in this regard, stakeholders outlined that despite having some financial resources there is a lack of appropriate financial support especially for developing new solutions-innovations. Moreover, stakeholders mentioned the need of developing common sales channels and collective purchase of machine equipment

Finally, stakeholders highlighted collaborations with advisors, research institutions, municipality, the community and collaborations among farmers, for example for setting up a cooperative.

###### - Capabilities

Concerning functional capabilities, stakeholders mentioned that there is the ability of recording/gathering data but there is a need for better skills related to the interpretation of the data. Stakeholders also outlined the need for advanced digital skills and ICT support. On the other hand, stakeholders stressed the competences in wine production, agronomy, technology and tourism with the LL, together with their skills to engage the younger generations.

In regard to dynamic capabilities, stakeholders highlighted the aptitude of integrating different forms of knowledge, for example combining traditional, family knowledge with new inventions for winegrowing and, the transfer of knowledge between stakeholders. Furthermore, stakeholders stressed the relevance of adaptive capabilities related to adaptation to climate change, to markets and technological updates. Finally, stakeholders mentioned attitudes and values such as motivation and peer support-mutual assistance as relevant capabilities for digital ecosystems conduciveness.

### **Systems elements of Digital Ecosystem Conduciveness for Sustainable Digitalisation**

The resources and capabilities mentioned above are enabled and/or hindered by elements of the systems which participate in the digitalisation processes (see Figure below). These elements of the systems not only set the conditions for the resources and capabilities of the LL but the interrelation among some of them are also significant for the conduciveness of digital ecosystems.

The LL is mainly formed by different **actors** including farmers and beekeepers, family members as employees, as well as other employees, customers, sensor providers, developers. In addition, other **actors** also collaborate and influence the LL, including cooperatives, advisory service, tourism authority, other close farmers, IT companies, university/research institutions, local municipality, Ministry of Agriculture, Forestry and Food, Ministry of the Economy, Tourism and Sport.

Farmers and beekeepers (**actors**), besides being the main actors to implement the technologies in the LL, play a key role in enhancing connections and collaborations with other farmers and with other stakeholders (**resource units**). Other **actors**, such as cooperatives and the tourism authority also contribute to enhancing collaborations among stakeholders. Stakeholders also mentioned other **actors**, such as universities/research institutions and advisors not only for providing support in form of advice but also enhancing information sharing and providing access to knowledge and information (**resource units**). Stakeholders also stressed the importance of technology providers and developers (**actors**) for technological resources and infrastructure development (**resource units**) and public institutions (**actors**) at national and European level in developing policies and regulations (**governance systems**) that affect the LL.

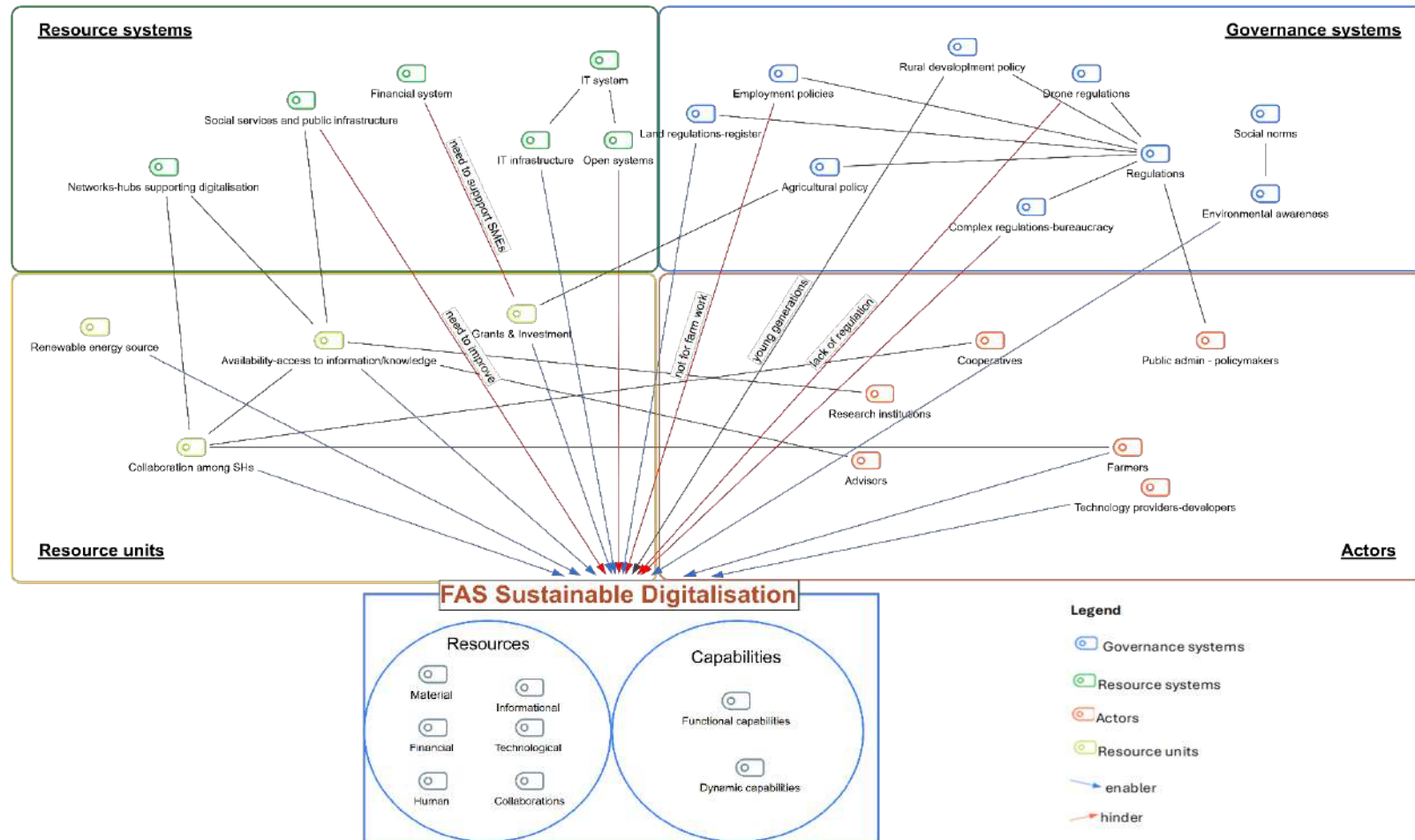
In terms of **governance systems**, stakeholders outlined a myriad of regulations/policies related to employment control in terms of working time which is challenging for farming real work ("24/7"), land regulations such as the land register that with the support of satellite tracking can help improve traceability, and the need of developing rules for the use of drones which can help for spraying and rural development policies for keeping young people in rural areas. Moreover, stakeholders stressed the importance of agricultural policy (**governance systems**) to access grants and investment (**resource units**), and the EU Recovery and Resilience Plan as providing important opportunities for financing (**resource units**). However, stakeholders outlined the need for improving reporting processes to local and national public institutions (**governance system**) for time saving and reducing the complexity of procedures-bureaucracy related to exports (**governance system**) for enhancing the agility of their business. Besides formal regulations, stakeholders pointed to the importance of social norms (**governance systems**) related to environmental awareness for example for participating in an event related to open wine cellars which require the use of eco-friendly products (less waste, circularity).

Stakeholders of the LL also stressed the importance of developing better social services and public infrastructure, such as educational and social support systems, health care, care for elderly people, and online access to systems of public services (**resource systems**). These will not only provide necessary services for the population but also enhance knowledge development, better time use and access to information and knowledge (**resource units**). In terms of natural resource systems (**resource systems**) stakeholders of the LL mentioned the development of solar power plants for renewable energy sources (**resource units**) and the land identification system (**resource systems**) as key elements for digital ecosystem conduciveness to sustainable agriculture. Moreover, stakeholders stressed the relevance of developing a financial support system (**resource systems**) for SMEs that would improve the whole ecosystem.

Regarding IT systems (**resource systems**), stakeholders highlighted the relevance of having a suitable IT infrastructure and connectivity. However, they pointed out that open systems (**resource systems**) are missing such as open cloud platforms for connecting service providers and those in need of a service. Furthermore, stakeholders outlined the relevance of developing systems of networks and hubs that support digitalisation (**resource systems**). These are mentioned as important for agricultural cooperation, enhance the availability and access to information and knowledge, the collaborations among stakeholders and training (**resource units**).

Figure below outlines the interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Smart villages Network LL.

Figure 48. Interrelations between systems' elements for digital ecosystem conduciveness and the FAS for sustainable digitalisation in Smart villages Network LL.



Source: UAL

**Conclusions and summary of digital ecosystem of the LL**

The Smart Villages Network LL in Slovenia illustrates several enablers and hindrances that shape its digital ecosystem conduciveness for sustainable digitalisation (see Figure below).

In terms of **enablers**, availability of material and technological resources, together with some funding and collaborations with different stakeholders support the conduciveness of the digital ecosystem of the LL. Moreover, capabilities on data recording, engaging young generations and know-how in production also represent enablers. The diversity of actors participating in the LL and their role in enhancing collaborations and transferring knowledge and information are also enablers. The land register/identification system, agricultural policies providing funding, environmental awareness, the development of renewable energy sources and IT infrastructure in terms of connectivity also support the conduciveness of the digital ecosystem.

In terms of **hindrances**, shortage of highly qualified staff and workers during peak season represent, together with inadequate funding especially for SMEs and for developing new solutions-innovations represent barriers for sustainable digitalisation. Moreover, there is a need for training related to data interpretation. The need for clearer drone regulations and rural development policies attracting young people as well as the complexity of some reporting and bureaucratic procedures represent hindering elements for the conduciveness of the digital ecosystem. Moreover, there is a need for better social services and public infrastructure and open IT systems that link service providers with users.

In conclusion, the digital ecosystem of the Smart Villages Network LL shows enablers and hindrances (see Figure below), in terms of enablers collaborations and knowledge sharing, some supportive policies and available IT infrastructure support digital ecosystem conduciveness. However, shortage of human resources, further development of regulations and complexity of procedures, together with the need of better services and infrastructure represent barriers to sustainable digitalisation in the LL.

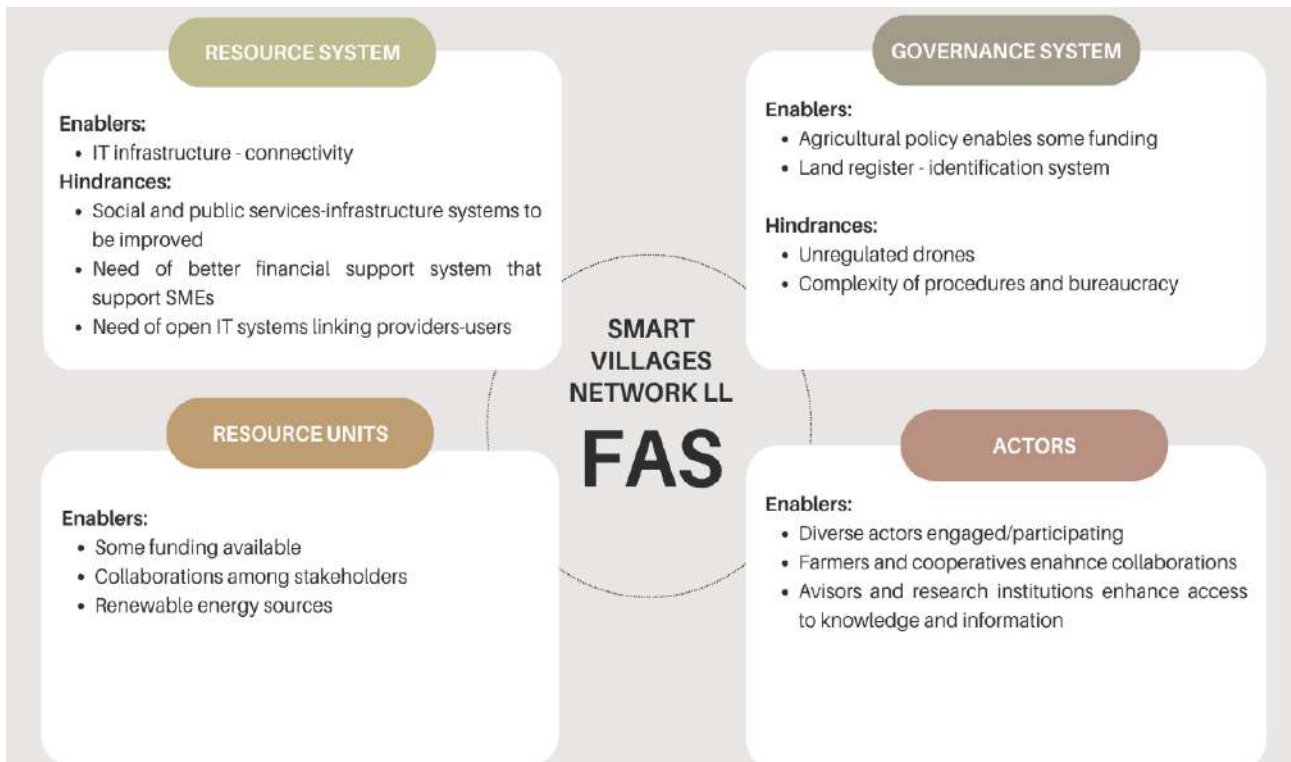


Figure 49. Main enablers-hindrances of Smart Villages Network LL.

Source: UAL

## 4.2. Agricultural Knowledge and Innovation System (AKIS): Actors and Governance - UHOH

In this section, we present the outcomes of the analysis described in Table 2. We analyse the key components of AKIS, in two subsections, the first one (4.2.1) as a summary of categories, subcategories and codes resultant from the content. The second one (4.2.2) presents the diagrams from the perspective of each LL.

The AKIS concept helps analyse knowledge and innovation infrastructures and is defined as knowledge flows between persons, organisations and institutions who use and produce knowledge for agriculture and interrelated fields. By linking people and institutions, AKIS promotes mutual learning and generate, share, and utilise agriculture related technology, knowledge, and information. We based our analysis on the assumption of Living Labs as open innovation spaces that create participatory environments where farmers, researchers, and other stakeholders collaborate to develop and test new agricultural technologies and practices (Potters et al., 2022). This constellation of actors interacts with one another, making choices that jointly determine outcomes which are influenced by the beliefs and incentives of the relevant individuals, the social expectations and by the information and knowledge available (Cole et al, 2019). Each LL identified governance mechanisms with respect to AKIS as well that reflect the perceived “processes through which collective decisions are made, implemented, interpreted, and reformed for some group” (McGinnis, 2011:6).

For the constellation of actors (Actor Subsystem), we identified the types of actors mentioned during the workshops. Following the initial phase of identification, we reclassified the actors based on the characterization of actors in the AKIS literature and the concept presented in section 2.1.2.

For the governance mechanisms (Governance Subsystem), we identified and categorized the types of rules, norms, and regulations related to the definition of AKIS governance mechanisms and the coordination of AKIS components based on the theoretical ground presented in section 2.1.2.

The third stage of structuring the results consisted in revisiting the information provided by each Living Lab. We used the results described in the previous paragraphs from the perspective of each Living Lab. The results reflect the disaggregated findings of the analysis and are presented in chapters 4.2.2 to 4.2.20. The diagrams are a graphical representation of the constellation of actors (presence and perceived degree of distance to the FAS) by the workshop participants, related to the Focal Action Situation and the governance mechanisms mentioned by the participants.

### 4.2.1 Actors and Governance in Agricultural Knowledge and Innovation System (AKIS)

In this section we present the results of the Step 2 described in the methodology in table 2, namely the framework of categories, subcategories and codes for *Actor Subsystem* and *Governance Subsystem*. Those categories were used to describe the analysis by LL and the diagrams presented in section 4.2.2.

#### *Actors Subsystem*

Within the *Actors Subsystem*, we identified 17 different types of actors that are recurrently mentioned around the LL, influencing the FAS. When we classify those types of actors into the main categories used in AKIS analysis literature we identified seven categories (Table 4).

Table 4. Actors mentioned by LL Workshops participants, according to AKIS categories.

Categories	Type of actor (subcategories)	Description (codes)
<b>1 Farmers</b>		
1.1	Farmers	Farmers: winegrowers, sheep farmers, beef farmers, family farms, demo farms, industrial scale farms, farm workers, informal economy farmers, farmers selling directly to consumers.

1.2	Farmers associations, farmers organisations	Chambers of agriculture, farmers groups (women, fruit growers, viticulture), farmers associations, agricultural consortiums, cooperatives, trade associations, farmers unions, farmers federations, machinery cooperatives.
<b>2 Education and research</b>		
2.1	Research	Research projects, research institutions, universities, research associations, research centres, laboratories, scientists.
2.2	Education	Educational institutions, universities, training institutions, high schools specialized in agriculture, vocational schools, vocational training farms, technical schools, teachers
<b>3 Bridging institutions-knowledge exchange (formal)</b>		
3.1	Advisors (public, private, NGOs)	Public advisors, agronomists, consultants, consulting companies, veterinarians, public health advisors, advisory networks, digital academies for agriculture, experts, veterinary association, research institutions providing advice, research projects including advice, input suppliers providing advice, training centres providing advice, extension or advisory system in general.
3.2	Networks: other LL, hubs, platforms, Local Action Groups	Advisory networks, hubs, agricultural fairs, laboratory networks, living labs, industry organizations, projects including networking activities, soil associations, local action groups
3.3	NGOs	Non-governmental organisations working with: local environment, animal rights, fund for nature.
<b>4 Public actors, authority</b>		
4.1	Public/authority	Ministries and authorities (agriculture, science, trade, economy, tourism, planning), European level institutions, policy makers, local governments, public agencies and offices (regional, local), national extension services, regulations.
4.2	Funding institutions	LEADER program, public institutions or agencies managing projects providing funding, tenders, agencies for financial support.
<b>5 Value chain-Business</b>		
5.1	Companies Agtech	Service providers, telecommunication companies, dashboard editors, software developers, technology developers, specific professionals (data analysis, technicians), technology vendors, internet providers.
5.2	Companies (supply chain)	Input providers (energy, seeds, fertilizers, irrigation, feed), equipment or machineries manufacturers, supply stores, contractors, cooperatives.
5.3	Companies (downstream)	Intermediaries, exporters, dealers, retail chains, distributors, marketing consultants, slaughterhouses, supermarkets, traders, tourists, processors.
5.4	Certification/audit bodies	Auditing organisations, certification bodies, certification companies, accredited laboratories, standards norms organisations.
5.5	Financial/investment institutions	Banks, financial institutions
<b>6 Non-formal knowledge exchange</b>		

6.1	Family, friends and neighbours, community, fairs	Family, neighbours and peers, community member, employees, local fairs
6.2	Consumers	Final consumers, consumers associations
<b>7 Media</b>		
7.1	Media	Influencers, opinion makers, mass media

Although the nature and interaction of actors is highly contextual and difficult to classify due to the heterogeneity of action situations, we can observe the salience of the **private actors**. We can identify there agritech/developers, input providers, machinery providers, telecommunication/internet providers, private advisors, certification and audit bodies and finally those related with the general process of production and marketing: retailers and buyers. Those actors play different roles with respect to digitalisation: i) providers of technological innovations, or ii) users or providers of information, data or knowledge generated in the production and selling process. **Bridging institutions** for formal knowledge exchange were also mentioned frequently. For example, the presence of advisors is widely given, although varying according to the characteristics of the national AKIS structures. Other relevant institutions are networks (spaces for co-production) relevant for the interaction between actors and instrumental in facilitating collaborations. Other actors important to mention are those that are not traditionally studied into the AKIS literature: communities, household members and peers that play an important role in the **informal knowledge flows** and in the process of co-creation, adoption or diffusion of innovations.

### Governance Subsystem

We analyse AKIS in the Governance Subsystems based on the answers provided by the participants to the question Q5. After a first coding and identification of main topics, during the second coding cycle, we identified and categorised we categorised the type of rules and norms that are relevant to the definition of AKIS and to those related to the definition of rules for access, extraction, management, exclusion and alienation of knowledge and information resources. The results reflect norms, rules and regulations for the coordination of AKIS components with two main levels of coordination mechanisms: global and macro level and local level (Table 5)

Table 4. Categories, subcategories and description of codes in Governance Subsystem.

Category and sub-category	Description of the sub- category (codes)
<b>1 Global and macro perspective</b>	
1.1 Global macro-trends	Aspects mentioned are the global crises, the interest in the environment and in general the negative perspective about agriculture
1.2 EU level public policies and regulations	The coordination mechanisms at EU level such as the CAP; the GDPR; the EU organic regulation, EU guidelines on plant protection products, information systems such as FADN, regulation on frequencies.
1.3 Public policies and regulations	The participants identified those public actors and policies relevant for the FAS. A long list of regulations and normative were mentioned: accounting, drones, young farmers, exports, environmental protection, fertilizers regulation, food legislation, health and safety regulations, land use, water management, manure management, education, technological innovations, livestock, GDO, nitrates, working time, spray regulatory framework, knowledge transfer strategies, subsidies, taxes, phytosanitary regulation. Some other aspects mentioned were the role of regions and municipalities, the participation on the policy making process, and the enforcement of those regulations. Finally, support instruments such funding grants, subsidies for specific innovations (precision agriculture) or entrepreneurs were included here.

1.4 Education related guidelines	Available normative with regard to curricula on digitalisation in technical schools, vocational schools or vocational training farms.
1.5 Private companies and market rules	Aspects included here are related with markets, farmers consumers and companies involved in the development of rules: some of them are large inputs (seed, planting materials or plant protection products) but also companies which implement rules such as insurance services or in control of geospatial analysis. It also includes norms dictated by certification mechanisms within the value chain, for example Biosert, monitoring social and environmental impact, quality certification bodies, impact certification bodies, food labels, GAP and PDO schemes.
<b>2 Local and regional perspective</b>	
2.1 Social rules or norms	Rules that are present in the community that supports or limit the adoption of innovations. For example, the approach of meetings; the visions on the social system or the availability or lack of collaborations around the FAS.
2.2 Networks rules	Those are groups are networks of producers (AG Porc / GT porc, data providers or users, LLs or activities (tourism or animal production) that have their own norms
2.3 Local associations norms	Statements describing norms and rules determined by groups of persons, associations) soil, trade, irrigation, GDOS; producers, communities and cooperatives)
2.4 Farm objectives incentives expectations	This reflects those norms or rules that are seen as pursued by farms, for example improvement on the efficiency in the use of resources, generation renewal (succession) at farm level or those norms that takes into account the farmer as the user of the innovation.

In the following sections, we present the disaggregated *analysis of actors* and *governance mechanisms* by LL bas described in section 4.2.1

#### 4.2.1. Pecorino Toscano DOP (Italy)

The LL Pecorino Toscano Living Lab has as a main purpose to facilitate farmers in the data collection of data related to farm processes and use such data in order to improve the quality of production, the quality of work and life of farmers, the visibility of the farm and the animal health and welfare.

First-level actors which are directly involved in the LL are from a diverse range of sectors, primarily including sheep farmer, agronomist advisors, cooperatives/dairy processing plants, consortium of Pecorino Toscano PDO, technology developers, university of Pisa, other sheep farmers, private veterinarians' advisors and input providers. Second-level actors that collaborate with the LL are public administration, other sheep farmers, other consultants, other dairy processing plants and other farmers. Third-level actors that have an influence but are not close to the LL are consumers, farmers associations, research entities, farmers unions, traders, farm machineries providers, large retailers, tourists, public health services veterinarians, banks, marketing and communication consultants, commercial consultants that support the information exchange on digital technologies to farmers and broadband and internet connection providers.

### Pecorino Toscano Living Lab

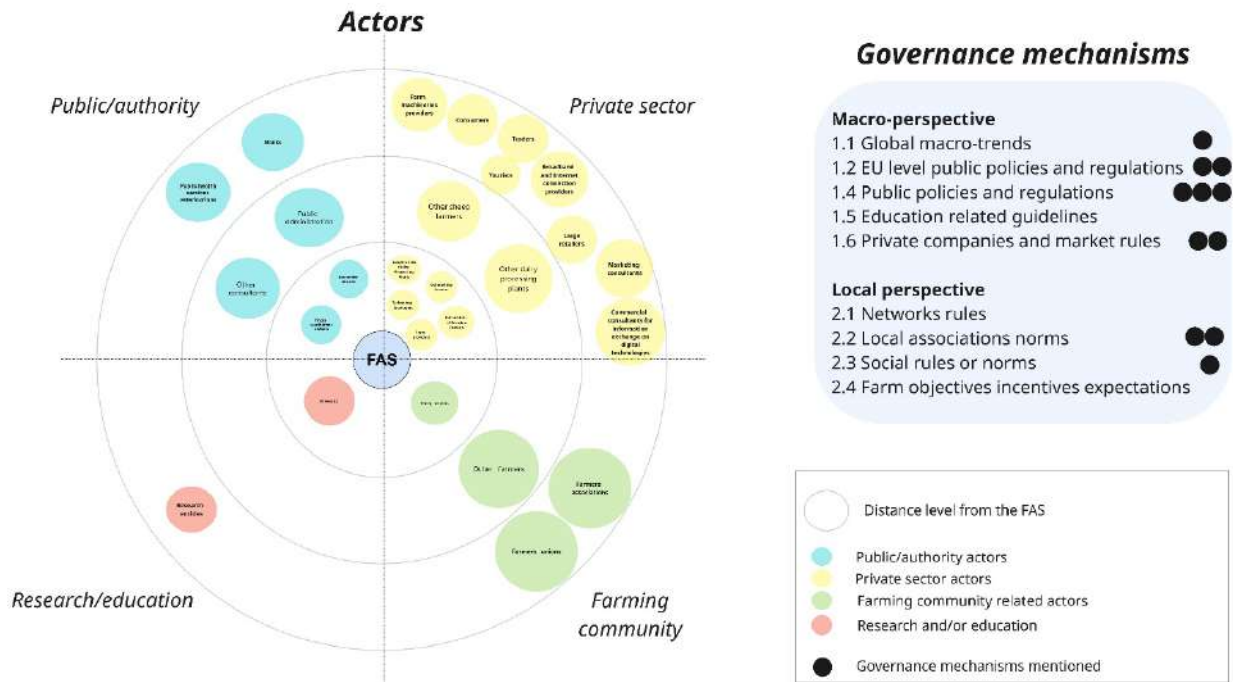


Figure 50. Actors and governance mechanisms mentioned in Pecorino Toscano DOP LL.

#### 4.2.2. APPETIT (Poland)

The LL APPETIT in Poland works on supporting self-organisation, growth and development of local food markets in terms of increasing numbers involved, product offering, and transactions, reducing cost per transaction and focusing on producers and consumers transacting directly with one another.

First-level actors which are directly involved in the LL are from a diverse range of sectors, primarily including small farm-leaders, farmers & food processors selling directly to consumers, consumers, local food market initiators, local food market organisers, municipal governments, national agricultural advisory centre, software developers, universities and research institutes, local action groups and non-governmental organisations.

Second-level actors that collaborate with the LL are small farm-leaders, farmers & food processors selling directly to consumers, consumers, local food market initiators, local food market organisers, municipal governments, national government (ministry of agriculture and rural development), agricultural advisory service, veterinary service, sanitary service, financial institutions, agricultural modernisation and restructuring agency, non-governmental organisations, farmer organisations and lawmakers.

Third-level actors that have an influence but are not close to the LL are small farm-leaders, farmers & food processors selling directly to consumers, farmers operating in the informal economy, industrial scale farmers, consumers, local food market initiators, local food market organisers, municipal governments, regional governments, national government, agricultural advisory service, investors and supermarkets & other actors making up the industrial food system.



### APPETIT Living Lab

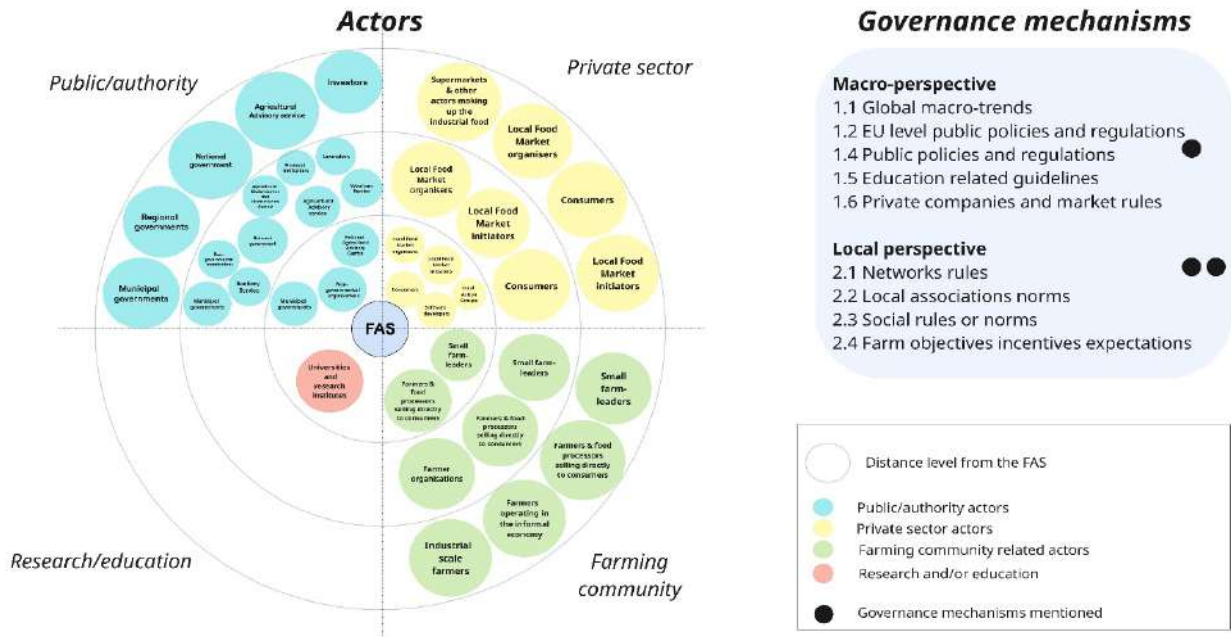


Figure 51. Actors and governance mechanisms mentioned in APPETIT LL.

#### 4.2.3. Automation of Orchard Management (Czech Republic)

The Orchard management and digitisation Living Lab is located in Czech Republic and has as an objective to reduce impact of adverse weather on crops, reduce water and pesticide use, automation of irrigation and facilitate reporting obligations.

First-level actors which are involved in the LL are from a diverse range of sectors, primarily including suppliers (pesticides and fertilizers), farmers, vocational and higher education institutions and national government from projects.

Second-level actors that collaborate with the LL are retail chains, retail companies/chain stores, farmers association, independent consultants, fruit grower's union, and research institutions such as Research and Breeding Institute of Pomology and Institute of Agricultural Economics and Information. Most second-level collaborators come from the farming community. Third-level actors that have an influence but are not close to the LL are government through policies, European Commission, agricultural public advisers and university research.



### Orchard management and digitisation LL

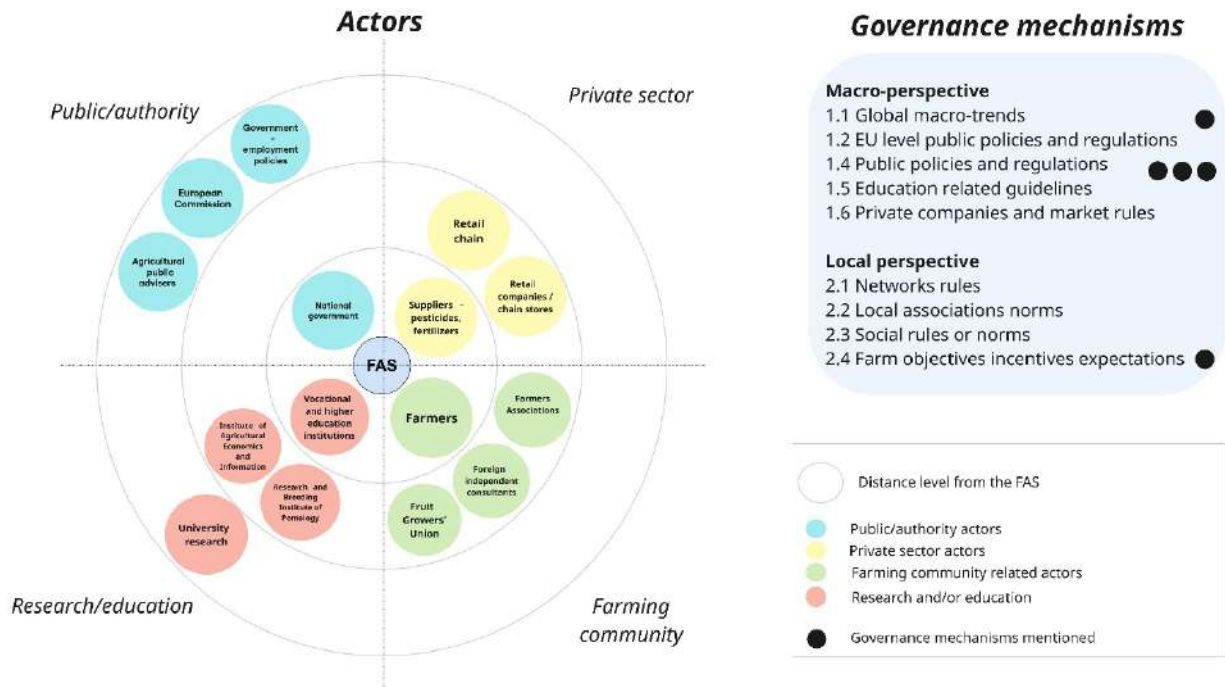


Figure 52. Actors and governance mechanisms mentioned in Automation of Orchard Management LL.

#### 4.2.4. Occitanum OLViticulture (France)

The Occitanum Living Lab (OL VITI) is located in France. The focal action situation addresses the main purpose of ensure successful fertilisation, which requires a clear understanding of the sources of heterogeneity within the plot, including its historical use and pedoclimatic context. Fertilisation is therefore managed according to the principles of precision viticulture: measure, decide, act.

In the VITI LL first-level actors, who are directly involved in the LL, primarily belong to the farming community and include the Chamber of Agriculture, cooperatives such as Vinnovalie, and Cave de la Bastide. They are supported by research and education actors such as research institutions and technical institutes, as well as by agtech company. Second-level actors, who collaborate with the LL but are less directly engaged, include high-level education institute, advisors, training centres, machinery cooperatives, service providers, and other farmers. Third-level actors, who influence the LL from a distance, include other Occitanum LL, state and regional public financial bodies, and a regional competitiveness cluster. Across all levels, the majority of actors are rooted in the farming community.

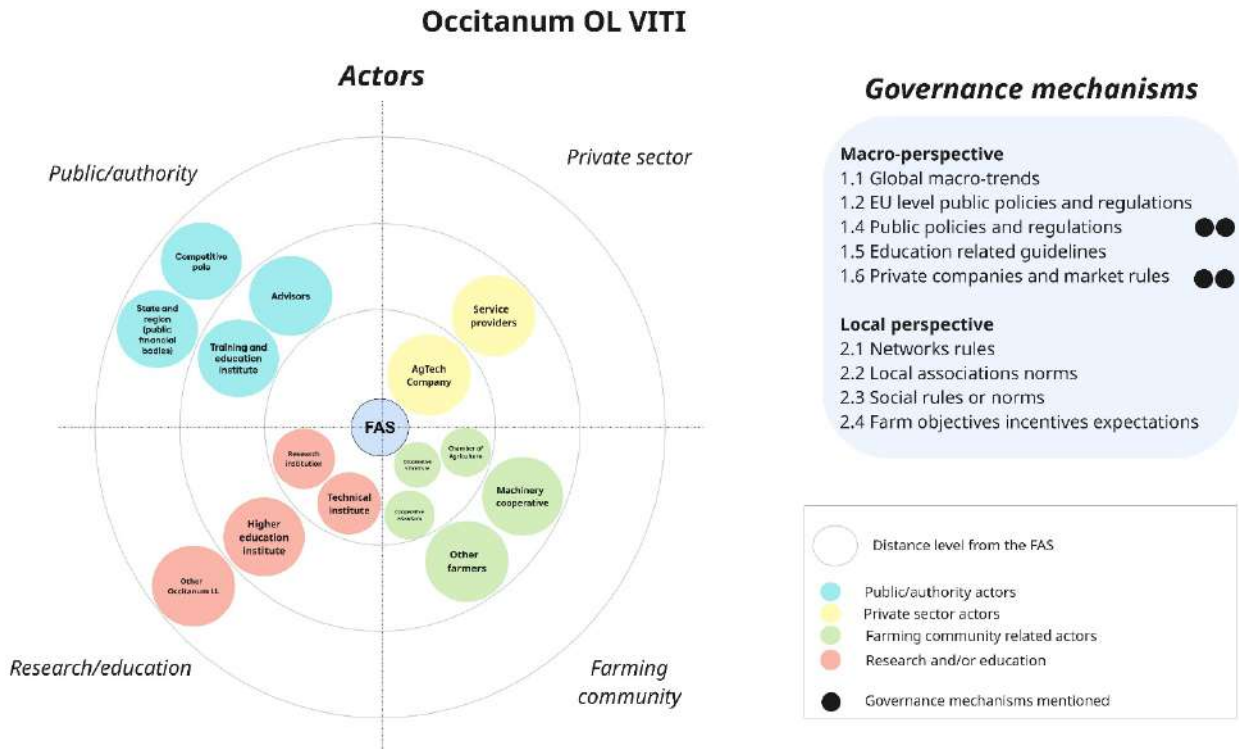


Figure 53. Actors and governance mechanisms mentioned Occitanum OL Viticulture LL.

#### 4.2.5. AgDiBi (Germany)

The AgDiBi Living Lab is located in Germany and works on knowledge transfer on digital technologies to increase the application of digital and precision farming technologies in crop production.

First-level actors, who are directly involved in the LL, primarily belong to research/education sector which includes two vocational schools, authority in agriculture, nutrition and rural areas, one technical school, the University of Hohenheim, a research project on digitalisation and an experimental farm. Second-level actors, who collaborate with the LL but are less directly engaged, include vocational training farms and technology developers and vendors in the region. Third-level actors, who influence the LL from a distance, include the Ministry of Agriculture, the Ministry of Education.

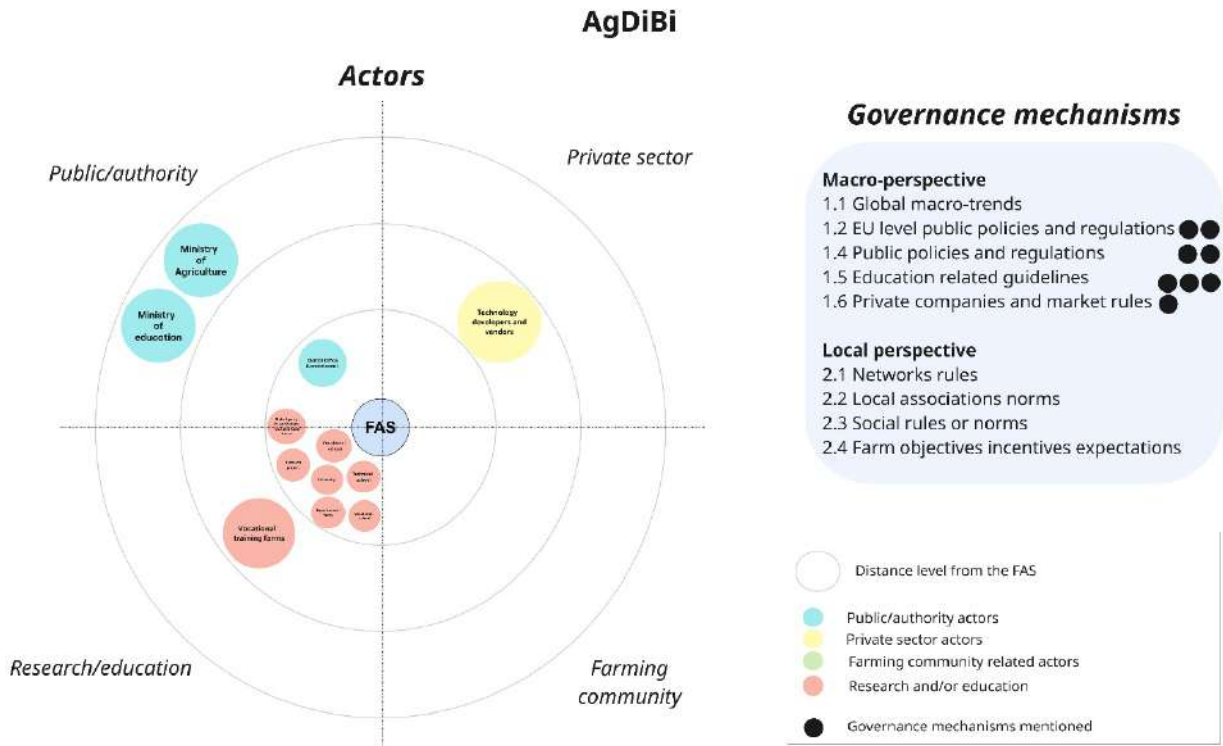


Figure 54. Actors and governance mechanisms mentioned AgDiBi LL.

#### 4.2.6. Spraying drones (Greece)

The Spraying Drones Living Lab is located in Greece. The focal action situation of the LL is related with vineyard spraying and crop protection, utilising advanced digital technologies to enhance the productivity, profitability, and sustainability of European agriculture.

Actors which are directly involved in the LL (first level) are from a diverse range of sectors, including farmers, research institutions, universities and companies providing technology equipment and services. Actors which are not in the LL but collaborate with it (second-level actors) are consulting companies, agricultural supply stores, companies providing technology equipment and services, Hellenic Crop protection association and certification bodies. Most second-level collaborators come from the private sector. Third-level actors identified that have an influence but are not close to the LL are legislative authorities.

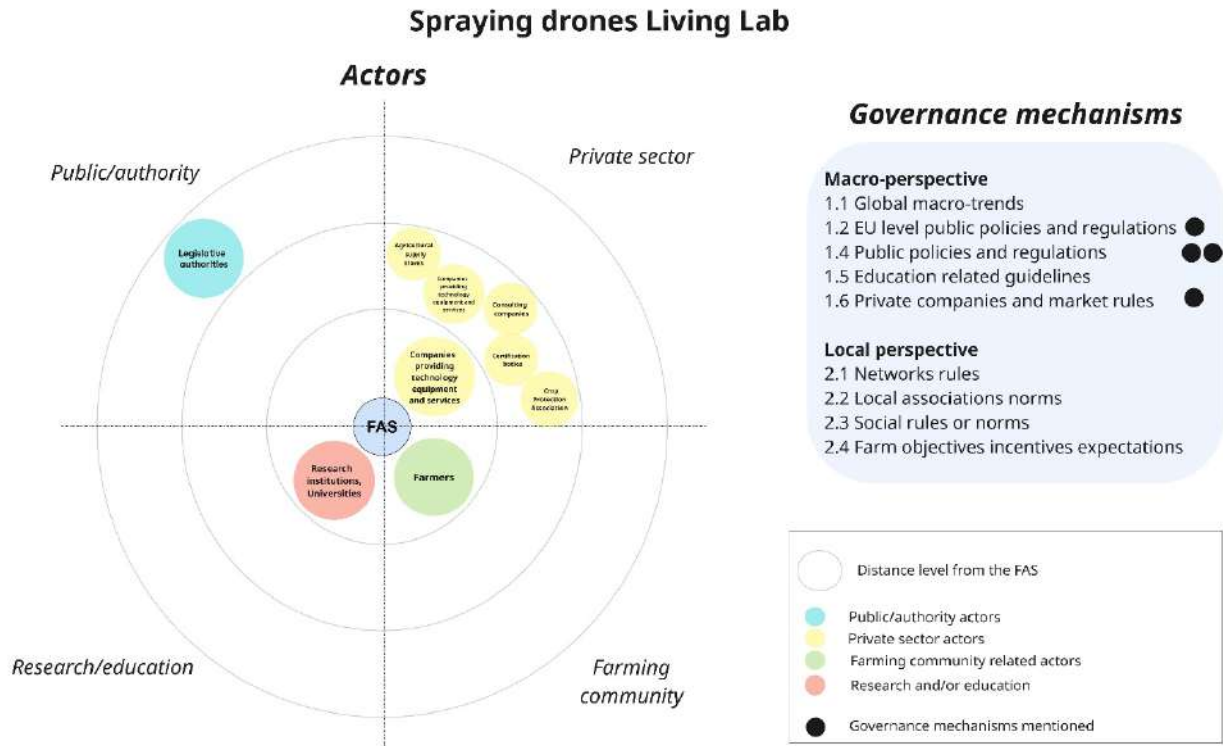


Figure 55. Actors and governance mechanisms mentioned Spraying drones LL.

#### 4.2.7. Innovative Soil Scanner (Hungary)

The LL Digital Ecosystem of the Innovative Soil Scanner technology for sustainable farming is located in Hungary. The LL addresses the problem of non-site-specific application of fertilisers on agricultural land which can cause environmental stress, inappropriate nutrient distribution in the soil and economic damage to farmers. Older generations of farmers tend to be afraid of new technology.

The LL identified first-level actors which are directly involved in the LL are from a diverse range of sectors, primarily including farmers and farmers community, ag-tech company providing the service of soil scanning, agricultural advisors, demo farms, the digital academy of agriculture and IoT companies. Actors that collaborate with the LL (second level actors) are auditing organisations, laboratory networks, advisory networks, municipalities, ministry of agriculture, Hungarian precision farming association, and other innovative projects. Most second-level collaborators come from the public/authority sector. Third-level actors that influences the FAS but are not close to the LL are consumers/society and other research institutions.

**Innovative Soil Scanner technology for sustainable farming**

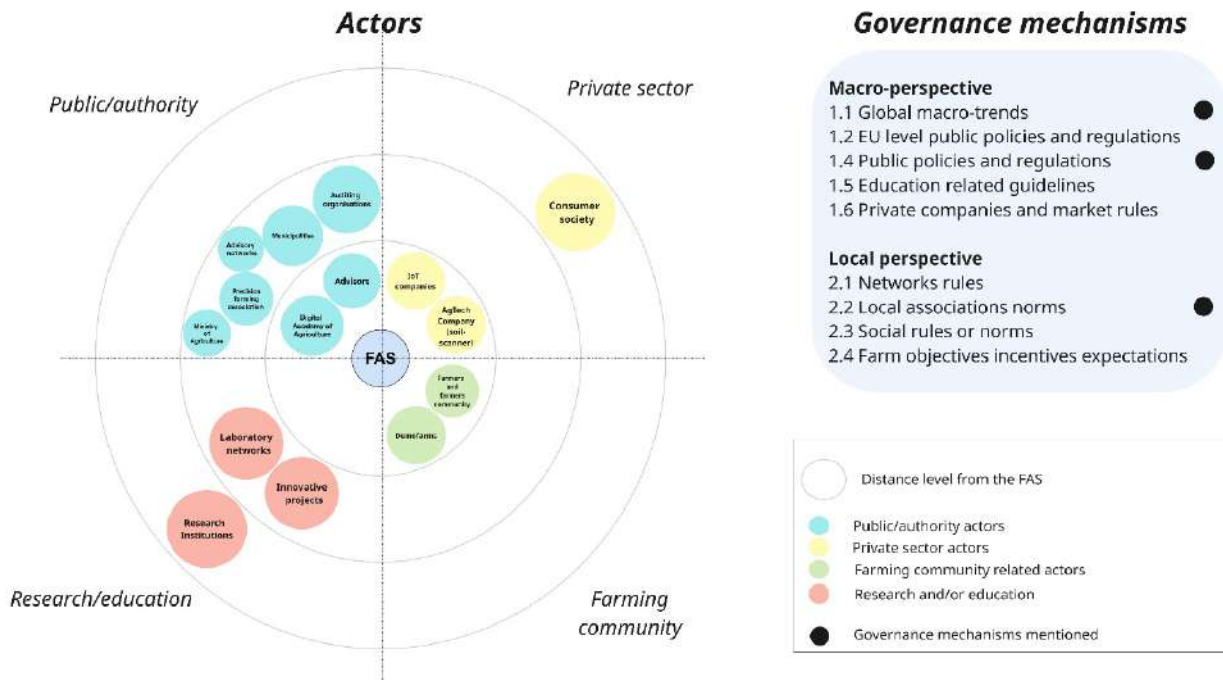


Figure 56. Actors and governance mechanisms mentioned Innovative Soil Scanner LL.

**4.2.8. Organic Table Grapes (Italy)**

The LL Organic Table Grapes is located in Italy. The focal action situation addressed by the LL is increasing the quality and quantity of organic table grape production by reducing the qualitative and quantitative pressure on the soil and water resources. First-level actors which are directly involved primarily include AGROLAB, innovation brokers, consumers, research institutions and AGRIPLAN.

Second-level actors that collaborate or potential to collaborate with the LL are trade associations, universities, Italian agricultural consortiums, advisory organisations specialized in grape production, fruit consulting, business consultants and all actors enabling farmers, technicians, researchers, suppliers of technical means such irrigation, pesticides, nutrition inputs, software developers, actors enabling cooperatives/OPs and cooperatives.

Third-level actors that have an influence but are not close to the LL are large-scale retail trade (GDO), wholesalers (commercial), large-scale distribution, IT companies, government, public institutions, intermediary players between the company and the large-scale retail trade, actors that do not allow GDO ('store keepers'), actors that hinder producers developing 'closed' systems, direct involvement of agricultural entrepreneurs, trade associations, service companies, large retailers 'imposing' guidelines on the basis of economic and market logic and companies producing digital tools.

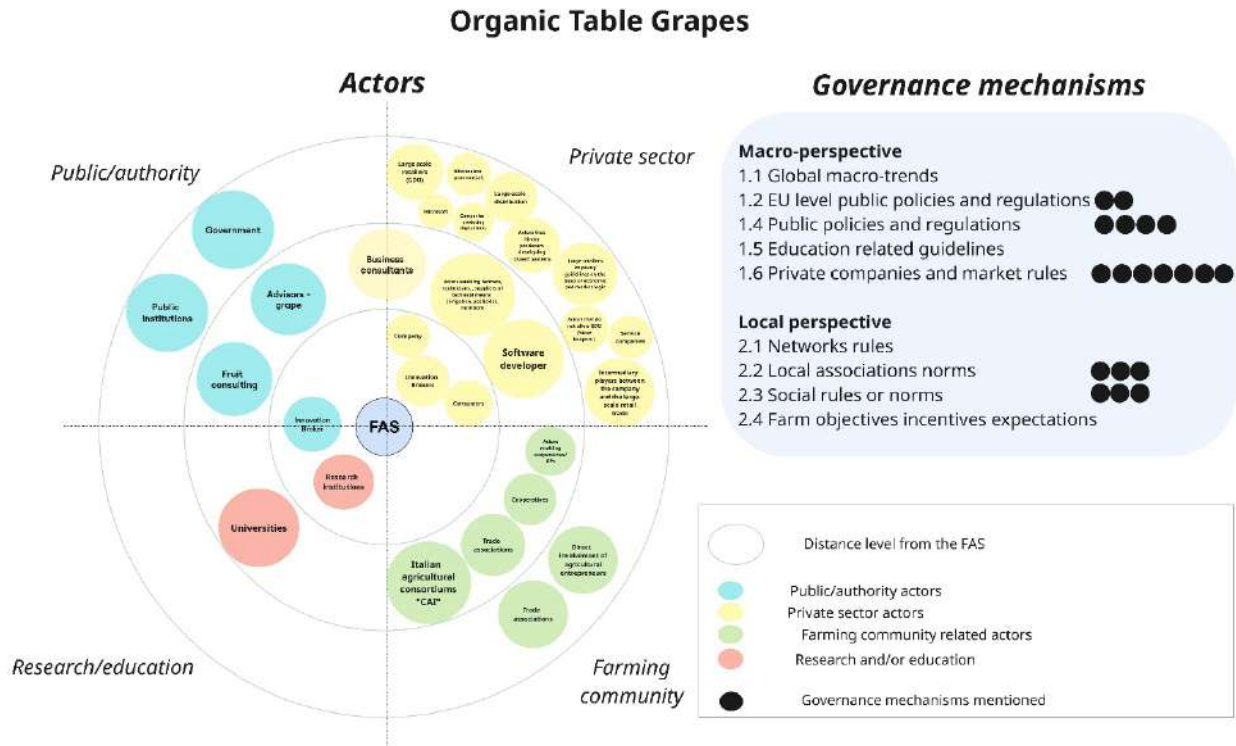


Figure 57. Actors and governance mechanisms mentioned Organic Table Grapes LL.

#### 4.2.9. Local Beef Cattle Farming (Latvia)

The LL Local Beef Cattle Farming is located in Latvia. The LL leverages digital technologies to reduce the use of crop protection products through site-specific spraying. First-level actors which are directly involved in the LL are industry organisations (NGOs) (e.g. Zemnieku saeima) and Latvian Fund for Nature. Second-level actors that collaborate with the LL are consultants/farm advisors (e.g. Latvian Rural Advisory and Training Centre), Farmers' cooperatives (e.g. Latvijas Liellops) and influencers in the topics of food / beef meat consumption (e.g., cooks etc.).

Third-level actors that have an influence but are not close to the LL are public institutions that provide funding, educational institutions, local environmental and animal rights NGOs and public food data registration organizations such as agricultural data centre and food veterinary service.

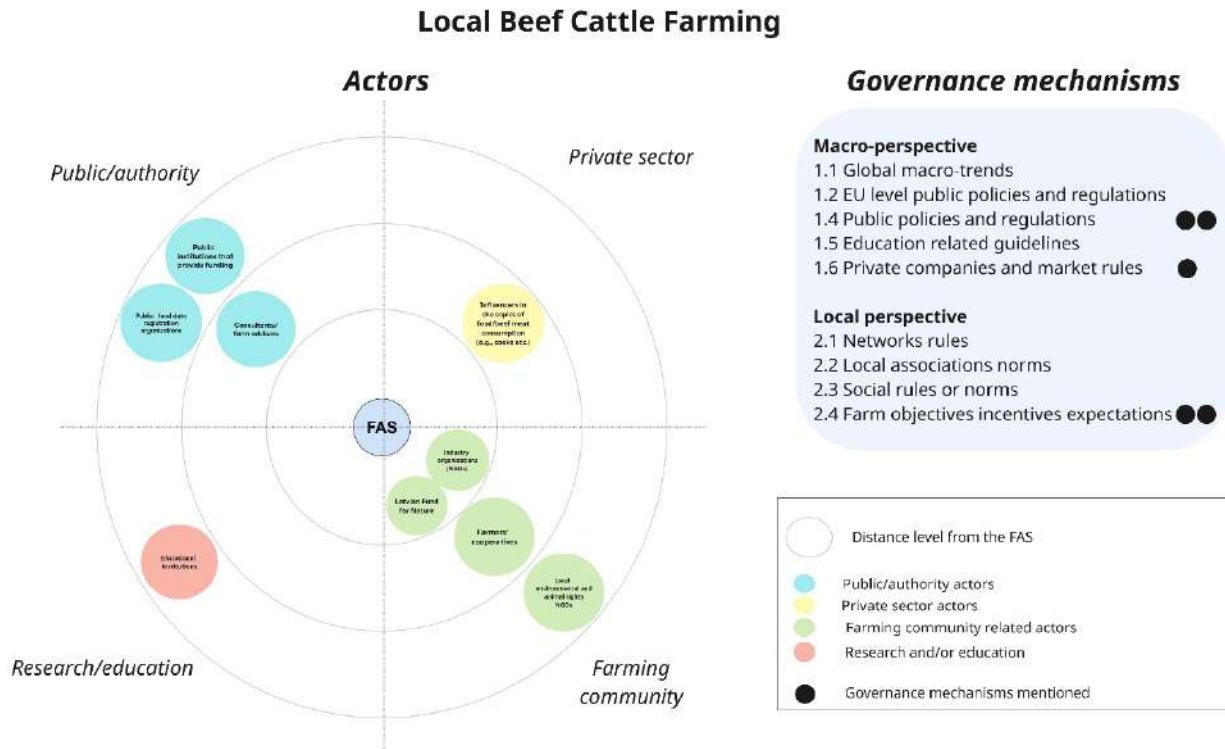


Figure 58. Actors and governance mechanisms mentioned Local Beef Cattle Farming LL.

#### 4.2.10. Scottish Small Farms and Digital Platforms (Scotland)

The LL Scottish Small Farms and Digital Platforms in Scotland works on farmers can harness the power of digital tools and platforms to support and improve sustainable agricultural practices; enhance diversification activities, reach broader audiences and markets, access mental health support; develop community relations; raise public awareness of farming issues - thereby strengthening their resilience in the face of the challenges they face.

First-level actors of the LL (directly involved in the LL) comes from farming sector, including neighbours, peers and local community. Second-level actors that collaborate with the LL are Aberdeen University, Moredun Research Association, SRUC/SAC, Rowett Institute, soil association, large scale green energy production, scottish agritourism, neighbours and peers and local community via online. Actors that have an influence but are not close to the LL (third level) are farm advisory service, councils and legislation, planning department, environmental health department, LEADER programme, CSA network UK, universities, research association, soil association, agrotourism, goat veterinary association, neighbours and peers and Local Community.



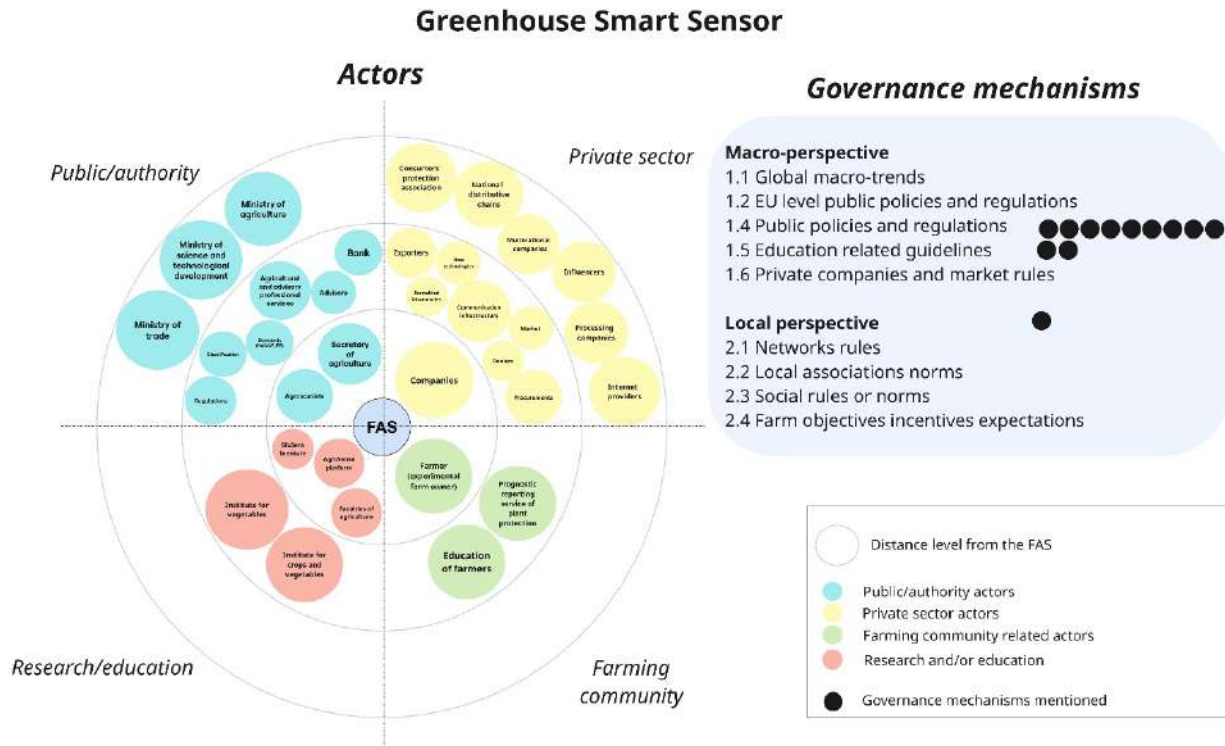


Figure 60. Actors and governance mechanisms mentioned Greenhouse Smart Sensor Laboratory LL.

#### 4.2.12. Almería Agroecology (Spain)

The Almería Agroecology Living Lab is located in Spain. The focal action situation addresses the problem of lack of data interoperability and difficulty in managing and optimising resources.

First-level actors which are directly involved in the LL are farmers, technological companies/providers and internet providers, producer associations, advisors, auxiliary industries and specific human resources (e.g., data analysis technicians/technicians/IT experts.) Second-level actors that collaborate with the LL are Research Centres and Universities, cooperatives, consulting companies and public administration, financial institutions and investors. Third-level actors that have an influence but are not close to the LL are certifiers, social agents (e.g., consumers) and retailers – value chain.

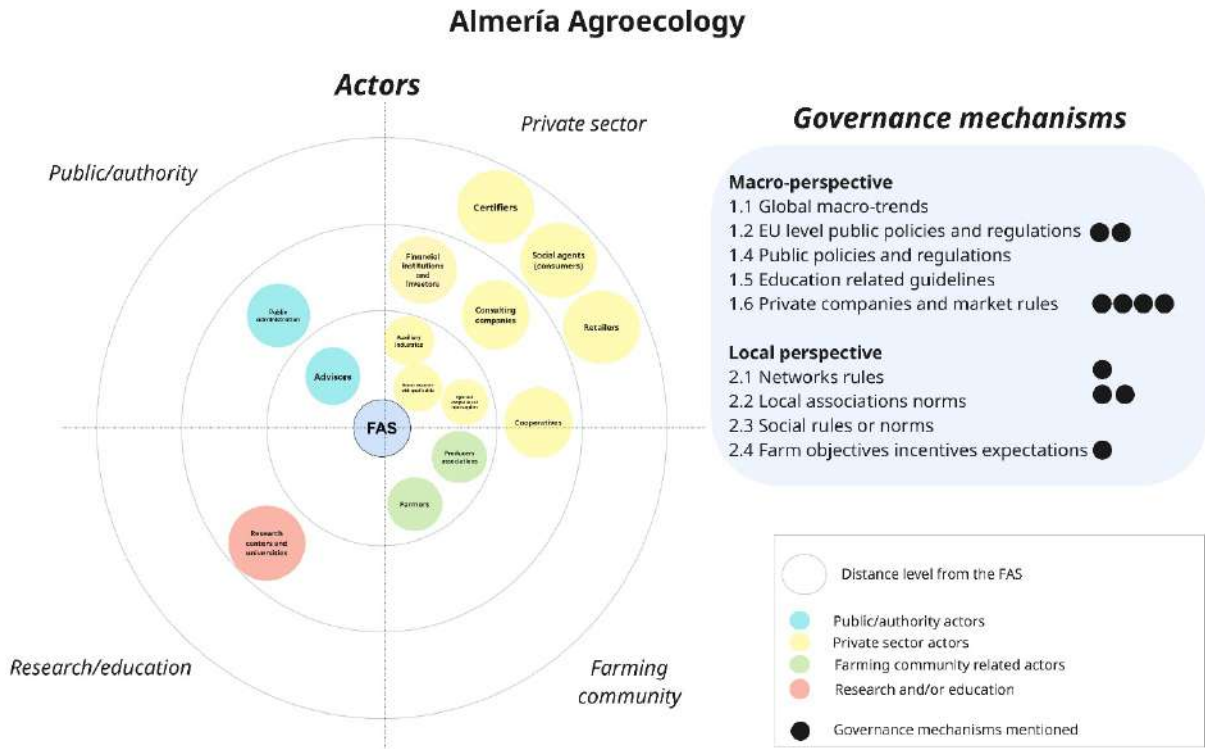


Figure 61. Actors and governance mechanisms mentioned Almería Agroecology LL.

#### 4.2.13. ChloughJordan Food Hub (Ireland)

ChloughJordan Food Hub Living Lab is located in Ireland. The LL aim to solve how can local farmers and suppliers get paid a fair price and ensure that people have the option of better, fairer ways to source their food directly from the producers?

The first-level actors which are directly involved in the LL are farmers and supply chain actors. Second-level actors that collaborate with the LL are consumers and public or private advisers. Third-level actors that have an influence but are not close to the LL are researcher and climate activists.

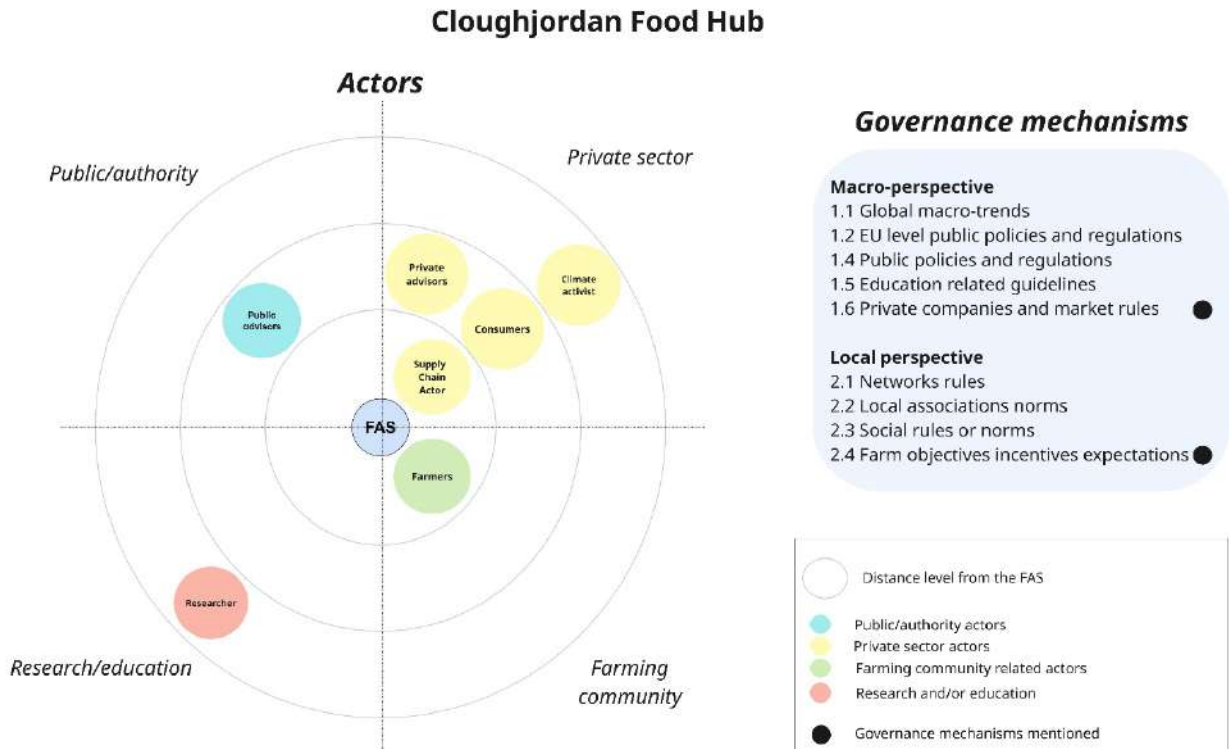


Figure 62. Actors and governance mechanisms mentioned Chloughjordan Food Hub LL.

#### 4.2.14. Agrifood Technology (Belgium)

The Agrifood Technology Living Lab located in Belgium, focuses on arable production and uses digital technologies to reduce the use of crop protection products by enabling site-specific spraying.

The Living Lab's participants come from a variety of sectors, including research institution, farmers, machine manufacturers with integrated data platforms, and technology providers from drones' technology or machineries manufacturers with integrated data platforms. Second-level collaborators include research institutions, universities, a farmers' association, supply chain companies, distributors and retailers, the government, and farmers. Most second-level collaborators come from the private sector. Third-level actors who influence the LL but are not closely involved are universities, supply chain companies, distribution/retail, governmental institutions and farmers.

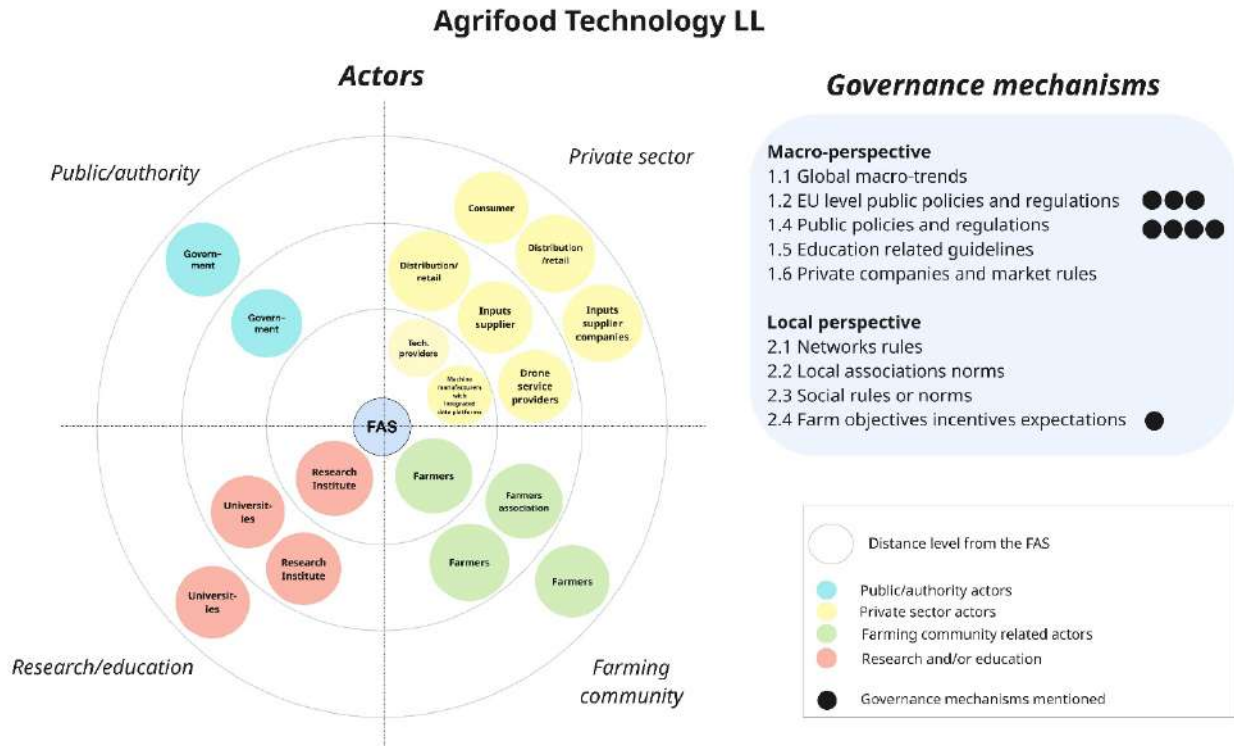


Figure 63. Actors and governance mechanisms mentioned Agrifood Technology LL.

#### 4.2.15. Artificial Irrigation Management (Slovakia)

The LL Artificial Irrigation Management System is located in Slovakia. The focal action situation is optimising irrigation to enhance crop production while conserving water.

First-level actors which are directly involved in the LL are from a diverse range of sectors, including farmers, agronomists, retail companies, national government and vocational and higher education institutions. Second-level actors that collaborate or has the potential to collaborate with the LL are Rural Parliament, National Agricultural and Food Research Centre, the Agricultural Knowledge and Innovation Institute, technology partners and several research and academic institutions. Third-level actors that have an influence but are not close to the LL are agricultural public advisers and government.

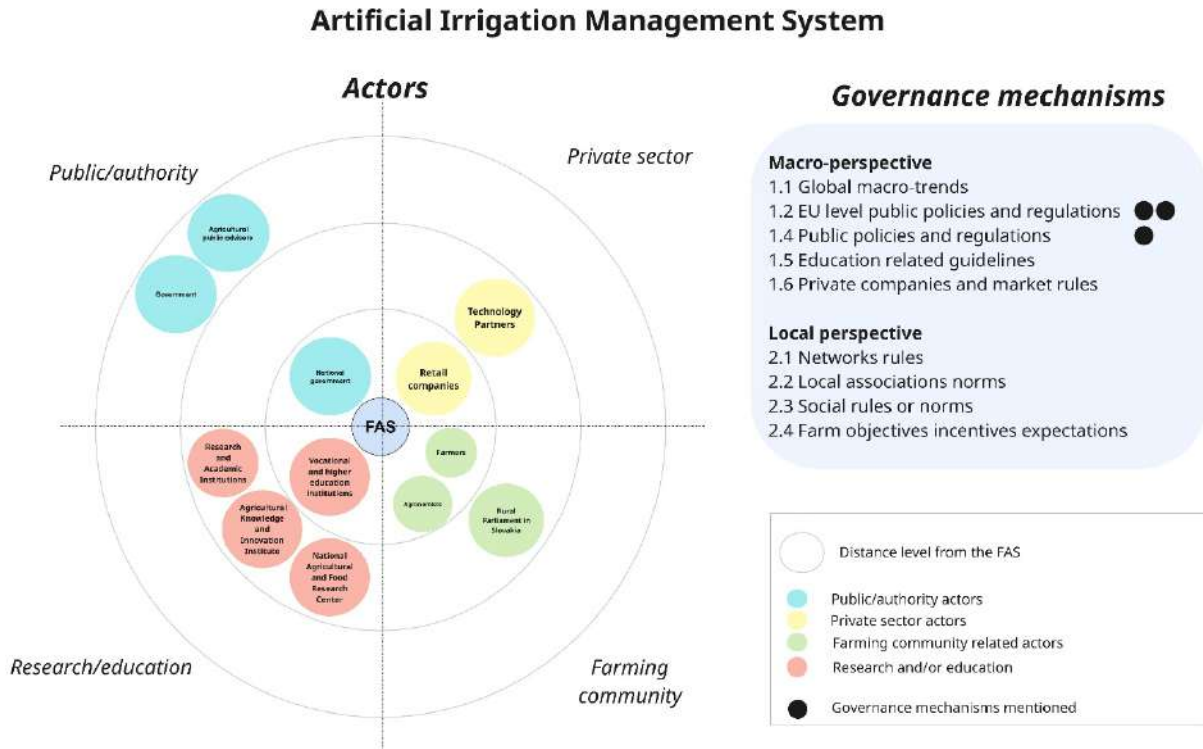


Figure 64. Actors and governance mechanisms mentioned Artificial Irrigation Management LL.

#### 4.2.16. LIT Ouesterel (France)

The LIT OUESTEREL Living Lab is located in France. The focal action situation is to use digital technologies to find non-invasive practice methods and technologies to improve pig welfare and workers' conditions at different stages of production.

First-level actors which are directly involved in the LL are from dashboard editors, IT company, equipment manufacturers, cooperatives, farmers and research institutes. Second-level actors that collaborate with the LL are slaughterhouses, BDPORC, BNO and PigConnect. Most second-level collaborators come from the farming community. Third-level actors that have an influence but are not close to the LL are consumers, policy makers, Microsoft, Google, internet providers and supermarkets. All of these actors are from private sector.

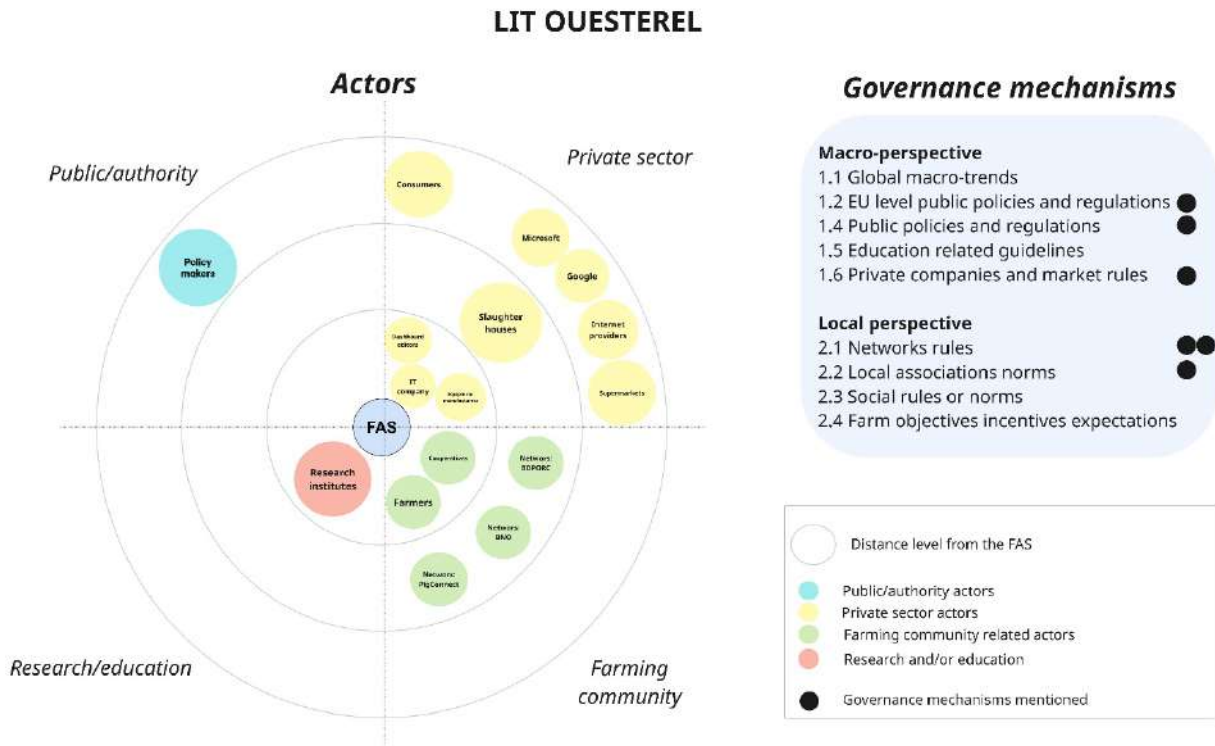


Figure 65. Actors and governance mechanisms mentioned LIT Ouesterel LL.

#### 4.2.17. Grassland Management (Estonia)

The Grassland Management Living Lab is located in Estonia. The LL has as an objective focal to improve monitoring of maintenance regimes of grasslands including both protected grassland and the cultivated ones managed for organic beef production.

First-level actors which are directly involved in the LL are drone operators, beef farmers (focussed on beef production with biodiverse wooded meadows), ecological teacher using the beef farm to showcase nature friendly farming and grassland expert. Second-level actors that collaborate with the LL are from Latvijas Valsts Meži LVM (Latvian State Forest) and Blooming Meadows group.

On a third-level actors that have an influence but are not close to the LL, we can find Lauku Atbalsta dienests LAD (Rural Support Service, Republic of Latvia) – which are administers of subsidies for farmers and a tourism operator.

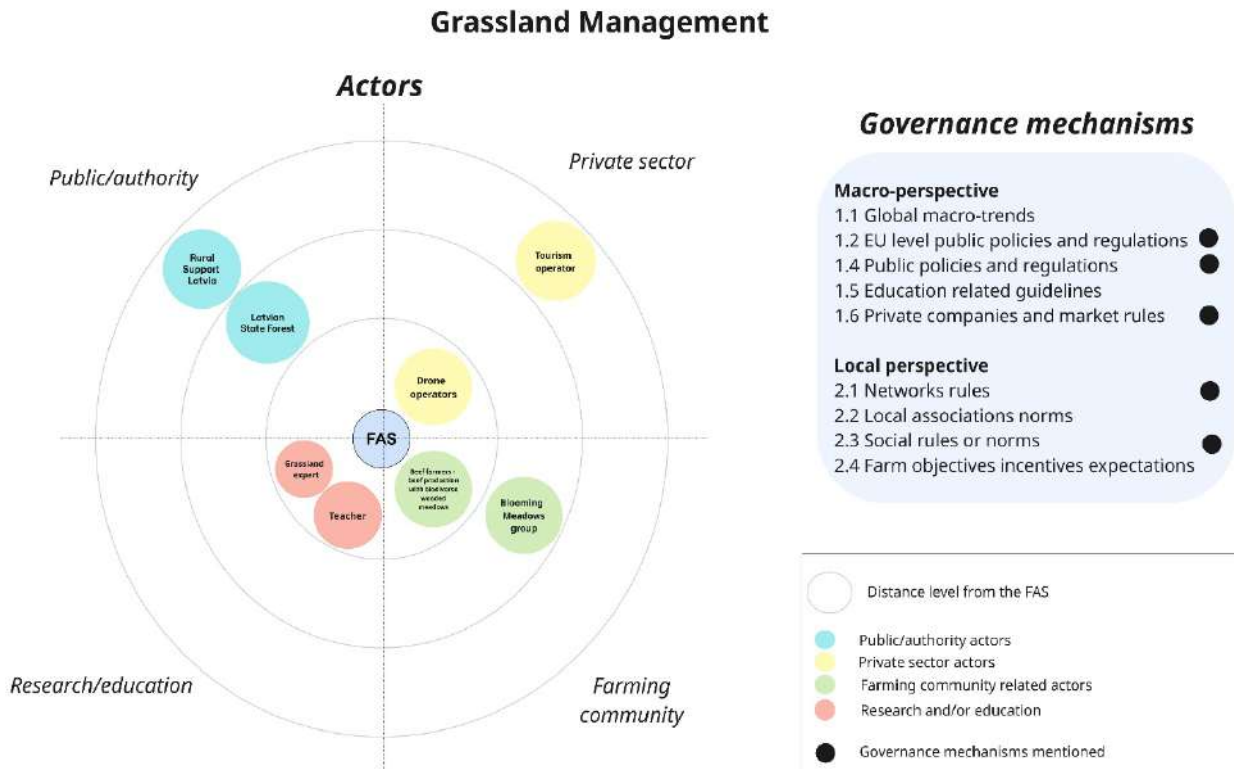


Figure 66. Actors and governance mechanisms mentioned Grassland Management LL.

#### 4.2.18. RAMAS (North Macedonia)

The LL RAMAS is located in Macedonia. RAMAS LL aims to establishing decision-making processes in agricultural production by providing advisory services in extensive, real-time field data gathered at every stage of the agricultural process.

First-level actors which are directly involved in the LL are from a diverse range of sectors, including Ministry of Agriculture, Forestry and Water Economy, Administration for Hydro-Meteorological Affairs, farmers, agricultural cooperatives, agronomists, UNILAB (accredited laboratory), Research Institute for Agriculture, IoT and IT companies, data analysis software and telecommunication companies.

Second-level actors that collaborate with the LL Agency for Financial Support of the Agriculture and Rural Development, National Extension Agency, Suppliers of Equipment and Repromaterials, higher educational institutions (faculty, academies), National Federation of Farmers, Fund for Innovation and Technological Development. Third-level actors that have an influence but are not close to the LL are food and veterinary agency, ministry of environment and physical planning, civil aviation agency, agency for real estate catastrophe, other AKIS actors, funds and donors.

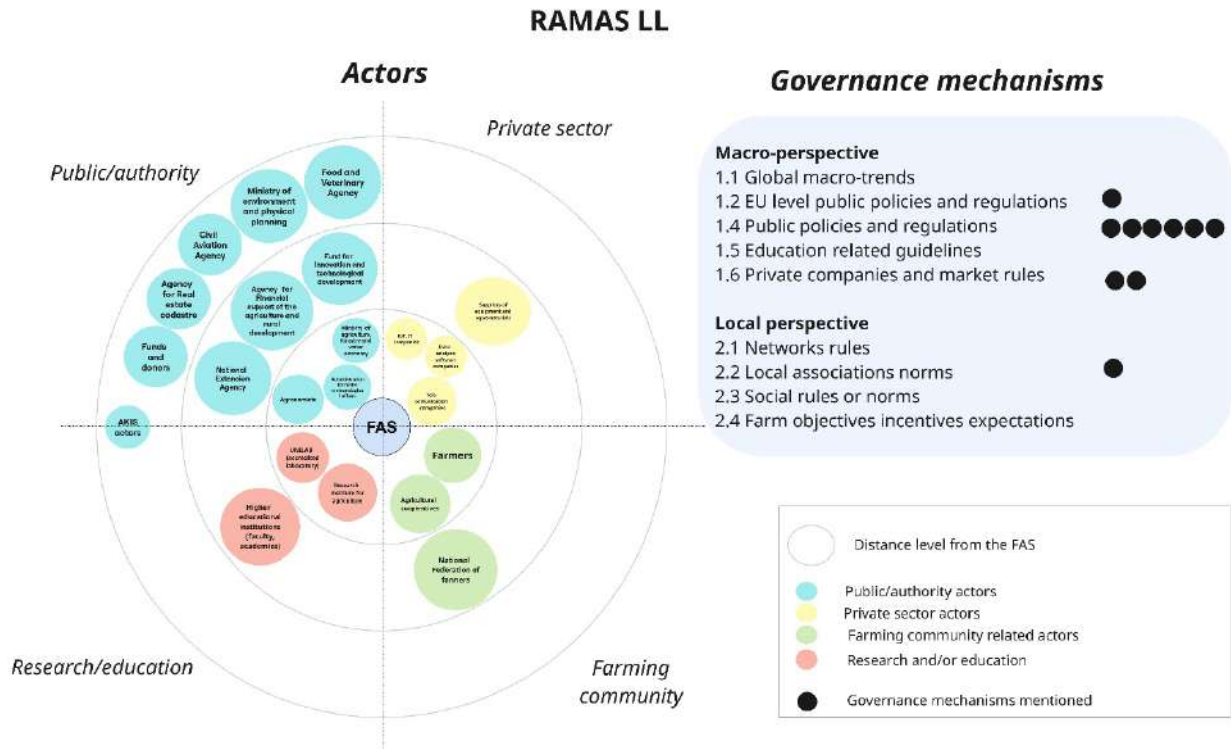


Figure 67. Actors and governance mechanisms mentioned RAMAS LL.

#### 4.2.19. Smart Villages Network (Slovenia)

The LL Smart Villages Network is located in Slovenia. Smart Villages Network LL deals with the question on how to use digital technology in viticulture, in order to affect the environmental, economic, and social aspects of sustainability.

First-level actors which are directly involved in the LL are farmers, employees, customers, knowledge providers, beekeepers and technology developers. Second-level actors that collaborate with the LL are cooperatives, advisory service, tourism authority, other farmers close to them, IT companies, faculties, Ministry of agriculture, forestry and food, Ministry of the economy, tourism and sport, Ministrstvo za digitalno preobrazbo, funding bodies, other winegrowers, telecommunications/infrastructure providers, energy companies, local municipality (educational and social support systems, health care, care for elderly people), agricultural fairs as info hubs, educational and social support systems and telecommunication services.

Third-level actors that have an influence but are not close to the LL are EU, electro and telecommunications companies, politics, national and EU regulations, experts, telecommunication services, national level politics (ministries) and European level policies and incentives.

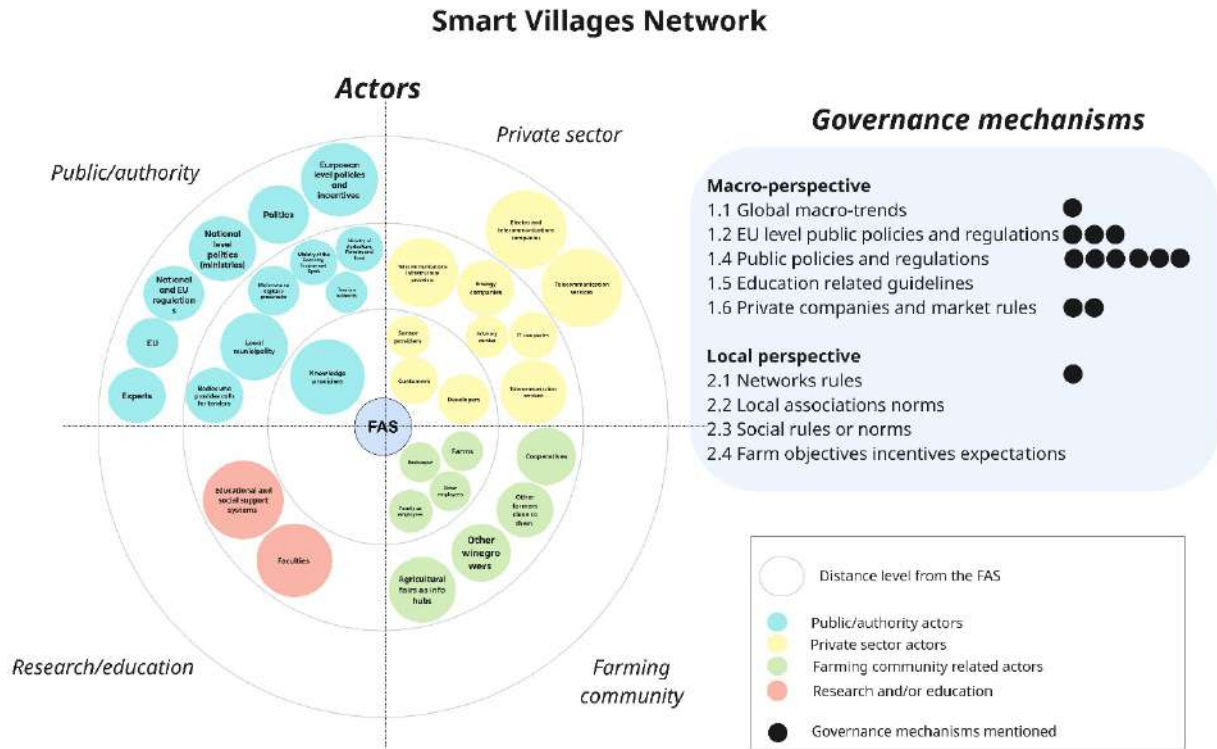


Figure 68. Actors and governance mechanisms mentioned Smart Villages Network LL.

## 5. Socio-technical process modelling of use cases (T.3.3) - CNR

The results presented in this section are the outcome of the activities of *Task 3.3 - Socio-technical process modelling of use cases*. All the phases of the procedure described in Section 3.2 have been successfully completed: 1) data collection, i.e., gathering process-relevant information from the LLs according to the established guidelines; 2) reporting, i.e., producing a report describing the process transformation following the provided template; 3) check, i.e., verifying that the information collected by the LLs in phase 1 and contained in the reports delivered in phase 2 is sufficient for modelling; 4) formalisation, i.e., developing the models; 5) agreement, i.e., validating the models in focus groups with the LL representatives. Results from phases 1 and 2 are available in the previous version of D3.1. Below, we present the results obtained from the activities carried out between M21 and M34 consisting of the developed process models, along with feedback collected during the evaluation of the models in focus groups with the LL coordinators.

### 5.1. Process Models

The models have been formalised for the 19 LLs that have submitted a report detailing the process transformation ongoing in their LL. The **final versions of these reports**, which served as input for the formalisation phase, are available on Zenodo: <https://doi.org/10.5281/zenodo.16372574> (Mannari, Ferrari and Bacco, 2025. Dataset REPORTS).

**All models**, along with the **short guide document** to support their comprehension, are available on Zenodo: <https://doi.org/10.5281/zenodo.16372882> (Mannari, Ferrari and Bacco, 2025. Dataset PROCESS MODELS).

In this document, we only focus on the **activity transformation models**, selected from the full set of available models. We do so because such models are the most representative of the changes resulting from the introduction of a digital solution in a LL, given that they illustrate the transformation through an **overlap of the processes before and after the digitalisation process**. The models presented here are the result of the application of the methodology described in Section 3.2 and correspond to the versions discussed during the focus groups with LL coordinators (see Section 5.2). A comparative analysis of the cases will be provided in D 3.2 due at M44.

We present the results case by case in what follows, according to the order in Table 1.

**High-resolution versions of the models  
enabling fullscreen view and zooming on details  
are available in the archive on Zenodo**  
<https://doi.org/10.5281/zenodo.16372882>

### 5.1.1 Pecorino Toscano Living Lab (Italy)

Within the Consorzio Pecorino Toscano LL, the digital solution has been chosen to enhance collaboration and efficiency across the cheese production chain. This solution centres around a **Farm Management Information System (FMIS)** that integrates various digital tools to collect, store, and share data on livestock and milk production. The primary goal is to optimise time and resource management in both livestock care and cheesemaking. The process involves coordinated activities among farmers, technical advisors, and the cheese factory, who interact through the FMIS to communicate and exchange information in real time, fostering a more connected and data-driven production system.

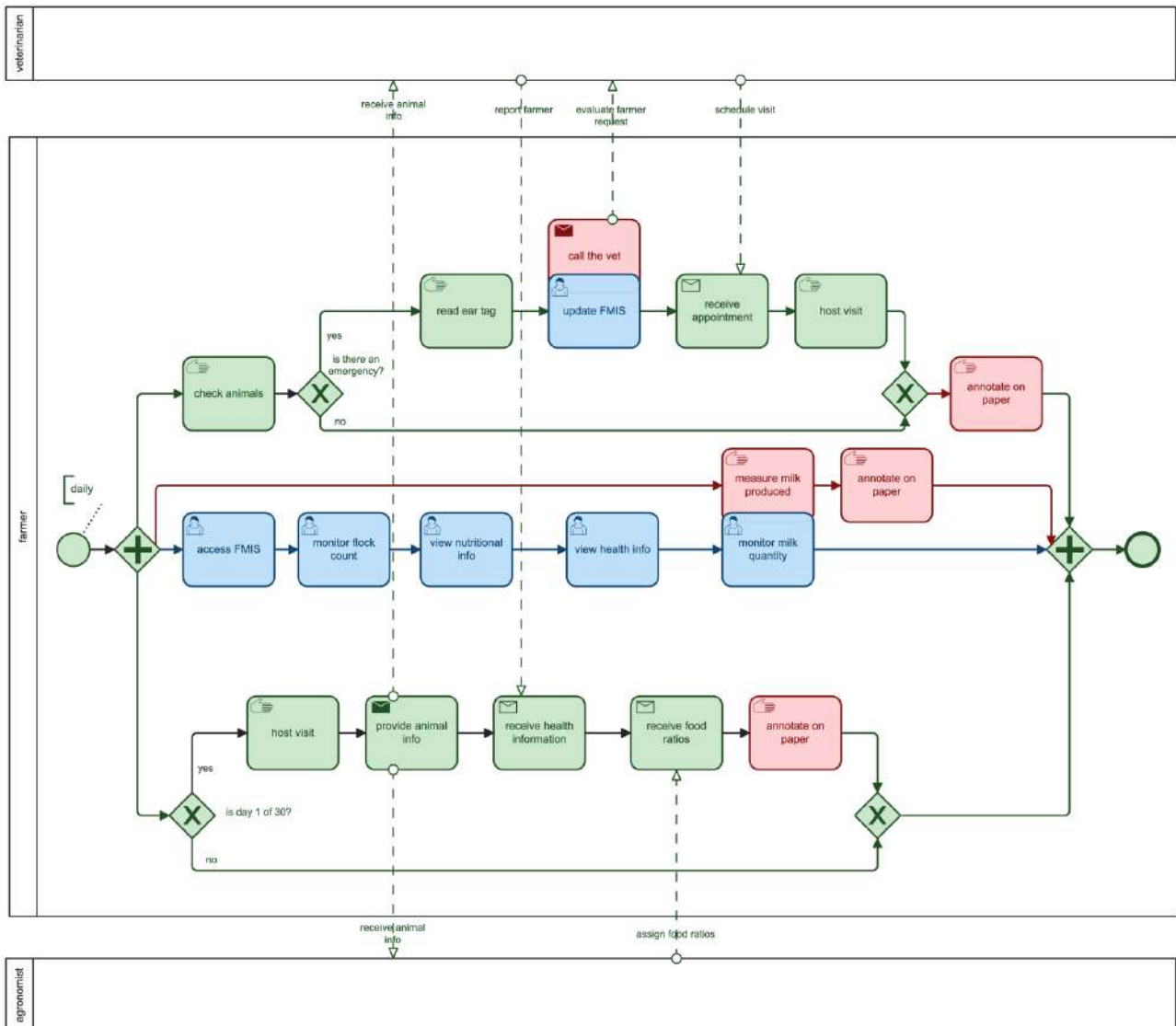


Figure 69. Process transformation diagram for Living Lab Pecorino Toscano.

The diagram illustrates how the farmer’s traditional workflow changes through the integration of the digital solution. The introduction of the FMIS introduces new practices while preserving essential hands-on responsibilities and eliminating several manual tasks related to record keeping. While hands-on animal care remains essential, the process shifts from manual data collection and traditional communication with advisors to a **data-informed approach** for more efficient and responsive livestock management.

### Unchanged Activities (green)

Core responsibilities related to animal care remain intact. The farmer continues to **check animals daily**, ensuring their well-being and remaining alert to signs of emergency. In urgent cases, the **ear tag is still used** to identify animals, and the farmer **hosts specialist visits**, providing contextual information as needed. On a routine basis (approximately once a month), the farmer continues to host visits and receive **updates on animal health and nutritional plans**.

### New Activities (blue)

The adoption of the FMIS significantly impacts the farmer's daily workflow. In emergencies, after reading the ear tag, the farmer now **updates the FMIS**, which acts as the main platform for communication and data sharing. On a regular basis, the farmer **logs into the FMIS** to monitor **flock numbers, milk production, and check updated information on nutrition and animal health**.

### **Removed Activities (red)**

Several manual and time-consuming tasks have been phased out. The farmer **no longer manually measures milk production or directly contacts veterinary services**—these processes are now handled automatically through the FMIS. Additionally, there is **no longer a need for paper-based data recording**, as all relevant information is now stored and updated digitally.

The archive on Zenodo (Mannari, Ferrari and Bacco, 2025. Dataset PROCESS MODELS) contains complementary diagrams representing the agronomist and veterinarian's processes.

### **5.1.2 APPETIT Living Lab (Poland)**

The Polish LL focuses on the **APPETIT platform**, which aims to enable a more efficient and transparent way to manage the local food market. This digital solution connects key actors such as **farmers, food producers, market organisers, and customers** through an integrated platform that supports both **virtual and physical spaces** for the exchange of local products. By facilitating communication, coordination, and transactions, the APPETIT platform enhances the visibility of local supply chains, simplifies logistics, and improves access to fresh, locally sourced food for consumers, while offering producers better market reach and operational tools.

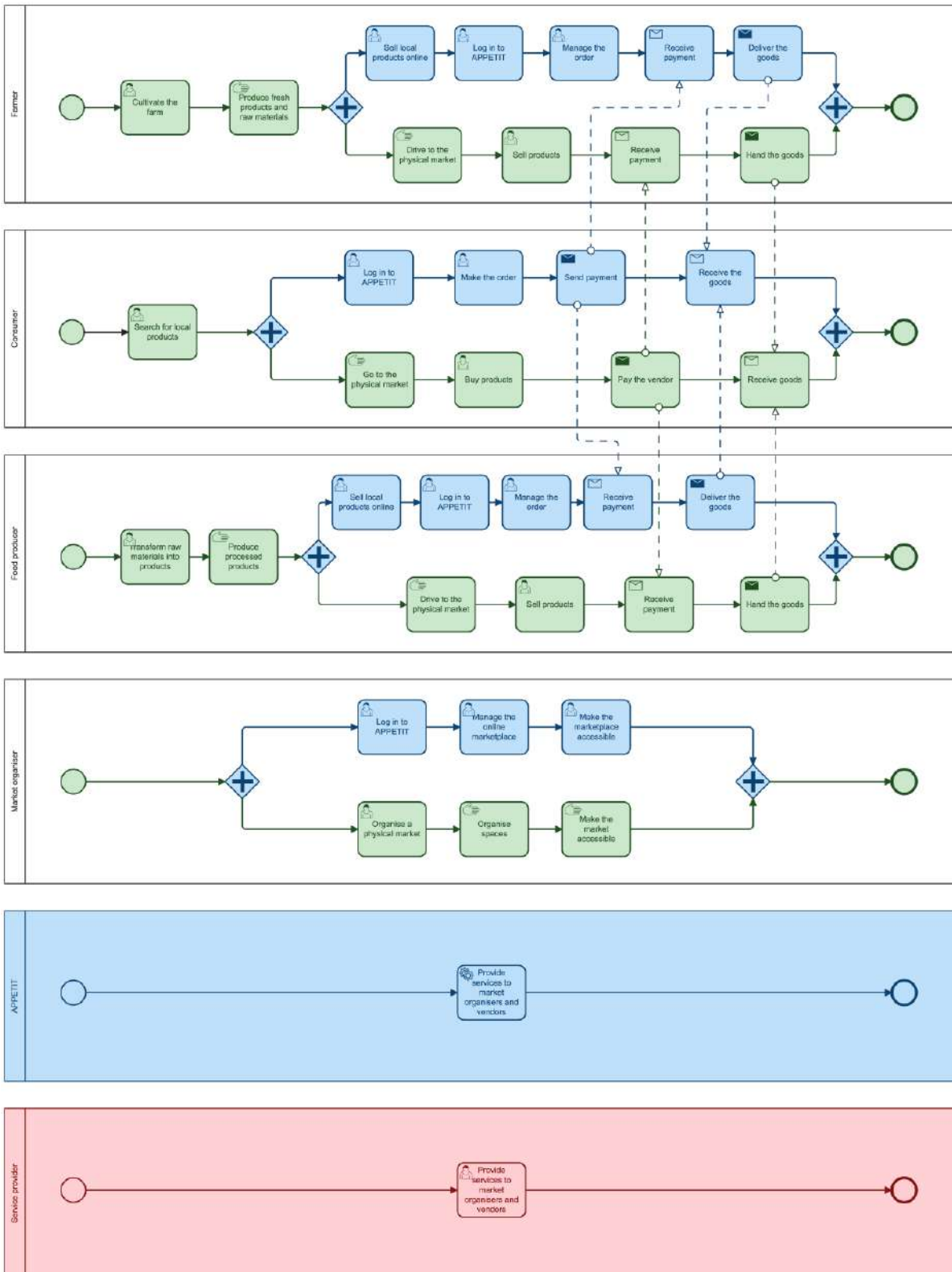


Figure 70. Process transformation diagram for Living Lab APPETIT.

The diagram illustrates how the traditional local food market workflow changes after the integration of the **APPETIT digital platform**. The platform introduces a digital layer that supports and enhances interactions among customers, food producers, and market organisers, while removing the need for certain intermediaries and manual processes. The local food market has shifted from a purely physical, service-dependent system to a **hybrid model that blends in-person and digital interactions**.

#### Unchanged Activities (green)

Core market activities remain consistent. **Customers** still **search for local products, visit physical markets, buy directly from vendors, make payments, and receive goods** in person. **Food producers** continue to **produce food, transport it to market locations, and sell their products directly to customers**, exchanging goods for payment.

**Market organisers** still play a key role in **setting up and managing physical markets**, ensuring that the spaces remain accessible and operational.

#### New Activities (blue)

The **APPETIT platform** offers tailored services for all actors involved. **Customers** can now **log into the platform, place orders online, make payments digitally, and receive goods through direct delivery or pickup**. **Food producers** gain the ability to **sell products online, log in to manage their listings, process orders, receive payments, and coordinate deliveries**.

**Market organisers** can **manage the online marketplace**, ensuring it is **accessible and up-to-date**, while continuing to support the physical market environment.

#### Removed Activities (red)

With the implementation of the APPETIT platform, there is no longer a need for external service providers to facilitate transactions or manage the online sales infrastructure. The platform itself centralises these functions, empowering direct interaction between market actors.

### 5.1.3 Orchard management and digitisation Living Lab (Czech Republic)

The LL has introduced a **farm-installed environmental sensor network and a decision support system accessible via a mobile application for remote orchard monitoring**. The monitoring system is integrated with the **remote irrigation infrastructure**, enhancing data availability and enabling more informed and timely irrigation decisions. This innovation aims to improve automatic irrigation, monitor climatic conditions, and streamline the management of orchard activities.

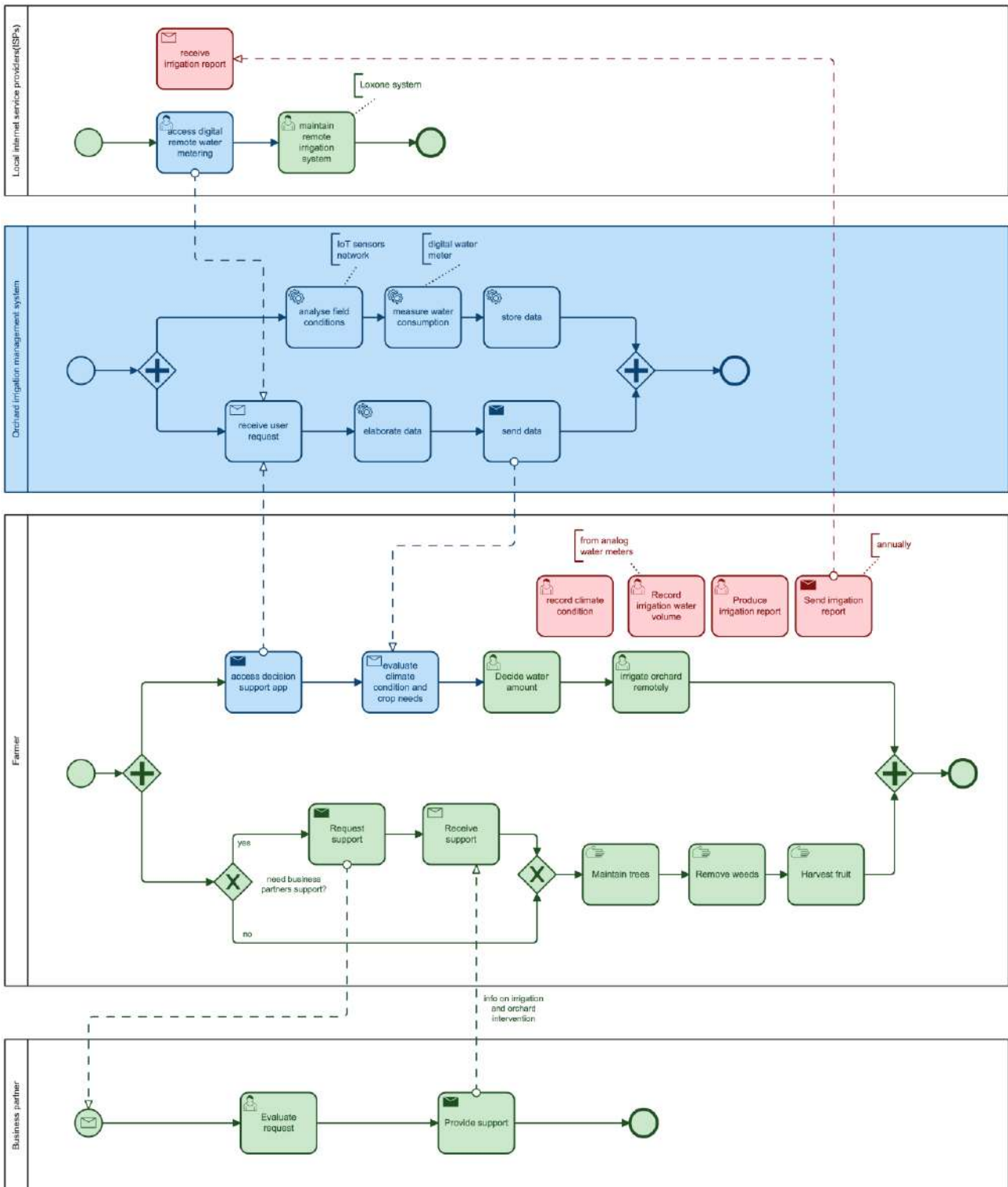


Figure 71. Process transformation diagram for Living Lab Orchard management and digitisation.

**The diagram illustrates how the process changes after the integration of the irrigation management system.** The platform introduces a digital layer that monitors field conditions and supports the farmer in making decisions about irrigation timing and water quantity, while reducing the need for visual monitoring and eliminating manual record-keeping and reporting efforts.

### Unchanged Activities (green)

Farmers continue the **manual routine of tree care**, harvesting, and weed control, all essential activities for maintaining healthy orchards and achieving productivity goals. Collaboration and **information-sharing between farmers** (business partners) regarding irrigation and orchard interventions remain unchanged, supporting optimal use of resources and interventions. The Loxone system, already configured and operated by the Local Internet Service Providers (ISP), enables the **remote irrigation control system**.

### New Activities (blue)

With the **IOT sensors**, field conditions are analysed. Data from sensors monitoring soil and air parameters is managed via a cloud-based platform, allowing seamless **decision support for irrigation**, and associated activities such as pest management and frost prevention. The **digital remote water meter** measures the irrigation water volume. From the data provided, farmers can evaluate climate conditions and crop needs with more precision.

### Removed Activities (red)

With the implementation of the digital system, there is no longer a need for the farmer to **manually record keeping** of activities and **produce reports** for the local service providers. The platform itself manages these functions.

#### 5.1.4 Occitanum Sheep (France)

The Occitanum Sheep Living Lab in France introduces a **Connected Milk Meters System** to enhance the monitoring of sheep milk quantity and quality. This digital solution **replaces manual estimation and paper records with automated milk measurement and real-time data access**. Farmers interact with the system during daily milking routines, while milk inspectors use the platform to verify and register milk production data. By digitising the process, the system enables greater accuracy, improved traceability, and a more efficient approach to managing milk quality and flock health.

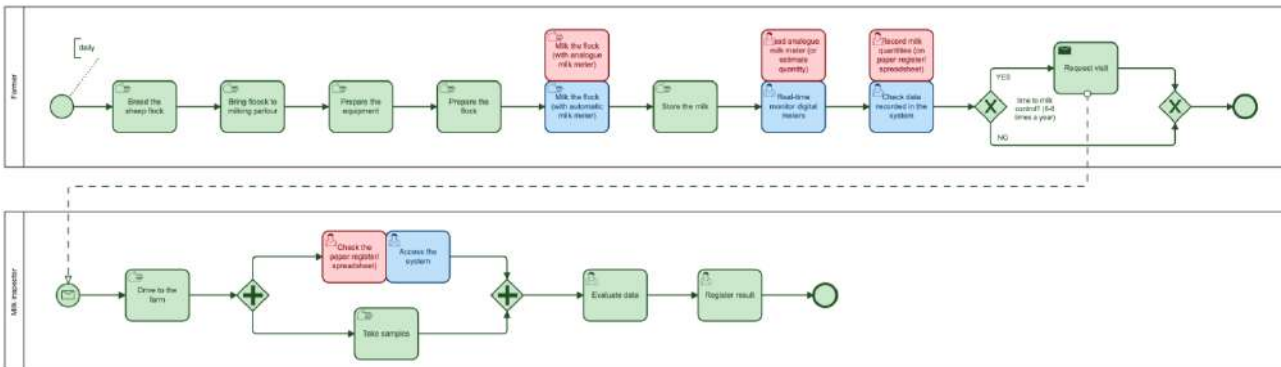


Figure 72. Process transformation diagram for Living Lab Occitanum sheep.

The diagram illustrates **how sheep milk monitoring practices evolve** with the integration of a system composed of connected digital milk meters. This digital solution enables the **real-time measurement of milk volume and chemical parameters**, supporting both farmers and milk inspectors in improving accuracy, traceability, and herd health monitoring.

### Unchanged Activities (green)

Core tasks within the milking routine and milk quality control remain unchanged. **Farmers** continue to **breed and manage their sheep flock**, **bring animals to the milking parlour**, and **prepare both the flock and equipment** for milking. They also **store the collected milk** and **request periodic visits from the milk inspector**. The **milk**

**inspector** still performs on-site visits, **takes milk samples**, **analyses them**, and **evaluates and registers quality results** as part of the official monitoring process.

#### **New Activities (blue)**

The connected milk meters introduce a new layer of automation and digital tracking. **Farmers** now **milk the flock using automated milk meters**, which perform **real-time analysis of milk quantity and composition**. The digital system provides farmers with **analysed data through a handheld device**, supporting performance monitoring for individual animals and the entire flock. The **milk inspector** can now **access the digital platform directly to register and verify individual sheep milk data**, streamlining data management and ensuring centralised records.

#### **Removed Activities (red)**

Several manual and analogue tasks have been eliminated, making the process more efficient and accurate. **Farmers** no longer use **traditional analogue milk meters**, nor do they **estimate milk quantities by eye** or **record results manually on paper sheets**. Similarly, the **milk inspector** no longer needs to **prepare paper spreadsheets** to register milk data, as all information is now logged and stored digitally within the system.

### **5.1.5 AgDiBi Living Lab (Germany)**

The **AgDiBi Living Lab** in Germany has introduced the **Stenon Farm Lab**, an **IoT- and AI-powered system** that enables real-time soil analysis to support **precision fertilisation**. Working alongside traditional laboratory testing, this digital solution allows farm managers to access instant nutrient data, monitor fertilisation effectiveness, and adapt their strategies more efficiently. Through collaboration between **farm managers and technology operators**, and supported by automated data collection and mapping, the system enhances **sustainability, speed, and accuracy** in soil and nutrient management.



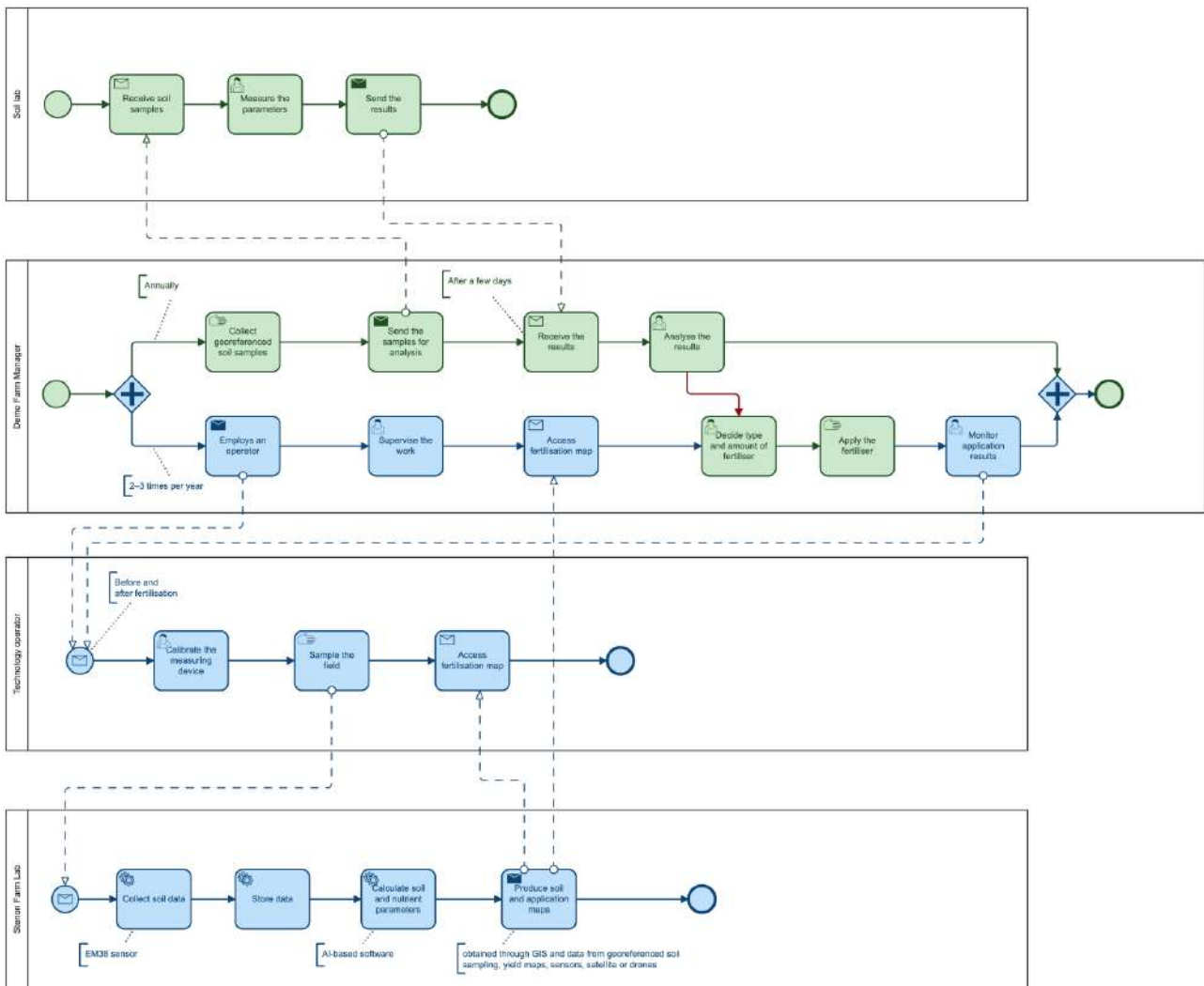


Figure 73. Process transformation diagram for Living Lab AgDiBi.

The diagram illustrates how soil analysis and fertilisation planning have evolved through the integration of the Stenon Farm Lab. This digital solution provides real-time, in-field soil analysis to support more precise and efficient fertilisation strategies, complementing existing laboratory-based methods.

### Unchanged Activities (green)

Certain key tasks remain unchanged and continue to play an important role in fertilisation planning. The **farm manager** still **collects georeferenced soil samples**, **sends them to the soil lab**, **receives lab results**, and **uses those results to plan and apply fertilisation** in accordance with agronomic needs and regulatory requirements. Similarly, the **soil lab** continues to **receive soil samples**, **analyse them**, and **delivers the results back** to the farm for decision-making.

### New Activities (blue)

The integration of the Stenon Farm Lab introduces new roles and workflows. A **technology operator**, newly involved in the process, is **contacted by the demo farm manager**, then **calibrates the device**, **samples the field**, and **accesses the resulting fertilisation maps**. The **demo farm manager** now **supervises the operator's work**, **accesses the digital fertilisation maps**, and **monitors the results of fertiliser application** using the real-time data generated by the system. The **Stenon Farm Lab** technology itself performs several tasks autonomously: it

**collects soil data, analyses and stores it, calculates nutrient needs, and generates fertilisation maps, enabling more tailored, site-specific recommendations.**

### **Removed Activities (red)**

Although **no activities have been eliminated**—since lab-based soil analysis remains mandatory for regulatory purposes—the diagram highlights an overlap between conventional and digital practices. Notably, the red arrow between the analysis of soil results from the lab and decision of type and amount of fertiliser, shows that **fertilisation decisions are now driven by the precision system, rather than by the lab results.**

### **5.1.6 Spraying drones Living Lab (Greece)**

The **Greek Living Lab** is evaluating an experimental **Spray Drone System** for the **targeted and efficient application of Plant Protection Products (PPPs)**. This digital solution combines **aerial spraying technology with smart software** to enhance accuracy, optimise chemical use, and reduce manual effort. Farmers interact with the drone system to survey fields, apply treatments, and assess results, while the supporting software generates **treatment maps and spray reports**. By shifting key steps from manual to automated processes, the system enables **data-driven crop protection practices** which hold the promise of improving input efficiency and reducing environmental impact.

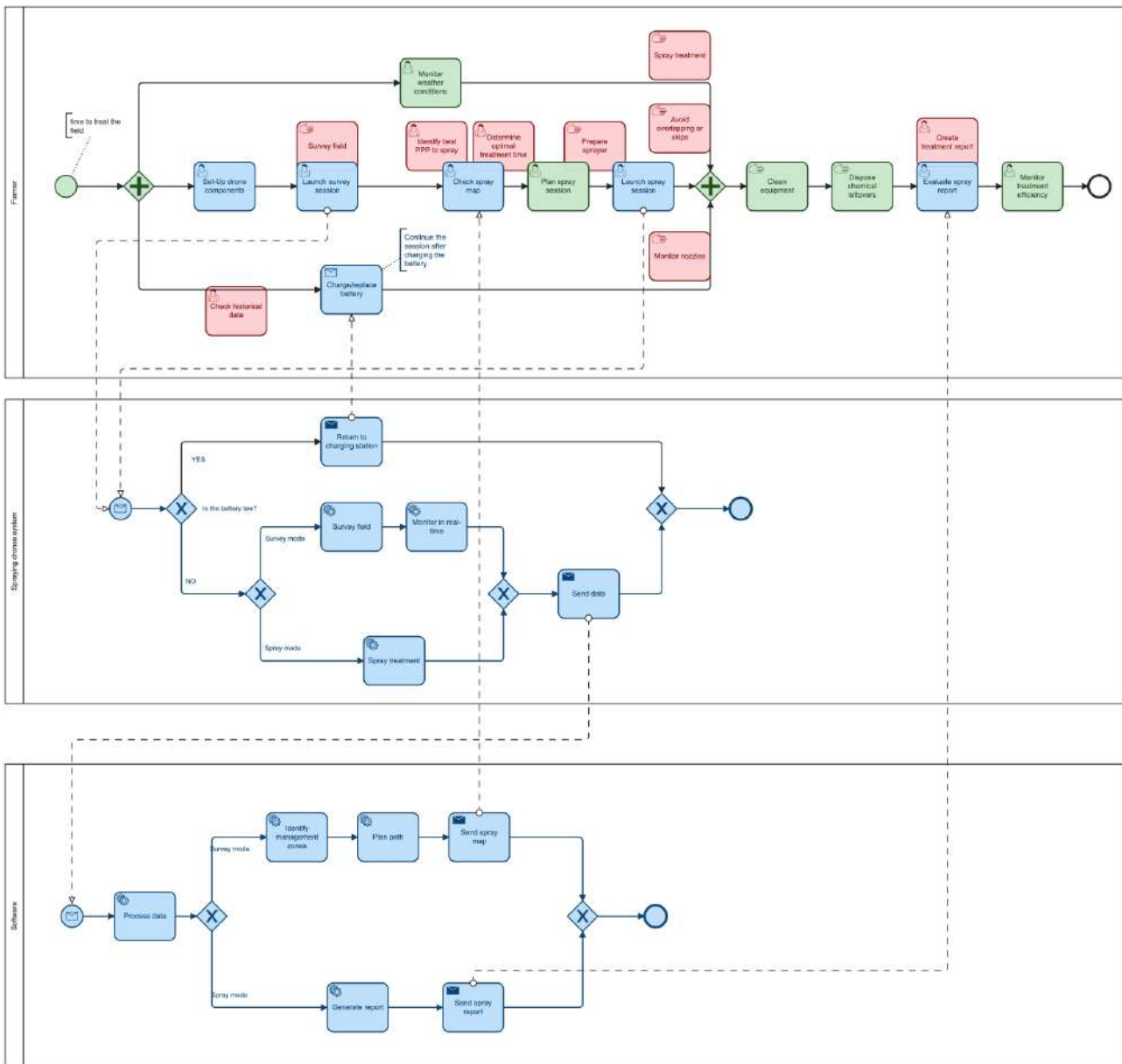


Figure 74. Process transformation diagram for Living Lab Spraying drones.

The diagram illustrates how manual pesticide application practices are transformed through the integration of a drone-based spraying system. This digital solution introduces a series of complex activities operated by hardware and software components, while reducing human manual work.

### Unchanged Activities (green)

Despite the integration of advanced technology, several core responsibilities remain unchanged. **Farmers** still **monitor weather conditions**, **plan spraying sessions**, **care for and maintain equipment**, **dispose of leftover chemicals properly**, and **monitor treatment effectiveness** in the field. These essential tasks continue to ensure the responsible and safe use of PPPs.

### New Activities (blue)

The adoption of spraying drones and digital software brings new tools and actors into the workflow. The **Spraying Drone System surveys and monitors the field in real time, applies treatments with high precision, and collects and transmits application data.** A dedicated **software platform** processes this data to **identify management zones, plan optimal spray paths, generate spray maps, and produce detailed reports,** which are sent back to the farmer. Within this new process, the **farmer** takes on new roles: **setting up drone components, launching survey sessions, reviewing the generated spray map, and initiating spray sessions.** After treatment, the **farmer evaluates the spray report** to verify coverage and performance.

### **Removed Activities (red)**

The digital solution significantly reduces the farmer's manual workload. **Farmers** no longer need to **survey the field, analyse historical data, or identify optimal PPPs** manually. The **system now determines the best treatment timing, and prepares the application process,** eliminating the need for traditional sprayer setup. Moreover, **monitoring for spray overlap or nozzle function** is no longer necessary, as the drone system handles this autonomously. **Spray reports** are now **automatically generated,** replacing manual documentation.

### **5.1.7 Innovative Soil Scanner technology for sustainable farming Living Lab (Hungary)**

The **Hungarian Living Lab** leverages the **Soil Scanner System,** a real-time technology that measures soil parameters directly in the field to support **site-specific fertilisation planning.** By eliminating the need for laboratory analysis, this system delivers **immediate, location-based data** through a cloud platform, allowing farmers and advisors to make quick and accurate decisions. Through collaboration between **farmers and soil specialists,** the technology enables **efficient, precise, and environmentally sustainable fertilization,** aligning nutrient application with the actual needs of each field zone.



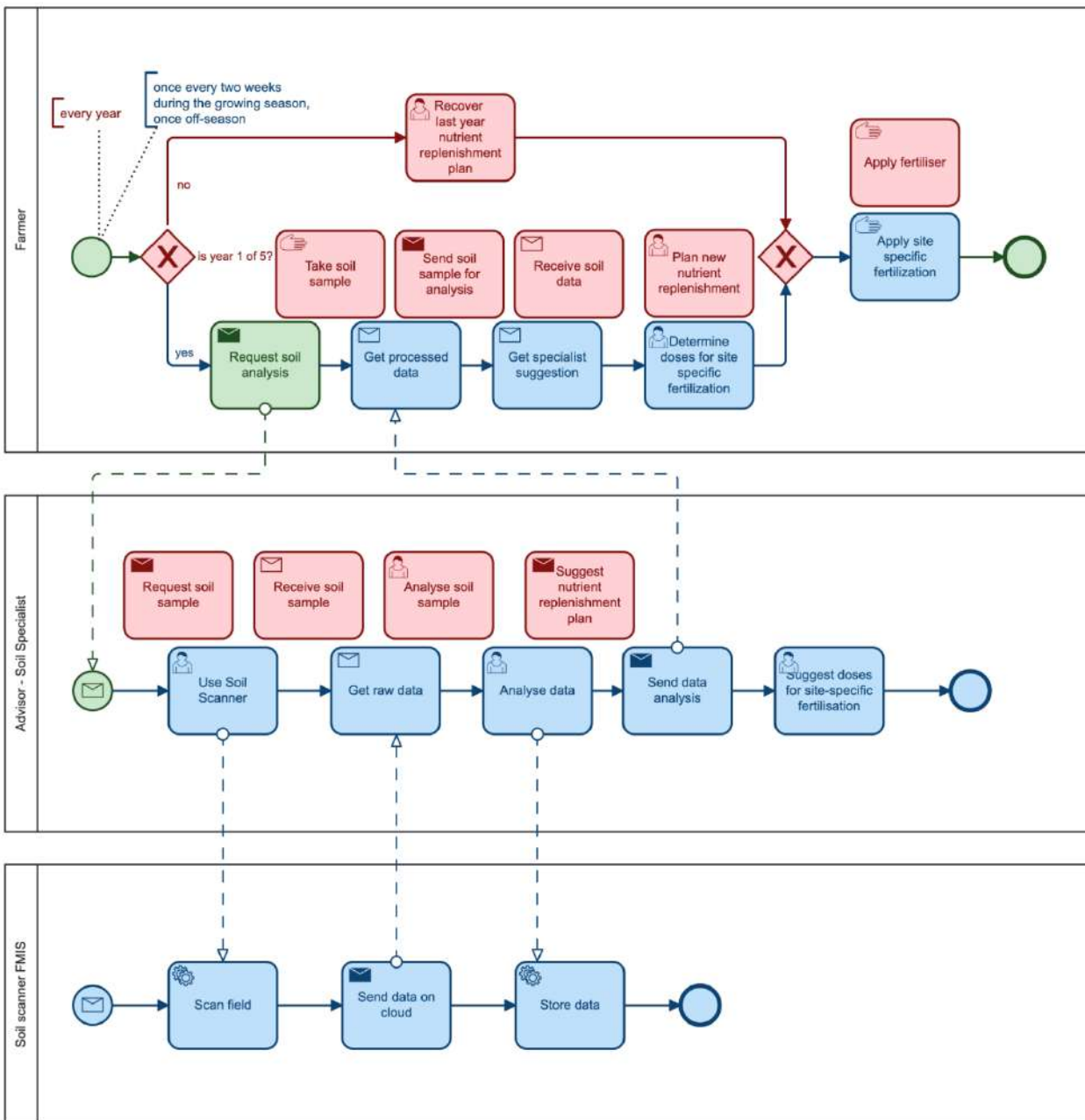


Figure 75. Process transformation diagram for Living Lab Innovative Soil Scanner technology for sustainable farming.

The diagram illustrates how traditional soil analysis and fertilisation planning have been transformed through the adoption of the Soil Scanner Farm Management Information System. The use of the portable soil scanner enables faster and more accurate soil diagnostics and supports fertilisation decisions based on real-time data, reducing the need for laboratory analysis and generalised fertilisation practices based on outdated data.

### Unchanged Activities (green)

Despite the technological shift, one key step remains the same: **farmers still request soil analysis** to guide fertilisation practices. This reflects the ongoing importance of understanding soil conditions for sustainable nutrient management.

### New Activities (blue)

The introduction of the **Soil Scanner System** has generated a new workflow based on rapid, in-field diagnostics and digital data sharing. The **soil scanner** now **scans the field**, **sends data to the cloud**, and **stores results in real time**, within minutes of analysis. **Advisors and soil specialists** use the **scanner to collect raw data**, **analyse it directly**, and provide **site-specific fertilisation suggestions**. **Farmers** receive the **analysed data through the platform**, determine **customised fertiliser doses** for different zones of their field, and then **apply fertilisers accordingly using precision tools**.

#### **Removed Activities (red)**

Several traditional steps have been eliminated thanks to the system ability to deliver immediate, location-specific data. **Farmers** no longer need to wait to **receive lab reports** or rely on data collected in previous seasons. They also no longer **plan generalised nutrient replenishment strategies** or **apply fertiliser uniformly**, as fertilisation can be tailored and applied with precision. Likewise, **advisors and specialists** no longer **request soil samples**, **analyse them in laboratories**, or **suggest broad nutrient plans**—these steps are replaced by **on-site scanning** and **digital site-specific recommendations**.

#### **5.1.8 Organic table grapes Living Lab (Italy)**

The **Italian Living Lab** has introduced a **Precision Irrigation System** designed to optimise water use and organic treatment planning in table grape vineyards. By integrating **weather data and sensor inputs**, the system enables farm managers to **monitor vineyard conditions remotely** and receive **automated suggestions** for irrigation and harvesting. Researchers also contribute by analysing data and recommending treatments tailored to current conditions. This collaborative, data-driven approach replaces manual monitoring and irrigation with a more **efficient, sustainable, and precise system** for managing organic vineyards.



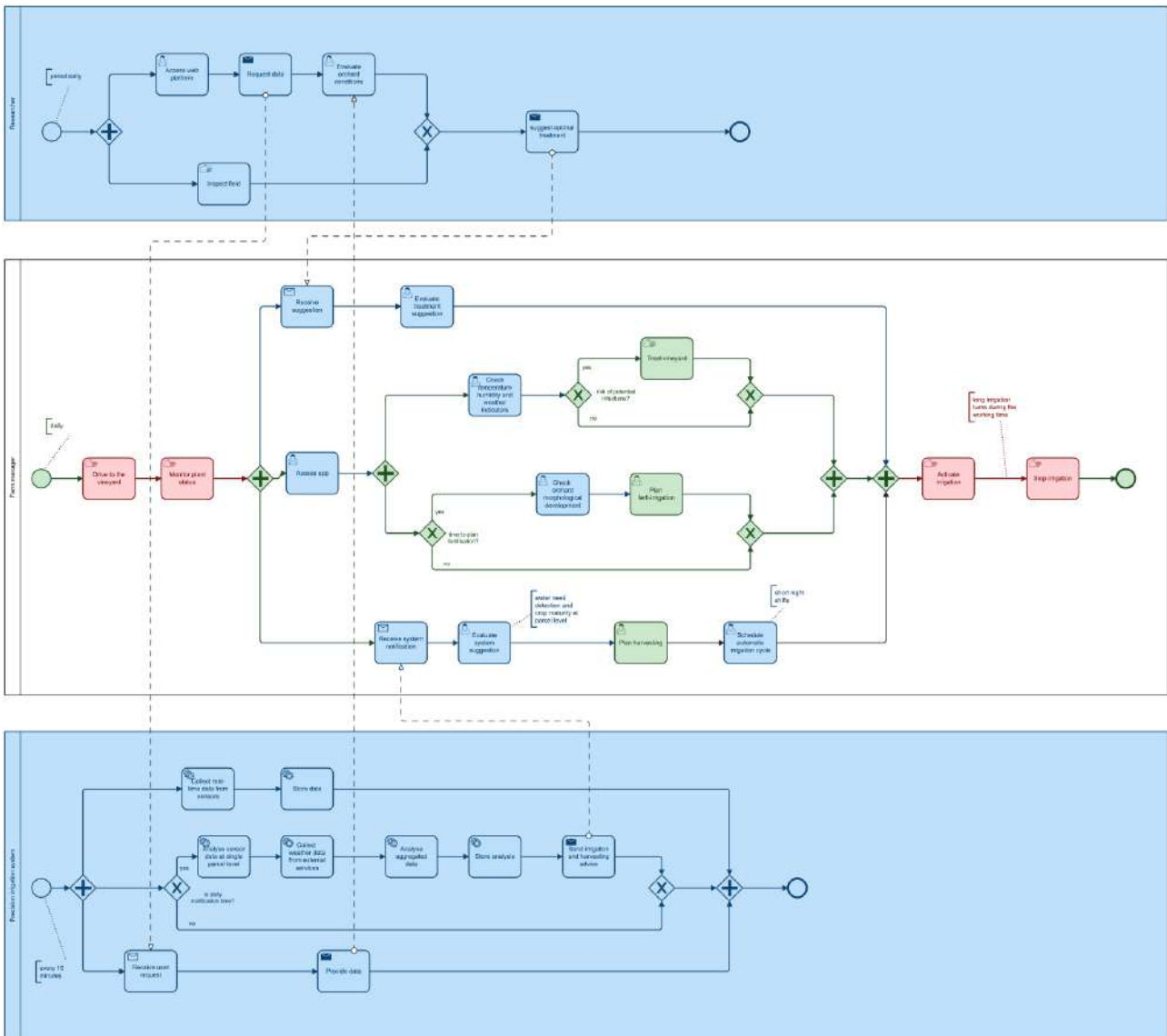


Figure 76. Process transformation diagram for Living Lab Organic table grapes.

The diagram illustrates how vineyard management practices—particularly related to irrigation and organic treatments—have been transformed through the integration of a precision irrigation system. This digital solution combines data from **weather stations and field sensors** to support timely, site-specific irrigation and treatment decisions, enhancing the efficiency and sustainability of organic table grape production.

### Unchanged Activities (green)

Core responsibilities of the **farm manager** remain an essential part of vineyard operations. The farm manager continues to **monitor conditions, plan irrigation and harvesting and apply treatments when there is a risk of infection**, ensuring that organic practices and seasonal demands are met effectively.

### New Activities (blue)

With the integration of digital tools, the **farm manager's role has evolved** to include new, data-informed practices. They now **access a dedicated mobile app, where they monitor key vineyard parameters, review morphological development, and evaluate system-generated irrigation plans**. Additionally, the manager **receives data-driven**

**treatment suggestions** from researchers and uses these insights to **schedule precise irrigation shifts** remotely. Two new actors also contribute to the digitalised process: the **researcher** that accesses the platform to **analyse vineyard data** and **recommend organic treatments** based on current field conditions, and the **precision irrigation system** that automatically **collects and stores sensor data, processes it**, and provides **irrigation and harvesting recommendations**, which are made available to users upon request.

### Removed Activities (red)

Several traditional, time-intensive tasks have been eliminated. The **farm manager no longer needs to physically drive through the vineyard to monitor conditions on a regular basis**, nor manually **activate and stop the irrigation system**. These activities are now automated and managed remotely via the digital platform.

### 5.1.9 Local beef cattle farming Living Lab (Latvia)

The Latvian Living Lab has introduced a **network of Online Marketing Platforms** designed to **promote local beef cattle products through digital branding, e-commerce, and traceability tools**. By integrating platforms such as the ZSA map and Grassland Product Label, the system enables farmers, customers, and specialised retailers to interact both online and offline. Farmers manage digital storefronts and update product data, while customers can evaluate and purchase products online. Supported by ICT providers, this multi-channel approach strengthens brands visibility, enhances direct sales, and supports the sustainable marketing of local, high-quality beef.



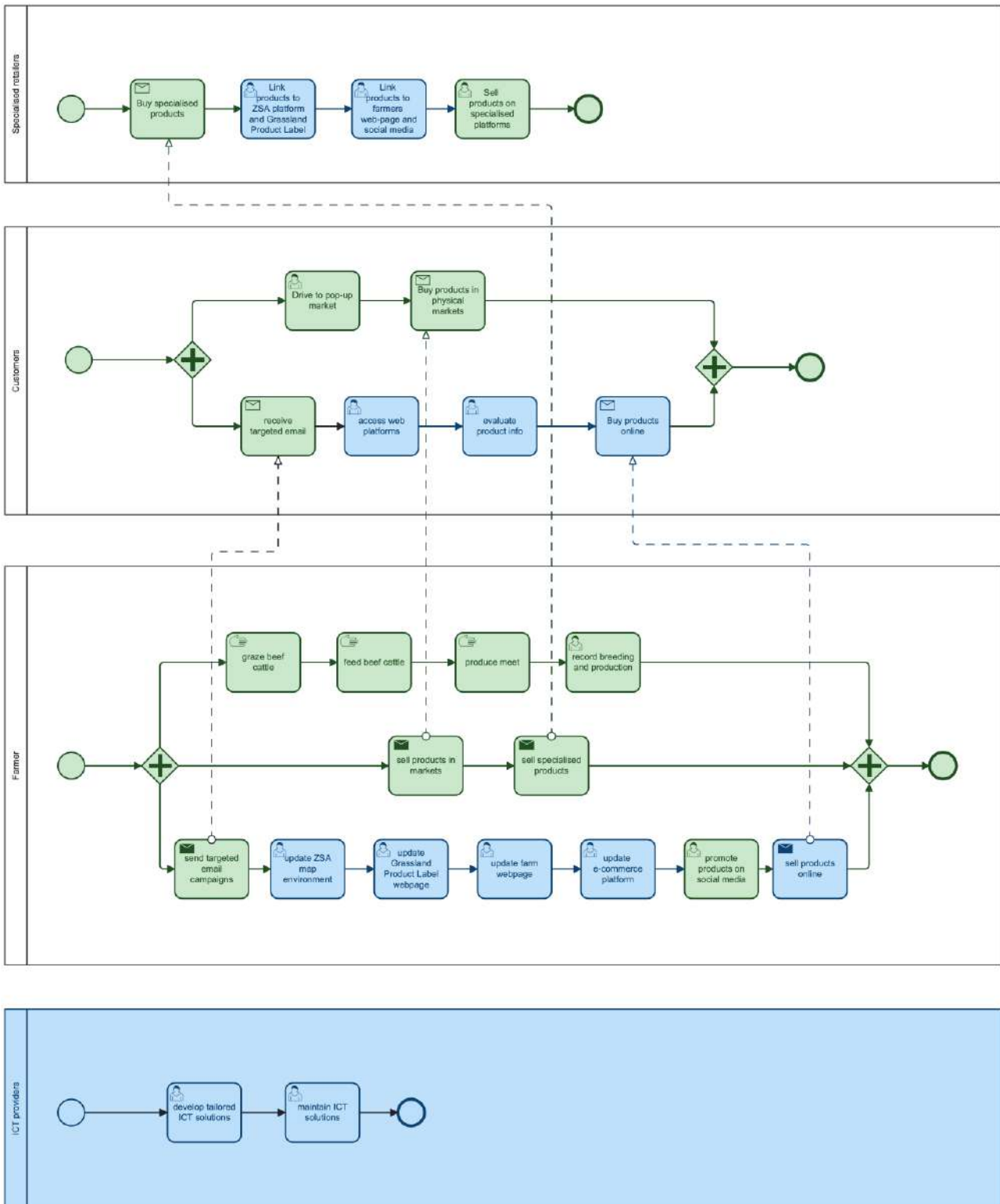


Figure 77. Process transformation diagram for Local beef cattle farming.

The diagram illustrates how local beef cattle marketing and sales practices have evolved through the integration of multiple online marketing platforms. These digital tools support direct-to-consumer sales, and connect farmers, consumers, and retailers in both physical and virtual marketplaces.

### Unchanged Activities (green)

Several key marketing and production practices remain consistent within the new system. **Farmers** continue to **graze and feed beef cattle, produce meat, and record breeding and production data**. They still **sell products in physical markets**, offer **specialised meat products**, and **promote their goods through targeted email campaigns and social media**. **Customers** still **visit physical marketplaces** to evaluate and purchase products directly. **Specialised retailers** continue to **purchase premium local products** and **sell them through established distribution channels**.

### New Activities (blue)

The digital technology introduces new actors and expands the marketing capabilities of existing ones. A new actor, the **ICT provider**, now **develops and maintains tailored digital solutions** to support online product visibility and transactions. **Farmers** now can manage several online tools: **update the ZSA map environment**, maintain their **grassland product label webpage**, **keep their own website and e-commerce** to sell products directly online to consumers. **Customers** have gained the ability to **browse online platforms, evaluate detailed product information**, and **complete purchases via e-commerce**. **Specialised retailers** can enhance visibility by **linking products to the ZSA platform, promoting the Grassland Product Label, and connecting products to farmers' webpages and social media channels**.

### Removed Activities (red)

**No activities are removed from the process**. Instead, the technology introduces new parallel tasks that can be performed remotely. What may be reduced is the frequency of in-person activities.

## 5.1.10 Scottish Small Farms and Digital Platforms Living Lab (Scotland)

The **Scottish Living Lab** is evaluating the introduction of a suite of **digital tools and online selling platforms** aimed at enhancing the **marketing and sales capabilities** of small farms. By integrating technologies such as e-commerce platforms, websites, and vending machines, the solution enables farmers to **reach consumers beyond traditional market settings**. Farmers now promote their products online, manage direct-to-consumer sales channels, and even host visitors on-farm to deepen engagement. Supported by IT providers and vending machine technicians, this Living Lab fosters a **resilient and diversified local food economy** rooted in both tradition and innovation.

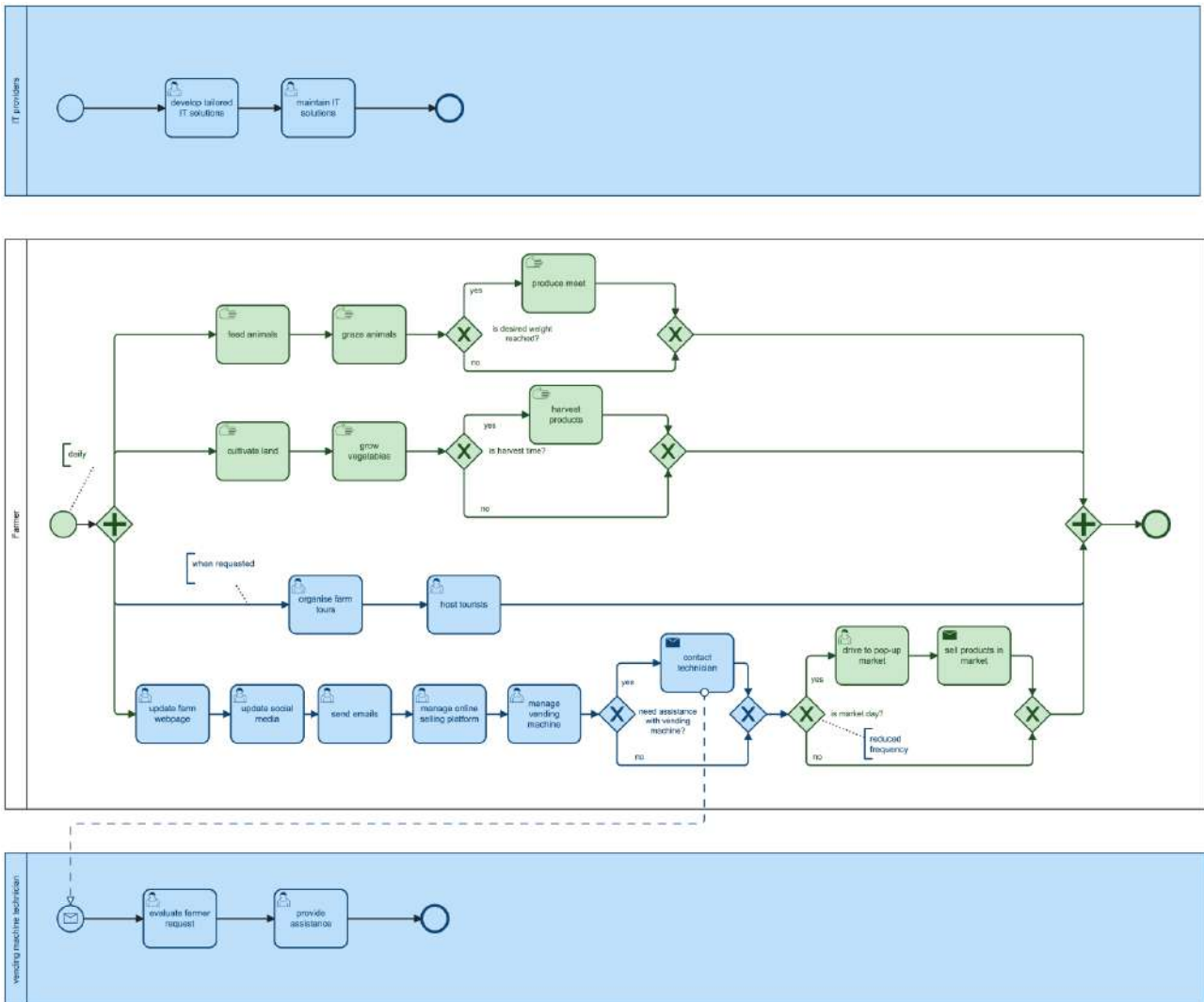


Figure 78. Process transformation diagram for Living Lab Scottish Small Farms and Digital Platforms.

The diagram outlines how small-scale farming operations evolve through the integration of digital marketing tools and online selling platforms. The transformation focuses on enhancing farmers' ability to promote and distribute products and services directly to consumers, both online and through innovative offerings such as farm tours and on-site experiences, which are advertised online. Digital networks help farmers reach a broader customer base and activate new services by increasing visibility and facilitating direct engagement with demand.

### Unchanged Activities (green)

Many of the farmers' core production activities remain the same. **Farmers** continue to **graze and feed animals**, **produce meats**, and **cultivate land to harvest agricultural products**. They also still **travel to local markets to sell their goods directly to consumers**, maintaining the traditional face-to-face sales approach alongside new digital strategies.

### New Activities (blue)

The integration of digital tools expands the range of tasks farmers now perform and introduces new actors into the system. **Farmers** now engage in **digital promotion and sales**, including **updating their websites**, **managing social media content**, **sending targeted email campaigns**, and **operating online sales platforms**. They also **host farm tours**, providing consumers with more engagement opportunities, and **manage vending machines** as

additional sales points. **IT providers** play a new role by **developing and maintaining the digital tools and platforms** that support these new forms of outreach and sales. Additionally, **vending machine technicians** are now part of the process, **ensuring the operation and maintenance** of these automated sales systems.

### 5.1.11 Greenhouse smart sensor lab Living Lab (Serbia)

The **Serbian Living Lab** has introduced a **Greenhouse Monitoring System** that leverages smart sensors and a digital platform to support **real-time environmental monitoring and data-driven decision-making**. By continuously measuring key parameters inside the greenhouse, the system provides farmers with **live data trends and cultivation advice** through the AgroSense platform. This enables farmers to **plan and adjust greenhouse activities more efficiently**, reducing the need for manual checks while still relying on expert support when needed. The result is a more **responsive, precise, and streamlined approach** to managing greenhouse production.

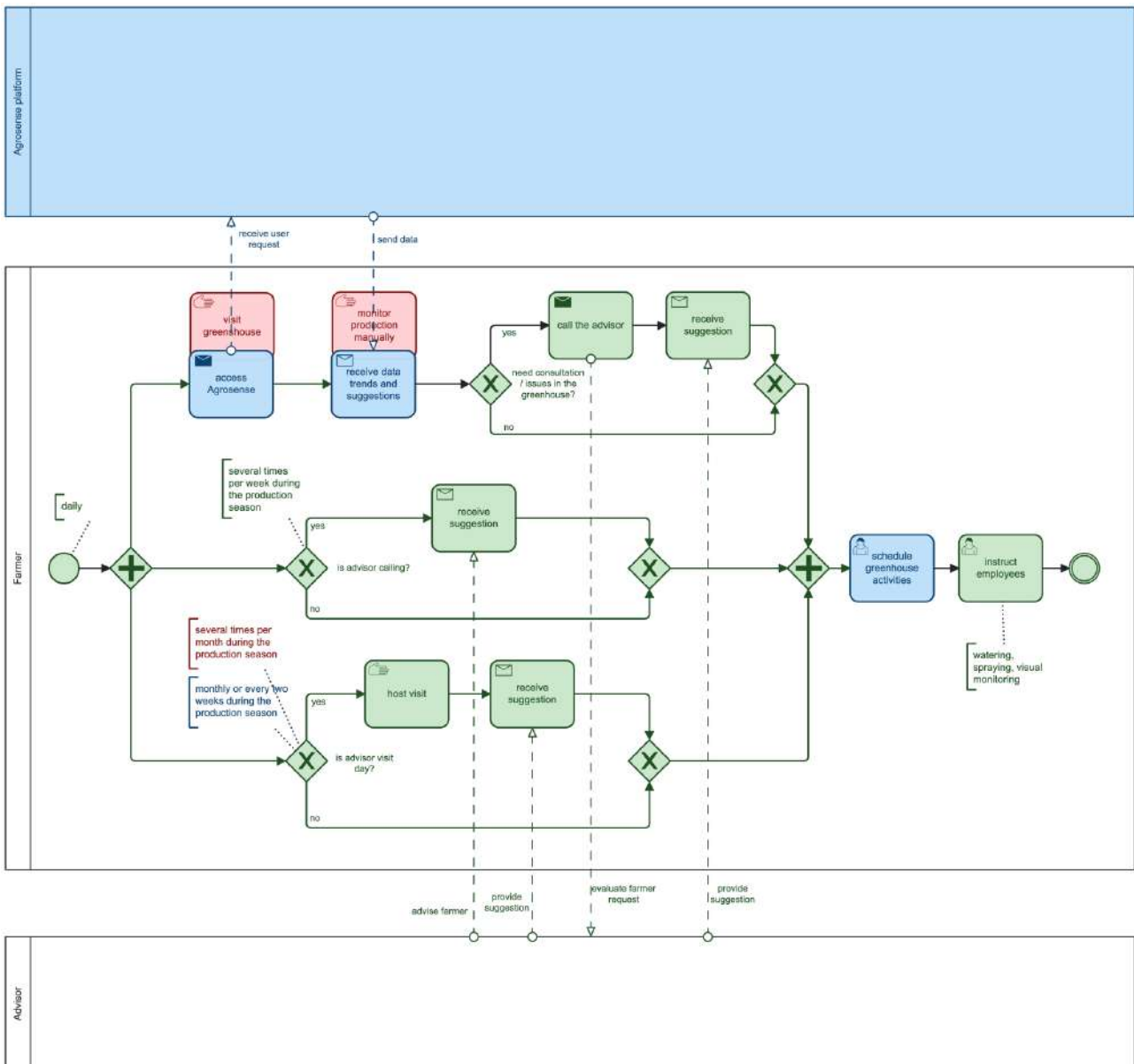


Figure 79. Process transformation diagram for Living Lab Greenhouse smart sensor lab.

The diagram illustrates how greenhouse monitoring and management activities carried out by farmers are transformed through the integration of a smart sensor-based monitoring system. This digital solution provides

real-time data and automated insights via the AgroSense platform, supporting decision-making in greenhouse operations.

### **Unchanged Activities (green)**

Certain essential practices remain the same despite the technological upgrade. In situations where **issues arise in the greenhouse**, the **farmer still contacts an advisor**, receives professional **suggestions**, and **instructs greenhouse staff accordingly**. Monitoring activity and direct communication remains a key part of the process.

### **New Activities (blue)**

The digital solution introduces new, data-driven routines for the farmer. The **farmer now accesses the AgroSense platform**, where they receive **real-time data, alerts, and cultivation suggestions** based on environmental sensor readings. With this information, the **farmer plans and schedules greenhouse activities**, adjusting operations based on up-to-date trends and recommendations.

### **Removed Activity (red)**

Manual monitoring tasks can be reduced due to automation. **Manual monitoring of production levels** is no longer necessary, as sensor data and automated reports provide comprehensive updates directly through the platform. In addition, **in-person visit to the greenhouse of advisor** to monitor environmental conditions or check crop status are reduced.

The archive on Zenodo (Mannari, Ferrari and Bacco, 2025. Dataset PROCESS MODELS) contains complementary models representing the Agrosense platform and advisor's processes.

## **5.1.12 Almería Agroecology Living Lab (Spain)**

The Almería Agroecology LL has adopted a digital solution designed to support the small family farming greenhouse fruit and vegetable sector. The digital solution is based on a system called **Plataforma iVeg** that **integrates various technologies already available in the market**. The system aims to address the lack of interoperability and standardisation between technologies and serve as a data management tool and a decision support system.

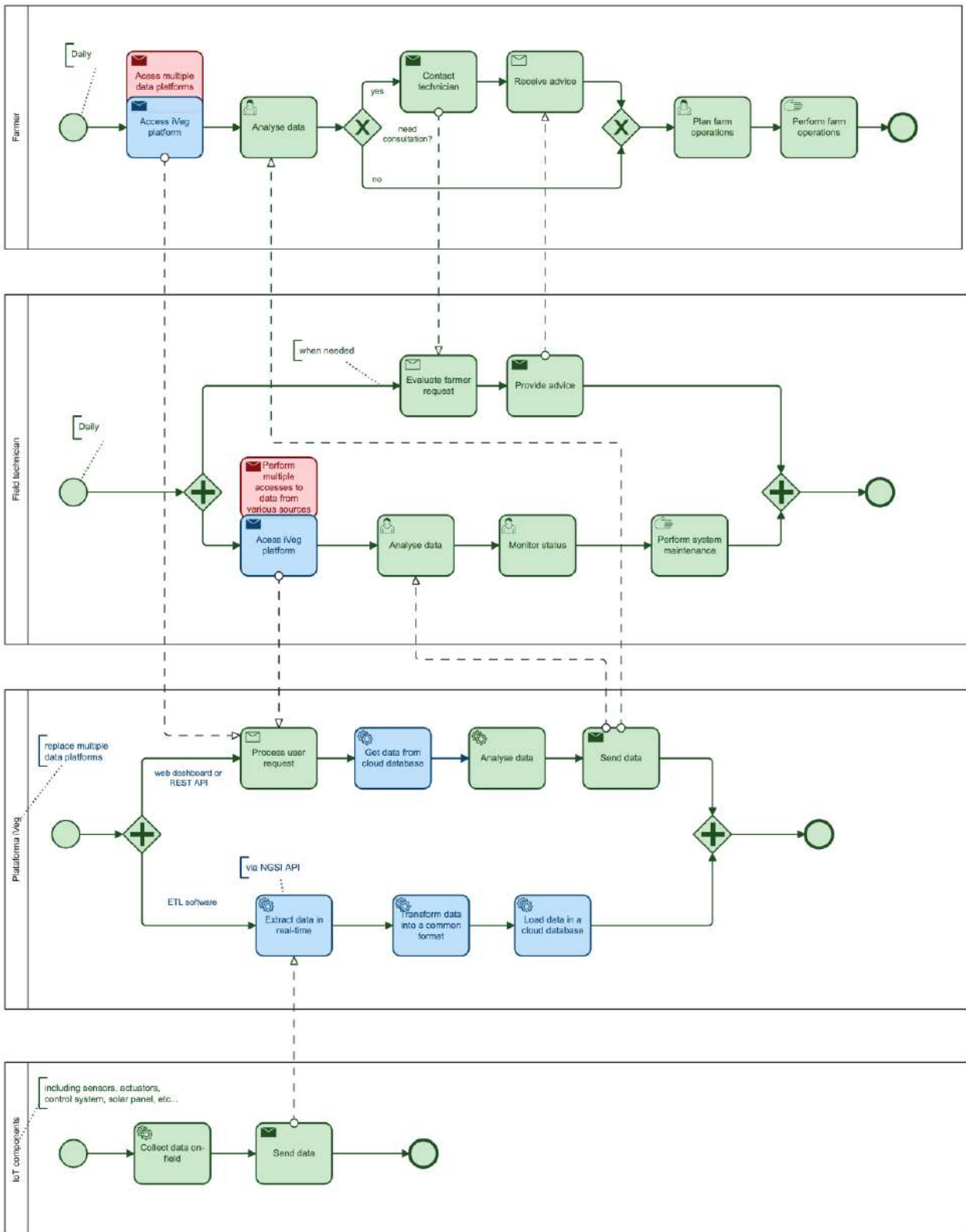


Figure 80. Process transformation diagram for Living Lab Almería Agroecology.

The diagram highlights the transformation of the iVeg digital platform on traditional greenhouse management workflows. By centralising and standardising data integration from diverse sources including IoT stations and REST API services, the platform provides advanced analytics and decision-making support.

### Unchanged Activities (green)

Core agricultural processes and interactions remain intact. **Farmers** continue to perform essential routine cultivation practices and regular farm operations, actively **manage agricultural production, apply cultivation techniques, utilise tools and equipment**. The **Field technicians** maintain their role in **daily monitoring**, data collection, and **equipment maintenance**.

### New Activities (blue)

**Farmers and technicians** now **access an integrated digital dashboard** for real-time monitoring and management of farm operations. This is achieved through an **Extract, Transform and Load (ETL)** process which **integrates data from multiple sources** and provides a standardised access point, based on a cloud-based tool for data processing and storage, servers in the Data Processing Centre (DPC) and IoT sensors.

### Removed Activities (red)

**Farmers and field technicians no longer need to manage multiple separate technological interfaces**. This complexity has been resolved by the integrated digital platform, significantly simplifying user operations.

## 5.1.13 Cloughjordan Food Hub Living Lab (Ireland)

The **Cloughjordan Food Hub Living Lab** in Ireland introduced the **Open Food Network platform**, a digital tool that connects farmers, suppliers, coordinators, and consumers in a more structured and accessible food system. By digitising product listings, order placements, and communications, the platform supports **efficient coordination of supply and demand** while maintaining the core values of local food production. New actors like **tech developers** ensure the smooth operation of the platform, while customers and producers engage regularly through an **intuitive and transparent interface**, transforming the way local food is traded and shared.



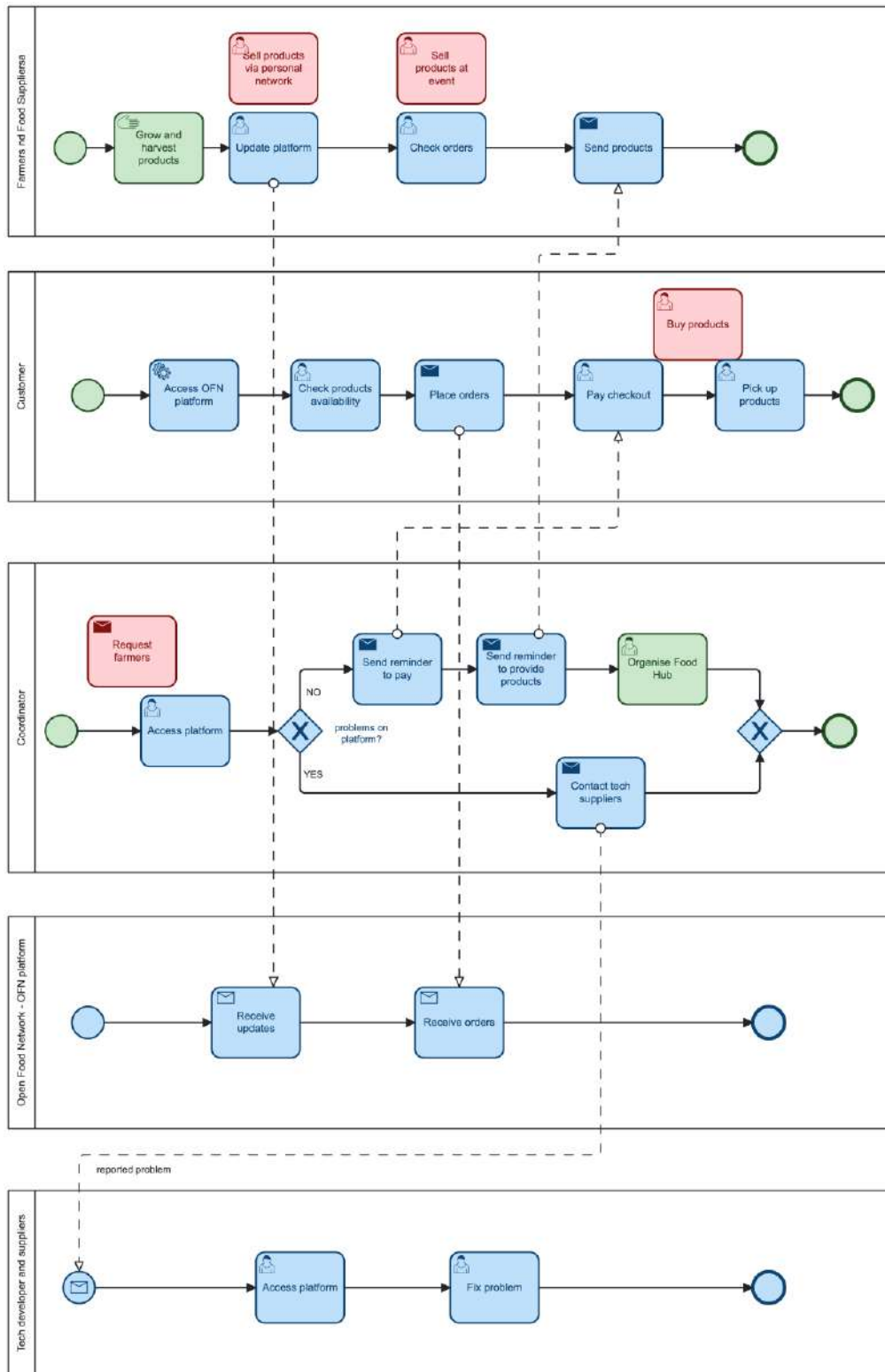


Figure 81. Process transformation diagram for Living Lab Cloughjordan Food Hub.

The diagram illustrates the transformation of local food distribution practices through the adoption of the Open Food Network platform. This digital solution redefines how farmers, food suppliers, customers, and coordinators interact, enhancing transparency and efficiency in the food hub ecosystem.

### Unchanged Activities (green)

Despite the digital integration, some foundational activities remain unchanged. **Farmers and food suppliers** continue to **grow and harvest agricultural products**, ensuring the steady supply of fresh, local food. **Coordinators** still play a central role in **organising and managing the food hub**, ensuring the flow of products between suppliers and consumers.

### New Activities (blue)

The **Open Food Network platform** introduces a new digital infrastructure to streamline the food hub's operations. A new actor, the **tech developer**, is responsible for **developing, maintaining, and supporting the platform**. The **Open Food Network itself** receives **product updates from farmers** and **orders from customers**, acting as the central tool for coordination. **Farmers and food suppliers** now **update their product listings, check incoming orders, and send products** according to the platform's instructions. **Customers** gain the ability to **browse product availability, place and pay for orders**, and then **pick up products** at scheduled times. **Coordinators** now use the platform to **send payment reminders to customers, remind farmers and suppliers to deliver products, and contact the tech team** if any platform issues arise.

### Removed Activities (Red)

The digital shift removes several informal and manual tasks: **farmers and suppliers** no longer need to rely on **personal networks or one-off events** to sell their products. **Customers** can reduce purchasing food at occasional events, instead using the platform for regular access to local goods. **Coordinators** no longer **manually contact each supplier** for their products, as this process is now automated through the platform.

## 5.1.14 Agrifood Technology Living Lab (Belgium)

The Agrifood Technology LL employs a digital solution that integrates **high-resolution RGB imagery and drone technology to generate detailed task maps and tailored spraying advice**. This approach aims to **optimise the use of Plant Protection Products (PPP)** by aligning application with the specific needs of each crop, thereby reducing excess and environmental impact. The process involves close collaboration between farmers and specialised operators, who interact with the digital tools to ensure precise and efficient PPP deployment.

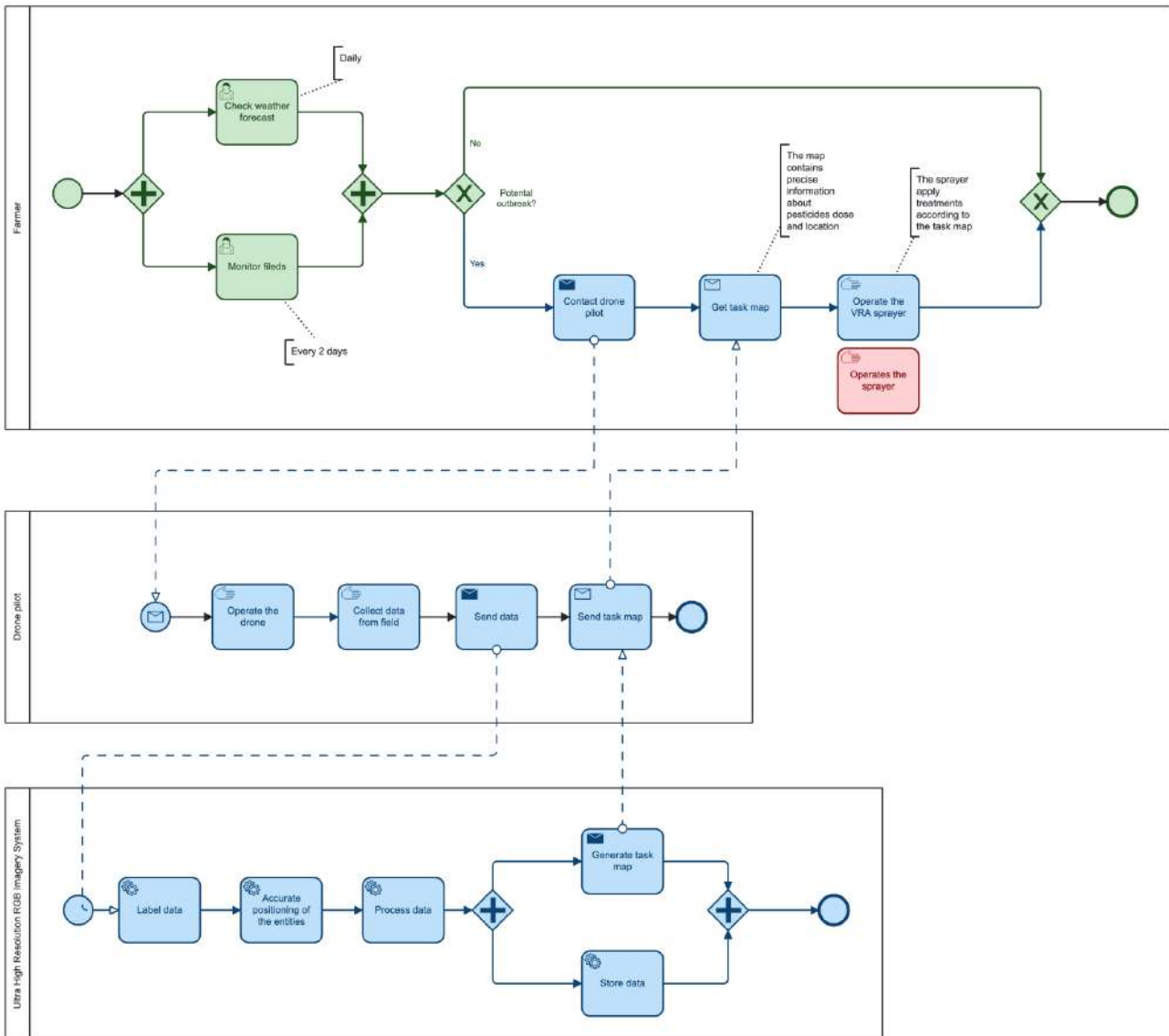


Figure 82. Process transformation diagram for Living Lab Agrifood Technology.

The diagram shows how a traditional PPPs application workflow is transformed through the integration of digital tools and drone-based data collection. The process shifts from manual and uniform treatment to a collaborative, data-informed and site-specific intervention.

### Unchanged Activities (green)

Core tasks performed by the **farmer** remain unchanged. **Checking the weather forecast** daily and **monitoring the fields** every two days are still essential steps to detect early signs of pest or disease outbreaks. Furthermore, the farmer continues to be the **decision-maker**, assessing the situation and initiating further action when a potential outbreak is identified.

### New Activities (blue)

The major transformation lies in the adoption of precision agriculture technologies. Instead of directly spraying the field, the **farmer** now **contacts a drone pilot**.

The drone pilot **operates the drone, collects data from the field** and sends this data to a processing system. An **Ultra High Resolution RGB Imagery System** processes the data: it labels the information, ensures accurate positioning and analyses it to **generate a task map**.

This task map includes precise information on pesticide dosage and application locations and is sent back through the drone pilot to the farmer.

The **farmer then uses a VRA sprayer**, which applies treatment precisely according to the task map.

#### **Removed Activities (red)**

The conventional task where the **farmer operates the sprayer manually and applies a uniform dose across the entire field has been removed**. This outdated method is replaced by the more precise, data-driven operation enabled by the VRA sprayer.

#### **5.1.15 Artificial Irrigation Management System Living Lab (Slovakia)**

The **Slovakian Living Lab** employs an **AI-based Artificial Irrigation Management System** designed to optimize water use by monitoring **field and weather conditions** in real time. This digital solution supports more efficient and sustainable irrigation by providing **data-driven insights** into when, where, and how much to irrigate. Farmers, agronomists, and researchers collaborate through a shared digital platform, where they access and update data, monitor crop conditions, and develop predictive irrigation models. By replacing manual data collection and weather tracking with automated sensing and intelligent scheduling, the system enables **precise, adaptive, and environmentally responsible irrigation management**.



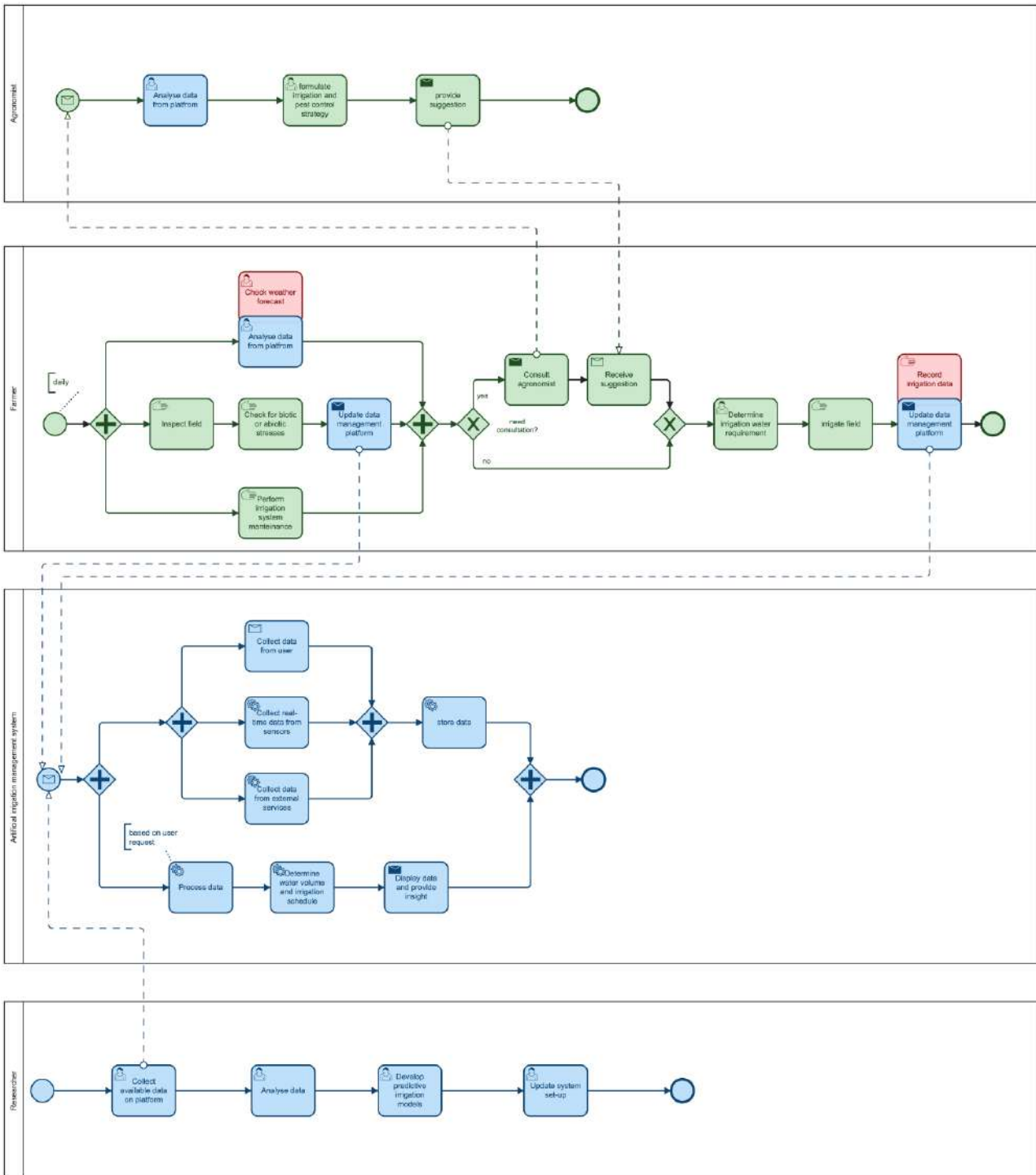


Figure 83. Process transformation diagram for Living Lab Artificial Irrigation Management System.

**The diagram illustrates how irrigation planning and management practices are transformed through the implementation of the Artificial Irrigation Management System.** This AI-based digital solution streamlines the process by integrating real-time data collection, predictive modelling, and digital monitoring to support informed and efficient irrigation decisions.

### Unchanged Activities (green)

Despite the digital transformation, essential hands-on activities remain unchanged. **Farmers** continue to **inspect fields, identify potential stress factors, and maintain irrigation infrastructure**. They also **consult agronomists** for advice and support, **determine irrigation water needs**, and **carry out field irrigation** as usual. **Agronomists** still play a key role in developing **irrigation and pest control strategies**, providing **technical advice and suggestions** to guide farmers in managing their crops effectively.

### New Activities (blue)

The digital solution introduces new digital components, workflows, and even actors into the irrigation management process. A new actor, the **researcher**, now works within the system to **collect and analyse data, develop predictive irrigation models, and update the system setup** to reflect evolving insights and conditions. The **Artificial Irrigation Management System** itself performs key functions: it **collects data** from users, sensors, and external services, **stores and processes** that data, determines **optimal water volumes and irrigation schedules**, and then **displays insights** through the platform for decision-makers. **Farmers** now have direct access to the platform, where they **analyse irrigation-related data and update their own farm information**. Similarly, **agronomists** use the platform to **analyse field conditions and support recommendations** based on up-to-date information.

### Removed Activities (red)

Several manual and time-consuming tasks can be reduced or eliminated thanks to the automation offered by the system and predictive features. **Farmers** are no longer required to **check weather forecasts manually or record irrigation data by hand**. These tasks are now handled by the system, freeing up time and improving data accuracy.

## 5.1.16 LIT OUESTEREL Living Lab (France)

The LIT OUESTEREL Living Lab in France has introduced PIGLink, **a digital data space solution designed to interconnect equipment and services used in pig breeding**. By standardising data formats and streamlining access for both farmers and technical advisors, PIGLink enables a more precise, real-time understanding of livestock conditions. This innovation reduces manual effort and communication issues, allowing for more efficient advisory support and better-informed farm management.

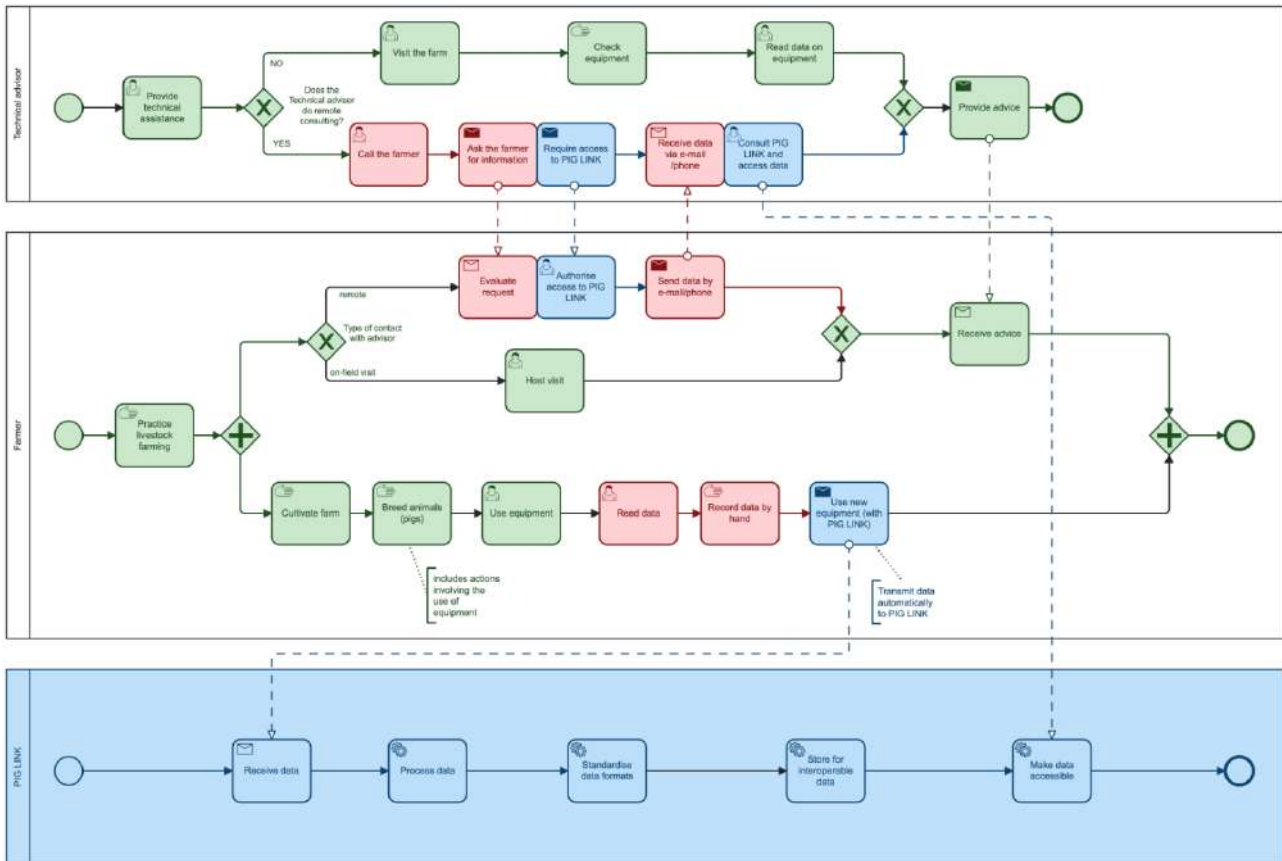


Figure 84. Process transformation diagram for Living Lab LIT OUESTEREL.

The diagram illustrates the transformation of pig breeding management practices enabled by the adoption of PIGLink, a data space system designed to interconnect equipment and services through interoperable data sharing. This digital integration improves the precision and efficiency of data flow between farmers and technical advisors, enhancing livestock monitoring and reducing manual workloads.

### Unchanged Activities (green)

Core responsibilities of both actors remain stable: **Technical advisors** continue to **visit farms, inspect equipment** directly, **read data from devices** on-site, and **provide tailored advice** to farmers. **Farmers** still perform essential tasks such as **livestock farming, breeding animals, cultivating land**, and hosting regular advisory visits. They also continue to use **livestock equipment** as part of their daily operations.

### New Activities (blue)

The introduction of PIGLink introduces a digital layer of data interoperability. **Technical advisors** now request **access to the PIGLink system** and can consult up-to-date data directly through the platform, enabling quick insights and remote support. **Farmers access and interact with the PIGLink platform, use equipment embedded with the system** that ensures data is automatically shared and updated. The **PIGLink system** itself takes on a key role in the process, **receiving data** from farm equipment, **processing** it into standardised formats, and **storing** it for accessibility by authorised users such as advisors and researchers.

### Removed Activities (red)

Manual and indirect communication tasks are eliminated: **Technical advisors** no longer need to call the farmer or **request data manually** via email or other informal methods. **Farmers** no longer need to **read data manually** from equipment, **record it on paper**, or **send it to advisors** themselves. The data flow is now automatic and platform based.

### 5.1.17 Grassland Management Living Lab (Estonia)

The **Estonian Living Lab** employs a digital solution that integrates **drone technology and remote sensing systems** to support precise and sustainable **grassland management**. By collecting and processing **multispectral imagery**, the system generates high-resolution maps that help assess grassland conditions and inform targeted management plans. This approach enhances decision-making for restoration, grazing, and conservation, reducing reliance on low-resolution public data. The process involves close collaboration between **farmers, remote sensing providers, and research advisors**, who interact with the digital tools to enable data-driven, efficient, and ecologically sound grassland monitoring.

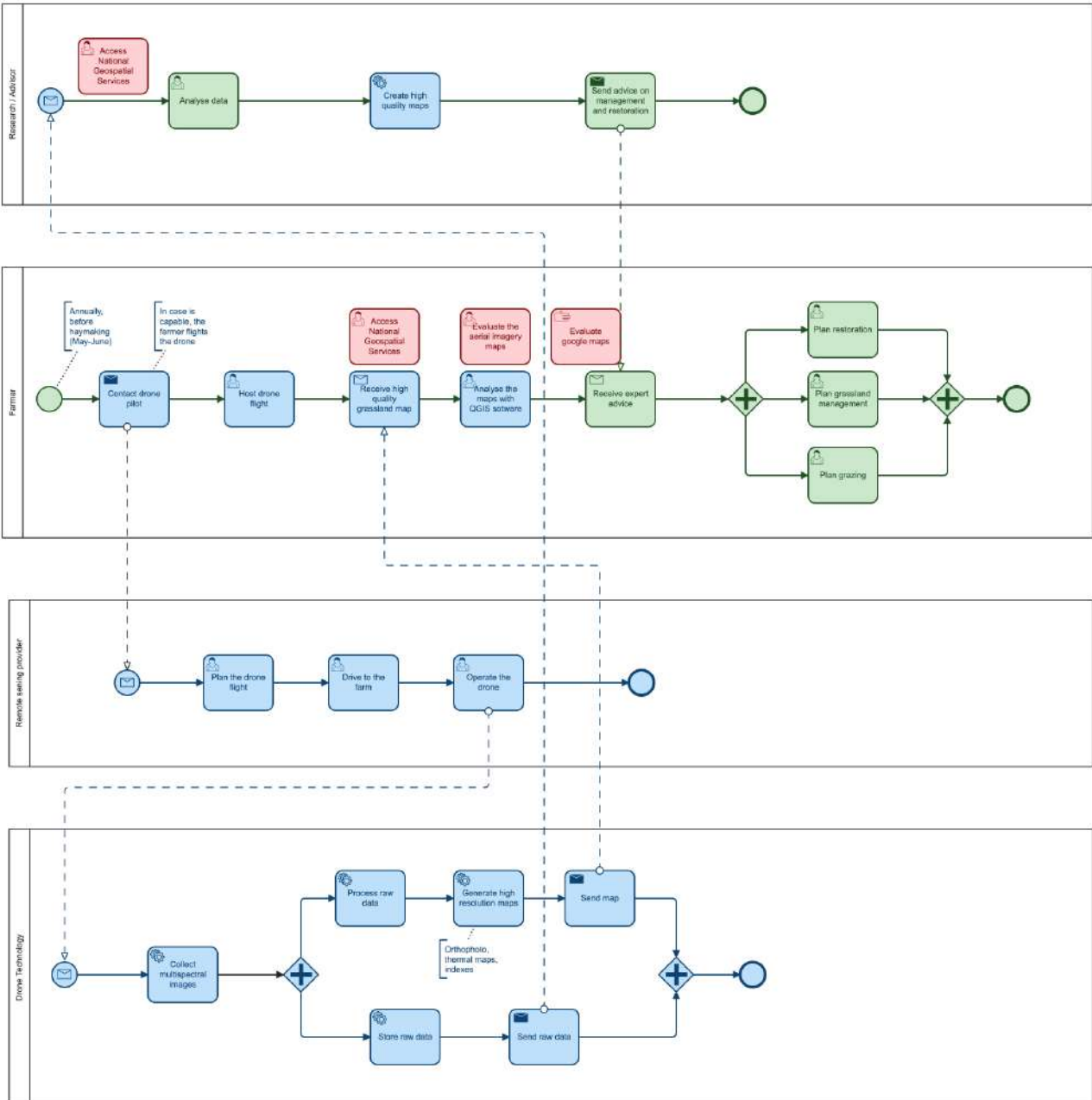


Figure 85. Process transformation diagram for Living Lab Grassland Management.

The diagram illustrates how traditional grassland monitoring and management practices are transformed through the integration of a drone-based digital system. The system enhances collaboration between farmers and advisors, while introducing new roles and tools to support precise and data-driven grassland management.

#### Unchanged Activities (green)

Key responsibilities remain central to the process. **Farmers** still **receive expert advice** and use it to **plan restoration, grazing strategies, and grassland management actions**. **Research** and **advisors** continue to **analyse field data** and provide **guidance and recommendations** to support sustainable management and conservation of grasslands.

#### New Activities (blue)

The introduction of drone technology and digital tools has created new activities for existing actors and has introduced entirely new digital-related roles. The **drone technology**, is now responsible for **collecting multispectral images, processing the data into high-resolution maps, and sending these maps to farmers**, while also **storing raw data** that may be shared with researchers for further analysis. The **remote sensing provider**, a new actor being introduced, **plans drone flights, travels to the farm, and operates the drone** during data collection campaigns. In this updated process, the **farmer** now **contacts the drone pilot, hosts the flight, and receives detailed maps of the grassland**, which they can then **analyse using GIS software (e.g., QGIS)**. **Researchers and advisors** may also **collaborate in creating high-quality maps**, enhancing the accuracy of the resulting data products and supporting more informed recommendations.

#### Removed Activities (red)

Several manual and indirect data collection steps have been eliminated. The **farmer** no longer needs to **access national geospatial services** or rely on **Google Maps or basic aerial imagery** to evaluate grassland condition. Similarly, **researchers and advisors** are no longer dependent on **national geospatial data services**, as they now receive more precise and up-to-date imagery directly from the drone system.

### 5.1.18 RAMAS Living Lab (Macedonia)

The LL in North Macedonia introduced a **Farm Management Information System (FMIS) called RAMAS to enhance decision-making in agricultural production**. RAMAS functions as a centralised advisory system and data repository, aiming to **increase the communication between farmers and advisors, improving advisory services and optimising resource management**. RAMAS leverages IoT sensors, UAV technology, satellite imagery, and extensive field data to monitor farm conditions and support agricultural practices.

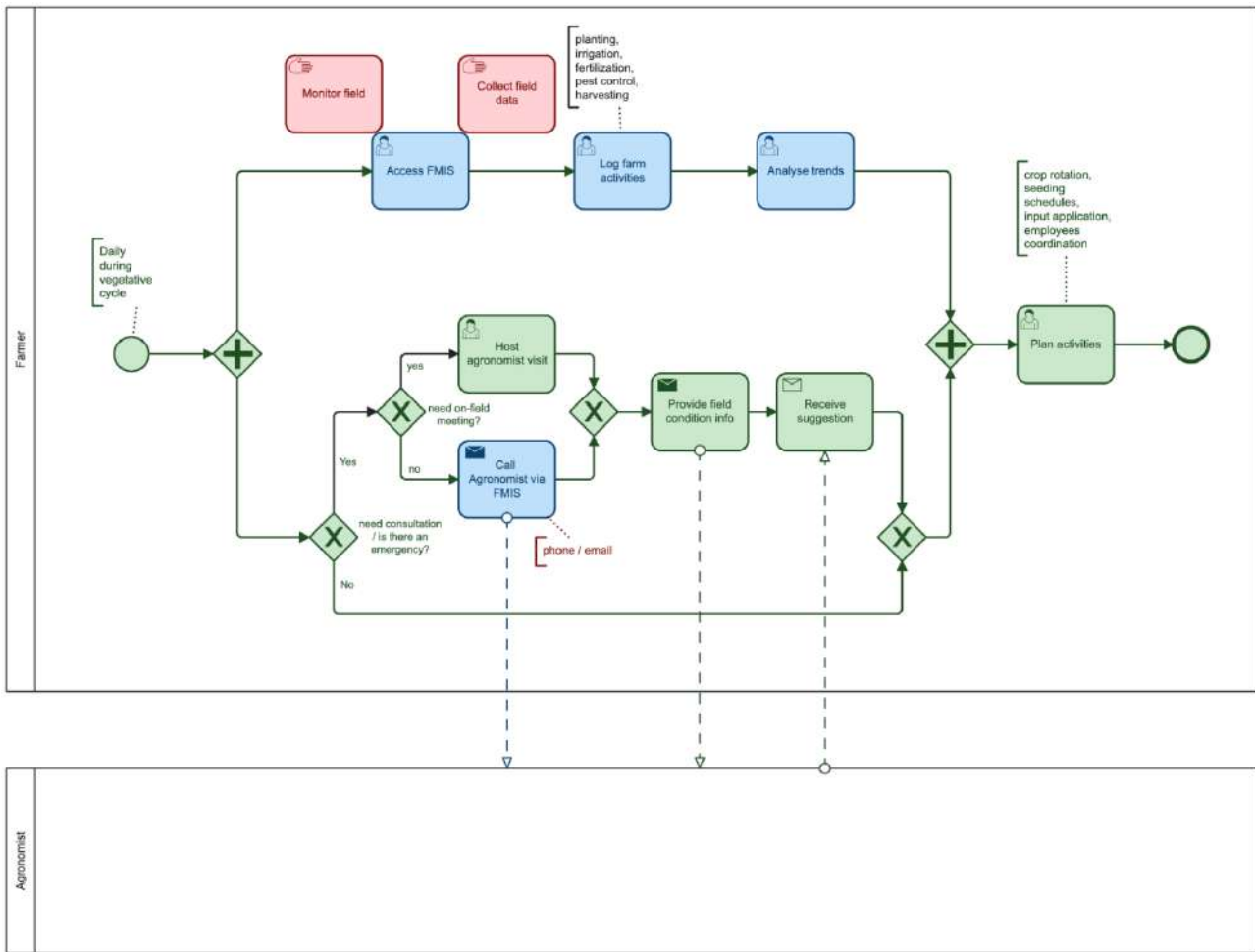


Figure 86. Process transformation diagram for Living Lab RAMAS.

The diagram illustrates the transformation of the farmer’s process with the introduction of RAMAS, showing that the farmer’s activities shift from intensive monitoring and manual data collection to user-based activities managed through the digital system.

### Unchanged Activities (green)

Core agricultural tasks remain central. **Farmers** continue conducting regular strategic **planning for crop management, collaboration with employees and advisors** for seeding, planting, irrigation, harvesting, and crop protection. **Advisors** maintain their role in performing monthly **on-farm visits** for monitoring and **responding promptly in emergency scenarios**, offering recommendations and **advisory services** based on field information received from farmers.

### New Activities (blue)

The implementation of RAMAS significantly transforms existing practices by integrating advanced digital tools. **Advisors and farmers** now **access a centralised digital platform** for data storage, entry, and analysis. The **FMIS** dashboard **provides tailored insights and recommendations**, enabling field monitoring and management tasks and sends notification to agronomists with up-to-date information.

### Removed Activities (red)

Farmer’s manual tasks such as field monitoring through **physical inspections** and **traditional record-keeping** have been reduced. Farmers no longer need to manually document data or **rely exclusively on experience-based**

**decisions.** Additionally, farmers no longer need to **send emails to request advisor visits**—instead, communication is managed directly through the FMIS.

The archive on Zenodo (Mannari, Ferrari and Bacco, 2025. Dataset PROCESS MODELS) contains complementary models representing the agronomist's processes.

### 5.1.19 Smart villages Network Living Lab (Slovenia)

The **Smart Villages Network LL** in Slovenia adopts a **Vineyard IoT Monitoring System**, a digital solution designed **to enhance organic vineyard management**. The system employs a network of sensors to monitor environmental conditions in real time and supports treatment planning through data-driven insights. By automating data collection and analysis, the technology reduces reliance on external weather services and manual inspections, enabling farmers to make more efficient and informed decisions for sustainable vineyard care.



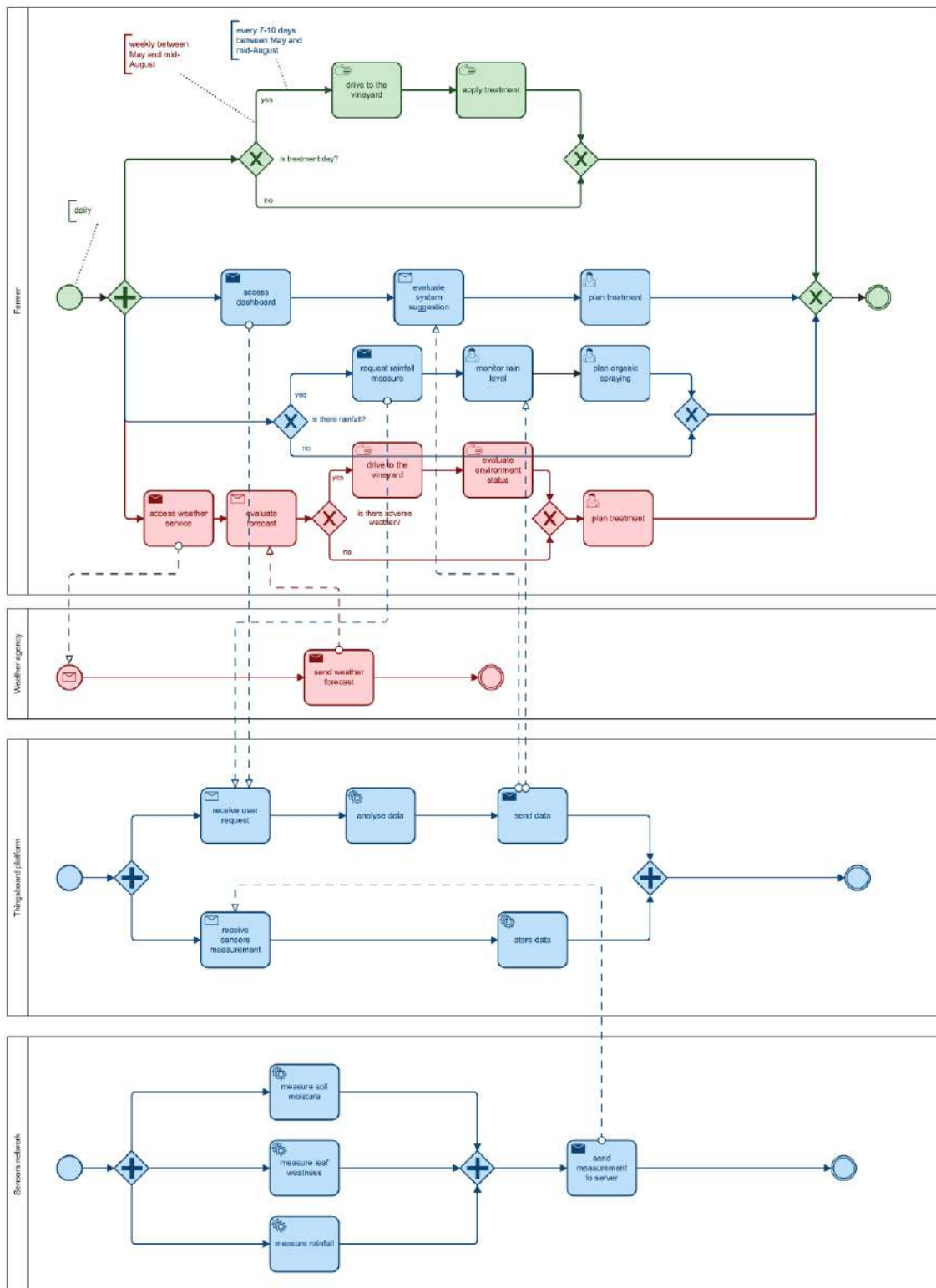


Figure 87. Process transformation diagram for Living Lab Smart Villages Network.

The diagram illustrates the transformation of the vineyard management process, showing how the farmer's activities shift from a manually intensive monitoring routine to one supported by automation and intelligent monitoring powered by precision data, enabling more efficient and sustainable approach to vineyard care.

### Unchanged Activities (green)

The **farmer** continues to **visit the vineyard in person** and **apply treatments** as needed. These fundamental tasks remain vital to maintaining crop health and ensuring proper vineyard care.

### New Activities (blue)

A **sensor network** has been installed in the vineyard to **continuously monitor key environmental parameters**. This data is transmitted to the **Things Board platform**, which **stores and processes** the information. Upon request, the platform provides the farmer with **actionable insights** to support more precise treatment planning and scheduling.

### Removed Activities (red)

The **farmer** no longer relies on external weather services or **manually interprets forecasts**. There is also no longer a need to **visit the vineyard solely to assess environmental conditions** or to plan treatments without technological support. These previously time-consuming tasks have been replaced by automated data collection, analysis and decision support.

## 5.2. Feedback on models

In this section, we present feedback gathered during the agreement phase conducted through focus groups with LL coordinators and surveys. From a methodological perspective, this phase corresponds to the evaluation of the proposed Socio-technical Process Modelling method (see Table 3, Cycle 3, Treatment Evaluation).

### 5.2.1 Feedback from Focus groups

Individual focus groups were organised with 18 LLs between M28 and M34, involving a total of 39 participants from the LLs, with group sizes ranging from 1 to 4 participants. These included the LL coordinators and key informants interested in discussing the models. In addition to the LL participants, each focus group included 2–4 members from CNR, who served as moderators and note-takers.

Feedback from the LLs is structured around questions that address three key aspects: (1) understandability: how understandable the models are; (2) completeness: whether the information shown is complete and accurate; and (3) usefulness: how useful the process modelling methodology is overall. For each type of model, participants were asked to interact with the diagram, report difficulties they encounter with the notations, their overall impressions and suggestions for improvements. Next, they were invited to point out any missing or incorrect information contained in the models. Finally, participants discussed how useful they find each model in practice, compared the different types, and reflected on the general benefits and limitations of the process modelling approach.

Below, we provide an aggregated summary of the answers, organised model by model, which highlights both aspects of appreciation and issues related to understandability, along with representative quotes.

#### Structure model (UML class diagram)

The **UML class diagrams** were generally found to be **the most immediately understandable**, especially as they represent concrete elements of the process structure by clearly differentiating actors, resources, and digital solution, *“The model is clear. I see that everything what we mentioned and what we discuss and what we are doing in the hours or shared...I think that static structure is designed very well”* (FG#12). Many participants described these models as *“really nice and really understandable”* (FG#4) and could **readily identify key system components and their interrelations** with little difficulty, particularly when the model accurately represented the specific context of their LL. One participant clearly affirmed that the structure model provides **additional clarity even for insiders** familiar with the LL context, *“This visual graph enables even us who are part of this process to better understand it*

and to see how these things are. I mean, we know it already, but somehow when you see it in this kind of structured visual way, it's even clarifying additionally for us as well" (FG#6).

However, some users experienced **challenges in finding entry-points** when reading the model; a user noted, "I find it difficult to find a starting point, but I guess it's the measuring device analyse soil, farmland... So that's how I would read it." (FG#10). There was some **confusion in distinguishing actors and resources**, because in this model, color is used solely as a visual cue to differentiate the digital elements; one participant noted, "I understand that the blue boxes are related to the digital technologies and then I would have colored the actors differently from the other boxes... So, I don't know if it was something you have envisioned to make a color for the actors" (FG16).

### Goal model (iStar diagram)

The **iStar diagrams** were appreciated for making actors' motivations explicit, helping answer not only "what" is done in the process, but "why". Multiple participants confirmed that this model helps **highlight added value for various actors**. A user noted, "I think it adds argumentation" (FG#11). Some stated that the model facilitates surfacing overlaps, identifying potential conflicts, and clarifying who is responsible for what—key for understanding **strategic positioning and dependencies among actors**. "It's indeed not always clear who should do what. And I think this can help to point out what is overlapping or what has to happen where" (FG#2).

Yet, many also described goal models as **the most challenging to interpret**: "For me, it was a bit more difficult to interpret this model, but it's clear" (FG#14). The complexity often stemmed from the non-straight lines and high level of abstraction required to distinguish between goals and tasks—elements that, although visually separated, are not always clearly differentiated in textual descriptions. Several participants reported that the **direction of arrows are sometimes confusing or not immediately evident**, especially in complex models with many interconnected elements: "Because it's so complex, it's not always possible to kind of see where the lines are going and which direction they're going in and that kind of thing, but I think it has captured a lot" (FG18). Additionally, some highlighted the **need to make collaboration more explicit though bi-directional connections** "is the farmer asking for advice and going to the researchers because also the researchers are there's ...It's almost like they're receiving or obtaining stuff from everybody else when in effect it's a living lab. They're also contributing. And I don't see that in the model" (FG#7).

### Activity models (BPMN diagrams)

The **BPMN** was experienced as the most **immediate to read**, with participants able to recognise tasks easily due to its sequential nature. However, since the language used in the activity model is richer and contains more elements than in the structure and goal models, some difficulties arose when **interpreting fine-grained details**. Participants applied **different approaches and varying levels of attention** when reading elements such as dashed lines or icons on boxes. While some engaged deeply with these details, others approached the diagram with more high-level reading, focusing primarily on the overall process flow rather than its specific components. Consequently, feedback on the understandability of activity diagrams revealed two distinct positions. On the one hand, many participants **appreciated the richness and detail**; on the other hand, several participants found the same richness and complexity to be a **source of difficulty**, reporting that the high density of information, numerous symbols, and visual elements sometimes made the diagrams visually overwhelming and cognitively demanding. For these users, understanding all the fine-grained details required additional effort, and they often **called for legends** to aid interpretation, "the fact that the dotted line means communication is not something I would suspect by myself to be honest. ...probably something like a legend explaining that dashed line is communication, straight line is sequential steps of the process. That would be beneficial" (FG#5).

**Activity transformation model**—the one overlapping process *before* and *after* by means of color coding—was highly valued for making process transformation tangible and helped participants reflect on how digitalisation changes daily practices. The **use of colour to highlight changes** was particularly appreciated, "I think it is a clear way to present all the changes that happened after introducing the solution, especially because of the colours... It made things pretty clear for me" (FG#2). Many participants remarked that this diagram provides an **accessible**

**summary of process-relevant details** that are otherwise complex to explain, making it possible to communicate key changes not only to project insiders, but also to stakeholders who might not have technical knowledge. Overall, participants agreed on the **strategic value** of the activity models in supporting evaluation and discussion, *“It’s a way for you to show the potential added value and if we are simplifying or complexifying the system before and after. And that’s a way for you to have our views to assess benefits and costs of the new solutions”* (FG#13). A limitation associated with this model is its **poor representativeness of qualitative aspects** related to the benefits emerging from the adoption of technology—such as improved work-life quality for farmers, being supported by technology in daily monitoring activities, enhanced precision and empowered access to information. Additionally, the model rigidity in representing process flow does not always align with the inherent variability of agricultural processes, which are often subject to frequent changes and adjustments.

### Completeness of the models

All participants confirmed that the models were **broadly representative of their LLs**, with the information generally complete, correct, and in line with the report. However, when discussing the models, most participants proposed additions or modifications to ensure the models more accurately reflect the realities of their respective LLs. Typical observations consisted of requests to **include missing actors**, suggestions to **clarify relationships between entities**, and proposals to **update certain connections**, such as including bi-directional arrows to better represent actual information flows or collaborations.

Observations concerned all three types of models, with more requests for change for the structure and activity models. In the structure model, some participants recommended greater detail in specifying the components of the digital solution to better differentiate between hardware and software elements, and to clarify the roles of advisory or technical support in the models. For example, in FG#4 a participant suggested, *“Maybe I will put one more ‘exchange software info’ between the technology provider and agronomist, because sometimes the farmer is not capable to read or to process or to utilise the technologies because he doesn’t have time, or he doesn’t want to. Because that is the reason why we are here to interpret the data, analyse the data, give them concrete directions and advice in order to what he or she will do”*.

In the activity models, the discussion centered on finding the right balance in the amount of information presented. Participants emphasised the challenge of identifying an appropriate level of abstraction—one that would capture the complexity of agricultural processes without overwhelming users with detail. The activity transformation model was at the center of this discussion, serving as the primary focus for debates about the appropriate level of granularity of the information. As one participant remarked, *“Obviously you can’t recreate life with a model and that’s not the point of the model”* (FG#18). The design of this model also highlighted just how intricate and varied agricultural workflows can be, with digital technologies often contributing to increased process complexity by adding new layers of information, additional interactions between actors, and more interdependent decision-making steps.

The active discussion confirmed the engagement of the LL coordinators in interacting with the models and contributing to their refinement. Several elements emerged as particularly noteworthy. First, the visual nature of the models was appreciated for enabling immediate feedback and fostering discussion around the digital solutions, their implementation, and their broader socio-technical implications. Second, participants recognised the evolving and open-ended nature of the models, emphasising that they are not static representations but living documents that require ongoing refinement and contextual adaptation. Third, the time allocated was tighter than ideal for thoroughly reviewing the completeness of the models, which not only highlights the coordinators’ willingness to engage more deeply but also points to the richness and complexity of information embedded within the models.

### Usefulness and limitations of the method

The process modelling methodology was generally perceived as **a useful tool** for application within the context of the project LLs, and it also shows promise for potential future use beyond CODECS. Participants **appreciated the use of three complementary but distinct diagrams** — UML diagrams for depicting process structure, iStar for focusing on goals and dependencies, and BPMN for process flow and transformation — and agreed on the

usefulness of keeping these perspectives separate to enhance clarity and support different dimensions of analysis. The discussion on usefulness focused on two main themes: the effectiveness of models for communication and for analysis.

**For communication**, participants agreed that **the models facilitate dialogue between stakeholders with diverse backgrounds** and varying levels of technical expertise, with the “*model acting as a tool for discussion*” (FG18). The visual nature of the models **helped make complex processes accessible** and fostered discussions, promoting a shared understanding of how digital tools influence farming practices “*we were pulling apart how complex these digital tools make farming for these farmers. So in that respect I can see that that is the case that these models are useful*” (FG18). Differing opinions on model understandability led to **contrasting views regarding how widely the models should be shared with stakeholders**. On the one hand, some participants believed that the models could be presented to a broad range of stakeholders—including technology providers, analysts, policymakers, advisors, and farmers—provided they were accompanied by appropriate guidance or simplified as needed for different audiences, “*I think it can be useful to show farmers who don't know how to implement technology at the farm level how it can work and how and which actors are involved, ... I think if we can provide them with some more background and information, they will be able to understand it and see the benefit*” (FG2). Some, however, were more cautious, suggesting that models are oriented to a scientific audience, “*I think we can present this model not for farmers or not for advisors, but for the scientific purpose*” (FG14).

**For analysis**, participants noted that the methodology was valuable not only for internal use within LLs—helping LL coordinators clarify the roles of elements and actors, as already emerged—but also as **a basis for engaging with technology providers for future implementation of the system**. Furthermore, several participants highlighted the potential of the models, particularly the activity transformation model—for **supporting cost-benefit analysis, impact assessment, and the identification of bottlenecks** or opportunities for further technological innovation. These analytical uses were considered especially valuable for understanding the broader implications of digital transformation in agricultural processes. However, while participants recognised that the **models could have an exploratory role for impact analysis**, they mostly rejected the idea that the models could directly highlight potential negative effects of digitalisation, reflecting the view that **additional analytical steps are needed to assess specific impacts**.

Among many strengths, some limitations emerged. As already discussed, a key challenge with the models is the **trade-off between richness of detail and ease of interpretation**, with highly detailed models risking overwhelming users, while oversimplified one's risking omitting critical parts of the process. Thus, some participants proposed to overcome the static nature of the diagrams with for more interactive features —such as enhanced color-coding and multi-layer representations—tailored to different audiences and purposes. **Difficulties related to diagram creation and update** were also highlighted. In fact, although the formalisation procedure was successfully applied by collaborators without prior knowledge of modelling languages, diagram creation remains time-consuming and cognitively demanding, requiring multiple rounds of editing over time and specific expertise related to graphical tools for modelling and information representation.

To address recurring feedback, **several improvements to the method are under consideration**. These include embedding legends directly within the diagrams to guide readers, increasing color coding in the structure model, adopting a distinct style for digital solutions in the goal model, and incrementing the use of annotations in the activity model to highlight better qualitative aspects. Further improvement of the method could lead to more intuitive symbols, better clarity in expressing relationships, and enhanced support to diagram interpretation. For the activity transformation models specifically, the introduction of layered or interactive views and a focus on key transformation points—rather than a comprehensive representation of all activities—were identified as potential strategies to improve understandability and stakeholder engagement.

## 5.2.2 Feedback from Survey

The survey was administered online after the focus groups and completed by **25 respondents** (16 males, 9 females) out of 39 invited participants, resulting in a response rate of approximately 64%. Most participants were in the 35–



44 (12) and 25–34 (7) age ranges, with smaller groups in the 45–54 (3), 55–64 (2), and 18–24 (1) categories. The majority of respondents were researchers (20), with others identifying as project managers, ICT providers, advisors, and representing a variety of Living Labs across Europe. Backgrounds were diverse, with the most common being **Agronomy** (9), **Computer Science** (4), **AgriTech** (3), and **Social Science** (3), along with individual representatives from fields such as Management, Engineering, and Landscape management.

The following Likert scale questions were asked to focus group participants regarding the use of process models. Each question, together with a summary of responses, is reported below. Figure 88 visually displays the results.

1. *It was easy to read the models.* Most participants (19, or 76%) found the models easy to read, with nearly half agreeing (12) and over a quarter strongly agreeing (7). No respondents expressed disagreement, suggesting the models were generally accessible. However, 6 remained neutral (24%), leaving some room for further simplification.
2. *The models are NOT useful to understand the impacts of the digital solution (negatively worded).* A large majority (22, or 88%) disagreed (15) or strongly disagreed (7) that the models were not useful for understanding impacts, confirming that most participants found the models helpful, indicating high perceived usefulness. Only a small minority were undecided (3, or 12%).
3. *I would recommend the use of models to represent the process transformation.* Most participants (17, or 68%) would recommend using the models, while almost a quarter (6, or 24%) were undecided. Only a small number expressed disagreement (2, or 8%).
4. *I would use the models in discussing aspects related to the digital solution with different stakeholders.* Similarly, a majority (17, or 68%) would use the models with stakeholders, with only 8% in disagreement and 24% undecided (6).
5. *The models help understand how the introduction of a digital solution can transform a process.* Most respondents (20, or 80%) agreed that the models help in understanding process transformation, with very few undecideds (16%) or disagreeing (4%).
6. *It was easy to interpret the process transformation.* A strong majority (17, or 68%) found it easy to interpret process transformation using the models, though almost a quarter were undecided (24%), and 2 disagreed (8%).
7. *The models have the potential to drive the analysis of costs and benefits.* More than half (14, or 56%) saw potential for the models to help with cost-benefit analysis, but almost a third were undecided (8, or 32%), and a minority disagreed (3, or 12%).
8. *Using the models would NOT bring benefits to assessing the impacts of digitalisation (negatively worded).* Most respondents (21, or 84%) rejected the idea that the models would not bring benefits, confirming positive perceptions of their value. Only 3 remained undecided (12%) and 1 completely agreed.
9. *I believe the models would NOT help my living lab in assessing the impacts of the digital solution. (negatively worded).* The majority (19, or 76%) disagreed (12) or strongly disagreed (7) with this negative statement, supporting the idea that the models are considered helpful. However, 5 remained undecided (20%) and 1 agreed (4%).
10. *The models are NOT easy to understand (negatively worded).* Most participants (20, or 80%) disagreed (44%) or strongly disagreed (36%) that the models are hard to understand, though a small group found them challenging (8%) and 12% was undecided.

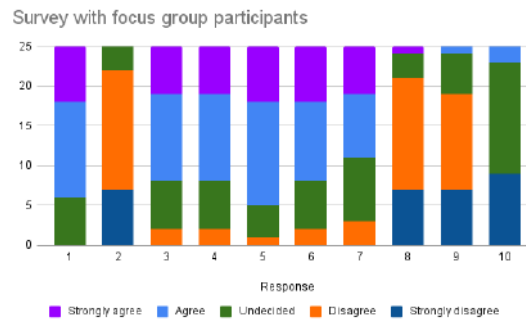


Figure 88. Feedback on process modelling from focus group participants.

Overall, the use of process models in LLs was generally perceived positively. Most respondents found the models easy to read and interpret, helpful for understanding the impact of digital transformation, and useful for stakeholder discussions. Some undecided and a few negative responses indicate possible areas for improvement, such as providing clearer representations or additional guidance.

In this section, we present feedback gathered during the agreement phase conducted through focus groups with LL coordinators and surveys. From a methodological perspective, this phase corresponds to the evaluation of the proposed Socio-technical Process Modelling method (see Table 3, Cycle 3, Treatment Evaluation).

#### 4.1 Synergies with WP4 – Cost-Benefit Analysis

In this section, we summarise the potential uses of the diagrams—along with their associated advantages—in the context of the cost-benefit analysis that WP4 is carrying out.

The models—especially the activity transformation model in BPMN—**highlight points of change** in the processes. Such change is due to the introduction of digital technology, which alters the way activities are carried out. These points of change represent **areas of variation, in terms of time, costs, workload, and required skills, to be further investigated**. As such, the models can serve as a reference for the cost-benefit analysis, thus supporting a more targeted and efficient evaluation. **Analysts can use the models to flag potential significant changes in business processes for further analysis in specific cost and benefit categories.**

The models can also **support the definition of system boundaries in life cycle assessment (LCA)**, providing elements to identifying which parts of the process should be included or excluded. Once impacts—such as environmental effects, financial costs, or labour implications—are quantified, they can be overlaid onto the model to visualise “hotspots” where digitalisation has evident impacts. This may **help prioritise actions and communicate findings**. At the same time, the accuracy and **traceability of inputs for LCA** can be improved by using the models to verify the completeness of the analysis and trace each identified change back to source reports. This could contribute to mitigate the risk of under- or over-estimating the impacts due to missing information.

When applied across multiple LLs, the models can also enable **comparative analysis, helping to identify which technologies or interventions may yield the most value across different contexts**. Their visual, colour-coded format enhances communication and common understanding among analysts and LL stakeholders because they make clear what is (and is not) included in the analysis.

## 5 Observations on Digital Ecosystems for sustainable digitalisation of farming

### Digital Ecosystem

The analysis of the data according to the four SESF subsystems revealed notable relationships, and noteworthy characteristics, both in terms of enablers and hinderances in DE. Below we set out the subsystems and observations related to some of the most relevant categories of RCCIs:

#### Resources Units

- There is a **clear relationship between resources and capabilities** for sustainable digitalisation in agri-food systems. Capabilities allow resources to be put into action and leveraged to create value, and resources are necessary to acquire or create capabilities.

Financial resources:

- The necessity **incentive schemes, grants/subsidies, research funds**, is still very evident. However, many LLs noted that **traditional finance and financing sources to enable digitalisation were not fit for purpose**.
- **Funding for acquisitions of digital tools** and systems, particularly those that are innovative, is necessary due to **high costs of such cutting-edge tools** or systems (financial resources). Also, **funds for human resource/actor knowledge and expertise** such as digital marketing specialists, specialist Agri digitalisation advisors, ICT specialists were also noted as relevant.

Technological resources:

- Despite the **availability of a wide range of technological resources**, there is also a significant **need for tailored technology** which is designed for small and diversified farms and adapted to local conditions.
- **Lack of domestic tech developers and providers** affects not only affordability, but also the customisation of technical solutions tailored to local social, economic, and environmental conditions.

Human resources, knowledge and informational resources:

- **Human resources in terms of knowledge is a critical resource** for the LLs as they consist of a variety of experienced and knowledgeable individuals.
- Many LLs noted a **lack of training for farmers, advisors, and other related stakeholders**. While reference was made to the presence of large quantities of data, it was noted that farmers may have little **critical capacity to analyse/interpret data and its usefulness (or not)** (absorptive capabilities).
- **Advanced aging of European farmers** was also noted as a challenge to sufficient human resources for sustainable digitalisation processes.
- **Acquisition of, access to and creation of knowledge related to digitalisation** were recurring themes across LLs.
- **Knowledge from farmers and agronomists is needed to enhance technical information**.
- **Training resources are needed** as there is a lack of educational programs and trained human resources, and advisors and private technical advisors are seen to be expensive. This **gap in human resources and informational and knowledge resources** hinders digital readiness.

Material and natural resources:

- There is a **need for testing and innovation infrastructure** in digitalisation (test before investing, as well as testing for “right scaling”). **Infrastructure resources** such as **demo farm** infrastructure, and **technical equipment** are emphasised, together with **physical space (facilities, land)**.

- **Natural resources** have an impact on digitalisation processes; scarcity of water is a great concern. Also **farm size** matters for digitalisation, being a tendency towards favouring digitalisation of big-industrial farmers.

Time

- The necessity to allocate **time for learning new digital skills and implementing digital tools** is emphasised. On the other hand, **once implemented digitalisation is linked to efficiency and time saving**

### Resource Systems

Human (knowledge and information):

- **Knowledge and information transfer/exchange and dissemination** systems are crucial for sustainable digitalisation. Often there are **insufficient communication of farmers' needs to IT developers** and other key stakeholders, which hinders the development of tailored digital solutions.

IT systems, collaborations, attitudes and values:

- **IT infrastructure**, and **especially reliable, fast and stable broadband connectivity is an ongoing problem** in (some) rural areas hindering sustainable digitalisation.
- **Interoperability of technologies** is conditioned by **openness/closeness of systems and data and from standardisation of guidelines/protocols**. How private ownership is organised influences interoperability and, particularly monopolistic ownership can hamper **collaborations and sharing of information, data and knowledge**.
- **Storage of information/data, and in general the ability to use it, benefit from, and control data** is key for sustainable digitalisation. **Data security systems (cybersecurity)** are crucial and could enable **collaborations**. The importance of secure transactions was emphasised, as it directly impacts consumer trust and the efficiency of digital payment systems (attitudes and values/ financial resources).
- **Simplification of the use of technologies and of knowledge transfer**, for example research results on digitalisation that are applicable and easy to understand by farmers.

Natural resources system:

- The **integration of ecological considerations** (natural resource systems) into the digitalisation process, is necessary in the creation of a sustainable and efficient farming environment.

Financial-funding system:

- Financial and **public support systems responsible for funding agriculture and innovation** need to adjust to higher risk scenarios that climate change brings.
- **Global economic and political instability impact the availability of resources** and the implementation of innovative agricultural practices.

### Actor subsystem

Human resources and adaptive capabilities:

- The **most predominant actors are farmers/farmer associations, private companies (including agri tech providers and developers), and researchers and advisors**.

Collaboration, informational resources and functional capabilities:

- **“Bridging” institutions for formal knowledge exchange** were frequently mentioned, particularly the presence of advisors or advisory services. Bridging institutions are important as local **advisory services, but innovation groups, networks and associations are relevant for co-production of knowledge exchange**, confirming that **complex agricultural innovation requires collaboration** and diffusion that transcends scale and traditional public-private distinctions.
- **Research** institutions, are key **contributors to human resources and knowledge/information** within the LLs, underpinning the development and refinement of new technologies and anchoring innovation.
- **Farmers act as data providers, implementers/users of digital solutions, and as testers.** Their level of **proactiveness and willingness to engage with new technologies**, as well as knowledge and skills, can either facilitate or hinder digitalisation.
- **Technology providers** may offer digital **platforms that support data driven decisions** in farming, but they may **also limit integrations with other platforms**, thus **restricting broader collaborations** and interoperability between different systems.
- **Collective action or collaborations** between actors, sharing initiatives, collective and common property *entities* such as marketing cooperatives or CUMAs (machinery sharing cooperatives), irrigation communities, etc. that were found amongst the actors of LL were seen to create improved dynamics for **innovation** in digitalisation and **sharing of decision-making, knowledge and risk**, yet were also seen to present challenges in terms of interaction with other actors, such as finance institutions, investors and insurers, as well as conventional supply chain actors.

Capability to anchor and scale digitalisation:

- **Certification bodies** in the value chain are the key in many cases to opening up markets in Europe and beyond, and these processes should require that **added value of digitalisation is integrated in all stages of the value chain**, not just production. This is a contentious issue, as the distribution of costs and benefits of digitalisation along the value chain is not evident.
- **Awareness of consumers (attitudes and values)** and their demands and needs may drive the digitalisation and innovation process, ensuring that new products meet market needs and promote sustainability. Digitalisation also allows farmers and other actors to access more information on markets and from consumers and to build relationships with them.

Actors that were *not present* within LLs were also pointedly mentioned by some LLs:

- **Not enough IT developers and tech companies**, particular those willing to invest time and collaborate and co-create with farmers, were seen to inhibit innovation, particularly with respect to the lack of appropriate adaptation and addressing specificities of digitalisation needs.
- **Lack of/low engagement with vocational and higher educational institutions**, thus hindering the development of human resources and related knowledge/workforce skilled in digital technologies.
- **Financial institutions** and service providers as well as funding entities were mentioned by various LLs as being absent, having far too complex procedures, or not fit for purpose. A lack of financial or funding providers for small farmers and businesses to innovate with digitalisation was noted, along with the perception across several LL that financial institutions were interested in financing large agri-industrial businesses. Also, an important element of such financing is also the absence/presence of insurers who are willing to reduce risk for farmers and other entities who seek to invest in innovations for digitalisation.
- **Advisors with great knowledge of digitalisation issues and processes**
- **Insufficient collaboration between research institutions and farm companies** indicate gaps that need to be addressed to foster a more supportive environment for digitalisation.
- **Low capacity of producer’s organisations and other collective actors to set demands from farmers against large-scale retail trade** which exercise control, amplified by digitalisation processes, who often follow a market logic that is not necessarily in the interests of sustainability or producer’s needs.

### Governance subsystems

Organisational resources:

- **Legal systems determine what may be used, traded, protected, as a common good.** Stakeholders stress the need of balance between unregulated areas and over legislation, both are hinders of digitalisation.
- **Financial management, regulatory compliance, and educational frameworks** are also seen as elements which influence in shaping digitalisation processes within LLs. In addition to compliance with regulatory requirements, **industry standards** were highlighted by LLs.
- Many LLs noted that comprehensive **technological integration, standards and interoperability** were fundamental.

Informational resources and functional capabilities:

- **Digitalisation processes may in and of themselves create new governance systems**, whether technological, social or economic.
- **Collective organisations, such as cooperatives, due to their participatory governance, may anchor the processes of digitalisation, knowledge sharing, risk sharing, and provide an alternative governance** – more democratic - structure for digitalisation and digital assets.
- LLs underscored the importance of **data accessibility and transparency**.
- Stakeholders have emphasised the need for a centralised, **easily accessible source of updated food legislation information**, where information is digitised and easy to find, thus facilitating regulatory compliance, actors requiring administrative resources, as well as market commodity information such as accurate pricing and costs.
- **Public data collection and accounting systems** have the potential to enable the innovations. However, several LLs noted that public systems require digital data collection but highlighted the **obligation of farmers to register the same data in different public systems and organisations**.

Collaborations:

- Some LLs underscored the need for **contractual arrangements to counterbalance lack of information exchange** throughout the supply chain, for example, supply chain agreements in production and branding or in trademark collaborations.
- **Digital platforms** were mentioned in several LLs, calling for **collaboration between advisors and farmers**. It was noted that although, platforms are available, there is a lack of know-how and digital skills (for farmers), to adapt them and use them the most efficiently, particularly aging farmers (functional capabilities).

Certification and market:

- **Lobbies, seed companies, and large producers** of technical means were seen to direct and control technology choices, therefore **influencing and “regulating” the market** in ways that may not align with the interests of smaller producers. This **misalignment hinders the digitalisation process** by imposing market-driven guidelines that may not support sustainable practices.
- Need for new services such as **certification and methodologies**, i.e. development of new analytical methods to support results from the use of digital tools is needed. Conversely, environmental **certification bodies ensure that the LL's practices meet regulatory standards** and industry best practices. These bodies enhance the credibility of the LL's initiatives and promote wider adoption of proven digital solutions (capability to anchor and scale digitalisation). However, navigating the certification **process can be challenging**, particularly for smaller producers who may lack the necessary resources and support.

## Agricultural Knowledge and Innovation System

We have explored from the AKIS perspective which actors are present and most likely to contribute to the final outcomes of the FASs present in CODECS. In this deliverable we have focused on the infrastructural perspective of AKIS (*Actors and Governance System*) which is part of a larger analysis of AKIS as a complex system.

For the actors, we found that the most predominant actors in the LLs FAS are farmers/farmers associations and private companies followed by researchers and advisors. Private actors, and more specific technology developers are predominant as part of the technology development and testing. Bridging institutions are also important both, in the form of local advisory services as well as organisations for the co-production and exchange of knowledge (innovation groups, networks, associations). The constellation of actors present in the LL is similar to configurations observed by Kernecker et al (2021) with the presence of heterogeneous actor groups or networks needed to initiate the innovation processes. This condition confirms the importance of bringing together different types of knowledge and aligns with findings of Eastwood et al (2017) who suggest that complex agricultural innovations require a collaborative approach for successful innovation and diffusion that transcends scales and the traditional expected functions that are expected from public and private actors.

With regard to the governance aspect, it was noted that the majority of the norms and rules identified at the various levels describe coordination mechanisms that are in place, either within the supply chain, in local associations and groups, or in the public policies that are applied. Related to AKIS coordination mechanisms, participants identified the CAP and national strategies for the spread of knowledge. Indirectly, participants identified mechanisms to foster innovation. To a lesser extent, knowledge governance issues such as data protection, property rights, as well as rules for exclusion and accessibility of knowledge were mentioned. Some categories were fewer mentioned such as global macro-trends, social rules or education guidelines. Regulations and policies at European and national level in general in the food production seem to affect the focal action situation of the Living Labs. Governance mechanisms derived from private companies as e.g. certification and labelling schemes and services, were identified as of high importance in the knowledge flows, particularly when these are interdependent with material or financial flows. Finally, there are mechanisms at local level, such as rules that are guiding interactions in the associations, networks or even among individual farms. The results suggest that AKIS behave as polycentric governance systems involving several dimensions and “missions”: multi-level, multi-purpose, multi sectorial and multi-functional.

About the methodology for data collection and analysis, we consider that the use of AKIS and relation with digitalisation provided a basis for the identification of actors and their functions, as long as boundaries of the system are clearly defined. Limitations in the scope and implementation of qualitative methodology should be also acknowledged. The findings reflect the workshops results which is highly dependent on the facilitation process conducted in each LL. In the future, the role of non-formal knowledge exchange and their role in the system should be analysed.

Adoption and diffusion of digital innovations are highly context-dependent and vary according to the multiple objectives of different actors (e.g., farmers, living labs). Digitalisation brings new actors, new roles, and new rules of interaction that affect how private and public actors interact, posing a challenge in terms of how data, information, and knowledge are shared and used. Some implications related with EU CAP AKIS an digitalisation policies and strategies can be derived:

Understanding the differences how formal institutions share knowledge and how informal channels increase access to knowledge enables better alignment and dialogue between different actors, reducing risks and maximising the benefits of new technologies for farmers. Farmers typically acquire practical knowledge through informal sources, such as peer exchange or hands-on experience, while they access scientific knowledge through formal and non-formal sources, such as research institutions, advisory services, or technical documentation. Policy instruments and innovation support services should facilitate the implementation and assessment of new ways of interactions between different public and private actors (e.g. interactive innovations, innovation networks, living labs) that enable this knowledge exchange.

With the process of digitalisation, the concept of AKIS evolves to make visible those new actors and the new multiple forms of interactions, recognizing several centres of governance. The use of analytical methods that are able to shed light on complex governance arrangements can support the monitoring and assessment of knowledge sharing. Our findings confirm e.g. EU's role in mainstreaming a pro-active data governance and upholding interoperability standards.

The strengthening of current advisory services and research subsystems and the reinforcement of digitalisation-related skills remain essential. Established actors can take new bridging functions such as understanding how knowledge flows are changing and their potential impacts and risks on a given farming system, and how acting as 'independent' information sources. Policy mechanism should strengthen capacities of AKIS actors and target digitalisation-related life-long learning to cope with the changing digital landscapes.

## Process modelling

We have explored the transformation of agricultural processes within the FAS of the CODECS LLs through a systematic approach based on process modelling. This deliverable presents a methodology designed to capture the diversity of digital solutions introduced by the LLs—ranging from precision agriculture technologies (e.g., drones and IoT devices) to integrated platforms and network-based systems—while accounting for varying stages of implementation and LL contexts. The methodology spans the entire modelling cycle—from data collection and validation within the collaborative, multi-stakeholder setting of the Living Labs to the formalisation of diagrams and their participatory discussion with LL representatives.

The diagrams depict the transformation of agricultural processes after the introduction of a digital solution from multiple complementary perspectives. The core focus lies in the *activity transformation models*, which represent the shift from the process as-is to the process to-be. The representations highlight how digital solutions (e.g., IoT systems, FMIS platforms, precision agriculture tools, and online marketplaces) integrate with existing workflows by overlapping activities before and after digitalisation. They highlight with colour three types of activities: *unchanged*—usually essential practices that persist, such as animal care, crop production, or in-person sales—; *new*—digitally enabled tasks, such as using remote sensing, logging data into platforms, or accessing real-time decision support—and *removed*—manual or redundant tasks eliminated by automation and data integration. Beyond activities, the diagrams also capture changes in the actor ecosystem. New actors are introduced—such as drone pilots and IT providers—who are responsible for technology maintenance and support. At the same time, existing actors like farmers and advisors take on expanded, data-driven roles, becoming more involved in remote monitoring, interpreting information, and guiding decisions, while performing fewer tasks related to manual data input and visual inspections.

Overall, the models reveal that digitalisation introduces new layers of complexity to existing workflows, with many activities being parallelised or redistributed across new digital agents and human actors. Manual tasks generally remain in place, but the quality of process execution is enriched through better information access, data integration, and communication.

The process modelling methodology has been the object of an accurate evaluation within the focus groups. The diagrams were generally well understood, especially when they reflected the specific LL context, and were valued for enabling reflection, clarification, and stakeholder engagement. However, some challenges emerged related to interpretability—particularly in models with abstract concepts or high information density—and the static nature of diagrams, which limits their adaptability to dynamic farming conditions.

Despite these limitations, participants recognised the usefulness of the models for both internal coordination and external communication. The diagrams were recognised as effective tools for analysis of digital transformation, supporting the identification of system boundaries for impact assessment. Moreover, they were regarded as *living artefacts* open to continuous refinement and adaptation as contexts evolve.

In the next phases of the project, the models will be further analysed to generate comparative insights across the LLs. This analysis will deepen our understanding of the patterns of digital transformation in agriculture and will inform



ongoing impact assessments of digital solutions, supporting evidence-based decision-making at both local and policy levels.

In addition, future work on the methodology will address the limitations that emerged during its first application, with a particular focus on improving the overall readability and interpretability of the models for a wider range of actors involved in the LLs. To support broader uptake, a toolkit will be developed to facilitate the application of the methodology in diverse contexts beyond the scope of the project. Finally, further enhancements will explore the integration of interactive and layered representations, with the goal of making the models more dynamic, adaptable, and engaging for different types of users and use cases.



## 6 Bibliography

- Aalst, van der, W. M. P. (2011). *Process mining: discovery, conformance and enhancement of business processes*. Springer.
- Aguilar-Savén, R. S. (2004). Business process modelling: Review and framework. *International Journal of production economics*, 90(2), 129-149.
- Alam, K. A., Ahmad, R., Akhunzada, A., Nasir, M. H. N. M., & Khan, S. U. (2015). Impact analysis and change propagation in service-oriented enterprises: A systematic review. *Information Systems*, 54, 43-73.
- Amrutesh, Chatterjee, J. (2010). *Digital Ecosystem for Knowledge, Learning and Exchange: Exploring Socio-technical Concepts and Adoption*. OPAALS 2010. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 67. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-14859-0\\_4](https://doi.org/10.1007/978-3-642-14859-0_4)
- Arinicheva, I. V., Bessarabova, S. S., & Lichot, U. A. (2018). The development of the digital economy in the agricultural sector. *Modern Fundamental and Applied Research*, 2(29), 36–38.
- Barney, J., Wright, M., Ketchen, D.J. (2001). The resource-based view of the firm: ten years after 1991. *J. Manag.* 27 (6), 625–641. <https://doi.org/10.1177/014920630102700601>.
- Barney, J.B. (1991). Firm resources and sustained competitive advantage. *Journal of Management*. 17(1): 99-120.
- Barringer, B.R., Harrison, J.S. (2000). Walking a tightrope: creating value through interorganizational relationships. *J. Manag.* 26 (3), 367–403. <https://doi.org/10.1177/014920630002600302>
- Bogoviz A.V, Alekseev A.N, Ragulina J.V. (2019). Budget limitations in the process of formation of the digital economy. *Lecture Notes in Netw. Syst.* 57:578–585.
- Object Management Group. (2010). *Business process model and notation (BPMN) v2.0*. <https://www.omg.org/spec/BPMN/2.0>
- Capron L, Mitchell W. (1998). Bilateral resource redeployment and capabilities improvement following horizontal acquisitions. *Industrial and Corporate Change* 7(3): 453–484. <https://doi.org/10.1093/icc/7.3.453>
- Colli, M., Madsen, O., Berger, U., Møller, C., Vejrum Wæhrens, B. & Bockholt, M. (2018). Contextualizing the outcome of a maturity assessment for Industry 4.0. *IFAC Papers Online*, 51-11, 1347-1352.
- Corradini, F., Ferrari, A., Fornari, F., Gnesi, S., Polini, A., Re, B., & Spagnolo, G. O. (2018). A guidelines framework for understandable BPMN models. *Data & Knowledge Engineering*, 113, 129-154.
- Dardenne, A., Van Lamsweerde, A., & Fickas, S. (1993). Goal-directed requirements acquisition. *Science of computer programming*, 20(1-2), 3-50.
- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MIS quarterly*, 319–340.
- Dietz, T.; Ostrom, E., Stern, P. C. (2003). The struggle to govern the commons. In: *Science* (New York, N.Y.) 302 (5652), S. 1907–1912. DOI: 10.1126/science.1091015.
- Dyer, J. H., & Singh, H. (1998). The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage. *The Academy of Management Review*, 23(4), 660–679. <https://doi.org/10.2307/259056>
- Easterby-Smith, M., Lyles, M. A., & Peteraf, M. A. (2009). Dynamic capabilities: Current debates and future directions. *British Journal of Management*, 20, S1-S8.
- Eastwood, C., Klerkx, L., Nettle, R. (2017). Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: Case studies of the implementation and adaptation of



- precision farming technologies. In: Journal of Rural Studies 49, S. 1–12. DOI: 10.1016/j.jrurstud.2016.11.008.
- EIP-Agri. (2018). Agricultural Knowledge and Innovation Systems. Stimulating creativity and learning. ochure Agricultural Knowledge and Innovation Systems. EIP-Agri
- EU SCAR. (2012). Agricultural knowledge and innovation systems in transition – a reflection paper. European Union.
- EU SCAR-AKIS (2023) Strengthening EU AKISs, Brussels, European Commission
- European Commission – Directorate-General for Agriculture and Rural Development – Unit A.3. (2023). Evaluating the AKIS strategic approach in CAP strategic plans: Guidelines. European Union.
- European Commission, Directorate-General for the Information Society and Media, Nicolai, A., Nachira, F., & Dini, P. (2007). Digital business ecosystems. Publications Office.
- European Commission. (2017). Digital readiness indicator.
- European Commission. (2018). A Digital Single Market Strategy for Europe.
- European Commission. (2018). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Strengthening Europe's Digital Competitiveness and Innovation: European Digital Innovation Hubs and Platforms.
- European Commission. (2021). Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021. Official Journal of the European Union.
- Falcão, R., Matar R., Rauch B., Elberzhager F., Koch M. (2023). A Reference Architecture for Enabling Interoperability and Data Sovereignty in the Agricultural Data Space. Information, 14, 197. <https://doi.org/10.3390/info14030197>
- FAO. (2022). Assessing agricultural innovation systems for action at country level A preliminary framework: FAO.Rome.
- Fernández, E., J.M. Montes, and C. Vázquez. (2000). Typology and strategic analysis of intangible resources. A resource-based approach. Technovation. 20(2): 81-92.
- Galbreath, J. (2005). Which resources matter the most to firm success? An exploratory study of resource-based theory? Technovation. 25(9): 979-987.
- Gartner. (2020). Gartner IT Glossary: Digital Readiness. Retrieved from <https://www.gartner.com/it-glossary/digital-readiness>
- Grant, R.M. (2016). "Contemporary strategy analysis". Chichester: Wiley, 9th edition.
- Gurkan Inan, G., & Bititci, U. S. (2015). Understanding organizational capabilities and dynamic capabilities in the context of micro enterprises: A research agenda. *Procedia - Social and Behavioral Sciences*, 210, 310-319. <https://doi.org/10.1016/j.sbspro.2015.11.371>
- Hall, R. (1993). A framework linking intangible resources and capabilities to sustainable competitive advantage. *Strategic Management Journal*, vol.14, no. 8, pp. 607-618
- Helfat C., Peteraf M. (2009). Understanding dynamic capabilities: progress along a developmental path. DOI:10.1177/1476127008100133
- Helfat, C., S. Finkelstein, W. Mitchell, M. A. Peteraf, H. Singh, D. Teece and S. Winter (2007). *Dynamic Capabilities: Understanding Strategic Change in Organisations*. Malden, MA: Blackwell.
- Hess C., Ostrom E. (2007). *Understanding Knowledge as a Commons: From Theory to Practice*, MIT Press.
- Hess, C. and Ostrom E. (2003): Ideas, Artifacts, and Facilities: Information as a Common-Pool Resource. *Law and contemporary problems* (66 (1/2)), S. 111–145. <https://www.jstor.org/stable/20059174>



- Horkoff, J., Aydemir, F. B., Cardoso, E., Li, T., Maté, A., Paja, E., Salnitri, M., Piras L., Mylopoulos, J., & Giorgini, P. (2019). Goal-oriented requirements engineering: an extended systematic mapping study. *Requirements engineering*, 24, 133-160.
- Ingram, Julie; Maye, Damian (2020): What Are the Implications of Digitalisation for Agricultural Knowledge? In: *Front. Sustain. Food Syst.* 4, Artikel 66. DOI: 10.3389/fsufs.2020.00066.
- [Ison, Ray](#) (2017). *Systems Practice: How to Act. In situations of uncertainty and complexity in a climate-change world. 2nd Edition.* Springer & The Open University.
- Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C., & Thorburn, P. (2019). "If they don't tell us what they do with it, why would we trust them?" Trust, transparency and benefit-sharing in Smart Farming. *NJAS: Wageningen Journal of Life Sciences*, 90-91(1), 1-13. <https://doi.org/10.1016/j.njas.2018.11.002>
- Johnson, E. (2022) 'Closing competency gaps for circularity: Exploring partner dynamics for circular-oriented innovation', *Sustainable Production and Consumption*, 34, pp. 130–147. doi: 10.1016/j.spc.2022.08.029.
- Kernecker, M., Busse, M., & Knierim, A. (2021). Exploring actors, their constellations, and roles in digital agricultural innovations. *Agricultural Systems*, 186, 102952. <https://doi.org/10.1016/j.agsy.2020.102952>
- Klerkx, L., Jakku, E., Labarthe, P. (2019): A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. In: *NJAS: Wageningen Journal of Life Sciences* 90-91 (1), S. 1–16. DOI: 10.1016/j.njas.2019.100315.
- Klerkx, L., van Mierlo, B. and Leeuwis, C. (2012): Evolution of systems approaches to agricultural innovation: Concepts, analysis and interventions. *Farming Systems Research into the 21st century*: 457-483.
- Knierim, A., Birke, F.M. (2023). Visualised AKIS diagnosis – an Instrumental Approach to Support AKIS Appraisal. *Eurochoices* 22 (2). 59-70 DOI: 10.1111/1746-692X.12397
- Knierim, A., Boenning, K., Caggiano, M., Cristóvão, A., Dirimanova, V., Koehnen, T. et al. (2015). The AKIS Concept and its Relevance in Selected EU Member States. In: *Outlook Agric* 44 (1), S. 29–36. DOI: 10.5367/oa.2015.0194.
- Knierim, A., Herrera, B., Paulus, M., Brunori, G., Hortigüela, R., & Giagnocavo, C. (2023). Making use of system concepts for interdisciplinary analysis of digitalisation in agriculture: Synergies, contradictions or voids? 26th European Society for Ecological Economics (ESEE) Conference.
- Koch M., Krohmer D., Naab M., Rost D., Trapp M. (2022). A matter of definition: Criteria for digital ecosystems. Elsevier. <https://doi.org/10.1016/j.digbus.2022.100027>
- Kogut B., Zander U. (1992). Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. <https://doi.org/10.1287/orsc.3.3.383>
- Kok, K. P.W. Klerkx, L.(2023) Addressing the politics of mission-oriented agricultural innovation systems, *Agricultural Systems*, 211, <https://doi.org/10.1016/j.agsy.2023.103747>.
- Kutnjak, A., Pihir, I., & Tomičić Furjan, M. (2020). Assessing digital transformation readiness using digital maturity indices. En *Proceedings of the Central European Conference on Information and Intelligent Systems* (pp. 307-314). Varaždin, Croatia. University of Zagreb, Faculty of Organisation and Informatics.
- Loniewski, G., Insfran, E., & Abrahão, S. (2010). A Systematic Review of the Use of Requirements Engineering Techniques in Model-Driven Development. 213-227.
- Mahoney, J. T. and Pandian, J. R. (1992). 'The resource-based view within the conversation of strategic management. *Strategic Management Journal*, 13, 5, 363– 80.
- Mannari C., Oronzo Spagnolo G., Bacco M. and Malizia A. (2023). Digitalisation of Agriculture: Development and Evaluation of a Model-based Requirements Engineering Process. In: A. Ferrari, B. Penzenstadler, I. Hadar, S. Oyedeji, S. Abualhaija, A. Vogelsang, G. Deshpande, A. Rachmann, J. Gulden, A. Wohlgemuth, A. Hess, S. Fricker, R. Guizzardi, J.

- Mannari, C., Ferrari, A. and Bacco, F. M. (2025). [CODECS T3.3] Socio-technical Process Modelling data collection - Living Lab REPORTS [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.16372574>
- Mannari, C., Ferrari, A. and Bacco, F. M. (2025). [CODECS T3.3] Socio-technical Process Modelling formalisation - Living Lab PROCESS MODELS [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.16372882>
- Manzhosova, I. B., Tunin, S. A., Kulish, N. V., Sytnik, O. E., & Germanova, V. S. (2021). Monitoring the readiness of agriculture for modernization in the digital economy. In A. V. Bogoviz (Ed.), *The Challenge of Sustainability in Agricultural Systems* (Lecture Notes in Networks and Systems, Vol. 205). Springer Nature Switzerland AG. [https://doi.org/10.1007/978-3-030-73097-0\\_41](https://doi.org/10.1007/978-3-030-73097-0_41)
- McGinnis, M. D., Ostrom, E. (2014). Social-ecological system framework: initial changes and continuing challenges. *Ecology and Society* 19(2): 30 DOI: 10.5751/ES-06387-190230.
- Metta, M., Ciliberti, S., Temple Obi, C., Brunori, G., Bartolini, F., & Matteo Metta, A. (2020). European agriculture, forestry and rural areas synthesis report of living labs' assessments needs, expectations, and impacts of digitalisation in European agriculture, forestry, and rural areas. [www.desira2020.eu](http://www.desira2020.eu)
- Monteiro Moretti, D., Baum, C. M., Ehlers, M.-H., Finger, R., & Bröring, S. (2023). Exploring actors' perceptions of the precision agriculture innovation system – A Group Concept Mapping approach in Germany and Switzerland. *Technological Forecasting and Social Change*, 189, 122270. <https://doi.org/10.1016/j.techfore.2022.122270>
- Moreddu, C., Poppe, K. (2013). Agricultural Research and Innovation Systems in Transition. *EuroChoices*, DOI: 10.1111/1746-692X.12014.
- Navas López, J. E., & Guerras Martín, L. A. (2018). *Fundamentals of strategic management* (2.<sup>a</sup> ed.). Civitas: Thomson Reuters.
- OECD. (2019). The future of education and skills: Education 2030. Retrieved from [https://www.oecd.org/education/2030/E2030%20Position%20Paper%20\(05.04.2018\).pdf](https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf)
- Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge.
- Ostrom, E. (1996): Crossing the great divide: Coproduction, synergy, and development. In: *World Development* 24 (6), S. 1073–1087. DOI: 10.1016/0305-750x(96)00023-x.
- Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science*, vol 325, pp., 419-422.
- Penrose, E. T. (1959). *The Theory of the Growth of the Firm*. New York: John Wiley.
- Rajagopalan R., Sarkar R. (2008). Information and communication technology, communities, and social capital — how the Digital Ecosystem approach can work. 2nd IEEE International Conference on Digital Ecosystems and Technologies, pp. 419-425, <https://api.semanticscholar.org/CorpusID:17276654>
- Rodimtsev, S. A., Gulyaeva, T. I., & Kalinicheva, E. Y. (2021). Digitalization assessment in agricultural organisations: Prospects for implementing a new initiative in the Oryol region (Russia). In A. V. Bogoviz (Ed.), *The challenge of sustainability in agricultural systems* (Lecture Notes in Networks and Systems, Vol. 206). Springer, Cham. [https://doi.org/10.1007/978-3-030-72110-7\\_10](https://doi.org/10.1007/978-3-030-72110-7_10)
- Saldana, J. (2016). *The Coding Manual for Qualitative Researchers*. Sage Publications Inc.
- Sarkar R., Prabhakar T.V., Chatterjee J. (2007). Towards digital ecosystems for skill based industrial clusters: Lessons from the 'Digital Mandi' project. Inaugural IEEE-IES International Conference on Digital Ecosystems and Technologies, Cairns, QLD, pp. 128-133.
- Stocker, M, et al. (2018). Curating Scientific Information in Knowledge Infrastructures. *Data Science Journal*, 17: 21, pp. 1–16, DOI: <https://doi.org/10.5334/dsj-2018-021>

- Sutherland L.A., Labarthe P. (2022). Introducing 'microAKIS': a farmer-centric approach to understanding the contribution of advice to agricultural innovation, *The Journal of Agricultural Education and Extension*, 28:5, 525-547, DOI: 10.1080/1389224X.2022.2121903
- Sutherland, L. A., Adamson-Fiskovica, A., Elzen, B., Koutsouris, A., Laurent, C., Stræte, E. P., & Labarthe, P. (2023). Advancing AKIS with assemblage thinking. *Journal of Rural Studies*, 97, 57-69.
- Teece D.J., Pisano G., Shuen A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal* 18(7): 509–533.
- Turner, J. A., Klerkx, L., White, T., Nelson, T., Everett-Hincks, J., Mackay, A., & Botha, N. (2017). Unpacking systemic innovation capacity as strategic ambidexterity: How projects dynamically configure capabilities for agricultural innovation. *Land Use Policy*, 68(January), 503–523. <https://doi.org/10.1016/j.landusepol.2017.07.054>
- Unified Modeling Language (UML) 2.5.1 Core Specification. (2017). Object Management Group (OMG). <https://www.omg.org/spec/UML>.
- United Nations Conference on Trade and Development. (2019). Digital Economy Report 2019: Value Creation and Capture: Implications for Developing Countries. United Nations. <https://unctad.org/webflyer/digital-economy-report-2019>
- Wagner, S., Fernández, D. M., Felderer, M., Vetrò, A., Kalinowski, M., Wieringa, R., Pfahl D., Conte T, Christiansson M.T., Greer Desmond. (2019). Status quo in requirements engineering: A theory and a global family of surveys. *ACM Transactions on Software Engineering and Methodology (TOSEM)*, 28(2), 1-48.
- Wang C. L., Ahmed P. K. (2007). Dynamic capabilities: A review and research agenda. <https://doi.org/10.1111/j.1468-2370.2007.00201.x>
- Wieringa, R. (2014). *Design Science Methodology for Information Systems and Software Engineering*. Springer Berlin Heidelberg.
- Wigboldus, S., McEwan, M. A., van Schagen, B., Okike, I., van Mourik, T. A., Rietveld, A., Wimba, B. R. (2022). Understanding capacities to scale innovations for sustainable development: a learning journey of scaling partnerships in three parts of Africa. In *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-022-02394-4>
- Willis A.J. (1997). *Forum. Functional Ecology*, 11: 268-271. <https://doi.org/10.1111/j.1365-2435.1997.00081.x>
- Winter, S. G. (2003). 'Understanding dynamic capabilities', *Strategic Management Journal*, 24, pp. 991–995.
- Winter, S. G. (2003). 'Understanding dynamic capabilities', *Strategic Management Journal*, 24, pp. 991–995. <https://doi.org/10.1002/smj.318>
- Wolfert, S., Verdouw, C., van Wassenae, L., Dolfisma, W., & Klerkx, L. (2023). Digital innovation ecosystems in agri-food: Design principles and organizational framework. *Agricultural Systems*, 204, 103558. <https://doi.org/10.1016/j.agsy.2022.103558>
- Wolfert S., Wassenae L.V., Burg S.V.D., Mark R., Klerkx L., Rijswijk M. McCampbell I., Beers A. (2021). Navigating the Twilight Zone - Pathways towards Digital Transformation of Food Systems, *Mansholt Lectures*. Wageningen University & Research, Wageningen, p. 70.
- World Bank. (2016). *World Development Report 2016: Digital Dividends*. World Bank Publications. <https://www.worldbank.org/en/publication/wdr2016>
- World Economic Forum. (2020). *The Future of Jobs Report 2020*. Retrieved from [http://www3.weforum.org/docs/WEF\\_Future\\_of\\_Jobs\\_2020.pdf](http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf)
- Yu, E.S., Giorgini, P., Maiden, N.A., & Mylopoulos, J. (2011). *Social Modeling for Requirements Engineering*. The MIT Press.

Zollo, M. (1998). Knowledge Codification, Process Routinization and the Creation of Organizational Capabilities: Post-Acquisition Management in the US Banking Industry. Doctoral dissertation, University of Pennsylvania, Philadelphia, PA <https://repository.upenn.edu/edissertations/1528>



## 6. Annexes

### ANNEX A. Activities of WP3 for D3.1

The Guidelines produced under Task 3.1 (Annex A) sets out how the characterisation of DEs occurs in three distinct phases during the life of the CODECS project (Figure 6). Initially, the process involves preparing, reviewing, and utilising existing information. The second phase emphasises engaging with LLs and stakeholders to collaboratively develop and validate the DE characterisation. This updated D3.1 (M36) presents the outcomes of the three phases. Stakeholders involved in the LL participated in two main activities: 1) Identification of RCCIs and characterising the SESF subsystems for mapping the socio-ecological context, and 2) developing process diagrams using formal notations for the socio-technical process modelling.

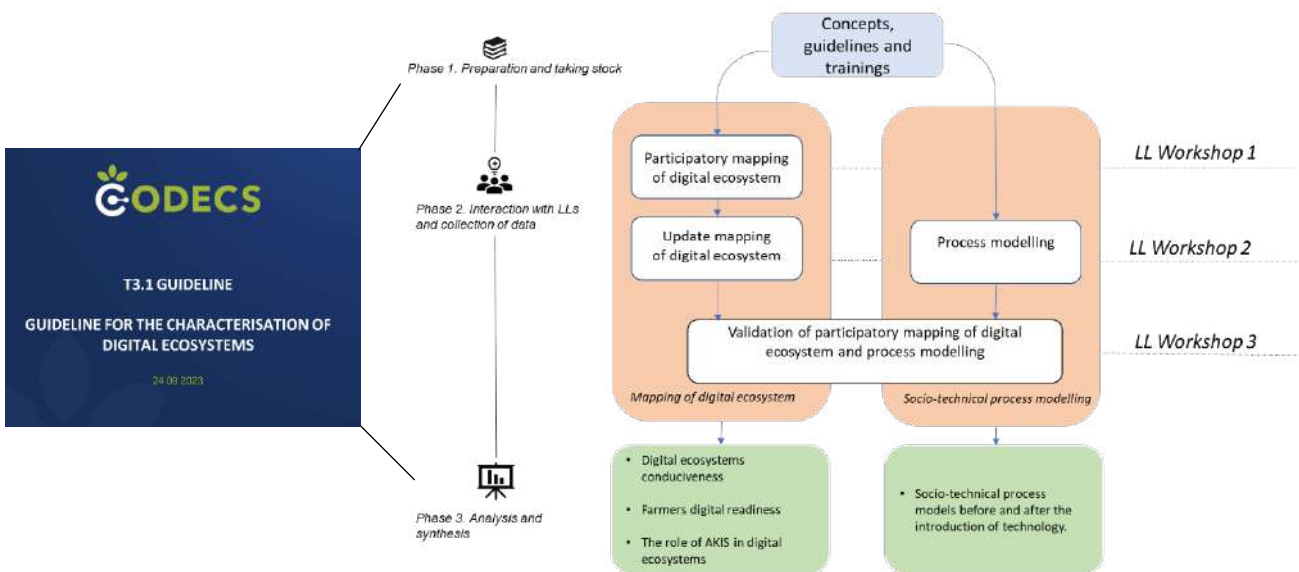


Figure 89. Guidelines for the characterisation of DEs within the CODECS project. It includes three phases: preparation, interaction with LL for data collection, and analysis. The methodology involves participatory mapping and socio-technical process modelling

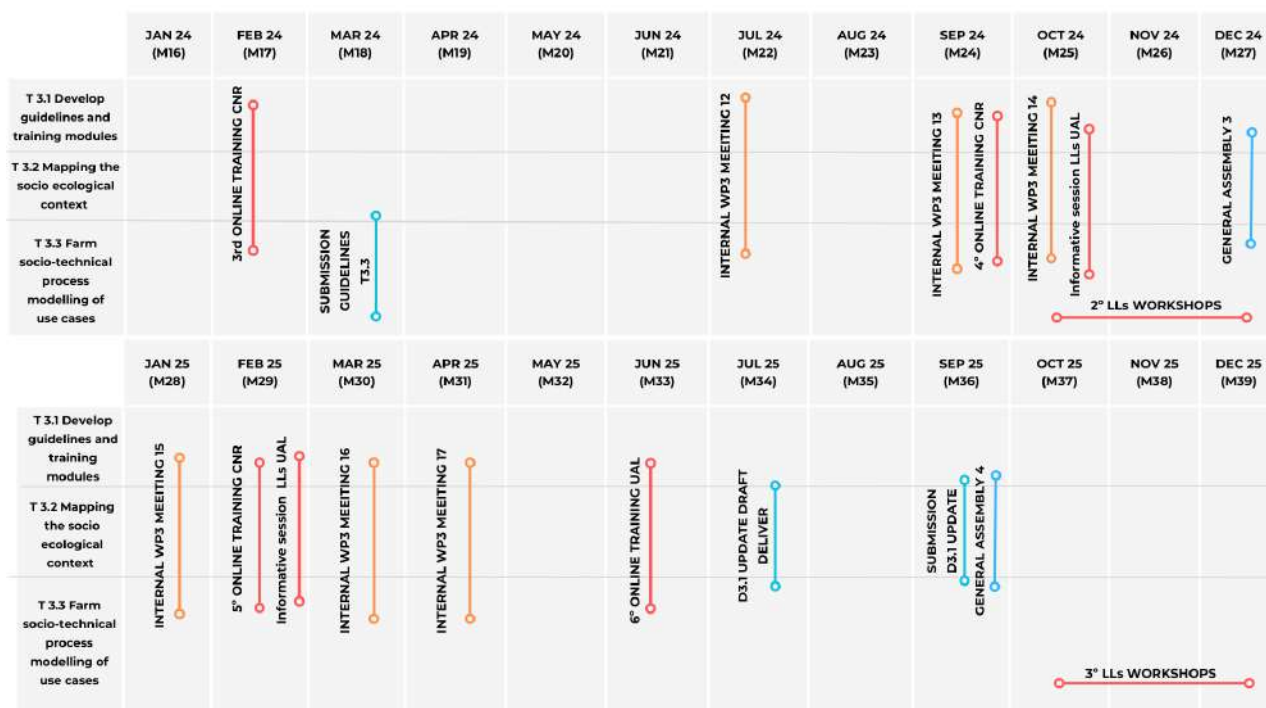


Figure 90. Timeline of key WP3 activities (meetings, workshops, training, and deadlines) from Jan. 2024 to Dec. 2025.

Figure 7 outlines the activities undertaken to achieve the objectives of each phase in the DEs characterisation. WP3 internal meetings were held during the initial phases to configure and co-create the theoretical framework to follow<sup>7</sup>. During the first general assembly in December 2022, the initial approach was explained to LLs and other project participants, and feedback was gathered to refine the methodology<sup>8</sup>.

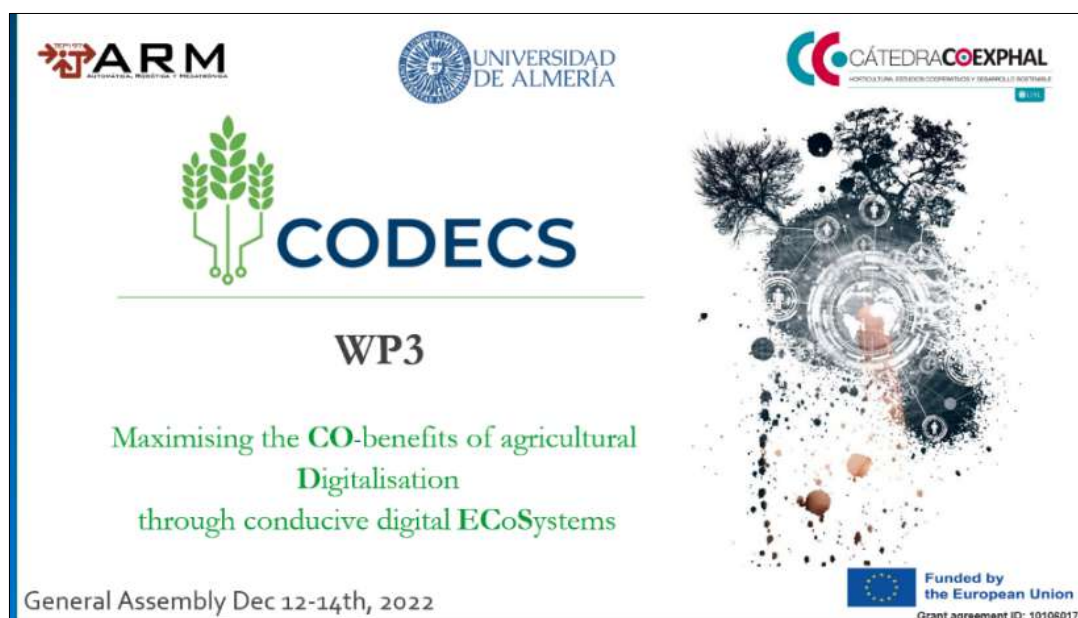


Figure 91. CODECS General Assembly WP3, December 12-14, 2022

<sup>7</sup> [WP3 Meeting material](#)

<sup>8</sup> [G. ASSEMBLY 2022](#)

In the following months until M12, work was focused on developing guides (T3.1)<sup>9</sup> and materials for the first workshop (templates, worksheets, PPTs., etc.) dedicated to the socio-ecological context mapping (T3.2), including two online training<sup>10</sup> sessions with LL coordinators for their use in their LL Workshops. Materials for reporting workshop results were provided, thus facilitating and standardising data collection.



Figure 92. Materials prepared for the participatory mapping of DEs and LLs workshops include a) Guidelines; b) Training sessions presentations and c) PowerPoint for LLs workshops and reporting templates for gathering data to support

In December 2023 M15, the second general assembly took place<sup>11</sup>, where an exercise was conducted to gather information on the “ideal DE” (conductiveness and readiness) within the SESF and to identify the characteristics

<sup>9</sup> [Task 3.1](#)  
<sup>10</sup> [WP3 Training](#)  
<sup>11</sup> [G. ASSEMBLY 2023](#)

according to subsystems. This exercise was to introduce the concept of indicators which will be carried out at a later stage.

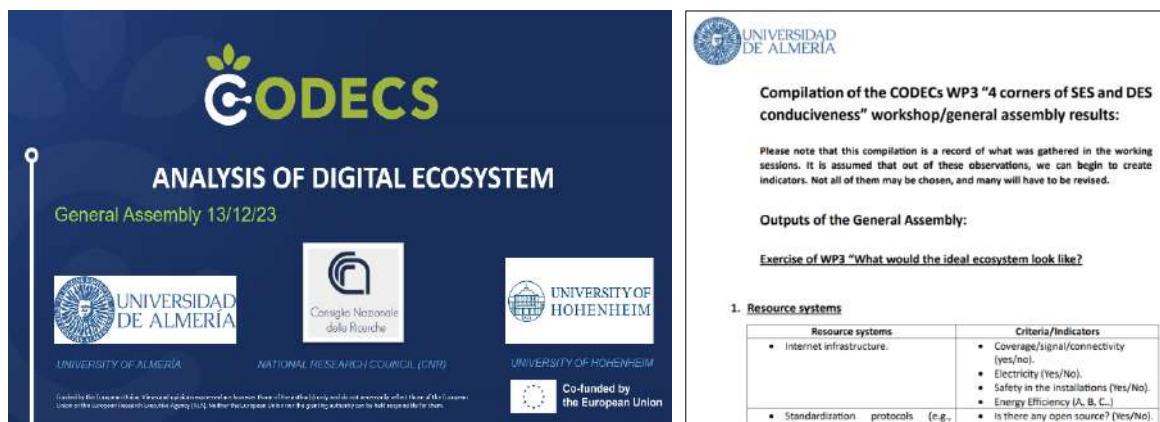


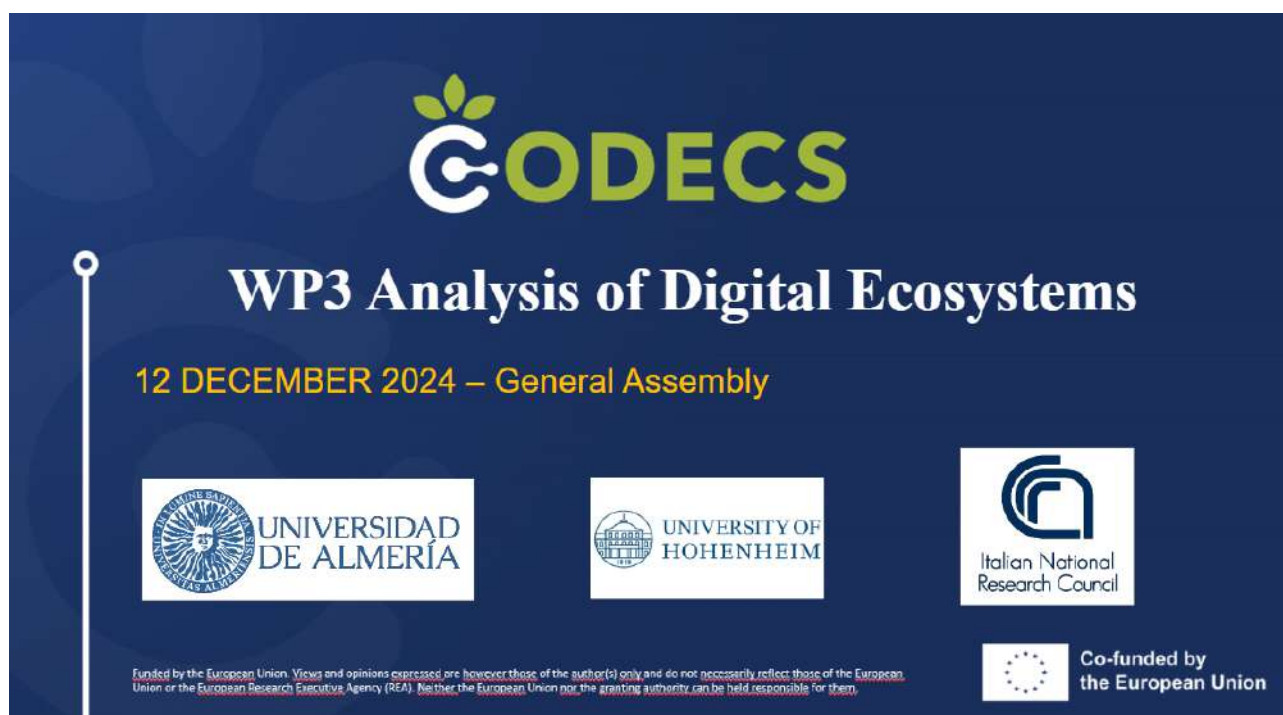
Figure 93. General Assembly materials and results from the "4 corners of SES and DES conduciveness" workshop held on December 13, 2023


Similarly, Guidelines (M18) and online training materials (M17) related to socio-technical process modelling (T3.3)<sup>12</sup> were created and carried out, providing necessary guidance to LL leaders to collect information. A pilot study was carried out and refined with feedback (M9-15) resulting in the consolidation of the methodology and Guidelines (M18). Data collection was performed from M17 to M20.




Figure 94. Material prepared for Socio-technical process modelling including Guidelines, Training material for LL coordinators and, Report template for collection of data


<sup>12</sup> [Task 3.3](#)




  
**WP3 Analysis of Digital Ecosystems**  
 12 DECEMBER 2024 – General Assembly



UNIVERSIDAD DE ALMERÍA




UNIVERSITY OF HOHENHEIM



Italian National Research Council

Funded by the European Union. 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.



Co-funded by the European Union

## ANNEX B. Glossary

Glossary	
Actors' subsystem	The actors (individual and collective) involved inhabit particular contexts within the FAS, with their own interests, ambitions, capabilities, access to resources, knowledge levels, and beliefs
Agricultural Knowledge and Innovation System (AKIS)	Knowledge flows between persons, organizations and institutions who use and produce knowledge for agriculture and interrelated fields, and by linking people and institutions, AKIS promotes mutual learning and generate, share, and utilize agriculture related technology, knowledge, and information.
Business process modelling	A specific type of system model that represents the sequence of activities, decisions, and resources involved in accomplishing a business objective. Business process models provide a visual representation of how work is performed within an organisation, highlighting dependencies, inputs, outputs, and control flows.
Capability	Individual/collective know-how/abilities to undertake specific activities, which implies a combination of resources and individual actions or organisational routines.
Collaborations	Understood as a capability and as a resource. It can be understood as the interactions that include the "sharing of information, resources, activities, and capabilities directed towards the achievement of a common goal or purpose that could not be achieved individually". E.g., A LL openness and willingness to collaborate is a capability, once there is a collaboration, for example, a working group or an association, that become a resource.
Digital ecosystem	Described as a socio-technical system which makes up the environment, where ICT, social-economic and knowledge networks converge

Digital Ecosystem Conduciveness	The extent to which the environment supports the growth and success of digital activities, such as the development of new technologies, the creation of new businesses, and the adoption of digital solutions.
Dynamic capabilities	Understood as the ability to mobilise/reorganize the assets and competences that a company/LL possesses not only to be able to respond to changing environments but also to increase its capacity for adaptation, survival, and competitiveness.
Farmer Readiness	The individual or organization's ability to adapt and effectively utilize digital technologies and tools in order to achieve their goals and objectives.
Focal Action Situation (FAS)	LL situation where subsystems of a socio-ecological system interact to provide an outcome. (Outcome =solution for the LL problem statement)
Governance systems	This subsystem looks into the processes through which decisions are made, implemented, reformed and reinforced. That is, "who decides what, and how?".
Innovation	Understood as a capability and as a resource. Social, organizational, technological, economic or environmental change involved in the FAS. Processes for exploring and exploiting opportunities to innovate. The attitude, willingness, and awareness to innovate is a capability, the innovation itself become a resource. E.g., I have willingness to explore IOT (capability) , once I have it (the IOT system) is an innovation (resource).
Living Lab (LL)	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
Social Ecological System Framework (SESF)	It conceptualizes the ecosystem into four main subsystems; resource systems, resource units, governance systems, and actors.
Subsystems - Core subsystems	Refer to Ostrom's SES "Governance Systems", "Actors", "Resource Units" and "Resource Systems".
Resources	(tangible and intangible) assets utilised in order to create value, achieve an objective, or solve a problem.
Resource systems	Resource systems describe the conditions in which resource units are managed and organised.
Resource units	This subsystem describes the assets that are available to actors within the agricultural and rural ecosystem, not just necessarily within the LL.
System modelling	A methodology used to represent and analyses complex systems. It involves creating abstractions of real-world systems, allowing stakeholders to gain insights into their structure, behaviour, and interactions. By using graphical or textual notations, system models capture the essential elements and relationships within a system, facilitating a holistic understanding of its dynamics.

#### ANNEX C. Socio-technical process modelling guidelines for data collection.

#### ANNEX D. Guidelines for development of the process models.



## T3.3 – FARM SOCIO-TECHNICAL PROCESS MODELLING

# GUIDELINES

20 FEBRUARY 2024

MANLIO BACCO (CNR), ALESSIO FERRARI (CNR), CHIARA MANNARI (CNR)



Co-funded by  
the European Union

CODECS has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060179. UK participants in Project CODECS are supported by UKRI grant numbers 10039965 (James Hutton Institute) and 10041831 (University of Southampton). 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.

## Contents

<b>1. Introduction</b> .....	<b>2</b>
1.1. Common terms .....	3
<b>2. Methodology</b> .....	<b>4</b>
<b>3. Data collection</b> .....	<b>5</b>
3.1. Focal action situation and problem statement .....	5
3.2. State of digitalisation .....	6
3.3. Procedure for Zero Digital .....	9
3.4. Procedure for Digitalising .....	21
3.5. Procedure for Digitalised .....	31
<b>4. Hints to conduct data collection</b> .....	<b>42</b>
<b>5. Training</b> .....	<b>43</b>
<b>6. Reporting and validation</b> .....	<b>43</b>
<b>7. References</b> .....	<b>44</b>

## 1. Introduction

This document presents the guidelines for conducting the data collection tasks that will support the farm socio-technical process modelling activity. This document is oriented to Living Lab (LL) coordinators, who will perform these data collection tasks through interviews and group discussions involving the LL participants.

The objective of the process modelling activity is to create easy-to-read **diagrams** of processes carried out in a farm before and after the introduction of digital solutions. The processes are sequences of steps performed by actors to address an objective, for example, irrigation or cattle monitoring. The results of the modelling activity consist of the creation of a graphical overview of the process, as envisioned by the LL, by describing actors, resources (units and systems), technological innovations, and relations thereof. The output of the activity will allow to focus on the transformation that occurred to a process after the introduction of a digital solution and will contribute to the analysis of the SESF (Socio-Ecological System Framework) in each LL.

The modelling activity itself, with the depiction of the diagrams, will be carried out by the Task 3.3 leader (CNR). **You, as LL coordinator**, will collect the data that are needed to depict the diagrams according to the guidelines described in this document. To report the collected data, **templates** are available in the folder [Task 3.3](#).

To ensure completeness, the following diagrams will be developed by CNR, based on your collected data:

- the **goal diagram** will model the goals of the process focusing on the intentional, social, and strategic dimensions;
- the **structure diagram** will provide an overview of the entities, i. e. actors, tools, infrastructures, and systems involved in the process and the relationships among them;
- the **process diagrams** will represent the detailed flow of the process and will allow comparisons between the process *before* and *after* the introduction of the digital solution.

A set of languages for graphical representation from software engineering has been identified, so the diagrams will be developed using such notations: i\*, goal diagram; UML, structure diagram; BPMN, process diagrams.

According to the project proposal, CODECS will carry out process modelling in all LLs. The activity will be carried out internally by each LL following a guided procedure.

**The aim of this document is to provide guidelines to collect the data needed to support process modelling in CODECS LLs**

**The data collection will be performed from February 2024 until May 2024 by LL coordinators through interviews, group interviews and group discussions.** No specific guidelines will be provided to carry out interviews and group discussions. Furthermore, if part of the required data has already been collected in previous phases of the CODECS project, for example during the first LL Workshop (WP3) and the first LL focus group (WP4) held in October-November 2023, these do not need to be collected again, and can directly be reported in the Reporting Template.

According to their state of digitalisation ([see 3.2](#)), LLs will fill one of the three alternative templates available in the folder [Task 3.3](#): **Case 1 – Zero Digital Reporting Template**, **Case 2 – Digitalising Reporting Template**, **Case 3 – Digitalised Reporting Template**. The data collected will be validated by LLs in a plenary workshop in October-November 2024. The final diagrams will be created by the task leaders and validated with LLs.

Chapter 2 presents the overall methodology to carry out data collection for process modelling within LLs. The step-by-step approach to be adopted for the development of the models is further described in the following chapters. Chapter 3 provides an explanation by example of three alternative procedures for data collection adapting to three possible states of digitalisation of the LLs. Chapter 4 contains hints for data collection. Chapter 5 presents further information on the training activities organised to explain the overall activity. Chapter 6 contains information on the report to be completed by LL coordinators to allow the formalisation of the models and the final validation step expected.

## 1.1. Common terms

A list of common terms is introduced to clarify the fundamental concepts mentioned in the document.

- **Actors** – individuals, groups, or system components that play a role in the process;
- **Capability** – the ability to undertake a specific activity, which implies a combination of resources and individual action or, collective or organisational routines;
- **Diagram** – a visual representation of information, typically simplified and structured to convey a specific concept or set of relationships among components;
- **Focal Action Situation (FAS)** – a situation where components of a socio-technical system interact to provide an outcome;
- **Goal diagram** – a type of diagram used to represent the actors' goals, relationships and dependencies within a process;
- **Living Lab (LL)** – 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;
- **Problem statement** – a concise description of an issue or challenge that needs to be addressed;
- **Process** – a series of actions, steps, or stages performed in a systematic and organised manner to achieve a specific outcome;
- **Process diagram** – a type of diagram that illustrates the sequential tasks, interactions, or events from the beginning to the end of a process;
- **Process modelling** – the act of creating a visual representation or abstraction of a process in order to understand, analyse, communicate, and improve it.
- **Resource** – (tangible and intangible) assets owned or accessed by the LL and utilised to create value, achieve an objective, or solve a problem;
- **Structure diagram** – a type of diagram used to represent the structure of a process by illustrating its static aspects, such as actors, resources, composition, and arrangement of the system.

## 2. Methodology

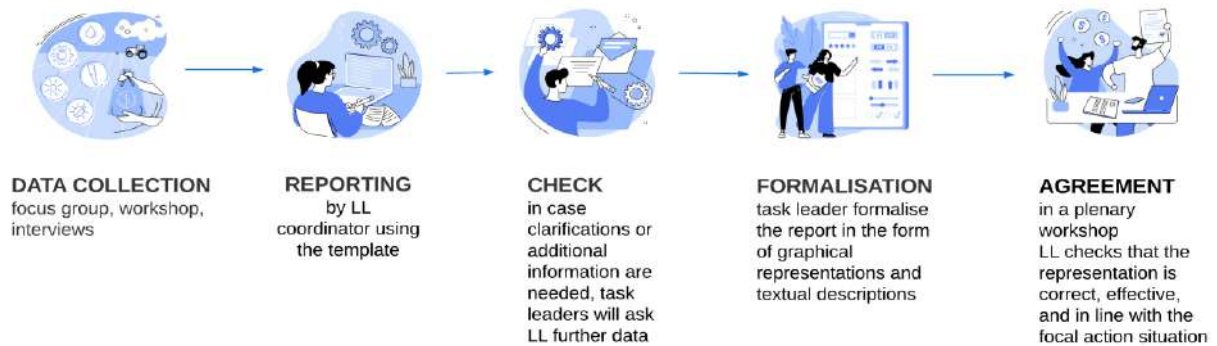


Fig. 1. Infographic describing the methodology to be used for process modelling

The infographic in Figure 1 describes the methodology to carry out the process modelling within LLs.

The process is articulated in subsequent phases:

1. **DATA COLLECTION:** LLs carry out the data collection employing various methods such as workshops, focus groups, and single and group interviews with key informants, i.e. farmers, advisors, technology providers, etc. These interactions allow for the gathering of diverse perspectives and insights relevant to the process modelling objectives;
2. **REPORTING:** LL coordinators assume the responsibility of reporting data using the template provided by the task leaders, ensuring completeness, consistency and accuracy of the report. The template includes a section of feedback useful to provide additional insights on the data collection activity, challenges and suggestions for improvements;
3. **CHECK:** after receiving the reports from LLs, task leaders proceed to a revision; should any uncertainties arise, or additional details be required, task leaders contact LL coordinators to obtain further data;
4. **FORMALISATION:** task leaders proceed to the formalisation of the report, translating the textual data collected into multiple diagrams focusing on different aspects, i.e. structure, goals and process;
5. **AGREEMENT:** in a plenary workshop, LL members validate the representations, assessing their correctness, effectiveness, and alignment with the focal action situation that emerged in the LL. Through this collaborative process, an agreement is reached on the representations, fostering a shared understanding of the diagrams and guiding further assessment and analysis.

### 3. Data collection

Overall, the idea is to exploit inputs coming from the focal action situation (FAS) to identify a **problem statement related to digital technology** aimed at meeting needs and expectations in the LL and then to collect data following one out of three proposed procedures. The procedures adapt to different states of digitalisation that may be associated with the LLs, i.e. **Zero Digital**, a state in which the digital solution to solve the problem statement has not been identified yet; **Digitalising**, a state in which the digital solution has been identified, but not yet fully adopted within the LL; and **Digitalised**, a state in which the digital solution has been adopted within the LL.

All procedures have in common a **step-by-step approach made of a series of questions** aiming at reconstructing the process carried out both *before* and *after* the introduction of the digital solution.

#### 3.1. Focal action situation and problem statement

The FAS is the starting point for data collection. To identify the process transformed by digital technology to be considered for process modelling, the LL is asked to expand on the FAS by providing contextual information and to make explicit a problem statement aimed at meeting needs and expectations in the LL.

**A. Shortly present the *focal action situation* of your Living Lab and any other information you deem relevant to describe the specific context.**

Starting from the focal action situation (FAS), provide a short description of the LL. Include information about the actors involved, geographic location, and other information useful to contextualise your LL, especially in terms of digital needs and actions already in place in this regard.

---

#### example

The Pecorino Toscano LL, based in Manciano (Tuscany, Italy), is composed of a network of farmers (cooperative), a cheese-making factory (pecorino), technical advisors (a veterinarian and an agronomist), the University of Pisa, and a spin-off company in the agricultural sector. In the area, milk production has been decreasing over the years because several farms have closed due to economic factors. It is increasingly critical for the factory to be able to estimate both milk quality and quantity in advance to better plan the production.

In this line, the LL is testing digital solutions to: 1. support the advisors' work in the field, so to have more stable milk quantity and quality over the year; 2. provide information to the factory about the expected milk quantity and quality; 3. exchange practices and information among the farmers, and provide them with e.g. optimal feed composition to improve the milk quality; 4. providing farmers with information on their milk after analyses carried out in the factory.

The Living Lab is working on the introduction of a Farm Management Information System (FMIS) that integrates new and existing databases managed by different actors. The FMIS is composed of a mobile app and of a web-based dashboard for decision support. Additional functionalities are under development.

---

**B. Make explicit the problem statement.**

In CODECS, the problem statement is related to the digital solution aimed at meeting needs and expectations in the LL.

Within the textual description of the FAS provided above, identify a problem statement. You can simply extract the sentences from the previous text or elaborate it with further details.

---

*example*

In the area, milk production has been decreasing over the years because several farms have closed due to economic factors. Hence, there are periods of milk scarcity, which impacts the cheese production. It is increasingly critical for the cheese factory to be able to estimate both milk quality and quantity in advance to better plan the cheese production.

---

### 3.2. State of digitalisation

Before starting the data collection, a preliminary step is required to identify the state of digitalisation of the LL. **Depending on the state of digitalisation, a different data collection procedure shall be followed, with an associated template.** We first describe the different states of digitalisation, and then we will guide the reader to the specific data collection procedure.

Three different states of digitalisation are possible:

**Case 1: *Zero digital – No digital solution in place, digital solution not identified***

This is a state in which **the digital solution to solve the problem statement has not been identified yet.** Starting from an evaluation of the current process in terms of assets, resources and capabilities available, the LL **explores alternative solutions** to solve the problem statement based on the adoption of different technologies.

**NOTE:** Please consider that you are in a Zero Digital state also if some technologies are used in your process, but the *specific* digital solution you are interested in to solve the problem statement has not been identified yet.

**Case 2: *Digitalising – Digital solution identified, not yet fully adopted***

In this state, **a digital solution to solve the problem statement has been identified but not yet adopted.** This occurs when the technology is available but not stable yet, or not fully adopted in the LL. For example, the LL could be in the process of introducing the technology within a restricted group (e.g. a demo farm), or a prototype has been developed and tests are being carried out. In this context, **the LL is able to compare the process today** (i.e., *before* the introduction of the digital solution) **and after the introduction** of the digital solution, by making an effort to envision the process in the future.

**Case 3: *Digitalised – Digital solution adopted, to be evaluated***

In this state, **a digital solution to solve the problem statement has been purchased or developed by the LL.** This occurs when, after a first period of in-field testing, the technology has been adopted within the LL. In this context, **the LL is able to evaluate the technology and compare the process today** (i.e., *after* the introduction of the digital solution), **and before the introduction** of the digital solution, by making an effort to recall the process in the past.

During the general assembly in December 2023, LLs assessed their state of digitalisation by taking part in a collective activity organised by WP4. Thus, according to that classification LLs can fill in the corresponding Reporting Template available in the folder [Task 3.3](#) (**Case 1 – Zero Digital Reporting Template**, **Case 2 – Digitalising Reporting Template**, **Case 3 – Digitalised Reporting Template**).

In case a LL is unconvinced of the state of digitalisation chosen and thinks that another case is more relevant, it is possible to choose a different procedure for data collection and refer to the corresponding template. Please, inform task leaders in case of this decision.

In case a LL has not taken part in the activity, it is possible to identify the state of digitalisation by answering this question:

**C. Having in mind the problem statement formulated above, identify the case (1. Zero digital, 2. Digitalising, or 3. Digitalised) most relevant for the Living Lab. Shortly explain the choice.**

Depending on the information reported in the FAS and LL description, it is possible to identify the three alternative states of digitalisation presented above. Each state of digitalisation leads to a different procedure for data collection.

**Case 1. Zero digital** – the digital solution to solve the problem statement has not been identified yet. The LL is evaluating alternatives considering available resources and capabilities.

---

**example**

Given the problem statement:

“Milk production has been decreasing over the years because several farms have closed due to economic factors. It is increasingly critical for the factory to being able to estimate both milk quality and quantity in advance to better plan the production...”

There is no digital solution in place. The LL is evaluating different digital tools that can link together actors and related activities towards the objective, for example a software that facilitates the computation of the degree of milk quality based on different factors, or a specific hardware that can facilitate milk analysis. The LL explores the different solutions and their impact on the current process.

---

**If your LL is in this situation, follow the procedure in 3.3 and fill in the Zero digital Reporting Template.**

**Case 2. *Digitalising*** – the digital solution to solve the problem statement has been identified, but not yet adopted. The technology is available but not stable yet or not fully adopted in the LL.

---

example

Given the problem statement:

“Milk production has been decreasing over the years because several farms have closed due to economic factors. It is increasingly critical for the factory to being able to estimate both milk quality and quantity in advance to better plan the production...”

A digital solution has been already identified (introduction of a Farm Management Information System and a mobile app). The solution is being tested by the advisors and a restricted group of farmers and will be further developed through co-design. The advisors and the involved farmers are assessing how the system is impacting their daily work, and the LL explores additional impacts on the digital ecosystem.

---

**If your LL is in this situation, follow the procedure in 3.4 and fill in the *Digitalising* Reporting Template.**

**Case 3. *Digitalised*** – the digital solution has been developed, tested and adopted within the LL. Now it has to be evaluated by providing a comparison with the process carried out in the past.

---

example

Given the problem statement:

“Milk production has been decreasing over the years because several farms have closed due to economic factors. It is increasingly critical for the factory to being able to estimate both milk quality and quantity in advance to better plan the production...”

The LL has introduced a digital solution that consists of a Farm Management Information System accessible via a mobile app and a dashboard. The FMIS is used by the advisors and other actors to improve both time and resource management in cheese making and livestock care. The LL analyses and describes how the process has changed in their ecosystem.

---

**If your LL is in this situation, follow the procedure in 3.5 and fill in the *Digitalised* Reporting Template.**

### 3.3. Procedure for Zero Digital

**Follow this procedure in case your living lab identifies with the state *Zero digital – digital solution not yet identified*, otherwise skip this paragraph.**

This procedure is divided into 5 STEPS, each step is composed of one or more questions.

#### Summary of the steps

- **STEP 1 – Emerging goals**: starting from the FAS in 3.1 and the problem statement in 3.2, express the emerging goals of the LL.
- **STEP 2 – Process before digital solution**: describe how the current process works providing information about actors and resources involved, and activities carried out; then explain the weaknesses of the current process.
- **STEP 3 – Potential digital solutions**: identify alternative solutions that rely on digital technologies and evaluate them in relation to their suitability, feasibility and acceptability.
- **STEP 4 – Process after digital solution**: choose one solution and envision the process in the future: describe how the system will work after the introduction of the digital solution.
- **STEP 5 – Transition**: provide information on the transition explaining how the LL will pass to the future process.

#### STEP 1 – Emerging goals

**1. What are the emerging goals of your living lab?**

Starting from the problem statement, present the **goals connected to the resolution of the problem**.

---

#### example

The digital solution should support all actors in fulfilling the following goals:

1. support the advisors' work in the field, so to have stable milk quantity and quality over the time;
  2. provide information to the factory about the expected milk quantity and quality;
  3. exchange practices and information among the farms and provide them with e.g. optimal feed composition;
  4. provide farmers with information about their milk after analyses in the factory.
-

**STEP 2 – Process before digital solution**

**2. Who are the actors involved now?**

The question aims to identify all actors involved in the current process. For each actor specify its role, the number of people involved in the LL and other relevant information.

**example**

- Farmers: sheep breeders. They form a dairy cooperative Caseificio Sociale di Manciano;
- Technical advisors: a veterinarian and an agronomist;
- Cheese making factory, also part of Caseificio Sociale di Manciano;
- University of Pisa (UNIFI), a group of researchers from the department of Agricultural, Food and Agro-Environmental Sciences. As formerly part of the UNIFI team, the technical advisors represent an interface between the cooperative and researchers.

**3. What are the resources involved in the process?**

The question aims to identify all resources involved in the process.

Resources may refer to: *physical assets* (land, tractors, crops, animals, etc.); *financing* (funds); *technologies* (hardware and software solutions); *knowledge* (scientific reports, training, etc.). Feel free to take inspiration from previous project activities for the identification of resources.

**NOTE:** to support the assessment of the digital solution, it is important to provide a comprehensive description of the technologies involved. The data collection should be accurate to ensure that a complete list of all the tech components and the infrastructure needed for making the technology work is provided. If relevant, include information on the manufacturer, provider, product version, etc.

**example**

Physical resources

- sheep (single animal or flock, managed by a farm);
- tools for annotating resources (e.g. notebook);

Technological resources

- digital devices (mobile/desktop);
- local data storage or cloud storage for farm data (e.g. local database, spreadsheet);
- external databases (e.g. national/regional animal registry).

Knowledge resources

- results of milk analysis (from external labs);
- reports and publications.

**4. What are the activities carried out by actors using the available resources?**

The question aims to collect information to **describe the current process**. Starting from each actor listed in 2, identify all activities in the process carried out by the actors and **provide a numbered sequence of activities**.

**NOTE:** this is one of the most important questions, so please be exhaustive, and provide as much information as possible.

If relevant, include information about the **frequency of the activities** (i.e. if they are carried out on daily, monthly, on a regular basis, etc..), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more actors are involved but they perform the SAME tasks, you do not need to repeat the activities for each actor.

Follow this structure to describe the activities: the **ACTOR** does **ACTION** because/to **MOTIVATION**.

You can also add further information (for example a **SPECIFIC CONDITION** or **FREQUENCY of ACTIVITY**), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

example

Farmer 1-2-3 (feeding)

1. **On a monthly basis**, the farmer asks the vet via text, whatsapp message, or telephone call to visit and monitor animals;
2. **In case of a sanitary emergency**, the farmer calls the vet to visit animals;
3. **Every three months**, the farmer contacts the agronomist via text, whatsapp or telephone to optimise the feeding plan in terms of cost and animals' health;
4. The farmer annotates on a notebook/digital device relevant facts about animals (e.g. birth, health problems, vaccinations, breeding...) to keep track of animals' health and wellbeing.

#### Farmer 4-5 (milking)

1. Every day, after milking, the farmer annotates on a notebook/digital device the amount of milk collected because wants to monitor the amount of milk produced;

#### Vet

1. The vet plans daily on a personal spreadsheet ordinary visits to the farms because wants to organise the work.
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet annotates data about animals on a notebook or a digital device because they wants to remember relevant facts about animals;
5. After any visit, the vet annotates results and registers the main events happened to a flock (new born, deaths, vaccines, etc ...) on a personal spreadsheet because they wants to keep records of animals' health status;
6. The vet accesses daily external data (e.g. animal registry) to keep track of animals' main facts;
7. The vet exchanges information about animals' health with the agronomist because they want to enhance the productivity of the animals;

#### Agronomist

1. The agronomist accesses monthly milk analysis results performed by an external lab because wants to optimise the feed ratios;
2. The agronomist plans daily on a personal spreadsheet ordinary visits to the farms because wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. The agronomist annotates monthly the optimal feeding plan for each farm and the results of milk analysis on a personal spreadsheet because they wants to keep records of feeding ratios;
5. The agronomist exchanges information about animals' feeding with the vet because they want to enhance the productivity of the animals;

#### Cheesemaking factory

1. Each month the cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. Each month the cheesemaking factory communicates milk analysis to the agronomist by providing access to data because it wants to formulate the optimal feed ratio;

#### University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.

#### Public institution

1. The Ministry of Health maintains an online animal registry which is accessed and updated by authorised professionals to keep track of animals.

### 5. What are the weaknesses of the current process?

The question aims to identify the weakness of the current process in terms of economic loss, waste of resources, and difficulties in process management. Refer to gaps in capabilities and resources already emerged from prior work, expand on them and provide examples of tasks that need to be improved.

#### example

There are difficulties at different levels:

- Information managed by different actors is not integrated;
- several spreadsheets are scattered among their respective owners, while other information is isolated, incomplete and sometimes repeated;
- data disaggregation and unstructured communication cause economic loss;
- the cheese factory is not capable of estimating milk quantity and quality;
- technical advisors struggle to manage on site interventions; without a scheduled calendar of the interventions agreed with farmers, they are not capable to organise in advance ordinary activities (e.g. vaccinations, feeding plans);
- farmers feel isolated in their business and have no clear idea of the expected income.

### STEP 3 – Potential digital solutions

### 6. Describe potential digital solutions. Explain why the living lab has identified such solutions.

Briefly present **2 or 3 alternative solutions based on the use of digital technology**. While thinking of possible solutions, take into account resources and capabilities of the LL, and focus on strategies that require different levels of “presence” and “intensity” of the technology (e.g. technology-intensive, human-intensive).

Indicate the **level of maturity of the digital solution in the context of the LL** choosing one option from the following:

#### 1. Proof of concept

Idea being actively designed / discussed for future implementation; evaluation of feasibility and functionalities are under discussion.

#### 2. Prototype

Working model that demonstrates functionalities, user experience, and potential features in a “preview” fashion.

#### 3. Pilot

A prototype tested in a real-world environment with actual users to assess effectiveness, usability, and scalability.

Add any relevant information on the maturity of the digital solution in the LL and related challenges (e.g. number of farms involved, objectives, technological infrastructure, etc.).

**example**

After an evaluation of the LL asset, resources available and capabilities, two solutions seem possible:

**Solution 1 – FMIS with app for advisors**

*[Description]*

This solution consists of the development of a farm management information system (FMIS) with a mobile app and a dashboard in use by advisors. Through an easy on field procedure starting with the scanning of animals, data about animals' health and feeding will be provided by advisors and shared with all stakeholders to improve both time and resources in cheese making and livestock care. The maturity level of the digital solution is *proof of concept*, as the LL aims to develop a custom software solution tailored to the LL needs with the support of a software agency specialised in agritech. The FMIS will also include different technologies already available on the market (e.g. cloud service, bluetooth tag scanner for animals) which need to be integrated into the system.

*[Motivation]*

Based on data interoperability, this solution can provide a positive impact and advantages within the LL. Furthermore, the solution seems promising to support the advisors' work in the short term with an affordable cost related mainly to the development of the FMIS and the app.

**Solution 2 – Farm sensors and smart collars**

*[Description]*

This solution consists of the installation of sensors in all the farms of the cooperative and the adoption of smart collars to monitor the production of milk and animals' health. Data collected by sensors are managed through a decision support system (DSS) that will provide singular and aggregated information about animals' health and milk quality and quantity that will be shared with all stakeholders. The maturity level of the digital solution is *proof of concept* as a new software component, i.e. DSS for aggregating data has to be developed and integrated with sensors and smart collars, that must be purchased.

*[Motivation]*

This solution can automate the collection of data about production performances and animal health while completely releasing the farmers from commitment of data input. The solution will support the advisors and the factory by providing up-to-date information to be used for operative decisions. A consistent initial investment for both hardware and software and further investments for maintenance have to be considered.

**7. Evaluate the digital solutions and choose one.**

The evaluation can be performed by answering three sub-questions.

Starting from the solutions identified, assess each solution by answering the following questions:

**1. Is the solution suitable?**

Suitability evaluates to what extent the solution addresses the identified problem statement and key weaknesses of the current process. Start from the weaknesses described in 5 and evaluate how the solution helps to solve the weaknesses.

**2. Is the solution feasible?**

Feasibility evaluates the real possibility of successful implementation of the solution. The question asks if the solution could be undertaken with the available resources and capabilities of the actors. Considering current capabilities and resources, explain the degree of feasibility of the solution (1 – not feasible; 2 – hardly feasible; 3 – moderately feasible; 4 – feasible; 5 – highly feasible).

**3. Is the solution acceptable?**

Acceptability evaluates to what extent the different stakeholders are keen to adopt the digital solution, based on its envisioned benefits and risks. The question asks if the solution is overall acceptable by considering the balancing of different points of view. Consider these main factors: (1) different kinds of benefits, e.g. economic, social and environmental, and for whom; (2) risks, usually economic, but also social and environmental; (3) positive and negative stakeholder reactions.

After the evaluation, choose the most promising solution for envisioning the process transformed by such a solution. Write the chosen solution and briefly explain the reason for the choice.

**example**

**Solution 1 – FMIS with app for advisors**

*[Suitability]*

The solution is suitable because it resolves the weaknesses of the current process. Integrating information managed by different actors, the FMIS will support advisors in the management of their work, the cheese factory in estimating milk quality and quantity and the farmers in the evaluation of expected income.

*[Feasibility]*

The solution has a degree of feasibility: 5.

The solution seems promising to support the advisors' work in the short term and provide immediate benefits to all other actors with an affordable cost related mainly to software development. Therefore, the resources required are deemed to be sufficiently available. In terms of capabilities, the advisors are well-prepared and eager to learn new tools to simplify the workflow. All the LL will be asked to collaborate on the co-designing of the new system.

*[Acceptability]*

Despite some minor risks related to its introduction, the solution is evaluated as overall acceptable.

Based on the sharing of knowledge and practices, this solution will bring advantages mainly in economic terms (time saved in data input). No major financial risks are expected. The main risk is related to the initial cost of the development, maintenance and further implementations of the FMIS. An additional risk is related to the will of the farmers to share data about their businesses; a central point will be to decide to what extent data will be shared.

**Solution 2 – Farm sensors and smart collars**

*[Suitability]*

The solution is highly suitable because it resolves the weaknesses of the current process. Integrating information automatically collected by sensors, the DSS will support advisors in the management of their work, the cheese factory in estimating milk quality and quantity and the farmers in the evaluation of expected income.

*[Feasibility]*

The solution has a degree of feasibility: 2.

In terms of capabilities, the advisors are eager to learn new tools to simplify the workflow; however, despite its high potential, the feasibility of the solution has been estimated highly critical, in terms of financial resources needed to put in place the system and capabilities of farmers to maintain on site sensor technology.

*[Acceptability]*

Due to major risks and high initial investments required, the solution has a low grade of acceptability. Despite the adoption of the same sensor technology in all the farms could help to reduce maintenance costs, it will expose the farms to risks related to the dependence on a single provider (e.g. high costs of future releases, possible issues with data management, frequent upgrades needed). Farmers are sceptical about investing in a technology that is limited to the organisational plan without having a relevant role in practical activities.

*[Chosen solution]*

Solution 1 – FMIS with app for advisors is considered the most promising in terms of suitability, feasibility and acceptability; thus, it has been chosen for the description of the process in the future.

**STEP 4 – Process *after* digital solution**

**8. Will the introduction of the digital solution require the involvement of new actors?  
If yes, which ones?**

Start providing a list of the new actors who will be involved in the process transformed by the digital solution. For each one of the actors explain its role and the relationship with other actors and resources.

*example*

New actors will be involved for the development and maintenance of the FMIS; they can be identified with:

- a software agency (but can be more than one) with the following specialisations: development of software in the agricultural sector; web applications; mobile applications;
- other software providers (optional, in support of software agency or in a second phase for data storage and maintenance);
- technology providers (for digital devices);
- assistance providers (for connectivity, software maintenance, assistance for devices, etc).

**9. Will the introduction of the digital solution remove existing actors from the current process?  
If yes, which ones?**

Based on the list provided in answer 2, assess the process in the future and list any actors that will be removed.

In certain cases, actors may be replaced by a technology that contributes to automating the system (e.g. robots, autonomous vehicles...), or by other actors with more technological skills (e.g. a drone pilot); if possible, connect the removed actors to the actors added in replacement.

**example**

The solution will remove the following actor:

- secretary of the cheesemaking factory who manually handles the milk analysis results, as these are automatically processed because of the introduction of the new FMIS.

**10. Which new resources will be added?**

Envision the system in the future and think about which resources (units and systems) will be added in the process. Based on the list of resources in 3, provide a list of added resources.

**example**

Technological resources

- Bluetooth tag scanner for vets in on-field activities (data access and data entry)
- server for data storage
- technological devices compatible with app (e.g smartphone/tablet/desktop)
- cloud storage and software

**11. Will the introduction of the digital solution remove resources from the current process?  
If yes, which ones?**

Envision the system in the future and think about which resources will not be part of the process anymore. Based on the list provided in answer 3, list any resources that will be removed.

**example**

Resources removed from the process are related to the previous way to store data.

Technological resources

- local data storage or cloud storage for farm data (e.g. local database, spreadsheet)

## 12. What will be the activities carried out by actors using the resources?

The question aims to collect information to trace the process transformed by the introduction of digital solution.

**NOTE:** this is one of the most important questions, so please be exhaustive, and provide as much information as possible.

Guidelines to perform this activity:

1. Copy-paste all the content that you wrote in answer 4
2. Remove the actors that are not part of the process anymore (according to the list in 9) and respective actions
3. Remove any other action that is not performed anymore
4. Add actors (according to the list in 8) and a numbered sequence of actions based on the envisioned process
5. Add any other action that will be part of the process when the technology will be introduced

If relevant, include information about the **frequency of the activities** (i.e., if they are carried out on daily, monthly, on a regular basis, etc.), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more actors are involved but they perform the SAME tasks, you do not need to repeat the activities for each actor.

Follow this structure to describe the activities: the **ACTOR** does **ACTION** because/to **MOTIVATION**.

You can also add further information (for example a **SPECIFIC CONDITION** or **FREQUENCY of ACTIVITY**), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

### example

Farmer 1-2-3 (feeding)

1. **On a monthly basis**, the farmer receives a notification from the vet via text or whatsapp message to plan a visit because he/she wants the health status of the animals to be monitored;
2. **In case of a sanitary emergency**, the farmer calls the vet because wants the animal to be visited;
3. **On a monthly basis**, the farmer receives a notification from the agronomist through sms or whatsapp to plan a meeting for discussing the feeding plan because they want the optimal feed plan in terms of economics and animals' health;
4. **On a weekly basis**, the farmer receives notifications from the FMIS through email with stats about productivity and quality performance of the farm and aggregated data about the performances in relation to other farms because they want to be updated with outcomes of their business;
5. **If interested**, the farmer accesses the dashboard or the app to record on the FMIS all the relevant facts about a sheep (e.g. birth, health problems, vaccinations, breeding...) because wants to keep track of all animals' health and wellbeing and share data with advisors;

Farmer 4-5 (milking)

1. Every day, after milking, the farmer accesses the dashboard or the app to record the amount of milk collected because wants to monitor the amount of milk produced;

Vet

1. The vet receives monthly a notification from the FMIS to schedule visits to the farms because they wants their work to be organised;
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet scans the animal through the bluetooth tag scan and accesses the app to annotate data about animals because they wants to record relevant facts about animals;
5. If needed, after a visit, the vet accesses the app or the dashboard to add new data or edit existing ones because they wants to keep up-to-date records of animals' health status;
6. The vet accesses the dashboard to see stats of farms productivity, data shared with the agronomist and data synchronised from external databases (e.g. animal registry) because they wants to enhance the productivity of the animals;

Agronomist

1. The agronomist accesses monthly the dashboard to see stats of farms productivity, data shared with the vet and data synchronised from external databases (e.g. milk analysis) because they wants to enhance the productivity of the animals.
2. The agronomist receives monthly a notification from the FMIS to schedule visits to the farms because they wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. During a visit, the agronomist accesses the app to annotate the optimal feeding plan for each farm because they wants to keep records of feeding ratios;
5. If needed, after a visit, the agronomist accesses the app or the dashboard to add new data or edit existing ones because they wants to keep records of feeding ratios;

Cheesemaking factory

1. On a monthly basis, the cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. On a monthly basis, the cheesemaking factory accesses the dashboard to see aggregated stats of farms productivity because it wants to estimate milk production;

University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.
2. Researchers from the University of Pisa access the dashboard to see aggregated stats of farms productivity because they want to enhance the LL productivity.

Public institution

1. The public institution offers a web service that provides interoperability between the national animal registry and the FMIS.

Software agency

1. The software agency maintains the software updated and provides assistance because they want the system to work in support of the LL.

Assistance provider

1. The assistance provider provides assistance services because they want the system to work in support of the LL;

Technology provider

1. Technology provider provides devices compatible with FMIS software and app because they want the system to work in support of the LL;

**STEP 5 – Transition**

**13. How will the living lab supposedly deal with the transition to the new system?**

This question aims to support the LL in envisioning the process towards the adoption of the digital solution. Reflect on the transition phase for the adoption of the digital solution in the LL and provide a list of the progressive steps necessary for the setup of the system. Consider actors, resources, activities, capabilities, including e.g. training, and investments necessary to the adoption of the digital solution.

**example**

The transition will include approximately these consecutive steps:

1. Buy necessary hardware: bluetooth tag readers, devices (e.g. smartphone, laptop, pc);
2. Check network coverage, if not available provide internet access or ask for;
3. Hire a software agency for the development of the software (FMIS, dashboard and app);
4. Co-design the system. A strong collaboration among the software agency, the advisors and the University is expected;
5. After a first release, the system will be tested by advisors within a limited number of pilot farms;
6. Once the system is stable, the technology will be extended to all the farms in the LL;
7. A training session with farmers and the cheese making factory is also expected;
8. Decide where to store FMIS and in case organise the system migration and buy new hardware or services (e.g. cloud storage);
9. Establish the maintenance interventions for software and hardware;
10. After an initial period of assessment and refinement, the technology could be considered stable and officially in use.

### 3.4. Procedure for Digitalising

**Follow this procedure in case your living lab identifies with the state *Digitalising* – digital solution *not fully adopted*, otherwise skip this paragraph.**

This procedure is divided into 4 STEPS, each step is composed of one or more questions.

#### Summary of the steps

- **STEP 1 – Digital solution**: present the digital solution that you have identified, then explain why you have chosen such digital solution in relation to the FAS in 3.1 and the problem statement in 3.2.
- **STEP 2 – Process before digital solution**: describe the current process providing information about actors and resources involved, and activities carried out; explain the weaknesses of the current process.
- **STEP 3 – Process after digital solution**: envision the process in the future and describe how the system will work after the digital solution will be adopted in all the LL.
- **STEP 4 – Transition**: provide information on the transition explaining how the LL will pass to the future process.

#### STEP 1 – Digital solution

##### 1. Which digital solution has the living lab decided to introduce?

Briefly describe the digital solution identified by the LL providing a concise description of the technological components involved and their role within the system.

Indicate the **level of maturity of the digital solution in the context of the LL** choosing one option from the following:

##### 1. **Proof of concept**

Idea being actively designed / discussed for future implementation; evaluation of feasibility and functionalities are under discussion.

##### 2. **Prototype**

Working model that demonstrates functionalities, user experience, and potential features in a “preview” fashion.

##### 3. **Pilot**

A prototype tested in a real-world environment with actual users to assess effectiveness, usability, and scalability.

##### 4. **Novel system**

A recently adopted solution (less than 3 years), mostly working, but still undergoing experimentation and refinement.

##### 5. **Mature system**

A fully developed system (being used since more than 3 years) that has undergone refinement, demonstrating stability, reliability, and efficiency.

Add any relevant information on the maturity of the digital solution in the LL and related challenges (e.g. number of farms involved, objectives, technological infrastructure, etc.).

**example**

The digital solution identified by the LL consists of a farm management information system (FMIS) to store information about sheep and milk production.

The FMIS will be used by the technical advisors (agronomist and veterinary) and all the farmers of the cooperative who will share the main facts about the animals (mainly productive and reproductive data). The actors working on the field will use a mobile app to access the FMIS and a bluetooth scanner connected to the app for identifying animals and sending data to the FMIS.

The system integrates several databases from different sources, such as the national animal registry (which is accessible by farmers or authorized intermediaries and contains mandatory identification data of owned livestock). The FMIS will also collect data coming from milk analyses, which are performed by the cheese factory and shared through a web service.

All the information in the FMIS will be accessible to different actors through a mobile app and a web dashboard; users will have different levels of access according to their roles

*[Maturity]*

The FMIS is currently a pilot, being tested by farm advisors and two farms. New functionalities are being co-developed within the LL.

**2. Explain why and how the living lab has identified this digital solution.**

Explain why the digital solution has been chosen, considering its suitability, feasibility and acceptability, as well as resources and capabilities available in the LL. Also explain how the digital solution has been identified, i.e. either if it was suggested by external experts or purchased independently by the farm, etc..

**example**

The solution addresses the weaknesses emerging from the problem statement. Integrating information managed by different actors, the FMIS will support advisors in the management of their work, the cheese factory in estimating milk quality and quantity and the farmers in the evaluation of expected income.

The solution has a high degree of feasibility, as the resources required are deemed to be sufficiently available in the LL. In terms of capabilities, the advisors are willing to learn the app and in the first phase, it will be extremely important the collaboration of the entire LL. This solution will bring advantages to all the stakeholders that will have economic benefits from access to data. The new process will contribute to further increasing the social relations within the LL, especially among the farmers who could count on a resource to support their productivity.

The FMIS is a product of co-design activities being carried out in the LL for more than ten years. The solution has been commonly agreed based on farmers' and researchers' needs. An IT company has been involved since the first design stages.

**STEP 2 – Process before digital solution**

**3. Who are the actors involved now?**

The question aims to identify the actors involved in the process. Since the digital solution is not yet fully adopted in the LL, describe the current process **without taking into consideration the new actors that will be involved after** the introduction of the digital solution (they will be presented in 7).

For each actor specify its role, the number of people in that role involved in the LL, and other relevant information.

*example*

- Farmers: sheep breeders. They form a dairy cooperative Caseificio Sociale di Manciano;
- Technical advisors: a veterinarian and an agronomist;
- Cheese making factory, also part of Caseificio Sociale di Manciano;
- University of Pisa (UNIFI), a group of researchers from the department of Agricultural, Food and Agro-Environmental Sciences. As formerly part of the UNIFI team, the technical advisors represent an interface between the cooperative and researchers;
- Public administration. They manage the national animal registry containing data about animals.

**4. What are the resources involved in the process?**

The question aims to identify all resources involved in the process.

Resources may refer to: physical assets (land, tractors, crops, animals, etc.); financing (funds); technologies (hardware and software solutions); knowledge (scientific reports, training, etc.). Feel free to take inspiration from previous project activities for the identification of resources.

**NOTE:** to support the assessment of the digital solution, it is important to provide a comprehensive description of the technologies involved. The data collection should be accurate to ensure that a complete list of all the tech components and the infrastructure needed for making the technology work is provided. If relevant, include information on the manufacturer, provider, product version, etc.

*example*

Physical resources

- sheep (single animal or flock, managed by a farm);
- tools for annotating resources (e.g. notebook);

Technological resources

- digital devices (mobile/desktop);
- local data storage or cloud storage for farm data (e.g. local database, spreadsheet);
- external databases (e.g. national/regional animal registry).

Knowledge resources

- results of milk analysis (from external labs);
- reports and publications.

**5. What are the activities carried out by actors using the available resources?**

The question aims to collect information to trace the current process. Starting from each actor listed in 3, identify all activities carried out which are relevant in the process and **provide a numbered sequence of activities**.

**NOTE: this is one of the most important questions, so please be exhaustive, and provide as much information as possible.**

If relevant, include information about the **frequency of the activities** (i.e. if they are carried out on daily, monthly, on a regular basis, etc.), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more actors are involved but they perform the SAME tasks, you do not need to repeat the activities for each actor.

Follow this structure to describe the activities: the **[ACTOR]** does **[ACTION]** because/to **[MOTIVATION]**.

You can also add further information (for example a **SPECIFIC CONDITION** or **FREQUENCY of ACTIVITY**), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

example

Farmer 1-2-3 (feeding)

1. On a monthly basis, the farmer asks the vet via text, whatsapp message, or telephone call to visit and monitor animals;
2. In case of a sanitary emergency, the farmer calls the vet to visit animals;
3. Every three months, the farmer contacts the agronomist via text, whatsapp or telephone to optimise the feeding plan in terms of cost and animals' health;
4. The farmer annotates on a notebook/digital device relevant facts about animals (e.g. birth, health problems, vaccinations, breeding...) to keep track of animals' health and wellbeing.

Farmer 4-5 (milking)

1. Every day, after milking, the farmer annotates on a notebook/digital device the amount of milk collected because wants to monitor the amount of milk produced;

Vet

1. The vet plans daily on a personal spreadsheet ordinary visits to the farms because wants to organise the work.
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet annotates data about animals on a notebook or a digital device because they wants to remember relevant facts about animals;
5. After any visit, the vet annotates results and registers the main events happened to a flock (new born, deaths, vaccines, etc ...) on a personal spreadsheet because they wants to keep records of animals' health status;
6. The vet accesses daily external data (e.g. animal registry) to keep track of animals' main facts;
7. The vet exchanges information about animals' health with the agronomist because they want to enhance the productivity of the animals;

Agronomist

1. The agronomist accesses monthly milk analysis results performed by an external lab because wants to optimise the feed ratios;
2. The agronomist plans daily on a personal spreadsheet ordinary visits to the farms because wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. The agronomist annotates monthly the optimal feeding plan for each farm and the results of milk analysis on a personal spreadsheet because they wants to keep records of feeding ratios;
5. The agronomist exchanges information about animals' feeding with the vet because they want to enhance the productivity of the animals;

Cheesemaking factory

1. Each month the cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. Each month the cheesemaking factory communicates milk analysis to the agronomist by providing access to data because it wants to formulate the optimal feed ratio;

University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.

Public institution

1. The Ministry of Health maintains an online animal registry which is accessed and updated by authorised professionals to keep track of animals.

**6. What are the weaknesses of the current process?**

The question aims to identify the weakness of the current process in terms of economic loss, waste of resources, and difficulties in process management. Refer to gaps in capabilities and resources already emerged from prior work, expand on them and provide examples of tasks that need to be improved.

example

There are difficulties at different levels:

- Information managed by different actors is not integrated;
- several spreadsheets are scattered among their respective owners, while other information is isolated, incomplete and sometimes repeated;
- data disaggregation and unstructured communication cause economic loss;
- the cheese factory is not capable of estimating milk quantity and quality;
- technical advisors struggle to manage on site interventions; without a scheduled calendar of the interventions agreed with farmers, they are not capable to organise in advance ordinary activities (e.g. vaccinations, feeding plans);
- farmers feel isolated in their business and have no clear idea of the expected income.

**STEP 3 – Process after digital solution**

**7. Will the introduction of the digital solution require the involvement of new actors?  
If yes, which ones?**

Start providing a list of the new actors who will be involved in the process transformed by the digital solution. For each one of the actors explain its role and the relationship with other actors and resources.

example

New actors will be involved for the maintenance of the system and hardware supply; they can be identified with:

- software agency (for the development of the software)
- software providers (optional, in support of software agency or in a second phase for data storage and maintenance);
- technology providers (for digital devices);
- assistance providers (for connectivity, software maintenance, assistance for devices, etc).

**8. Will the introduction of the digital solution remove existing actors from the current process?  
If yes, which ones?**

Based on the list provided in answer 3, assess the process in the future and list any **actors that will be removed**.

In certain cases, actors may be replaced by a technology that contributes to automating the system (e.g. robots, autonomous vehicles...), or by other actors with more technological skills (e.g. a drone pilot); if possible, connect the removed actors to the actors added in replacement.

example

The solution will remove the following actor:

- secretary of the cheesemaking factory who manually handles the milk analysis results, as these are automatically processed because of the introduction of the new FMIS.

**9. Which new resources will be added?**

Envision the system in the future and think about which resources (units and systems) will be added in the process. Based on the list of resources in 4, provide the list of added resources.

example

Technological resources

- Bluetooth tag scanner for vets in on-field activities (data access and data entry)
- server for data storage
- technological devices compatible with app (e.g smartphone/tablet/desktop)
- cloud storage and software

**10. Will the introduction of the digital solution remove resources from the current process?  
If yes, which ones?**

Based on the list in 4, provide the list of resources that will not be part of the process anymore.

**example**

Resources removed from the process are related to the previous way to store data.

Technological resources

- local data storage or cloud storage for farm data (e.g. local database, spreadsheet);

**11. What will be the activities carried out by actors using the resources?**

The question aims to collect information to trace the process transformed by the digital solution.

**NOTE: this is one of the most important questions, so please be exhaustive, and provide as much information as possible.**

Guidelines to perform this activity:

1. Copy-paste all the content that you wrote in answer 5
2. Remove the actors that will not be part of the process anymore and respective actions (list in 8)
3. Remove actions that will not be performed anymore
4. Add actors that belong to the envisioned process (list in 7), and a numbered sequence of respective actions
5. Add any other action that will be part of the process when the digital solution will be introduced

If relevant, include information about the **frequency of the activities** (i.e. if they are carried out on daily, monthly, on a regular basis, etc..), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more actors are involved but they perform the SAME tasks, you do not need to repeat the activities for each actor.

Follow this structure to describe the activities: the **ACTOR** does **ACTION** because/to **MOTIVATION**.

You can also add further information (for example a **SPECIFIC CONDITION** or **FREQUENCY of ACTIVITY**), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

example

Farmer 1-2-3 (feeding)

1. On a monthly basis, the farmer receives a notification from the vet via text or whatsapp message to plan a visit because he/she wants the health status of the animals to be monitored;
2. In case of a sanitary emergency, the farmer calls the vet because wants the animal to be visited;
3. On a monthly basis, the farmer receives a notification from the agronomist through sms or whatsapp to plan a meeting for discussing the feeding plan because they want the optimal feed plan in terms of economics and animals' health;
4. On a weekly basis, the farmer receives notifications from the FMIS through email with stats about productivity and quality performance of the farm and aggregated data about the performances in relation to other farms because they want to be updated with outcomes of their business;
5. If interested, the farmer accesses the dashboard or the app to record on the FMIS all the relevant facts about a sheep (e.g. birth, health problems, vaccinations, breeding...) because wants to keep track of all animals' health and wellbeing and share data with advisors;

Farmer 4-5 (milking)

1. Every day, after milking, the farmer accesses the dashboard or the app to record the amount of milk collected because wants to monitor the amount of milk produced;

Vet

1. The vet receives monthly a notification from the FMIS to schedule visits to the farms because they wants their work to be organised;
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet scans the animal through the bluetooth tag scan and accesses the app to annotate data about animals because they wants to record relevant facts about animals;
5. If needed, after a visit, the vet accesses the app or the dashboard to add new data or edit existing ones because they wants to keep up-to-date records of animals' health status;
6. The vet accesses the dashboard to see stats of farms productivity, data shared with the agronomist and data synchronised from external databases (e.g. animal registry) because they wants to enhance the productivity of the animals.

Agronomist

1. The agronomist accesses monthly the dashboard to see stats of farms productivity, data shared with the vet and data synchronised from external databases (e.g. milk analysis) because they wants to enhance the productivity of the animals.
2. The agronomist receives monthly a notification from the FMIS to schedule visits to the farms because they wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. During a visit, the agronomist accesses the app to annotate the optimal feeding plan for each farm because they wants to keep records of feeding ratios;
5. If needed, after a visit, the agronomist accesses the app or the dashboard to add new data or edit existing ones because they wants to keep records of feeding ratios;

Cheesemaking factory

1. On a monthly basis, the cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. On a monthly basis, the cheesemaking factory accesses the dashboard to see aggregated stats of farms productivity because it wants to estimate milk production;

University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.
2. Researchers from the University of Pisa access the dashboard to see aggregated stats of farms productivity because they want to enhance the LL productivity.

Public institution

1. The public institution offers a web service that provides interoperability between the national animal registry and the FMIS.

Software agency

1. The software agency maintains the software updated and provides assistance because they want the system to work in support of the LL.

Assistance provider

1. The assistance provider provides assistance services because they want the system to work in support of the LL;

Technology provider

1. Technology provider provides devices compatible with FMIS software and app because they want the system to work in support of the LL.

**STEP 4 – Transition**

**12. How is the living lab dealing with the transition to the new system?**

This question aims to support the LL in envisioning the process towards the adoption of the digital solution. Reflect on the transition phase for the adoption of the digital solution in the LL and provide a list of the progressive steps necessary for the setup of the system. Consider actors, resources, activities, capabilities, including e.g. training, and investments necessary to the adoption of the digital solution.

**example**

The transition includes approximately these consecutive steps:

1. Check network coverage in all the new farms adopting the system, if not available provide internet access or ask for;
2. The software agency organises the system migration in collaboration with an external provider in charge for data storage (e.g. cloud solution);
3. After the test of the prototype and refinements, the software agency provides a stable version of the FMIS, dashboard and app to be adopted in all the farms of the living lab;
4. A training session with farmers and the cheese making factory is organised;
5. Test of the system in all the farms. A strong collaboration among the software agency, the advisors and farmers is expected;
6. After an initial period of assessment and refinement, the technology can be considered stable and officially in use;
7. Plan system updates, maintenance interventions for software and hardware.

### 3.5. Procedure for Digitalised

**Follow this procedure in case your living lab identifies with the state *Digitalised – digital solution adopted*, otherwise skip this paragraph.**

This procedure is divided into 4 STEPS, each step is composed of one or more questions.

#### Summary of the steps

- **STEP 1 – Digital solution:** present the digital solution that you have identified, then explain why you have chosen such digital solution in relation to the FAS in 3.1 and the problem statement in 3.2.
- **STEP 2 – Process after digital solution:** describe the current process providing information about actors and resources involved and activities carried out; explain the advantages of the current process.
- **STEP 3 – Process before digital solution:** recall the process in the past and describe how the system worked before the introduction of the digital solution.
- **STEP 4 – Transition:** provide information on the transition explaining how the LL has passed to the current process.

#### STEP 1 – Digital solution

##### 1. Which digital solution did the living lab introduce?

Briefly describe the digital solution identified by the LL providing a concise description of the technological components involved and their role within the system.

Indicate the **level of maturity of the digital solution in the context of the LL** choosing one option from the following:

**1. Proof of concept**

Idea being actively designed / discussed for future implementation; evaluation of feasibility and functionalities are under discussion.

**2. Prototype**

Working model that demonstrates functionalities, user experience, and potential features in a “preview” fashion.

**3. Pilot**

A prototype tested in a real-world environment with actual users to assess effectiveness, usability, and scalability.

**4. Novel system**

A recently adopted solution (less than 3 years), mostly working, but still undergoing experimentation and refinement.

**5. Mature system**

A fully developed system (being used since more than 3 years) that has undergone refinement, demonstrating stability, reliability, and efficiency.



Add any relevant information on the maturity of the digital solution in the LL and related challenges (e.g. number of farms involved, objectives, technological infrastructure, etc.).

---

**example**

The digital solution introduced in the LL consists of a farm management information system (FMIS) to store information about sheep and milk production.

Data in the FMIS are updated by the technical advisors (agronomist and veterinary) and the farmers of the cooperative, adding data and events (such as productive and reproductive data). Actors in the field use a mobile app to access the FMIS and a bluetooth scanner connected to the app to identify the animals and share data with the FMIS.

The system integrates multiple web services providing additional data, such as those related to milk analyses that are managed by the cheese factory, and those from the national animal registry, which is managed by the Ministry of Health.

The information in the FMIS is accessible to different actors through a mobile app and a web dashboard; users have different levels of access to the system depending on their role.

**[Maturity]**

The FMIS is currently a mature system. After a first period of testing with a restricted number of farms, it has been used by the cheese factory and all the farms in the Cooperative for more than three years.

**2. Explain why and how the living lab has introduced this digital solution.**

Provide a motivation for having chosen the solution considering its suitability, feasibility and acceptability, as well as resources and capabilities available in the LL. Explain how the digital solution was identified, i.e. either if it was suggested by external experts or purchased independently by the farm, etc...

---

**example**

The solution resolved the weaknesses emerging from the problem statement. Integrating information managed by different actors, the FMIS supports advisors in the management of their work, the cheese factory in estimating milk quality and quantity and the farmers in the evaluation of expected income.

The resources required for the introduction of the digital solution were sufficiently available. In terms of capabilities, in a first phase it has been extremely important the collaboration of the entire LL for the co-design of the system.

This solution has brought advantages to all the stakeholders that have economic benefit from the access to shared data and new data produced by the system. The new process contributes to further increase the social relations within the LL, especially among the farmers that can now count on a shared resource in support of their productivity. The FMIS is a product of co-design activities being carried out in the LL for more than ten years. The solution has been commonly agreed based on farmers' and researchers' needs. An IT company has been involved since the first design stages.

---

**STEP 2 – Process *after* digital solution**

**3. Who are the actors involved now?**

The question aims to identify all actors involved in the current process. For each actor specify its role, the number of people involved in the LL and other relevant information.

**example**

- Farmers: sheep breeders. They form a dairy cooperative Caseificio Sociale di Manciano;
- Technical advisors: a veterinarian and an agronomist;
- Cheese making factory, also part of Caseificio Sociale di Manciano;
- University of Pisa (UNIFI), a group of researchers from the department of Agricultural, Food and Agro-Environmental Sciences. As formerly part of the UNIFI team, the technical advisors represent an interface between the cooperative and researchers;
- a spin-off company specialised in agritech, hired by the LL for the development of FMIS, application, dashboard;
- software providers (in support of software agency for data storage and maintenance);
- technology providers (for digital devices);
- assistance providers (for connectivity, software maintenance, assistance for devices, etc).

**4. What are the resources involved in the process?**

The question aims to identify all resources involved in the process. Resources may refer to: physical assets (land, tractors, crops, animals, etc.); financing (funds); technologies (hardware and software solutions); knowledge (scientific reports, training, etc.). Feel free to take inspiration from previous project activities for the identification of resources.

**NOTE:** to support the assessment of the digital solution, it is important to provide a comprehensive description of the technologies involved. The data collection should be accurate to ensure that a complete list of all the tech components and the infrastructure needed for making the technology work is provided. If relevant, include information on the manufacturer, provider, product version, etc.

example

Physical resources

- sheep (single animal or flock, managed by a farm);

Technological resources

- bluetooth tag scan in use by the vet for on field data access and data entry;
- server for data storage;
- technological devices compatible with app (e.g smartphone/tablet/desktop);
- cloud storage and FMIS software

Knowledge resources

- milk analysis (from external labs)
- reports and publications

**5. What are the activities carried out by actors using the available resources?**

The question aims to collect information to trace the current process. Starting from each actor listed in 3, identify all activities carried out which are relevant in the process and **provide a numbered sequence of activities**.

**NOTE:** this is one of the most important questions, so please be exhaustive, and provide as much information as possible.

If relevant, include information about the **frequency of the activities** (i.e. if they are carried out on daily, monthly, on a regular basis, etc..), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more actors are involved but they perform the SAME tasks, you do not need to repeat the activities for each actor.

Follow this structure to describe the activities: the [ACTOR] does [ACTION] because/to [MOTIVATION].

You can also add further information (for example a [SPECIFIC CONDITION] or [FREQUENCY of ACTIVITY]), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

example

Farmer 1-2-3 (feeding)

1. On a monthly basis, the farmer receives a notification from the vet via text or whatsapp message to plan a visit because he/she wants the health status of the animals to be monitored;
2. In case of a sanitary emergency, the farmer calls the vet because wants the animal to be visited;
3. On a monthly basis, the farmer receives a notification from the agronomist through sms or whatsapp to plan a meeting for discussing the feeding plan because they want the optimal feed plan in terms of economics and animals' health;
4. On a weekly basis, the farmer receives notifications from the FMIS through email with stats about productivity and quality performance of the farm and aggregated data about the performances in relation to other farms because they want to be updated with outcomes of their business;
5. If interested, the farmer accesses the dashboard or the app to record on the FMIS all the relevant facts about a sheep (e.g. birth, health problems, vaccinations, breeding...) because wants to keep track of all animals' health and wellbeing and share data with advisors;

Farmer 4-5 (milking)

1. Every day, after milking, the farmer accesses the dashboard or the app to record the amount of milk collected because wants to monitor the amount of milk produced;

Vet

1. The vet receives monthly a notification from the FMIS to schedule visits to the farms because they wants their work to be organised;
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet scans the animal through the bluetooth tag scan and accesses the app to annotate data about animals because they wants to record relevant facts about animals;
5. If needed, after a visit, the vet accesses the app or the dashboard to add new data or edit existing ones because they wants to keep up-to-date records of animals' health status;
6. The vet accesses the dashboard to see stats of farms productivity, data shared with the agronomist and data synchronised from external databases (e.g. animal registry) because they wants to enhance the productivity of the animals.

Agronomist

1. The agronomist accesses monthly the dashboard to see stats of farms productivity, data shared with the vet and data synchronised from external databases (e.g. milk analysis) because they wants to enhance the productivity of the animals.
2. The agronomist receives monthly a notification from the FMIS to schedule visits to the farms because they wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. During a visit, the agronomist accesses the app to annotate the optimal feeding plan for each farm because they wants to keep records of feeding ratios;
5. If needed, after a visit, the agronomist accesses the app or the dashboard to add new data or edit existing ones because they wants to keep records of feeding ratios;

Cheesemaking factory

1. On a monthly basis, the cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. On a monthly basis, the cheesemaking factory accesses the dashboard to see aggregated stats of farms productivity because it wants to estimate milk production;

University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.
2. Researchers from the University of Pisa access the dashboard to see aggregated stats of farms productivity because they want to enhance the LL productivity.

Public institution

1. The public institution offers a web service that provides interoperability between the national animal registry and the FMIS.

Software agency

1. The software agency maintains the software updated and provides assistance because they want the system to work in support of the LL.

Assistance provider

1. The assistance provider provides assistance services because they want the system to work in support of the LL;

Technology provider

1. Technology provider provides devices compatible with FMIS software and app because they want the system to work in support of the LL

**6. What are the advantages of the current process for each actor?**

The question aims to identify in which ways the digital solution is helping the different actors to improve the current process in terms of economic increase, resource optimisation, and advantages in process management. Starting from the problem statement, provide examples of tasks that have improved after the introduction of the digital solution.

example

Information managed by different actors is now well integrated into the FMIS. Data aggregation and structured communication has brought economic advantages and major benefits to all stakeholders.

The main advantages are the following:

- The FMIS supports the cheese factory in managing the activities. The expected milk quality and quantity is now correctly estimated; this allows the factory to allocate the right amount of resources for production;
- Technical advisors have adopted the app for the management of on site interventions. Furthermore, they use the FMIS as a decision supporting system in ordinary activities (i.e., feed ratios, health monitoring);

- Farmers interact with the FMIS to receive up-to-date information about health status and feeding of their sheeps, evaluate expected income and access stats about their business performances;
- Globally, the LL benefits from the introduction of the technology because information provided by FMIS help to evaluate the performance of the LL and schedule future activities.

**STEP 3 – Process *before* digital solution**

**7. Has the introduction of the digital solution required the involvement of new actors?  
If yes, which ones?**

Think about the process before the introduction of the digital solution. Start from the list of actors provided in 3 and identify the actors that have been involved with the introduction of the digital solution. For each one of the actors explain its role and the relationship with other actors and resources.

*example*

New actors were involved for the maintenance of the system and hardware supply; they can be identified with:

- a spin-off company specialised in agritech, hired by the LL for the development of FMIS, application, dashboard;
- software providers (in support of software agency for data storage and maintenance);
- technology providers (for digital devices);
- assistance providers (for connectivity, software maintenance, assistance for devices, etc).

**8. Have actors been removed because of the introduction of the digital solution?  
If yes, which ones?**

Focus on the process *before* the introduction of the digital solution and think if any actor was removed from the process after the introduction of the digital solution. If possible, connect the removed actors to the actors added in replacement (list in question 3).

*example*

The solution removed the following actor:

- secretary of the cheesemaking factory who manually handles the milk analysis results, as these are automatically processed because of the introduction of the new FMIS.

**9. Which new resources have been added?**

Think about the process before the introduction of the digital solution. Start from the list of resources provided in 4 and identify the resources that have been added with the introduction of the digital solution. Provide the list of added resources.

*example*

Technological resources

- Bluetooth tag scanner for vets in on-field activities (data access and data entry)
- server for data storage
- technological devices compatible with app (e.g smartphone/tablet/desktop)
- cloud storage and software

**10. Which resources have been removed?**

Think about the process *before* the introduction of the digital solution. Based on the list of resources in 4, list any resources which have been removed from the current process.

*example*

Physical assets

- tools for data recording (notebooks, pens, etc);

Technological resources

- local data storage or cloud storage for farm data (e.g. local database, spreadsheet)

**11. Before the introduction of the digital solution, how were the activities carried out by actors?**

The question aims to collect information to trace the process before the introduction of the digital solution.

**NOTE:** this is one of the most important questions, so please be exhaustive, and provide as much information as possible.

Guidelines to perform this activity:

1. Copy-paste all the content that you wrote in answer 5
2. Remove the actors that were not part of the process when the digital solution was not introduced and respective actions (list in 7)
3. Remove any other action that was not part of the process when the digital solution was not introduced yet
4. Add actors that belonged to the previous process (list in 8), and a numbered sequence of respective actions
5. Add any other action that was part of the process when the digital solution was not introduced yet

If relevant, include information about the **frequency of the activities** (i.e. if they are carried out on daily, monthly, on a regular basis, etc.), the resources used and other actors involved in the activity.

In case more than one actor (e.g., farmer) is involved in the process and they perform DIFFERENT tasks, repeat each actor grouping their activities. You can also use different names according to their specialised role. For instance: farmer 1-2-3 –feeding, farmer 4-5 – milking, ...

Instead, if more farmers are involved but they perform the SAME tasks, you do not need to repeat the activities for each farmer.

Follow this structure to describe the activities: the **ACTOR** does **ACTION** because/to **MOTIVATION**.

You can also add further information (for example a **SPECIFIC CONDITION** or **FREQUENCY of ACTIVITY**), but the ACTOR, ACTION and MOTIVATION shall be present.

**You do not need to add the colours to your text.** These are added to the examples below to clarify the meaning of ACTOR, ACTION, MOTIVATION and SPECIFIC CONDITION/FREQUENCY of ACTIVITY in a real context.

example

Farmer 1-2-3 (feeding)

1. **On a monthly basis**, **the farmer** asks the vet via text, whatsapp message, or telephone call **to visit and monitor animals**;
2. **In case of a sanitary emergency**, **the farmer** calls the vet **to visit animals**;
3. **Every three months**, **the farmer** contacts the agronomist via text, whatsapp or telephone **to optimise the feeding plan in terms of cost and animals' health**;
4. **The farmer** **annotates on a notebook/digital device relevant facts about animals** (e.g. birth, health problems, vaccinations, breeding...) **to keep track of animals' health and wellbeing**.

Farmer 4-5 (milking)

1. Every day, after milking, the farmer annotates on a notebook/digital device the amount of milk collected because wants to monitor the amount of milk produced;

#### Vet

1. The vet plans on a personal spreadsheet ordinary visits to the farms because wants to organise the work.
2. The vet visits each farm monthly to monitor the health status of animals;
3. In case of emergency, the vet goes to the farm to visit an animal;
4. During a visit, the vet annotates data about animals on a notebook or a digital device because they wants to remember relevant facts about animals;
5. After any visit, the vet annotates results and registers the main events happened to a flock (new born, deaths, vaccines, etc ...) on a personal spreadsheet because they wants to keep records of animals' health status;
6. The vet accesses external data (e.g. animal registry) to keep track of animals' main facts;
7. The vet exchanges information about animals' health with the agronomist because they want to enhance the productivity of the animals;

#### Agronomist

1. The agronomist accesses milk analysis performed by an external lab because wants to optimise feed ratios;
2. The agronomist plans on a personal spreadsheet ordinary visits to the farms because wants to monitor the animals' feeding;
3. The agronomist visits each farm monthly to agree with the farmers on the optimal feeding plan;
4. The agronomist annotates the optimal feeding plan for each farm and the results of milk analysis on a personal spreadsheet because they wants to keep records of feeding ratios;
5. The agronomist exchanges information about animals' feeding with the vet because they want to enhance the productivity of the animals;

#### Cheesemaking factory

1. The cheesemaking factory analyses milk through an external laboratory because wants to estimate milk value and quality of cheese;
2. The cheesemaking factory communicates milk analysis to the agronomist by providing access to data because it wants to formulate the optimal feed ratio;

#### University of Pisa

1. Researchers from the University of Pisa exchange communication with advisors because they want to monitor and support the LL.

**STEP 4 – Transition**

**12. How did the living lab deal with the transition to the new system?**

Reflect on the transition phase necessary for the adoption of the digital solution in the LL and recall resources and capabilities needed for setting up the system and adopting the digital solution. Formulate the answer as a list of progressive steps, starting from actors, resources and activities which have been carried out, up to training and maintenance.

---

**example**

The transition included approximately these consecutive steps:

1. Purchase of all necessary hardware for all the farms adopting the system: bluetooth tag readers, devices (e.g. smartphone, laptop, pc);
  2. Network coverage check in all the farms adopting the system. If not available, internet access was provided;
  3. Co-design and development of the software (FMIS, dashboard and app) by a software agency, in collaboration with technical advisors and the University;
  4. After an initial period of assessment and refinement with pilot farms, the technology was considered stable and officially adopted in all the farms.
  5. The software agency organised the system migration in collaboration with an external provider in charge for data storage (based on a cloud solution);
  6. Several training sessions with farmers and the cheese making factory were organised;
  7. Test of the system in all the farms;
  8. Execute the maintenance interventions for software and hardware.
-

## 4. Hints to conduct data collection

A few hints:

- The information is focused on technology – even if you are sceptical about a digital solution, try to reflect on how things change after its adoption.
- No need to push ICT-heavy solutions. Identify the digital solution of interest for the LL and strive to fully describe it through the process modelling methodology, assess why and how it can support local activities, and collectively reflect on the transformation occurred to the business process.
- Consistency: always use the same name to refer to the same thing (no synonyms), especially in writing.
- No need for complex outputs, keep the answers clear and simple and follow the proposed structure and examples. Especially for the activities list, it is better to have 5 simple and clear task descriptions than 3 too complex to handle.
- We just require the information to be reported according to the questions in the template (template are available in the folder [Task 3.3](#)).
- The information required may have been already collected in the WP3 workshop and WP4 focus group held in October-November 2023, or in previous interviews and LL meetings. First, refer to previous reports and fill the template with this already collected information, then organise new data collection activities with key informants that can complement the information.
- You choose the most appropriate method for data collection. We recommend that you coordinate with other project activities. For example, you can decide to organise single and group interviews with key informants of the LL merging questions coming from other project activities. (See next section for a timeline of suggested activities).

### IMPORTANT NOTES:

- You will likely perform data collection by means of interviews (including group interviews) and public focus groups or workshops. In these cases, you are highly encouraged to share the transcripts of the interviews and focus groups. To produce the transcripts, you should **record** the conversations, and transcribe them (also using automated transcription software). The transcriptions shall be anonymised.
- If your organization **already has informed consent documents**, please use those, and share the anonymised transcripts.
- The transcriptions shall be uploaded, along with reports and additional material, in the dedicated folder that will be created for each LL in the in the main folder [LL Reports](#).
- If you are sharing the transcriptions, you should make sure that your interview/focus group participants fill in the **informed consent documents** in the folder [Informed Consent Documents](#).
  - If you are performing an interview, including group interviews, ask your participant to read and sign the following documents: **1\_GeneralInfoTreatmentPersonalData, 2a\_NonAnonymousInterviews\_Information Sheet, 2b\_NonAnonymousInterviews\_Consent form**;
  - If you are performing a public event (focus group or workshop), ask your participant to sign the following documents: **2b\_NonAnonymousInterviews\_Consent form, 5b\_PublicParticipation-FocusGroup\_ConsentForm, 5a\_PublicParticipation-FocusGroup\_InformationSheet**.
- Before using the informed consent documents, these need to be completed and translated in the local language.

## 5. Training

A training activity will be carried out in February 2024 by task leaders to explain the methodology and the expected results from LLs. Additional training meetings will be organised with LLs, if necessary, before the validation workshop to be held in October-November 2024.

## 6. Reporting and validation

LL coordinators are responsible for the data collection activities and for reporting the results. A template to be followed is provided for reporting.

According to the state of digitalisation of the LL ([see 3.2](#)), LL coordinators are asked to fill one of the three alternative templates available in the folder [Task 3.3](#):

- **Case 1 – *Zero digital* Reporting Template**
- **Case 2 – *Digitalising* Reporting Template**
- **Case 3 – *Digitalised* Reporting Template**

A final section of the template is dedicated to gathering feedback through a short survey and two open questions. Additional materials, including transcripts of the workshops, focus groups, and single and group interviews, are requested as well.

LL coordinators are kindly asked to fill in accurately all the parts of the template and verify that the transcripts have been correctly anonymised before uploading.

A dedicated folder will be created for each LL in the main folder [LL Reports](#) to **upload the reporting template** and additional materials. LLs are asked to notify task leaders when the template is uploaded.

After completing the reporting template and handing it back **by 15th May 2024**, the description of the process will be formalised by the task leaders through the creation of diagrams. If necessary, task leaders will ask for additional information and feedback.

A plenary workshop will be carried out by each LL in October-November 2024 to collectively validate the data contained in the report. If additional data will emerge from the validation, an updated version of the report will be delivered to task leaders within January 2025.

The final phase of the activity will be held from February 2025 to September 2025 with further interactions between LL coordinators and task leaders. The process diagrams will be discussed and checked for consistency by the LLs, concluding this activity.

## 7. References

“Business Process Model and Notation (BPMN)”, Version 2. <https://www.omg.org/spec/BPMN/2.0/>, 2015 — Online; accessed 2 February 2024.

“Unified Modeling Language (UML) 2.5.1 Core Specification”, Version 2.5.1. <https://www.omg.org/spec/UML>, 2017 — Online; accessed 2 February 2024.

“iStar 2.0 Language Guide”, Version. <https://sites.google.com/site/istarlanguage/home>, 2016 — Online; accessed 2 February 2024.

M. Dumas, M. La Rosa, J. Mendling and H.A. Reijers, “Fundamentals of Business Process Management”. Springer, 2018.

A. Ferrari, M. Bacco, K. Gaber, A. Jedlitschka, S. Hess, J. Kaipainen, P. Koltsida, E. Toli and G. Brunori, “Drivers, Barriers and Impacts of Digitalisation in Rural Areas from the Viewpoint of Experts”. Information and Software Technology, Elsevier 145, 2022.

C. Mannari, G. O. Spagnolo, M. Bacco and A. Malizia “Digitalisation of Agriculture: Development and Evaluation of a Model-based Requirements Engineering Process”, REFSQ 2023 – 29th International Working Conference on Requirement Engineering: Foundation for Software Quality: Posters and Tools, Barcelona, Spain, 17-20/04/2023, 2023.

C. Mannari, M. Bacco, A. Ferrari, L. Ortolani, M.B. Lai, C. Mignani, A. Silvi, A. Malizia, G. Brunori: A methodology for process modelling in living labs to foster agricultural digitalisation. In: 2023 IEEE MetroAgriFor. 2023.

K. Rijswijk, L. Klerkx, M. Bacco, F. Bartolini, E. Bulten, L. Debruyne, J. Dessein, I. Scotti and G. Brunori, “Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsabilisation”. Journal of Rural Studies, Volume 85, 2021.

E. Yu, P. Giorgini, N. Maiden, J. Mylopoulos and S. Fickas, “Social Modeling for Requirements Engineering”, The MIT Press, 2011.



## T3.3 – FARM SOCIO-TECHNICAL PROCESS MODELLING

### CHECK AND FORMALISATION PHASE

### GUIDELINES FOR MODELLING

25 JULY 2025

MANLIO BACCO (CNR), ALESSIO FERRARI (CNR), CHIARA MANNARI (CNR)



Co-funded by  
the European Union

CODECS has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060179. UK participants in Project CODECS are supported by UKRI grant numbers 10039965 (James Hutton Institute) and 10041831 (University of Southampton). 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.

## Introduction

As part of CODECS Task 3.3 - Farm Socio-technical Process Modelling, the T3.3 team applied a **systematic modelling approach** based on guidelines provided by the Task Leaders.

The Annex is composed of two documents:

- **Guidelines for Modelling – procedure for *Digitalising***
- **Guidelines for Modelling – procedure for *Digitalised***

# Procedure Report-to-Diagrams

## CODECS Socio-technical process modelling

### Procedure for Digitalising

*CNR*

*Version 1 - 5 June 2024*

<b>Introduction</b>	<b>3</b>
Common terms	4
<b>Checklist</b>	<b>6</b>
<b>Diagrams</b>	<b>8</b>
Goal diagram	8
Structure diagram	10
Process diagrams	12
<b>Modelling software and templates</b>	<b>14</b>
Suggested tools	14
Templates	14
<b>Overview: questions to diagrams</b>	<b>15</b>
<b>Procedure</b>	<b>17</b>
<b>Goal diagram - iStar</b>	<b>17</b>
1) Actors and Technology boundary	17
2) Goals	17
3) Tasks	18
4) Tools	19
5) Connections	19
6) Export and save	20
<b>Structure diagram - UML</b>	<b>20</b>
1) Technology	20
2) Actors and resources	20
3) Connections	21
4) Export and save	22
<b>Process diagrams - BPMN</b>	<b>23</b>
Diagram 1: BPMN process after	23
1) Actor pools	23
2) Start/End process	23
3) Tasks	24
4) Connections	24
5) Gateways	24
6) Text annotations	25
7) Export and save	25
Diagram 2: BPMN process before	26
1) Actor pools	26
2) Tasks, connections, gateways	26
3) Export and save	26
Diagram 3: BPMN processes overlap	26
1) Actor pools	26
2) Green elements	27
3) Red elements	27
4) Blue elements	27
6) Export and save	27

# Introduction

As part of CODECS Task 3.3 - Farm Socio-technical Process Modelling, this document presents the procedure for creating the process diagrams starting from the **Living Lab Reports case *Digitalising***. This document is oriented to the task leaders' collaborators, who will check the consistency of the reports and create the diagrams.

The reports are the output of previous activities carried out by Living Lab coordinators, who performed data collection through interviews and group discussions involving the Living Lab participants and filled in the template file according to the guidelines provided (refer to [Task 3.3 Folder](#) for further information).

The objective of the process modelling activity is to create easy-to-read diagrams of processes carried out in a farm before and after the introduction of digital solutions. The output of the activity will allow to focus on the transformation that occurred to a process after the introduction of a digital solution and will contribute to the cost-benefit analysis.

To ensure completeness, the following diagrams are developed, based on the data from the reports:

- the **goal diagram** models the goals of the process focusing on the intentional, social, and strategic dimensions;
- the **structure diagram** provides an overview of the entities, i.e., actors, tools, infrastructures, and systems involved in the process and the relationships among them;
- the **process diagrams** represent the detailed flow of the process and will allow comparisons between the process before and after the introduction of the digital solution.

The goal and the structure diagrams focus on the process *after* the introduction of digital technology (process *as-is*), whereas the process diagram focuses both on the process *after* (process *as-is*) and on the process *before* the introduction of the digital technology (process *as-is*).

A set of languages for graphical representation from software engineering has been identified, so the diagrams will be developed using the following notations: iStar, goal diagram; UML, structure diagram; BPMN, process diagrams.

To maximise the readability of the diagrams a small set of elements for each notation has been selected. Furthermore, the authors adopted a modified style for the iStar notation by

creating an enhanced version consisting of icons for representing actors and a different style for the symbols. This is to obtain more user-friendly representations.

Chapter 2 presents the checklist to be applied in the preliminary step of revision of the reports before starting the diagram creation. Depending on the quality of the data contained in the reports, further iterations with LLs may be needed. Chapter 3 provides an explanation by example of the diagrams to be created. Chapter 4 contains hints on the software for creating the diagrams and provides access to three templates. Chapter 5 presents an overview of the contents to be extracted from the reports. Chapter 6 contains step-by-step instructions on how to create the diagrams.

## Common terms

Actor – individuals, groups, or system components that play a role in the process;

Diagram – a visual representation of information, typically simplified and structured to convey a specific concept or set of relationships among components;

Focal Action Situation (FAS) – a situation where components of a socio-technical system interact to provide an outcome;

Goal – is a desired outcome or target that an actor or group of actors aims to achieve within a specific process or task;

Goal diagram – a type of diagram used to represent the actors' goals, relationships and dependencies within a process;

Living Lab (LL) – 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;

Model – a simplified representation or abstraction of reality designed to explain, predict, or analyse aspects of the real world. Models can take various forms depending on their purpose and the field in which they are used;

Notation – a system of symbols, signs, or characters used to represent information in a concise and standardised way;

Problem statement – a concise description of an issue or challenge that needs to be addressed;

Process – a sequence of steps performed by actors to address an objective, for example, irrigation or cattle monitoring;

Process as-is – process *before* the introduction of a digital solution;

Process diagram – a type of diagram that illustrates the sequential tasks, interactions, or events from the beginning to the end of a process;

Process modelling – the act of creating a visual representation or abstraction of a process in order to understand, analyse, communicate, and improve it;

Process to-be – process *after* the introduction of a digital solution;

Resource – tangible and intangible) assets owned or accessed by the LL and utilised to create value, achieve an objective, or solve a problem;

Structure diagram – a type of diagram used to represent the structure of a process by illustrating its static aspects, such as actors, resources, composition, and arrangement of the system;

Task – a specific, defined activity that needs to be completed as part of a larger process;

Tech component – an individual part or element of a tech system. Each component has a specific function and contributes to the overall operation of the system;

Tech system – an interconnected set of hardware, software, data, and procedures designed to perform specific functions and achieve certain goals;

# Checklist

This checklist applies to the **Living Lab Reports case *Digitalising***. Please answer the questions below to verify whether the information in the report can be used for the purposes of T 3.3 (process modelling).

In the case some inconsistencies or missing information are highlighted by your answers to the checklist, please check the report and fill in the *Notes* field indicating what answers can integrate the information (example: STEP 19: *The answer in 5.5 contains a clear list of actions associated with the actors of the process after* - NO. Notes: missing information is related to activities that do not change and can be complemented by actions listed in 4.3).

If you think that missing information cannot be integrated, fill in the field *Question for LL coordinator* with the question to be asked in future iterations (example: STEP 17: *The answer in 5.5 contains a clear list of actions associated with the actors of the process after* - NO. Notes: no information is provided for drone pilot. Question for LL coordinator: in the list of added actors in 4.4. a drone pilot is mentioned but no information is provided in 5.5 about the actions performed by this actor. Could you please integrate 5.5 with a list of actions performed by the drone pilot? Please also indicate the frequency).

	Y E S	N O	Step	Notes	Question for LL coordinator
1			Answers 1.2 and 1.3 are sufficiently informative to gain an understanding of the living lab context		
2			Based on the example table provided, the answer in 1.4 includes all the information		
3			The description of the focal action situation in 2.1 is exhaustive and the problem statement in 2.2 is consistent		
4			The state of digitalisation matches the information provided in 2.1 and 2.2		
5			The answer in 3.1 clearly identifies the specific digital solution introduced by the living lab and is sufficiently detailed		
6			Based on your background and understanding of the context, the list of actors in 4.1 is complete		

7			Based on your background and understanding of the context, the list of resources in 4.2 is complete		
8			The actors mentioned in 4.3 are consistent with the list in 4.1		
9			Based on your background and understanding of the context, the list of actions in 4.3 is complete		
10			The answer in 4.3 provides sufficient information on the process frequency, motivation and actors' relationships		
11			Actors removed in the process <i>after</i> in 5.2 are listed in the process <i>before</i> in 4.1, while added actors in 5.1 are not listed in 4.1		
12			A list of the relevant actors involved in the process <i>after</i> can be extracted from 4.1, 5.1 and 5.2		
13			Based on your background and understanding of the context, the list of actors in the process <i>after</i> that can be extracted from 4.1, 5.1 and 5.2 is complete		
14			The technological resources in 5.3 are consistent with the digital solution in 3.1		
15			Based on your background and understanding of the context, the list of resources in 5.3 is complete		
16			Resources removed in the process <i>after</i> in 5.3 are listed in the process <i>before</i> in 4.2, while added resources in 5.4 are not listed in 4.2		
17			The answer in 5.5 contains a clear list of actions associated with the actors of the process <i>after</i>		
18			Based on your background and understanding of the context, the list of actions in 5.5 is complete		
19			The answer in 5.5 provides sufficient information on the process frequency, motivation and actors' relationships		
20			A list of goals associated with each actor can be extracted from 3.2, 4.4, 5.5 and 2.1		

# Diagrams

The process modelling methodology is based on a set of different diagrams leveraging on standard notations from software engineering.

According to the process modelling methodology, to ensure completeness of the process representation, the following diagrams are developed: (1) goal diagram - process after; (2) structure diagram - process after; (3) process diagram - process before; (4) process diagram - process after; (5) processes overlap.

As the report refers to a **Digitalising case**, we identify the process in the present as the process *before* the introduction of digital technology, i.e., the process *as-is* and the process in the future as the process *after* the introduction of digital technology, i.e., the process *to-be* (refer to the [CODECS T3.3-Process-Modelling-Guidelines](#) and [Template-DIGITALISING](#) for further information).

This section introduces the different types of diagrams providing a legend and an explanation of the symbols used.

## Goal diagram

The goal diagram models the goals of the process *after* focusing on the intentional, social, and strategic dimensions.

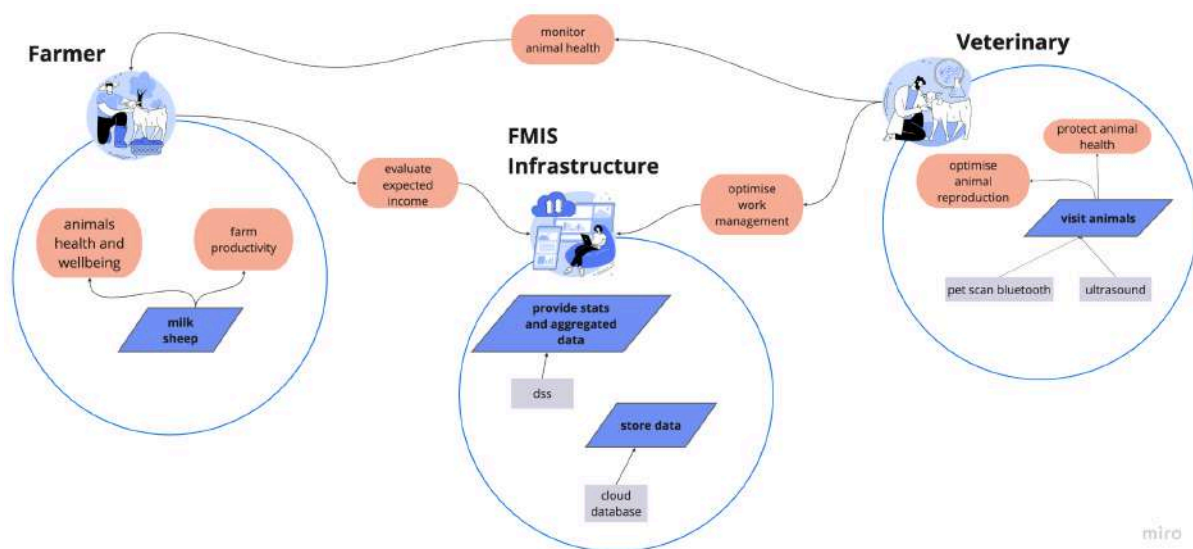


Figure 1: Example of a goal diagram

Figure 1 contains an example of a goal diagram for a Farm Management Information System in the context of a cheese production process. For this type of diagram, we adopt a modified

style for the iStar notation by creating an enhanced version consisting of icons for representing actors and a different style for the symbols.

The complete case study can be downloaded here: [iStar goal diagram](#)

## Legend

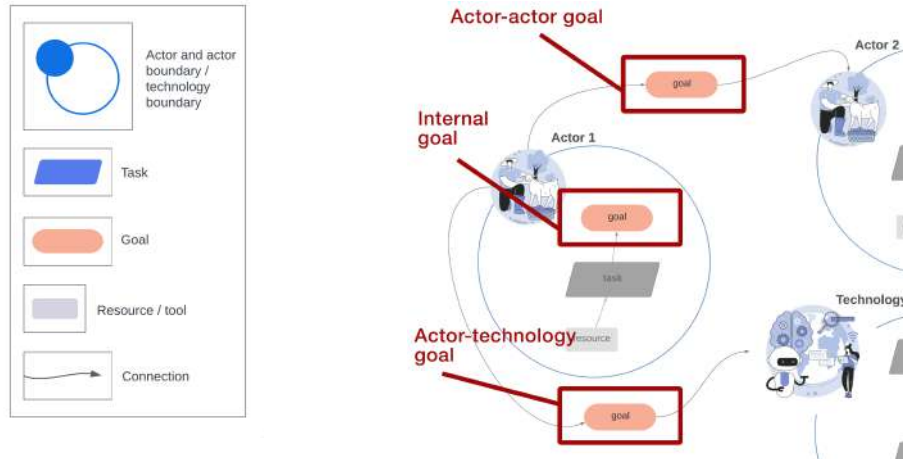


Figure 2: Legend of symbols used (on the left); portion of diagram with types of goals highlighted (on the right).

## Explanation of symbols

**Actor:** an active, autonomous entity that performs tasks by exercising its know-how, in collaboration with other actors;

**Actor boundary:** contains all tasks, goals and resources/tools related to a single actor;

**Technology boundary:** same as actor boundary but with no goals associated;

**Task:** represents an action that an actor wants to be executed;

**Resource/tool:** a physical or informational entity that actors require to perform tasks

**Goal:** a state of affairs that the actor wants to achieve;

### *Types of goals*

**Internal goals:** actor's goals within its activity/role;

**Actor-actor goals:** actor's goals with respect to other actors;

**Actor-technology goals:** actor's goals with respect to digital technology

## Structure diagram

The structure diagram provides an overview of the entities, i.e., actors, tools, infrastructures, and systems involved in the process *to-be* and the relationships among them.

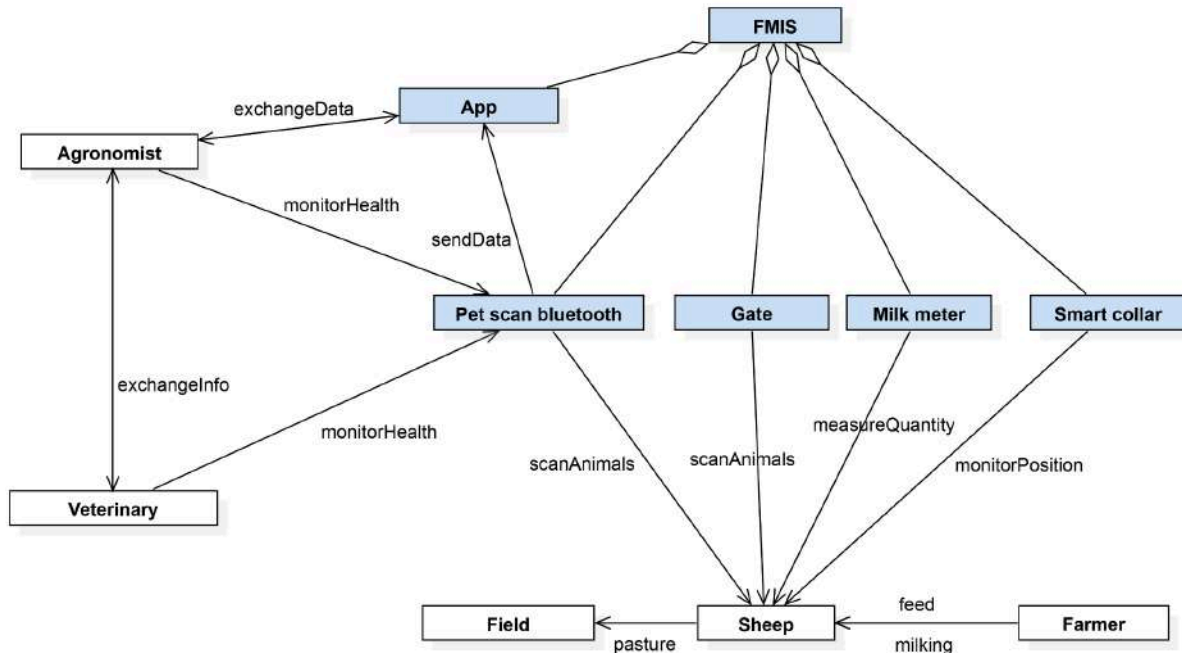
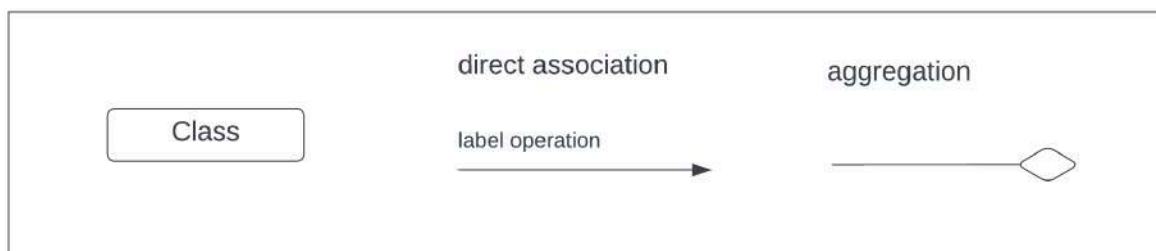


Figure 3: Example of a structure diagram

Figure 3 contains an example of a UML class diagram for a Farm Management Information System in the context of a cheese production process.

The complete case study can be downloaded here: [UML class diagram](#)

## Legend



## Explanation of symbols

**Class:** defines the core elements, i.e., actors and resources. It is represented by a box with a title label;

**Operations:** the operations are performed by a class interacting with another class;

**Relations:** connect classes and are expressed by arrows.

### *Types of relations*

**Direct association:** connects two classes by means of an operation. The arrow is directed from the active class which starts the operation to the passive class that is the recipient. Arrows placed in both directions mean that the two classes are both active.

**Aggregation:** means that a class is part of another class. This type of relation can be used to represent technological systems and components.

## Process diagrams

The process diagrams represent the detailed flow of both the process *before* and the process *after*. The overlap of the two representations allows comparisons between the process before and after the introduction of the digital solution.

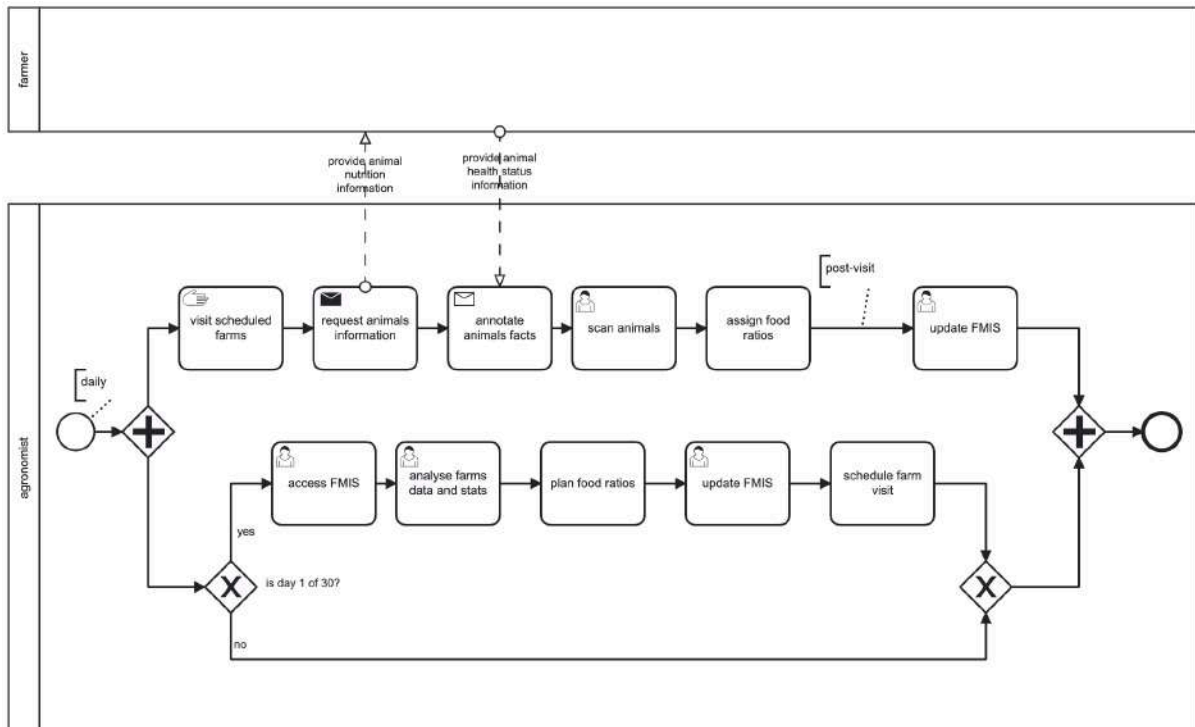


Figure 4: Example of a process diagram

Figure 4 contains an example of a BPMN diagram for a Farm Management Information System in the context of a cheese production process. This example represents the agronomist's process *after* the introduction of the Farm Management Information System (the process *to-be*).

The complete example containing multiple views from the perspective of multiple actors and the high-resolution images can be downloaded here: [Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#).

An additional example of process diagrams for a Precision Irrigation System in the context of a fruit farm can be downloaded here:

[Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#)

The model represents a single view of the global process.

## Legend

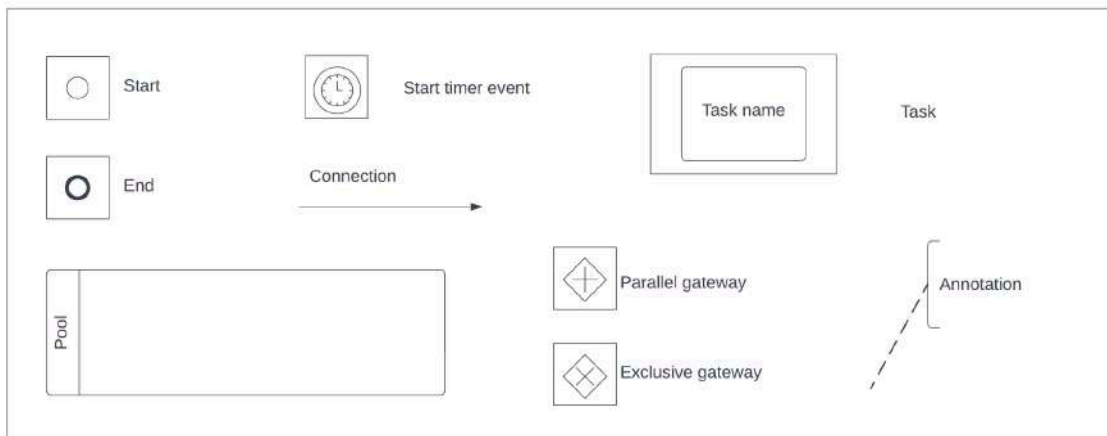


Figure 2: Legend of BPMN symbols used

## Explanation of symbols

**Start event:** the starting point of a process;

**Start timer event:** a start event containing a message and triggered by another process;

**End event:** the ending point of a process;

**Task:** an atomic activity within a process flow. It can be of different types: manual, service, send, receive;

**Parallel gateway:** used to create concurrent paths within a process flow; for a single execution of the process, the paths can be taken in parallel;

**Exclusive gateway:** used to create alternative paths within a process flow. For a single execution of the process, only one of the paths can be taken;

**Pool:** A pool represents a participant who takes part in a process. All actions performed by the participant are represented inside the same pool. If multiple participants are involved in a process, multiple pools are defined. Each pool has a start and end event.

**Connection:** link with arrows between tasks and/or pools. Connections between pools represent communication flows and are represented with dashed lines.

**Text annotation:** additional elements that provide further explanation.

# Modelling software and templates

Diagrams can be created with any tool supporting the languages UML, BPMN and iStar.

## Suggested tools

For UML and BPMN diagrams we recommend the use of software enabling the export of UML/XML and BPMN formats. Instead, iStar diagrams can be created with any graphical tool supporting the elements of the notation.

We suggest the following tools:

- iStar: LucidSpark <https://lucidspark.com/it>
- UML: StarUML <https://staruml.io/>
- BPMN: Camunda <https://camunda.com/>

Additional information and alternative solutions

*iStar* - In case you are interested in generating goal models in the original iStar notation, you can use the online tool piStar: <https://www.cin.ufpe.br/~jhcp/pistar/>.

*UML* - The evaluation version of StarUML (freely available) presents some limitations in file exporting, e.g., adding a watermark in SVG files. The pro version (license needed) allows the creation of BPMN (BPMN diagrams creation in StarUML has not been tested for our purposes).

*BPMN* - For fast development of the model you can use the online tool:

<https://demo.bpmn.io/s/start> The online tool presents limitations in the generation of the overlapping view.

## Templates

Use the following templates as a starting point for the creation of your diagrams.

1. Goal diagram iStar: [View on Lucidspark](#) (create a copy of the template before editing)
2. Structure diagram UML: [Download .mdl template](#)
3. Process diagram BPMN: [Download .bpmn template](#)

# Overview: questions to diagrams

This section provides a general overview of the information to be extracted from the **Living Lab Reports case *Digitalising***.

In the following, questions of the report are mapped to specific information that needs to be extracted, elaborated and associated with one or more diagrams.

Please note that the report may present inconsistencies and missing information that could result in information being displaced and the need for further iterations with the Living Lab.

Furthermore, as the report is the outcome of multiple data collection activities carried out in CODECS, it may contain additional information not strictly necessary for the models. Use this information as a support to better contextualise the process and abstract all the relevant information.

Read the reports accurately and compile the checklist (see sec. [Checklist](#)) before creating the diagrams.

## DIGITAL SOLUTION

- **[Question 3.1]** - *Which digital solution has the living lab decided to introduce?*

Information to extract: tech system, components, actors and preliminary process

DIAGRAMS → UML iStar BPMN

- **[Question 3.2]** - *Explain why and how the living lab has introduced this digital solution*

Information to extract: goals

DIAGRAM → iStar

## PROCESS BEFORE

- **[Question 4.1]** - *Who are the actors involved now?*

Information to extract: actors

DIAGRAMS → UML iStar BPMN

- **[Question 4.2]** - *What are the resources involved in the process?*

Information to extract: resources

DIAGRAMS → UML iStar BPMN

- **[Question 4.3]** - *What are the activities carried out by actors using the available resources?*

Information to extract: activities/tasks process before

DIAGRAMS → UML iStar BPMN

- **[Question 4.4]** - *What are the weaknesses of the current process?*

Information to extract: goals

DIAGRAMS → iStar

## PROCESS AFTER

- **[Question 5.1]** - *Will the introduction of the digital solution involve new actors? If yes, which ones?*
- **[Question 5.2]** - *Will the introduction of the digital solution remove existing actors from the current process? If yes, which ones?*

Information to extract: added/removed actors, actors process after

DIAGRAM → UML iStar BPMN

- **[Question 5.3]** - *Which new resources will be added?*
- **[Question 5.4]** - *Will the introduction of the digital solution remove resources from the current process? If yes, which ones?*

Information to extract: added/removed resources, resources process after

DIAGRAM → UML iStar BPMN

- **[Question 5.5]** - *What will be the activities carried out by actors using the resources?*

Information to extract: activities process after, actors process after

DIAGRAM → BPMN

## TRANSITION

- **[Question 6.1]** - *How is the living lab dealing with the transition to the new system?*

Information to extract: additional information

DIAGRAMS → **UML** **iStar** **BPMN**

## Procedure

This section contains the procedure for creating the diagrams. Please read the reports accurately and compile the checklist (see sec. [Checklist](#)) before starting the procedure.

### Goal diagram - iStar

Follow this procedure to create Goal diagrams in iStar notation.

#### 1) Actors and Technology boundary

- a) Select actors of process *after* from **[Question 4.1] ACTORS PROCESS BEFORE**, **[Question 5.1] ADDED ACTORS**, **[Question 5.2] REMOVED ACTORS** and create an Actor boundary.
- b) Select technology from **[Question 3.1] DIGITAL SOLUTION** and create an Actor boundary (Technology boundary); possibly place it at the centre of the diagram.

#### 2) Goals

- a) For each actor - except for technology - select goals list from: **[Question 3.2] WHY AND HOW DIGITAL SOLUTION**; **[Question 5.5] ACTIVITIES PROCESS AFTER**.

**NOTE:** You can elaborate more on goals taking inspiration from focal action situation, problem statement and info on **[Question 6.1] TRANSITION** and **[Question 4.4] WEAKNESSES**

- b) Classify and create goals. Place goals in *internal, actor-actor* or *actor-technology* positions. Express goals through a short sentence containing a verb (e.g., *optimise* animal health; *share* data; *support* farmer)

#### Example - Vet's goals

**Report** - [Question 3.2]: *Integrating information managed by different actors, the farm management information system supports advisors in the management of their work ...*; [Question 5.5]: *The vet accesses stats of farms productivity because they wants to enhance the productivity of the animals*; [Question 4.4]: *technical advisors struggle to manage on site interventions; without a scheduled calendar of the interventions agreed with farmers ...*

**Vet's goals** - Optimise animal production (Internal goal); Monitor animal health (Actor-actor goal); Optimise work management (Actor-technology goal)

### 3) Tasks

- a) For each actor - except for technology - select main activities relevant to strategic aspects from **[Question 5.5] ACTIVITIES PROCESS AFTER** and abstract tasks. Place tasks inside the actor's boundaries.  
**NOTE:** *tasks* are general activities that are necessary for the fulfilment of a goal and can be obtained from the abstraction of a list of activities.
- b) For the technology actor take inspiration from **[Question 3.1] DIGITAL SOLUTION** and **[Question 5.5] ACTIVITIES PROCESS AFTER** and abstract key tasks.

#### Example - Vet's tasks

**Report** - [Question 5.5]: *The vet visits each farm monthly to monitor the health status of animals; During a visit, the vet scans the animal through the bluetooth tag scan and accesses the app to annotate data about animals because they wants to record relevant facts about animals*;

**Vet's tasks**- Visit animals; Scan animals.

## 4) Tools

- a) Select technological resources that are part of the process *after* from **[Question 4.2] RESOURCES PROCESS BEFORE, [Question 5.3] ADDED RESOURCES, [Question 5.4] REMOVED RESOURCES**, create and place tools inside the actor's boundaries, possibly below the correspondent task.  
**NOTE:** in selecting resources, consider digital tools and technological components used by the actor for performing tasks and mentioned in **[Question 5.5] ACTIVITIES PROCESS AFTER** and **[Question 3.1] DIGITAL SOLUTION**. Try to associate each task with a tool.

### Example - Vet's tools

**Report** - [Question 5.3]: bluetooth tag scan in use by the vet for on field data access and data entry; [Question 5.5]: During a visit, the vet scans the animal through the bluetooth tag scan...

**Vet's tool**- Pet scan bluetooth

## 5) Connections

- a) *Tool-task*: for each tool, add a link between the tool and its corresponding task with the arrow directed from the tool to the task.
- b) *Task-goal*: for each task - except for tasks in technology boundary - add a link between the task and its corresponding goal with the arrow directed from the task to the goal. **NOTE:** one task can be connected to multiple goals. Each goal in the actor boundary has to be linked at least to one task. Each task in the actor boundary has to be linked at least to one goal. Possibly, place the goals above the tasks.
- c) *Actor-actor goal*: for each actor-actor goal, add a link connecting the two actor boundaries and the goal. The arrow should be directed from the active actor, e.g., the actor performing actions to fulfil the goal, to the recipient actor. If the actors share the same goal, e.g., *communication exchange*, the arrow should be put in both directions.
- d) *Actor-technology goal*: for each actor-technology goal, add a link connecting the actor boundary to the technology boundary with the arrow directed from the actor to the technology.

## 6) Export and save

Export a high-quality image in PNG format and save the current session. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *goal-diagram\_V1.png*

## Structure diagram - UML

Follow this procedure to create structure diagrams in UML notation.

### 1) Technology

- a) Select the tech system from **[Question 3.1] DIGITAL SOLUTION** and represent it as a class.
- b) Identify components (hardware and software) of the tech system that are part of the process *after* from **[Question 3.1] DIGITAL SOLUTION** and **[Question 5.3] ADDED RESOURCES**; represent them as class and link with aggregation, (i.e., diamond).
- c) Add a blue background to the classes.

**NOTE:** Depending on the digital solution adopted, it is possible that there are multiple tech systems. It is also possible that there are classes that are not linked with any component. Try to provide a complete representation of the tech system in use; if necessary, consider technological resources mentioned in **[Question 4.2] RESOURCES PROCESS BEFORE**

### Example

**Report** - [Question 3.1]: The digital solution consists of a farm management information system (FMIS) to store information about sheep and milk production...; the system integrates multiple web services providing additional data that are managed by the cheese factory... [Question 5.3]: Bluetooth tag scan in use by the vet for on-field data access and data entry; server for data storage; technological devices compatible with the app (e.g., smartphone/tablet/desktop); cloud storage and FMIS software.

**Technology class** - System: FMIS class, components: app, web dashboard, pet scan bluetooth, management software.

### 2) Actors and resources

- a) Select actors of process *after* from **[Question 4.1] ACTORS PROCESS BEFORE**, **[Question 5.1] ADDED ACTORS**, **[Question 5.2] REMOVED ACTORS** and resources – except for technological resources – from **[Question 4.2] RESOURCES PROCESS BEFORE**, **[Question 5.3] ADDED RESOURCES**, **[Question 5.4] REMOVED RESOURCES** and represent them as class.
- NOTE:** In selecting resources, prioritise the elements mentioned in **[Question 5.5] ACTIVITIES PROCESS AFTER**, in the focal action situation, problem statement and **[Question 6.1] TRANSITION**.

Example

**Report** - [Question 4.1]: farmer; ...; [Question 4.2]: sheep

**Classes** - Farmer, Sheep

### 3) Connections

- a) *Actors-technology*: take inspiration from **[Question 5.5] ACTIVITIES PROCESS AFTER** and add a link between the actors and the technology. Add a label on the link with the action performed by the actor using the technology. The arrow direction should go from the actor to the technology.
- b) *Actors-resources*: take inspiration from **[Question 5.5] ACTIVITIES PROCESS AFTER** and add a link between the actors and the resources they use. Add a label on the link with the action performed by the actor using the resource. The arrow direction should go from the actor to the resource.
- c) *Actors-actor*: if actors have direct interactions, add a link between the actors. Take inspiration from **[Question 5.5] ACTIVITIES PROCESS AFTER** and put a label on the link with the action performed by the actors in their interaction. The arrow direction should go from the *active* actor to the *passive*. In case both actors are active e.g., information exchange activity, add arrows on both sides or omit arrows.

**NOTE:** All blocks in the diagram should be connected to other blocks. Balance the readability and completeness of the diagram and choose a limited number of connections.

Example

**Report** - [Question 5.5]: Every day, after milking, the farmer accesses the web dashboard to record the amount of milk collected because wants to monitor the amount of milk produced; the vet annotates data about animals to record relevant facts about animals; the vet

annotates animals feeding plan; the vet accesses the dashboard to see data shared with the agronomist...; the agronomist accesses the dashboard to see data shared with the vet;

**Actors-technology connection:** - Link from class *farmer* to class *web dashboard* with label *access data*

**Actors-resources connection:** - Link from class *farmer* to class *sheep* with label *milking*.

Arrow direction: from *farmer* to *sheep*.

**Actors-actors connection:** - Link from class *veterinary* to class *agronomist* with label information exchange. Arrow direction: *both*.

#### 4) Export and save

Export an image in SVG format and save the file in the UML software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g.,

*structure-diagram\_V1.svg*

# Process diagrams - BPMN

Follow this procedure to create process diagrams in BPMN notation.

## Diagram 1: BPMN process after

### 1) Actor pools

- a) Select actors of process *after* from **[Question 4.1] ACTORS PROCESS BEFORE**, **[Question 5.1] ADDED ACTORS**, **[Question 5.2] REMOVED ACTORS** and create a pool for each actor.
- b) Assess the description of the technology and the preliminary process in **[Question 3.1] DIGITAL SOLUTION** and in case you deem it relevant, create a pool for the digital solution and its components.

**NOTE:** Create a pool for the technology in case the digital solution is presented as an autonomous entity, e.g. autonomous system, dss, etc. Example: A precision irrigation process can be represented by the following pools: farmer, decision support system, wireless sensors network. [See the example on precision irrigation.](#)

In case the process is composed of more than two actors having multiple interactions, create a model for each actor with empty pools around referring to the other actors. This should enhance the readability of the diagrams. Example: The cheese-making process in the farm management information system example is composed of the following models: farmer, vet, agronomist, and cheese factory. [See the example on the farm management information system.](#)

### 2) Start/End process

- a) Add a start event and an end event inside each pool.
- b) Add a text annotation on the start event and indicate the frequency of the process: daily, weekly, every three minutes, etc.

### 3) Tasks

- a) Following the numbered lists of activities provided for each actor in **[Question 5.5] ACTIVITIES PROCESS AFTER**, create a sequence of connected tasks inside each actor boundary and within the start and end event.
- b) Assign a type to each task choosing among: manual, system, receive, send.  
**NOTE:** Some tasks can be left without a type specification.

#### Example

**Report** - [Question 5.5]: The agronomist accesses the FMIS dashboard to see stats of farms productivity, data shared with the vet and data synchronised from external databases (e.g. milk analysis) because they wants to enhance the productivity of the animals.

**Agronomist's task** - access FMIS, analyse data, plan food ratios, update FMIS, schedule visits

### 4) Connections

- a) Identify send tasks and create a link starting from the send task to the corresponding recipient's receive task / pool. In case the send task triggers the beginning of the recipient's process, transform the start event of the recipient into a message start event and connect the send task to this event.
- b) Add a label on the dotted line resulting from the connection with the object of the activity.

**NOTE:** In case the list in **[Question 5.5] ACTIVITIES PROCESS AFTER** does not explicitly contain send and receive tasks, feel free to create these tasks maintaining consistency with the process description.

#### Example

**Report** - [Question 5.5]: The farmer plans a meeting with the agronomist for discussing the feeding plan...;

**Agronomist's tasks** - visit farm (task) - request animal information (send task directed to farmer pool) - annotate animal facts (receive task incoming from farmer pool)

### 5) Gateways

- a) Parallel gateways: take inspiration from **[Question 5.5] ACTIVITIES PROCESS AFTER** and for each actor extract activities that are executed in parallel. In case there are activities executed in parallel, place a parallel gateway before the first task executed to create multiple paths and add on each path a task or a sequence of tasks. Repeat the gateway after the last tasks.

- b) Exclusive gateways: take inspiration from **[Question 5.5] ACTIVITIES PROCESS AFTER** and for each actor extract activities that are executed optionally, i.e., under particular conditions. In case there are optional activities, place an exclusive gateway to create multiple paths, and add on each path a task or a sequence of tasks. Add a label on the gateway explaining the condition and add a label on each path explaining the verification of the condition. Repeat the gateway after the last tasks.

### Example

**Report** - [Question 5.5]: In case of a sanitary emergency, the farmer calls the vet because wants the animal to be visited; The vet receives monthly a notification from the FMIS to schedule visits to the farms; The vet visits each farm monthly to monitor the health status of animals;

**Vet's parallel gateway** - tasks path 1- access FMIS; schedule visit; tasks path 2- visit farms

**Vet's exclusive gateway** - label condition: is there an emergency? - condition verification: yes, path 1- evaluate farm request (receive task incoming from farmer pool) - schedule visit (send task directed to farmer pool); condition verification: no, path 2 - empty

## 6) Text annotations

- a) Add text annotations on tasks to express additional relevant information provided in **[Question 5.5] ACTIVITIES PROCESS AFTER**, e.g., frequency, motivation, etc.. that is not expressed in the diagram. Place the text annotations before each task.

**NOTE:** In adding text annotations, consider the elements mentioned in the focal action situation, problem statement and **[Question 6.1] TRANSITION**.

## 7) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-after-diagram\_V1.png*

## Diagram 2: BPMN process before

### 1) Actor pools

- a) Copy in a new file the model/s created in **Diagram 1: BPMN process after**
- b) Select actors that are not part of the process before in **[Question 5.1] ADDED ACTORS** and delete their pools.
- c) Check technological resources that are not part of the process before in **[Question 5.3] ADDED RESOURCES** and delete or edit the pool of the digital solution.
- d) Select actors that are part of the process before and will be replaced in **[Question 5.2] REMOVED ACTORS** and create new pools. Add start and end events inside the pool.

### 2) Tasks, connections, gateways

- a) Take inspiration from **[Question 4.3] ACTIVITIES PROCESS BEFORE** and edit the pool of each actor with corresponding tasks, relationships, gateways and annotations following the instructions provided in **Diagram 1: BPMN process after**.  
**NOTE:** try to maintain consistency with the structure of the process after. Take inspiration from the information provided in **[Question 6.1] TRANSITION**.

### 3) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-before-diagram\_V1.png*

## Diagram 3: BPMN processes overlap

Please consider the examples provided (i.e., [Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#)) to understand how to create the overlapping view. In addition, download this BPMN source file with an example of overlap: [BPMN source overlap](#).

### 1) Actor pools

- a) Copy in a new file the model(s) created in **Diagram1: BPMN process before**.
- b) Paste in the new file the content created in **Diagram2: BPMN process after**. Place Diagram2 next to Diagram1 and compare the two processes.

# Procedure Report-to-Diagrams

## CODECS Socio-technical process modelling

### Procedure for Digitalised

*CNR*

*Version 1 - 5 June 2024*

<b>Introduction</b>	<b>3</b>
Common terms	4
<b>Checklist</b>	<b>6</b>
<b>Diagrams</b>	<b>8</b>
Goal diagram	8
Structure diagram	10
Process diagrams	12
<b>Modelling software and templates</b>	<b>14</b>
Suggested tools	14
Templates	14
<b>Overview: questions to diagrams</b>	<b>15</b>
<b>Procedure</b>	<b>17</b>
<b>Goal diagram - iStar</b>	<b>17</b>
1) Actors and Technology boundary	17
2) Goals	17
3) Tasks	18
4) Tools	18
5) Connections	19
6) Export and save	19
<b>Structure diagram - UML</b>	<b>20</b>
1) Technology	20
2) Actors and resources	20
3) Connections	21
4) Export and save	22
<b>Process diagrams - BPMN</b>	<b>23</b>
Diagram 1: BPMN process after	23
1) Actor pools	23
2) Start/End process	23
3) Tasks	24
4) Connections	24
5) Gateways	24
6) Text annotations	25
7) Export and save	25
Diagram 2: BPMN process before	26
1) Actor pools	26
2) Tasks, connections, gateways	26
3) Export and save	26
Diagram 3: BPMN processes overlap	26
1) Actor pools	26
2) Green elements	27
3) Red elements	27
4) Blue elements	27
6) Export and save	27

# Introduction

As part of CODECS Task 3.3 - Farm Socio-technical Process Modelling, this document presents the procedure for creating the process diagrams starting from the **Living Lab Reports case *Digitalised***. This document is oriented to the task leaders' collaborators, who will check the consistency of the reports and create the diagrams.

The reports are the output of previous activities carried out by Living Lab coordinators, who performed data collection through interviews and group discussions involving the Living Lab participants and filled in the template file according to the guidelines provided (refer to [Task 3.3 Folder](#) for further information).

The objective of the process modelling activity is to create easy-to-read diagrams of processes carried out in a farm before and after the introduction of digital solutions. The output of the activity will allow to focus on the transformation that occurred to a process after the introduction of a digital solution and will contribute to the cost-benefit analysis.

To ensure completeness, the following diagrams are developed, based on the data from the reports:

- the **goal diagram** models the goals of the process focusing on the intentional, social, and strategic dimensions;
- the **structure diagram** provides an overview of the entities, i.e., actors, tools, infrastructures, and systems involved in the process and the relationships among them;
- the **process diagrams** represent the detailed flow of the process and will allow comparisons between the process before and after the introduction of the digital solution.

The goal and the structure diagrams focus on the process *after* the introduction of digital technology (process *as-is*), whereas the process diagram focuses both on the process *after* (process *as-is*) and on the process *before* the introduction of the digital technology (process *as-is*).

A set of languages for graphical representation from software engineering has been identified, so the diagrams will be developed using the following notations: iStar, goal diagram; UML, structure diagram; BPMN, process diagrams.

To maximise the readability of the diagrams a small set of elements for each notation has been selected. Furthermore, the authors adopted a modified style for the iStar notation by

creating an enhanced version consisting of icons for representing actors and a different style for the symbols. This is to obtain more user-friendly representations.

Chapter 2 presents the checklist to be applied in the preliminary step of revision of the reports before starting the diagram creation. Depending on the quality of the data contained in the reports, further iterations with LLs may be needed. Chapter 3 provides an explanation by example of the diagrams to be created. Chapter 4 contains hints on the software for creating the diagrams and provides access to three templates. Chapter 5 presents an overview of the contents to be extracted from the reports. Chapter 6 contains step-by-step instructions on how to create the diagrams.

## Common terms

Actor – individuals, groups, or system components that play a role in the process;

Diagram – a visual representation of information, typically simplified and structured to convey a specific concept or set of relationships among components;

Focal Action Situation (FAS) – a situation where components of a socio-technical system interact to provide an outcome;

Goal – is a desired outcome or target that an actor or group of actors aims to achieve within a specific process or task;

Goal diagram – a type of diagram used to represent the actors' goals, relationships and dependencies within a process;

Living Lab (LL) – 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;

Model – a simplified representation or abstraction of reality designed to explain, predict, or analyse aspects of the real world. Models can take various forms depending on their purpose and the field in which they are used;

Notation – a system of symbols, signs, or characters used to represent information in a concise and standardised way;

Problem statement – a concise description of an issue or challenge that needs to be addressed;

Process – a sequence of steps performed by actors to address an objective, for example, irrigation or cattle monitoring;

Process as-is – process *before* the introduction of a digital solution;

Process diagram – a type of diagram that illustrates the sequential tasks, interactions, or events from the beginning to the end of a process;

Process modelling – the act of creating a visual representation or abstraction of a process in order to understand, analyse, communicate, and improve it;

Process to-be – process *after* the introduction of a digital solution;

Resource – tangible and intangible) assets owned or accessed by the LL and utilised to create value, achieve an objective, or solve a problem;

Structure diagram – a type of diagram used to represent the structure of a process by illustrating its static aspects, such as actors, resources, composition, and arrangement of the system;

Task – a specific, defined activity that needs to be completed as part of a larger process;

Tech component – an individual part or element of a tech system. Each component has a specific function and contributes to the overall operation of the system;

Tech system – an interconnected set of hardware, software, data, and procedures designed to perform specific functions and achieve certain goals;

# Checklist

This checklist applies to the **Living Lab Reports case *Digitalised***. Please answer the questions below to verify whether the information in the report can be used for the purposes of T 3.3 (process modelling).

In the case some inconsistencies or missing information are highlighted by your answers to the checklist, please check the report and fill in the *notes* field indicating what answers can integrate the information (example: STEP 13: *A list of goals associated with each actor can be extracted from 4.4* - NO. Notes: actors' goals are reported in answer 3.2).

If you think that missing information cannot be integrated, fill in the field *Question for LL coordinator* with the question to be asked in future iterations (example: STEP 18: *The answer in 5.5 contains a clear list of actions associated with the actors in the process before* - NO. Notes: no information is provided for breeders in process *before*. Question for LL coordinator: in the list of removed actors in 5.2. breeder are mentioned but no information is provided in 5.5 about the actions performed by this actors. Could you please integrate 5.5 with a list of actions performed? Please also indicate the frequency).

	Y E S	N O	Step	Notes	Question for LL coordinator
1			Answers 1.2 and 1.3 are sufficiently informative to gain an understanding of the living lab context		
2			Based on the example table provided, the answer in 1.4 includes all the information		
3			The description of the focal action situation in 2.1 is exhaustive and the problem statement in 2.2 is consistent		
4			The state of digitalisation matches the information provided in 2.1 and 2.2		
5			The answer in 3.1 clearly identifies the specific digital solution introduced by the living lab and is sufficiently detailed		
6			A list of relevant actors with a clear role associated can be extracted from 4.1		

7		Based on your background and understanding of the context, the list of actors in 4.1 is complete		
8		The technological resources in 4.2 are consistent with the digital solution in 3.1		
9		Based on your background and understanding of the context, the list of resources in 4.2 is complete		
10		The actors mentioned in 4.3 are consistent with the list in 4.1		
11		Based on your background and understanding of the context, the list of actions in 4.3 is complete		
12		The answer in 4.3 provides sufficient information on the process frequency, motivation and actors' relationships		
13		A list of goals associated with each actor can be extracted from 4.4, 4.3, 2.1 and 3.2		
14		The lists of added/removed actors in 5.1 and 5.2 are consistent with the description of the digital solution in 3.1 and actors in 4.1		
15		Based on your background and understanding of the context, the list of actors in the process <i>before</i> that can be extracted from 4.1, 5.1 and 5.2 is complete		
16		The lists of added/removed resources in 5.3 and 5.4 are consistent with resources in 4.2 and with the digital solution in 3.1		
17		Based on your background and understanding of the context, the list of resources in the process <i>before</i> that can be extracted from 4.2, 5.3 and 5.4 is complete		
18		The answer in 5.5 contains a clear list of actions associated with the actors in the process <i>before</i>		
19		Based on your background and understanding of the context, the list of actions in 5.5 is complete		
20		The answer in 5.5 provides sufficient information on the process frequency, motivation and actors' relationships		

# Diagrams

The process modelling methodology is based on a set of different diagrams leveraging on standard notations from software engineering.

According to the process modelling methodology, to ensure completeness of the process representation, the following diagrams are developed: (1) goal diagram - process *after*; (2) structure diagram - process *after*; (3) process diagram - process *before*; (4) process diagram - process *after*; (5) processes overlap.

As the report refers to a **Digitalised case**, we identify the process in the present as the process *after* the introduction of digital technology, i.e., the process *to-be* and the process in the past as the process *before* the introduction of digital technology, i.e., the process *as-is* (refer to the [CODECS T3.3-Process-Modelling-Guidelines](#) and [Template-DIGITALISED](#) for further information).

This section introduces the different types of diagrams providing a legend and an explanation of the symbols used.

## Goal diagram

The goal diagram models the goals of the process *after* focusing on the intentional, social, and strategic dimensions.

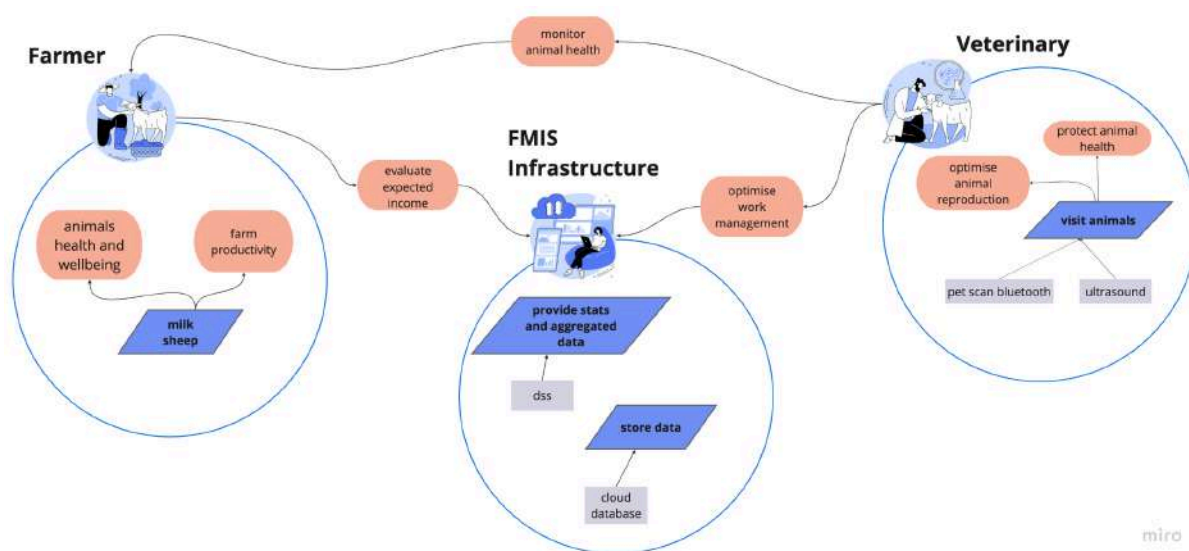


Figure 1: Example of a goal diagram

Figure 1 contains an example of a goal diagram for a Farm Management Information System in the context of a cheese production process. For this type of diagram, we adopt a modified

style for the iStar notation by creating an enhanced version consisting of icons for representing actors and a different style for the symbols.

The complete case study can be downloaded here: [iStar goal diagram](#)

## Legend

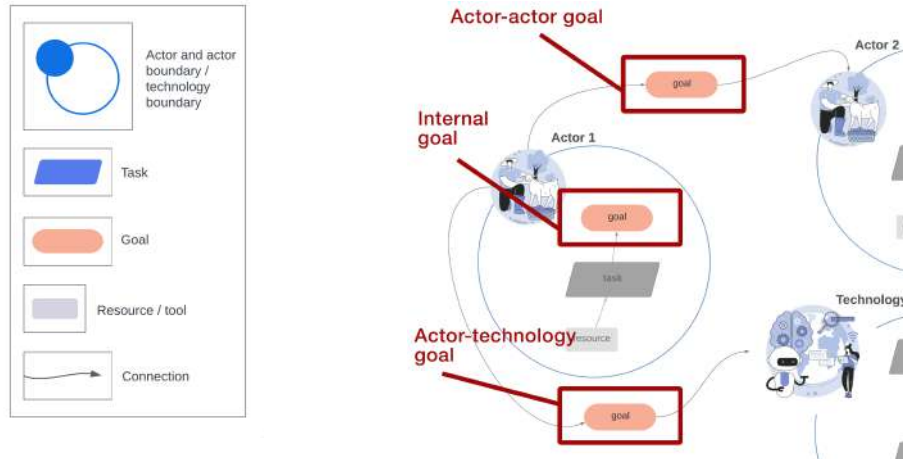


Figure 2: Legend of symbols used (on the left); portion of diagram with types of goals highlighted (on the right).

## Explanation of symbols

**Actor:** an active, autonomous entity that performs tasks by exercising its know-how, in collaboration with other actors;

**Actor boundary:** contains all tasks, goals and resources/tools related to a single actor;

**Technology boundary:** same as actor boundary but with no goals associated;

**Task:** represents an action that an actor wants to be executed;

**Resource/tool:** a physical or informational entity that actors require to perform tasks

**Goal:** a state of affairs that the actor wants to achieve;

### *Types of goals*

**Internal goals:** actor's goals within its activity/role;

**Actor-actor goals:** actor's goals with respect to other actors;

**Actor-technology goals:** actor's goals with respect to digital technology

## Structure diagram

The structure diagram provides an overview of the entities, i.e., actors, tools, infrastructures, and systems involved in the process *to-be* and the relationships among them.

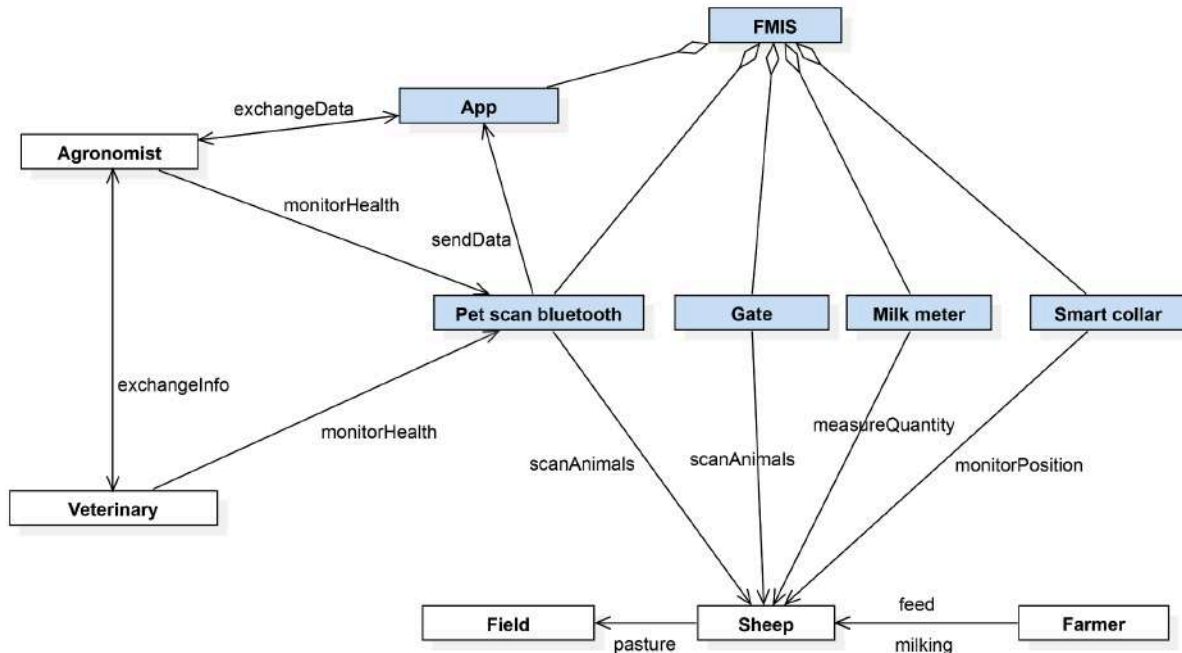
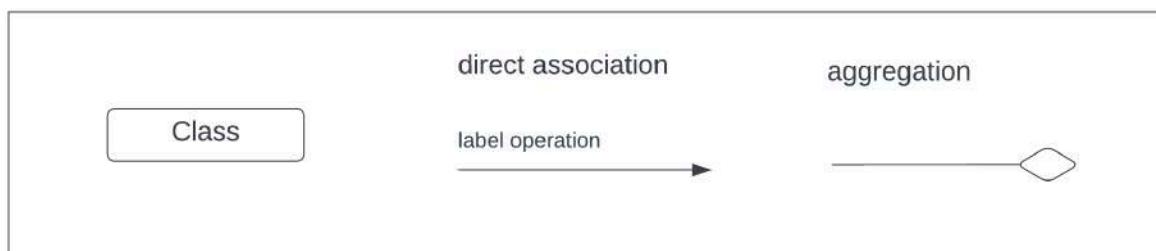


Figure 3: Example of a structure diagram

Figure 3 contains an example of a UML class diagram for a Farm Management Information System in the context of a cheese production process.

The complete case study can be downloaded here: [UML class diagram](#)

## Legend



## Explanation of symbols

**Class:** defines the core elements, i.e., actors and resources. It is represented by a box with a title label;

**Operations:** the operations are performed by a class interacting with another class;

**Relations:** connect classes and are expressed by arrows.

### *Types of relations*

**Direct association:** connects two classes by means of an operation. The arrow is directed from the active class which starts the operation to the passive class that is the recipient. Arrows placed in both directions mean that the two classes are both active.

**Aggregation:** means that a class is part of another class. This type of relation can be used to represent technological systems and components.

## Process diagrams

The process diagrams represent the detailed flow of both the process *before* and the process *after*. The overlap of the two representations allows comparisons between the process before and after the introduction of the digital solution.

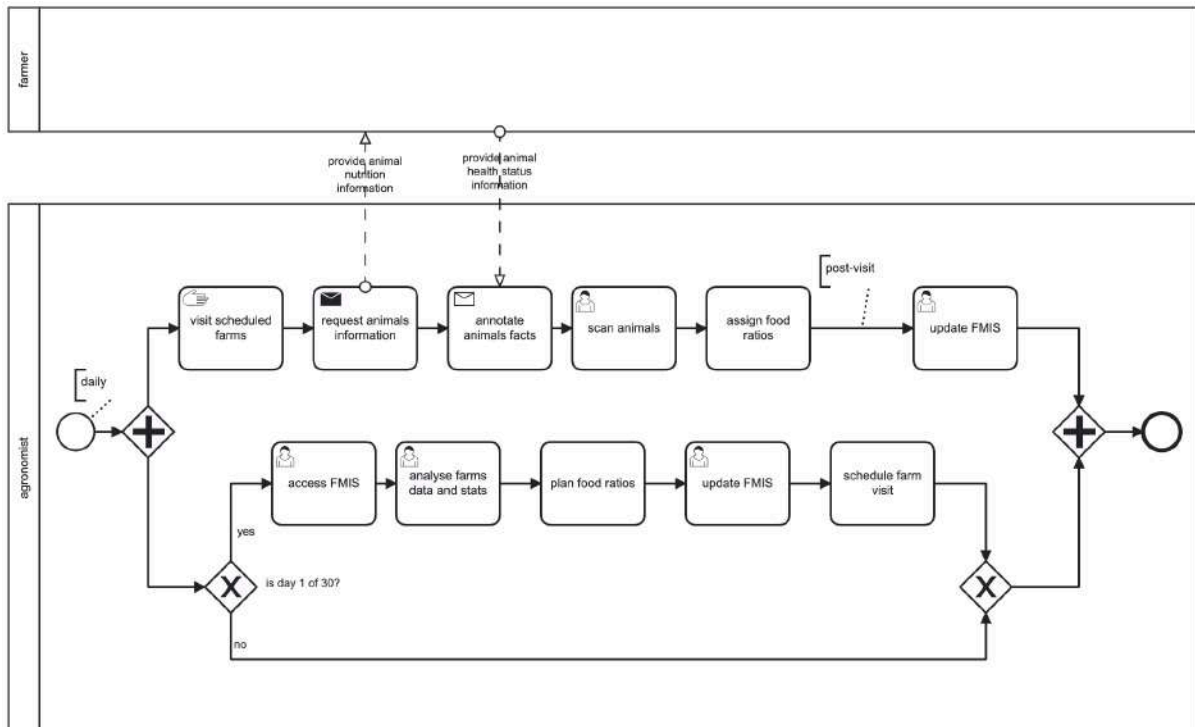


Figure 4: Example of a process diagram

Figure 4 contains an example of a BPMN diagram for a Farm Management Information System in the context of a cheese production process. This example represents the agronomist's process *after* the introduction of the Farm Management Information System (process *to-be*).

The complete example containing multiple views from the perspective of multiple actors and the high-resolution images can be downloaded here: [Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#).

An additional example of process diagrams for a Precision Irrigation System in the context of a fruit farm can be downloaded here:

[Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#)

The model represents a single view of the global process.

## Legend

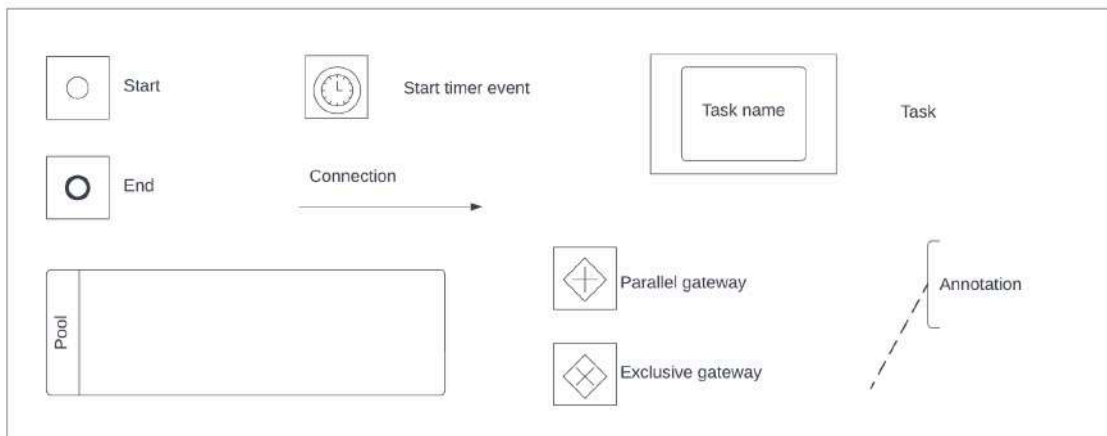


Figure 2: Legend of BPMN symbols used

## Explanation of symbols

**Start event:** the starting point of a process;

**Start timer event:** a start event containing a message and triggered by another process;

**End event:** the ending point of a process;

**Task:** an atomic activity within a process flow. It can be of different types: manual, service, send, receive;

**Parallel gateway:** used to create concurrent paths within a process flow; for a single execution of the process, the paths can be taken in parallel;

**Exclusive gateway:** used to create alternative paths within a process flow. For a single execution of the process, only one of the paths can be taken;

**Pool:** A pool represents a participant who takes part in a process. All actions performed by the participant are represented inside the same pool. If multiple participants are involved in a process, multiple pools are defined. Each pool has a start and end event.

**Connection:** link with arrows between tasks and/or pools. Connections between pools represent communication flows and are represented with dashed lines.

**Text annotation:** additional elements that provide further explanation.

# Modelling software and templates

Diagrams can be created with any tool supporting the languages UML, BPMN and iStar.

## Suggested tools

For UML and BPMN diagrams we recommend the use of software enabling the export of UML/XML and BPMN formats. Instead, iStar diagrams can be created with any graphical tool supporting the elements of the notation.

We suggest the following tools:

- iStar: LucidSpark <https://lucidspark.com/it>
- UML: StarUML <https://staruml.io/>
- BPMN: Camunda <https://camunda.com/>

Additional information and alternative solutions

*iStar* - In case you are interested in generating goal models in the original iStar notation, you can use the online tool piStar: <https://www.cin.ufpe.br/~jhcp/pistar/>.

*UML* - The evaluation version of StarUML (freely available) presents some limitations in file exporting, e.g., adding a watermark in SVG files. The pro version (license needed) allows the creation of BPMN (BPMN diagrams creation in StarUML has not been tested for our purposes).

*BPMN* - For fast development of the model you can use the online tool:

<https://demo.bpmn.io/s/start> The online tool presents limitations in the generation of the overlapping view.

## Templates

Use the following templates as a starting point for the creation of your diagrams.

1. Goal diagram iStar: [View on Lucidspark](#) (create a copy of the template before editing)
2. Structure diagram UML: [Download .mdl template](#)
3. Process diagram BPMN: [Download .bpmn template](#)

# Overview: questions to diagrams

This section provides a general overview of the information to be extracted from the **Living Lab Reports case *Digitalised***. In the following, questions of the report are mapped to specific information that needs to be extracted, elaborated and associated with one or more diagrams.

Please note that the report may present inconsistencies and missing information that could result in information being displaced and the need for further iterations with the Living Lab. Furthermore, as the report is the outcome of multiple data collection activities carried out in CODECS, it may contain additional information not strictly necessary for the models. Use this information as a support to better contextualise the process and abstract all the relevant information. Read the reports accurately and compile the checklist (see sec. [Checklist](#)) before creating the diagrams.

## DIGITAL SOLUTION

- **[Question 3.1]** - *Which digital solution did the living lab introduce?*

Information to extract: tech system, components, actors and preliminary process

DIAGRAMS → UML iStar BPMN

- **[Question 3.2]** - *Explain why and how the living lab has introduced this digital solution*

Information to extract: goals

DIAGRAM → iStar

## PROCESS AFTER

- **[Question 4.1]** - *Who are the actors involved now?*

Information to extract: actors

DIAGRAMS → UML iStar BPMN

- **[Question 4.2]** - *What are the resources involved in the process?*

Information to extract: resources

DIAGRAMS → UML iStar BPMN

- **[Question 4.3]** - *What are the activities carried out by actors using the available resources?*

Information to extract: activities/tasks

DIAGRAMS → UML iStar BPMN

- **[Question 4.4]** - *What are the advantages of the current process for each actor?*

Information to extract: goals

DIAGRAMS → iStar

## PROCESS BEFORE

- **[Question 5.1]** - *Has the introduction of the digital solution required the involvement of new actors? If yes, which ones?*
- **[Question 5.2]** - *Have actors been removed because of the introduction of the digital solution? If yes, which ones?*

Information to extract: added/removed actors, actors process before

DIAGRAM → BPMN

- **[Question 5.3]** - *Which new resources have been added?*
- **[Question 5.4]** - *Which resources have been removed?*

Information to extract: added/removed resources

DIAGRAM → BPMN

- **[Question 5.5]** - *Before the introduction of the digital solution, how were the activities carried out by actors?*

Information to extract: activities process before, actors process before

DIAGRAM → BPMN

## TRANSITION

- **[Question 6.1]** - *How did the living lab deal with the transition to the new system?*

Information to extract: additional information

DIAGRAMS → UML iStar BPMN

# Procedure

This section contains the procedure for creating the diagrams. Please read the reports accurately and compile the checklist (see sec. [Checklist](#)) before starting the procedure.

## Goal diagram - iStar

Follow this procedure to create Goal diagrams in iStar notation.

### 1) Actors and Technology boundary

- a) Select actors from **[Question 4.1] ACTORS PROCESS AFTER** and create an Actor boundary.
- b) Select technology from **[Question 3.1] DIGITAL SOLUTION** and create an Actor boundary (Technology boundary); possibly place it at the centre of the diagram.

### 2) Goals

- a) For each actor - except for technology - select goals list from: **[Question 3.2] WHY AND HOW DIGITAL SOLUTION; [Question 4.3] ACTIVITIES PROCESS AFTER; [Question 4.4] ADVANTAGES**  
**NOTE:** You can elaborate more on goals taking inspiration from focal action situation, problem statement and info on **[Question 6.1] TRANSITION**
- b) Classify and create goals. Place goals in *internal*, *actor-actor* or *actor-technology* positions. Express goals through a short sentence containing a verb (e.g., *optimise* animal health; *share* data; *support* farmer)

Example - Vet's goals

**Report** - [Question 4.3]: *Integrating information managed by different actors, the farm management information system supports advisors in the management of their work ...; The vet accesses stats of farms productivity because they wants to enhance the productivity of the animals*; [Question 4.4]: *information provided help to schedule future activities ...*

**Vet's goals** - Optimise animal production (Internal goal); Monitor animal health (Actor-actor goal); Optimise work management (Actor-technology goal)

### 3) Tasks

- a) For each actor - except for technology - select main activities relevant to strategic aspects from **[Question 4.3] ACTIVITIES PROCESS AFTER** and abstract tasks. Place tasks inside the actor's boundaries.  
**NOTE:** *tasks* are general activities that are necessary for the fulfilment of a goal and can be obtained from the abstraction of a list of activities.
- b) For the technology actor take inspiration from **[Question 3.1] DIGITAL SOLUTION** and **[Question 4.3] ACTIVITIES PROCESS AFTER** and abstract key tasks.

#### Example - Vet's tasks

**Report** - [Question 4.3]: The vet visits each farm monthly to monitor the health status of animals; During a visit, the vet scans the animal through the bluetooth tag scan and accesses the app to annotate data about animals because they wants to record relevant facts about animals;

**Vet's tasks**- Visit animals; Scan animals.

### 4) Tools

- a) Select technological resources from **[Question 4.2] RESOURCES PROCESS AFTER**, **[Question 4.3] ACTIVITIES PROCESS AFTER** and **[Question 3.1] DIGITAL SOLUTION**; create and place tools inside the actor's boundaries, possibly below the correspondent task.  
**NOTE:** in selecting resources, consider digital tools and technological components used by the actor for performing a task. Try to associate each task with a tool.

### Example - Vet's tools

**Report** - [Question 4.2]: bluetooth tag scan in use by the vet for on field data access and data entry; [Question 4.3]: During a visit, the vet scans the animal through the bluetooth tag scan...

**Vet's tool-** Pet scan bluetooth

## 5) Connections

- a) *Tool-task*: for each tool, add a link between the tool and its corresponding task with the arrow directed from the tool to the task.
- b) *Task-goal*: for each task - except for tasks in technology boundary - add a link between the task and its corresponding goal with the arrow directed from the task to the goal. **NOTE**: one task can be connected to multiple goals. Each goal in the actor boundary has to be linked at least to one task. Each task in the actor boundary has to be linked at least to one goal. Possibly, place the goals above the tasks.
- c) *Actor-actor goal*: for each actor-actor goal, add a link connecting the two actor boundaries and the goal. The arrow should be directed from the active actor, e.g., the actor performing actions to fulfil the goal, to the recipient actor. If the actors share the same goal, e.g., *communication exchange*, the arrow should be put in both directions.
- d) *Actor-technology goal*: for each actor-technology goal, add a link connecting the actor boundary to the technology boundary with the arrow directed from the actor to the technology.

## 6) Export and save

Export a high-quality image in PNG format and save the current session. If you produce multiple versions of the diagram, add the version number on the filename. E.g.,

*goal-diagram\_V1.png*

## Structure diagram - UML

Follow this procedure to create structure diagrams in UML notation.

### 1) Technology

- a) Select the tech system from **[Question 3.1] DIGITAL SOLUTION** and represent it as a class.
- b) Identify components (hardware and software) of the tech system from **[Question 3.1] DIGITAL SOLUTION** and **[Question 4.2] RESOURCES PROCESS AFTER**; represent them as class and link with aggregation, (i.e., diamond).
- c) Add a blue background to the classes.

**NOTE:** Depending on the digital solution adopted, it is possible that there are multiple tech systems. It is also possible that there are classes that are not linked with any component.

### Example

**Report** - [Question 3.1]: The digital solution consists of a farm management information system (FMIS) to store information about sheep and milk production...; the system integrates multiple web services providing additional data that are managed by the cheese factory... [Question 4.2]: Bluetooth tag scan in use by the vet for on-field data access and data entry; server for data storage; technological devices compatible with the app (e.g., smartphone/tablet/desktop); cloud storage and FMIS software.

**Technology class** - System: FMIS class, components: app, web dashboard, pet scan bluetooth, management software.

### 2) Actors and resources

- a) Select actors from **[Question 4.1] ACTORS PROCESS AFTER** and resources – except for technological resources – from **[Question 4.2] RESOURCES PROCESS AFTER** and represent them as class.

**NOTE:** In selecting resources, prioritise the elements mentioned in **[Question 4.3] ACTIVITIES PROCESS AFTER**, in the focal action situation, problem statement and **[Question 6.1] TRANSITION**.

Example

**Report** - [Question 4.1]: farmer; ...; [Question 4.2]: sheep

**Classes** - Farmer, Sheep

### 3) Connections

- a) *Actors-technology*: take inspiration from **[Question 4.3] ACTIVITIES PROCESS AFTER** and add a link between the actors and the technology. Add a label on the link with the action performed by the actor using the technology. The arrow direction should go from the actor to the technology.
- b) *Actors-resources*: take inspiration from **[Question 4.3] ACTIVITIES PROCESS AFTER** and add a link between the actors and the resources they use. Add a label on the link with the action performed by the actor using the resource. The arrow direction should go from the actor to the resource.
- c) *Actors-actor*: if actors have direct interactions, add a link between the actors. Take inspiration from **[Question 4.3] ACTIVITIES PROCESS AFTER** and put a label on the link with the action performed by the actors in their interaction. The arrow direction should go from the *active* actor to the *passive*. In case both actors are active e.g., information exchange activity, add arrows on both sides or omit arrows.

**NOTE:** All blocks in the diagram should be connected to other blocks. Balance the readability and completeness of the diagram and choose a limited number of connections.

Example

**Report** - [Question 4.3]: Every day, after milking, the farmer accesses the web dashboard to record the amount of milk collected because wants to monitor the amount of milk produced; the vet annotates data about animals to record relevant facts about animals; the vet annotates animals feeding plan; the vet accesses the dashboard to see data shared with the agronomist...; the agronomist accesses the dashboard to see data shared with the vet;

**Actors-technology connection:** - Link from class *farmer* to class *web dashboard* with label *access data*

**Actors-resources connection:** - Link from class *farmer* to class *sheep* with label *milking*.

Arrow direction: from *farmer* to *sheep*.

**Actors-actors connection:** - Link from class *veterinary* to class *agronomist* with label information exchange. Arrow direction: *both*.

#### 4) Export and save

Export an image in SVG format and save the file in the UML software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *structure-diagram\_V1.svg*

# Process diagrams - BPMN

Follow this procedure to create process diagrams in BPMN notation.

## Diagram 1: BPMN process after

### 1) Actor pools

- a) Select actors from **[Question 4.1] ACTORS PROCESS AFTER** and create a pool for each actor.
- b) Assess the description of the technology and the preliminary process in **[Question 3.1] DIGITAL SOLUTION** and in case you deem it relevant, create a pool for the digital solution and its components.

**NOTE:** Create a pool for the technology in case the digital solution is presented as an autonomous entity, e.g. autonomous system, dss, etc. Example: A precision irrigation process can be represented by the following pools: farmer, decision support system, wireless sensors network. [See the example on precision irrigation.](#)

In case the process is composed of more than two actors having multiple interactions, create a model for each actor with empty pools around referring to the other actors. This should enhance the readability of the diagrams. Example: The cheese-making process in the farm management information system example is composed of the following models: farmer, vet, agronomist, and cheese factory. [See the example on the farm management information system.](#)

### 2) Start/End process

- a) Add a start event and an end event inside each pool.
- b) Add a text annotation on the start event and indicate the frequency of the process: daily, weekly, every three minutes, etc.

### 3) Tasks

- a) Following the numbered lists of activities provided for each actor in **[Question 4.3] ACTIVITIES PROCESS AFTER**, create a sequence of connected tasks inside each actor boundary and within the start and end event.
- b) Assign a type to each task choosing among: manual, system, receive, send.  
**NOTE:** Some tasks can be left without a type specification.

#### Example

**Report** - [Question 4.3]: The agronomist accesses the FMIS dashboard to see stats of farms productivity, data shared with the vet and data synchronised from external databases (e.g. milk analysis) because they wants to enhance the productivity of the animals.

**Agronomist's task** - access FMIS, analyse data, plan food ratios, update FMIS, schedule visits

### 4) Connections

- a) Identify send tasks and create a link starting from the send task to the corresponding recipient's receive task / pool. In case the send task triggers the beginning of the recipient's process, transform the start event of the recipient into a message start event and connect the send task to this event.
- b) Add a label on the dotted line resulting from the connection with the object of the activity.

**NOTE:** In case the list in **[Question 4.3] ACTIVITIES PROCESS AFTER** does not explicitly contain send and receive tasks, feel free to create these tasks maintaining consistency with the process description.

#### Example

**Report** - [Question 4.3]: The farmer plans a meeting with the agronomist for discussing the feeding plan...;

**Agronomist's tasks** - visit farm (task) - request animal information (send task directed to farmer pool) - annotate animal facts (receive task incoming from farmer pool)

### 5) Gateways

- a) Parallel gateways: take inspiration from **[Question 4.3] ACTIVITIES PROCESS AFTER** and for each actor extract activities that are executed in parallel. In case there are activities executed in parallel, place a parallel gateway before the first task executed to create multiple paths and add on each path a task or a sequence of tasks. Repeat the gateway after the last tasks.

- b) Exclusive gateways: take inspiration from **[Question 4.3] ACTIVITIES PROCESS AFTER** and for each actor extract activities that are executed optionally, i.e., under particular conditions. In case there are optional activities, place an exclusive gateway to create multiple paths, and add on each path a task or a sequence of tasks. Add a label on the gateway explaining the condition and add a label on each path explaining the verification of the condition. Repeat the gateway after the last tasks.

### Example

**Report** - [Question 4.3]: In case of a sanitary emergency, the farmer calls the vet because wants the animal to be visited; The vet receives monthly a notification from the FMIS to schedule visits to the farms; The vet visits each farm monthly to monitor the health status of animals;

**Vet's parallel gateway** - tasks path 1- access FMIS; schedule visit; tasks path 2- visit farms

**Vet's exclusive gateway** - label condition: is there an emergency? - condition verification: yes, path 1- evaluate farm request (receive task incoming from farmer pool) - schedule visit (send task directed to farmer pool); condition verification: no, path 2 - empty

## 6) Text annotations

- a) Add text annotations on tasks to express additional relevant information provided in **[Question 4.3] ACTIVITIES PROCESS AFTER**, e.g., frequency, motivation, etc.. that is not expressed in the diagram. Place the text annotations before each task.

**NOTE:** In adding text annotations, consider the elements mentioned in the focal action situation, problem statement and **[Question 6.1] TRANSITION**.

## 7) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-before-diagram\_V1.png*

## Diagram 2: BPMN process before

### 1) Actor pools

- a) Copy in a new file the model/s created in **Diagram 1: BPMN process after**
- b) Select actors that were not part of the process before in **[Question 5.1 - Question 5.2] NEW/REMOVED ACTORS** and delete their pools.
- c) Check technological resources in **[Question 5.3 - Question 5.4] NEW/REMOVED RESOURCES** and delete or edit the pool of the digital solution.
- d) Select actors that were part of the process before and have been replaced in **[Question 5.1 - Question 5.2] NEW/REMOVED ACTORS** and create new pools. Add start and end events inside the pool.

### 2) Tasks, connections, gateways

- a) Take inspiration from **[Question 5.5] ACTIVITIES PROCESS BEFORE** and edit the pool of each actor with corresponding tasks, relationships, gateways and annotations following the instructions provided in **Diagram 1: BPMN process after**.  
**NOTE:** try to maintain consistency with the structure of the process after. Take inspiration from the information provided in **[Question 6.1] TRANSITION**.

### 3) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-after-diagram\_V1.png*

## Diagram 3: BPMN processes overlap

Please consider the examples provided (i.e., [Process before - BPMN](#) - [Process after - BPMN](#) - [Process overlap - BPMN](#)) to understand how to create the overlapping view. In addition, download this BPMN source file with an example of overlap: [BPMN source overlap](#).

### 1) Actor pools

- a) Copy in a new file the model(s) created in **Diagram1: BPMN process before**.
- b) Paste in the new file the content created in **Diagram2: BPMN process after**. Place Diagram2 next to Diagram1 and compare the two processes.

## 2) Green elements

- a) Colour in green all the elements of **Diagram1** that do not change in **Diagram2**.

## 3) Red elements

- a) Colour in red all the elements of **Diagram1** that are no longer present in **Diagram2**.

## 4) Blue elements

- a) Copy-paste all the new elements from **Diagram2**, colour in blue and overlap to **Diagram1**.

## 5) Remove Diagram2

## 6) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-overlap-diagram\_V1.png*

## 2) Green elements

- a) Colour in green all the elements of **Diagram1** that do not change in **Diagram2**.

## 3) Red elements

- a) Colour in red all the elements of **Diagram1** that are no longer present in **Diagram2**.

## 4) Blue elements

- a) Copy-paste all the new elements from **Diagram2**, colour in blue and overlap to **Diagram1**.

## 5) Remove Diagram2

## 6) Export and save

Export a high-quality image in PNG format and save the file in the BPMN software format. If you produce multiple versions of the diagram, add the version number on the filename. E.g., *process-overlap-diagram\_V1.png*