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DESIRA

DIGITISATION: ECONOMIC AND SOCIAL IMPACTS IN RURAL AREAS

D2.2 NEEDS, EXPECTATIONS, AND IMPACTS SYNTHESIS REPORT

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KEY FINDINGS

This synthesis report summarises the assessments of Needs, Expectations, and Impacts of digitalisation (NEI assessments) carried by 21 Living Labs (LL). In this report, LL were multi-stakeholder platforms set up to evaluate the past and present impacts of digitalisation. Despite the COVID-19 challenges, primary and secondary data was collected between May 2020 – March 2021.

CONTEXT AND FOCAL QUESTIONS

Agriculture, forestry, and rural areas have inherited a complex political, economic, geographical, cultural and regulatory matrix. Digitalisation happens in a European context full of opportunities, yet challenged by various threats such as rural depopulation, illegal wood logging and trade, biodiversity decline, and the dominance of corporative and consumerist food systems. Understanding the contextual threats and opportunities set the basis for the LL's focal questions.

LEVEL OF DIGITALISATION ACROSS THE LL's FOCAL QUESTIONS

Harmonised statistical data on the level of digitalisation is lacking at lower administrative levels of European rural areas (e.g. DESI index). Semi-structured interviews and two questions of the DESIRA online survey were used by the LL to deepen the context analysis. The findings reveal that internet connectivity and broadband coverage is perceived as generally medium-high, although not uniformly (costs, stability, speed, ownership). Higher scores were given also to women participation and use of internet service by people in the field of agriculture, forestry, and rural areas. Comparable lower scores were awarded to the level of digital skills and use of digital tools in public services. Internet services such as websites and online platforms, social media, cloud services and applications are the leading digital technologies trumping more advanced digital technologies such as sensors, drones, satellite imagery, blockchain, and 3D printing.

SOCIO, CYBER, AND PHYSICAL ENTITIES ARE INCREASINGLY INTEGRATED

With the increasing datafication and connectivity in agri-rural and forestry areas, social entities, physical objects, and their performed activities coagulate and become integrated in '*digitalised milieux*': everyday life places and ecosystems where digital technologies mediate and affect the relationships among entities in order to perform a vast array of functionalities (e.g. matching, comparing, filtering, predicting).

In digitalised milieux, the boundaries between socio, cyber, and physical entities diminish and get blurred. Main cyber-entities emerged in the DESIRA Living Labs' participatory mapping exercise were internet connectivity; social media and network; web-based technologies; autonomous systems and robots; cloud/edge computing; remote sensing; data-analytics software; artificial intelligence and Internet of Things.

DEVELOPMENT AND DIGITAL NEEDS OF SOCIO, CYBER, AND PHYSICAL SYSTEMS

Among the development needs, LL reported the gaps between the current and desired state of SCPS such as reducing livestock emissions, increasing cost efficiency in weed control, raising societal awareness about climate change and wildfire, creating conditions for accessible housing and more. Digital needs were strictly connected to digitalisation, but highly connected to the development needs. Some examples were connectivity, data availability, data security, or digital skills.

DIGITALISATION IS IMPACTING THE EFFICIENCY OF AGRICULTURAL, FORESTRY AND RURAL ACTIVITIES

As part of *boosting effects*, digitalisation is reducing information asymmetry, lowering transaction costs, reduce risks of human errors, speeding up procedures, and more. On the other hand, *depleting effects* were found on the ratio between input/outputs and other intangible aspects, for instance when considering negative externalities (digital pollution or information obesity), investments and time for adopting new digital skills and practices, adding more stress on workers and increasing tensions between individual private and professional lives.

DIGITALISATION IS IMPACTING THE EFFECTIVENESS OF AGRICULTURAL, FORESTRY AND RURAL ACTIVITIES

In terms on *enabling effects*, digititalisation is contributing to the creation of new activities, products and services, such as monitoring and analysing agri-environmental data, market stock pooling, on-farm and off-farm diversification activities, remote working, and real-time alerts in case of forest fires. On the other hand, digitalisation is also generating *disenabling effects*, like displacing agricultural workers in rural areas, losing of traditional skills and human knowledge, deteriorating autonomy, and diminishing in-person contacts and services in rural areas.

DIGITALISATION MEANS MORE THAN WINNERS, LOSERS, PROPONENTS AND OPPONENTS

When it comes to entities, *winners* are those who gains the benefits of this transformation, like farmers using online tools to facilitate the organisation of their direct selling or on-farm community-gatherings. At the same time, farmers can *lose* if they must bear additional costs while the added value is still captured by data owners or supply chain intermediators. Animals and nature in general might be further 'objectified', 'genetically engineered', and 'dominated' by precision farming innovations instead of enhancing their welfare and social agency (e.g. in biodynamic or social farming). Under different conditions, the same entities can win or lose, oppose or propose. Understanding these conditions is key to reconcile tensions between private, public, and individual objectives and rights, and foster a just and sustainable digitalisation.

TRADE-OFFS EXIST IN THE CONTRIBUTIONS OF DIGITALISATION TOWARDS THE UNITED NATIONS' SDGs

Most of the links found by the Living Labs between digitalisation and the SDGs were positive, especially for the *'productive' goals*, like SDG 8 (Decent work and economic growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 12 (Responsible consumption and reproduction). Apart from climate action (SDG 13), less positive and negative links were identified between digitalisation and *'environmental' goals*. The achievement of the SDGs cannot be attributed only to **design** of digital technologies, skills, data infrastructures and flows. **Access** to digitalisation, as well as other socio-economic, environmental or cultural factors (**System complexity**) mediate the attainment of the SDGs.

THREE AREAS TO WORK ON A JUST AND SUSTAINABLE DIGITALISATION IN AGRICULTURE, FORESTRY, AND RURAL AREAS

In terms of ***design***, future policy-making and technological development must consider a number of aspects like: functionality; flexibility; adaptability; transferability; scalability; control; internal biases; health security and compliance with data protection regulation; copy-rights and licenses; data infrastructure; material requirements; reparation and recycling, and more importantly the ratio between investments and value-creation, capturing, and distribution.

In terms of **access**, the following aspects emerged as crucial elements for a just digitalisation: ownership; quality of connectivity; opportunity costs of learning; easiness of mastering; purchasing capacity; transparency and data sharing code of practices that enable an open data society; socio-geographical entry barriers; and anthropological, political, and cultural considerations.

In terms of **system complexity behind digitalisation**, the Living Labs' assessments suggest looking at advisory and innovation-risk bearing systems; official protocols and standards to design and commercialise digital technologies (agricultural robots or unmanned vehicle); the power and political context; technological path dependency; cooperation among actors involved data systems and service providers; regulations, policies, and collective actions for a sustainable digitalisation.

SETTING THE DIRECTIONS FOR FUTURE EVALUATIONS OF DIGITALISATION

In the era of data abundancy, statistical data about the level of digitalisation across European rural areas is lacking. Without sound and longitudinal datasets, how can future evaluations demonstrate robust evidence about the assumptions carried by digital tools (e.g. lower pesticides thanks to precision farming)? How can advisors and decision makers move away from commercial claims and technofix approaches supported by simplistic comparison methods and poor data?

The further application of mixed quantitative and qualitative analyses is needed to verify conclusions and consider the multiple factors interfering with the causal-links between digitalisation and its impacts. The synergies and tensions emerging from multiple views add a learning and empowering layer to summative, expert-restricted evaluations.

Finally, this report suggests future evaluations like cost-benefits analyses at technology level to consider the life-cycle, energetic, ecological, and material costs of technologies, until waste disposal and recycle. Other intangible and indirect factors should not be neglected, like the implicit research assumptions and interests, timespan, stakeholder involvement, and the deeper consequences that digitalisation has on society, labour, biodiversity, and knowledge.

List of abbreviations

Abbreviation	Definition
ICT	Information Communication Technology
IoT	Internet of Things
LL	Living Lab(s)
LL AT	LL in Austria, focusing on wood traceability
LL BE Flanders	LL in Belgium, focusing on ammonia emissions monitoring
LL CH	LL in Switzerland, focusing on weed control in organic farming
LL DE Lake of Constance	LL in Germany, focusing on fruit production
LL DE Rhineland-Palatinate	LL in Germany, focusing on digital village
LL EL	LL in Greece, focusing on smart rural communities
LL EL Trikala	LL in Greece, focusing on water management
LL ES Andalucia	LL in Spain, focusing on contrasting forest fires
LL ES Aragon	LL in Spain, focusing on territorial attractiveness
LL FI Central Osthrobotnia	LL in Finland, focusing on bioeconomy
LL FR Inno'vin	LL in France, focusing on the wine sector
LL FR AgrOnov	LL in France, focusing on the agro-ecology transition
LL FR Végépolys Valle	LL in France, focusing on horticultural companies
LL HR	LL in Croatia, focusing on farm diversification like direct selling
LL IE	LL in Ireland, focusing on local livelihoods and low carbon societies
LL IT Toscana Nord	LL in Italy, focusing on community and land management
LL IT PEFC	LL in Italy, focusing on wood-energy traceability
LL LV	LL in Latvia, focusing on digital marketing of beef meat
LL NL Flevoland	LL in the Netherlands, focusing on digital short food chains
LL PL	LL in Poland, focusing on enhancing participation in rural planning.
LL Scotland	LL in Scotland, focusing on crofting communities
NEI assessment	Needs, Expectations, and Impact Assessment
SCPS	Socio-Cyber-Physical System(s)
UN SDGs	United Nations' Sustainable Development Goals

1. Introduction

In various ways and to various extents, agri-food systems, forestry and rural areas in Europe are undergoing a process of digital transformation in a context full of opportunities, yet threatened by high environmental and climate pressure, rural depopulation, social inequalities, and biodiversity decline.

Deeply rooted in the idea of converting analogue information into digital formats (i.e. digitisation or datafication), digital transformation encompasses a larger set of dimensions that can affect these contexts: connectivity, skills, the use of digital tools in private, public, and civil society organisations.

Measuring the levels and impacts of digitalisation is conceptually and methodologically challenging. The concept of digitalisation is still embracing the evolutions and multiple disciplines at stake. Up to date, comparable statistical datasets to carry out robust counterfactual impact assessments are lacking at regional or local levels, expect for data on fixed broadband coverage (Clercq et al., 2020).

For anyone committed to evaluate the impacts of digitalisation, this exercise means framing and questioning their own **research purposes and assumptions**; disentangling **direct from indirect** consequences; observing changes in the **short and long terms**; understanding the **positive, neutral, and negative contributions**, as well as the **trade-offs** among them; distinguishing **relevant vs irrelevant** impacts in relation to needs; unpacking **desired vs undesired** impacts in relation to societal expectations, like the UN SDGs. The effective **stakeholder involvement** throughout the evaluation process adds another ethical and methodological layer to carry out **responsible evaluations** that close the gaps between science, technology, and society.

These challenges are reflected also in most of the publications currently available in the scientific, private, and policy domains, which limit the impact analysis to ex-ante assessments (e.g. what digital solutions could offer and potentially deliver), rather than bringing ex-post evidences and advancing the understanding of the deeper consequences of the digital transformation in the context of European agriculture, forestry, and rural areas.

This synthesis report shares the findings, lessons and challenges of applying a qualitative impact evaluation of digitalisation based on the conceptual framework of Socio-Cyber-Physical (SCPS) system, linking the analysis directly to the United Nation's Sustainable Development Goals (Rijswijk et al., 2021).

By operationalising the Responsible Research and Innovation approach (Owen et al., 2012; Stilgoe et al., 2013), 21 DESIRA Living Labs (LL) were established to enrol agriculture, forestry and rural stakeholders in this participatory impact assessment. The synthesis report is based on the individual needs, expectations, and impacts assessments (NEI assessments) carried out by the LL scattered across Europe. In line with other researchers (Dietrich et al., 2021; Marone et al., 2020), LL were set up as a participatory research methodology following specific DESIRA's ethical guidance. Their stakeholder composition varies to encompass the different actors relevant to address their focal questions in a real-life setting.

This report is structured as follows: **Chapter 2** presents the methodology and data underpinning this qualitative assessment. **Chapter 3** gives an overview of the Living Labs' contexts and focal questions, zooming more in-depth into the level of digitalisation. **Chapter 4** summarises the socio-cyber-physical entities, relationships, and needs identified by the LL in relation to their focal questions. **Chapter 5** describes the digital impacts identified on activities, entities, relationships and the UN's SDGs. Finally, **Chapter 6** identifies key questions and areas to consider in future policy making and technological development for a just and sustainable digitalisation of agriculture, forestry, and rural areas.

2. Methodology and data

2.1 NEI assessments at Living Lab level

As first step to gather stakeholders and carry out the NEI assessments of digitalisation, each LL elaborated their own **focal question** (see Annex 8.1). These questions allowed LL's to frame the scope, identify the specific topic, unit of analysis, geographic area, and possible hypothesis or sub-questions.

To facilitate the analysis of a complex process like digitalisation, the LL applied the concept of **Socio-Cyber-Physical Systems** (SCPS) as an analytical lens to research and gain insights on its past and present impacts (Figure 1).

Digitalisation or *digital transformation* is a process strictly connected to *digitisation*: i.e. the **technical conversion of information from analogue to digital format** (Autio, 2017). Through digitisation, data is generated from everyday life ("datafication"): peoples, social interactions, business activities or physical objects. However, **digitalisation goes beyond digitisation** (datafication).

Given the increased capacity to connect people and things through data infrastructures and flows, digitalisation entails the continuous **design and application of digital technologies and strategies**. Hence, digitalisation includes the design and use of **digital technologies**, **skills** and **infrastructure**.

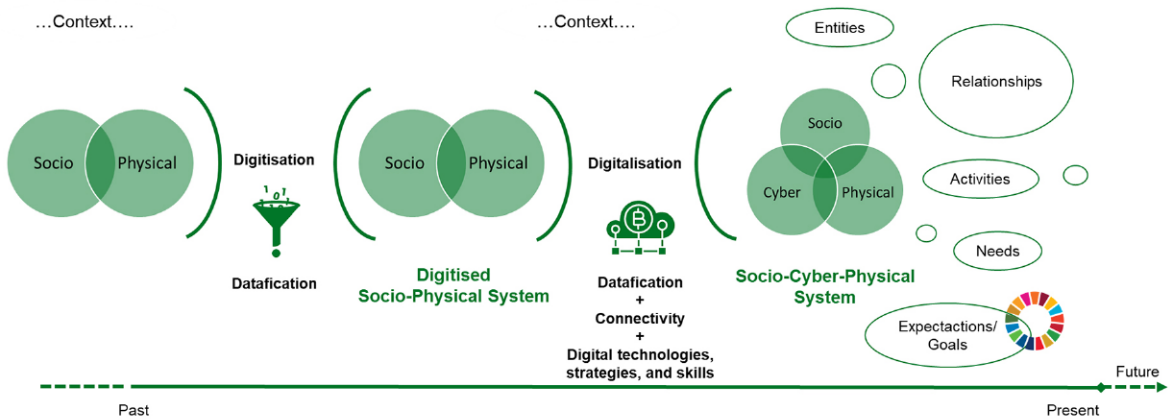
As pointed out by Rijswijk et al. (2021) and Vial (2019), the digital transformation is a process that can impact the complexity of socio-physical systems, i.e. the interactions between the various aspects of a system, such as (digital) technologies, skills, institutions, organisations, people, and the environment. Digital technologies, in these contexts, can become *game changers* when they alter the basic rule of functioning of the socio-physical systems in which they are embodied.

In more detail, a SCPS is delimited and at the same time includes the following elements (Figure 1):

- **A wider context**, which influences the structure or performance of the system (e.g. new socio-economic opportunities, climate or financial threats, long term demographic trends, deeply rooted values and intangible heritage).
- **Entities**, distinguished in those of the social domain (people and their social rules, laws, markets; institutions; animals); physical (natural or artificial things); and cyber domain (e.g. data infrastructure, software, digital devises and artefacts).

- **Relationships among entities**, the way in which two or more entities are connected within the same domain (e.g. farmers associated with cooperatives through a membership agreement, mutual trust, and sharing of assets) or among different domains (e.g. citizens registered in social media platforms; or an online platform matching suppliers and buyers).
- **Activities**, tasks or entire processes performed by individual or multiple entities (e.g. finance advisory service provided to citizens through mobile apps).
- **Needs**, defined in relation to the different entities and activities of the system (for whom?). These can be identified as the qualitative or quantitative gaps between the current and desired state.
- **Expectations**, which can be prospects of changes. They set the missions or targets, formulated in qualitative or quantitative ways, like the United Nations' Sustainable Development Goals.

Fig. 1: Socio-Cyber-Physical System as analytical tool for Living Labs' NEI assessment



Source: Own elaboration

To perform the NEI assessments, LLs used a **mix of data collection tools**: desk research, semi-structured interviews, online surveys, interactive workshops. These were applied in three phases:

1. **Living Labs' context analysis and assessment of main needs**

In this phase, the LL analysed the context of their focal questions in terms of strengths, weaknesses, opportunities and threats (SWOT analysis). By doing so, LLs were able to understand the larger trends, conditions, and forces that influence the composition and performance of the SCPS, as well as its level of digitalisation. The SWOT analysis considered various dimensions, such as social, economic, governance, environmental, gender aspects, but paid more attention to the level of digitalisation, based on the Digital Economy and Society Index[1]. The context analysis helped narrowing down the analysis on major needs, elements, and issues at stake in the SCPS.

1 Due to the lack of data for the DESI index at NUTS3 or NUTS4 level, Living Labs gave a qualitative estimation (1=low to 7=high) in relation to the level of digital connectivity, skills, use of internet services by citizens, integration of digital technologies by business, public services, and women in the area under study.

2. **Living Labs' description and visualisation of the Socio-Cyber-Physical Systems**

In this phase, LLs prepared a preliminary drawing of the SCPS before its final validation and assessment with the participants. This phase provided the opportunity to list and visualise the relationships between entities across different or within the same domain (socio-socio, socio-cyber, etc.). To facilitate the identification of existing and already adopted cyber-entities, the LLs relied on their own expertise and the DESIRA's taxonomy and inventory of digital technologies.

3. **Living Labs' participatory impact assessment**

Impacts were assessed *ex post* (past and present). To engage stakeholders in the participatory assessment, impacts were defined as the direct and indirect, positive or negative implications of existing digitalisation upon the entities, relationships, activities mapped out by the LLs in their SCPS, as well as upon the 17 SDGs. These impacts were captured in qualitative terms based on the perception of the respondents and participants of LLs' research activities. The assessment of future or 'potential' impacts was demarcated from the past and present ones. Future-oriented assessments are conducted in another separate DESIRA Working Package 3 (Developing scenarios).

NEI assessments in practice: Living Labs' experiences during COVID-19

Though the above-described phases served to guide the assessments across the LLs, their logical sequence was re-adapted to the specific circumstances of the LLs. For instance, as part of the formation process of a bottom-up and participatory assessment, some LL coordinator went back to fine tune the initial focal question after having carried out the SWOT analysis and need assessment together with the invited actors. Similarly, some LLs readapted their SCPS preliminary mapping after having reflected on the perceived changes and impacts of digitalisation. In practice, LLs implemented this methodology through an iterative rather than linear sequence.

The number and definition of stakeholders for each NEI assessment was left up to the LLs for the purpose of inviting meaningful and active actors who have a stake on the issue addressed by the focal question. During the COVID-19 lockdown, the initial plans to mobilise stakeholders with in-person, physical gatherings accessible to the target stakeholder group had to be readapted. Hand-outs, brown papers for large and small group exercises, post-its, pens and flipcharts had to be digitalised in PPT, online meeting rooms, and collaborative online platforms. Given the overload of online encounters experienced during COVID-19 pandemic, the time dedicated to online, in-depth discussion and participatory appraisal had to be shortened compared to the planned in-person working sessions.

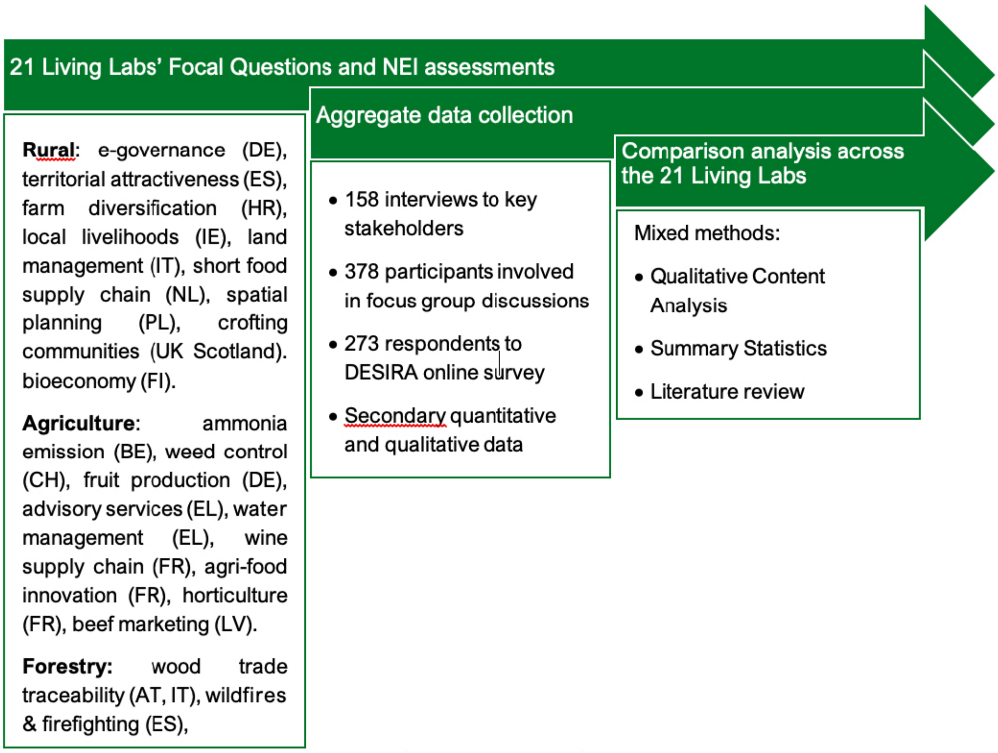
Finally, the generic terminology and analytical tasks proposed in this methodology required considerable translation and re-grounding efforts from the LLs to contextualise and simplify the activities in a real-life setting. While such translation was an opportunity to organically address a novel topic like digitalisation in a mixed group in terms of age, gender, roles, stakes, and views, yet some of the underlying features and purpose of each analytical tools became blurred, overlooked, or diverted. The lost-in-translation effect became particularly challenging to avoid when group work questions had to clearly distinguish between ex-post vs ex-ante impacts, or when they aimed to sharpen a generic listing of digital categories (e.g., social media, platforms) with more concrete, specific examples of digitalisation existing in practice.

2.2 Comparison analysis across the Living Labs

The online survey set up by DESIRA Working Package 2 was largely standardised (see Annex 8.2) in order to collect comparable information across the LLs. The remaining data collection tools were then tailored by the LL to cover their main information gaps and needs. The COVID-19 outbreak has hugely affected the organisation and accomplishment of participatory assessments. Especially in those LL where stakeholders engagement was limited by poor internet connection in remote rural areas, high number of online meetings spurred during the pandemic because participants were difficult to reach via online methods.

To ensure harmonisation of key concepts and methods throughout the process, LL followed common guidelines, written notes, and online trainings about research method tools (see tool about assessing the digital impacts on activities in Annex 8.3). The collected data were reported to the University of Pisa by means of a common template. The findings were firstly exchanged in a peer-to-peer meeting among Living Labs, then summarised in this Synthesis Report. Figure 2 gives an overview of the entire methodology underpinning this synthesis report, from the LL's NEI assessments to their comparison.

Fig. 2: Overview of methods underpinning the comparison analysis across the LL



Source: own elaboration

As regards the LLs' contexts, this analysis and synthesis tried to answer the following questions:

- What are the main opportunity and threats, strength and weakness related to the 21 Living Labs' focal questions?
- What are the stakeholders' perceptions about the current level of digitalisation related to their focal questions?

As regards the LLs' description of the SCPS, these were cross-compared to answer the questions:

- What are the main commonalities/differences across SCPSs, both in terms of entities and relationships involved in the socio, cyber and physical domains?
- Which are the main examples of digital technologies provided by LLs?

Afterwards, a narrative was built around the concept of "digital(ised) milieu" (Hui, 2012) and "application scenario" (Bacco et al., 2020) in order to answer these additional questions:

- How are cyber entities affecting the common life of those who live in rural areas and deal with agri-food and/or forestry activities?
- What are the application scenarios where cyber entities have been incorporated and are affecting relationships among socio, cyber and physical entities?

Once these polysemous macro entities were identified, then attention was paid to synthetically map and describe the main (intra- or extra- domains) relationships which had been created, eliminated, and/or modified by the interventions of digital artefacts in the last ten years. In doing so, a narrative was built around the concept of "digital(ised) milieu" (Hui, 2012) and "application scenario" (Bacco et al., 2020).

As regards the LLs' assessment of impacts, the following comparison questions were addressed:

- What and how has digitalisation impacted the SCPS activities until today?
- Who benefits, looses, promotes, opposes to digitalisation, and why (under which conditions)?
- How has digitalisation contributed to the achievement of the 17 SDGs?

All of this said, some caveats are certainly deemed appropriate, to make the reader aware of possible drawbacks of this synthesis report and enable a good use of its content. Main limitations are henceforth listed and briefly described:

- **Research biases**: The individual NEI assessments were restricted to the Living Labs' focal questions and, in some cases, determined by the LL's own research agendas. Common guidelines and trainings were provided by the Work Package leading partners to harmonise the multiple analyses.
- **Selection bias**: e.g. in the stakeholder engagement and composition of Living Labs (e.g. gender, age, education, professional status, location).
- **Digital bias in data collection tools**: some stakeholders were excluded by the digital means of data collection (online focus groups, online survey) and this issue was further exacerbated by the COVID-19 restrictions.

- **Low level of digitalisation**: for some Living Labs', focal questions were selected where none or few general examples of digitalisation were available (e.g. social media).
- **Conceptual challenges**: difficulties in distinguishing past, present, and future impacts of technologies and skills widely used or still under developing and piloting phase.

The findings were certainly affected by these shortcomings. Therefore, they cannot be interpreted as representative of all the interests and expectations at stake in the sectors under analysis. It follows that conclusions cannot be certainly generalised, being greatly based on specific case-studies carried by the LL. Further application of mix method research is needed to overcome some of these caveats.

3. Understanding the context

The complex political, economic, geographical, cultural and regulatory matrix that rural areas have inherited set up an evolving context for studying socio-cyber-physical systems. Understanding the context means recognizing the internal strengths and weaknesses of a system, as well as the opportunities and threats that are stemming from the surrounding structure and situation. The combinations of these factors were the ingredients used in the formation of the focal question of each Living Labs as shown in Annex 8.1. More in detail, the context diagnosis carried out by the LL prior to this NEI assessments looked at the overall **level of digitalisation** (Chapter 3.2) in the areas under analysis (e.g. community, local, regional or national areas depending on the focal question).

This section summarises the main strengths, opportunities, weaknesses and opportunities of the context underpinning the LL' focal questions and their socio-cyber-physical systems, with an in-depth analysis of the level of digitalisation based on the Digital Economy and Society Index's dimensions.

3.1 Living Labs: context and focal questions

3.1.1 Agriculture domain

The LL in West Flanders focused on the question: "*What is the impact of individual farm-based airborne monitoring of emissions of ammonia, particulate matter, and odour in the intensive livestock sector for agriculture policy and society in Flanders?*" Ammonia emissions from livestock are a source of tensions between stakeholders. On one hand, rural populations and nature organizations ask for a substantial reduction of emissions; on the other, farmers are concerned about their future, as they see the regulation on emissions as a threat to their existence. Digital technologies and data systems, in this context, can operate both as a means for improving farm processes (as data useful to better management of livestock), but also as an instrument of surveillance, with the risks related to the pressure of regulators and public opinion and to the falling reputation in case of transgression. A win-win solution, if possible, will have to link appropriate technologies to revised rules, practices, and infrastructures.

The LL in Switzerland focused on the question: "*How to control weeds effectively and efficiently in Swiss organic vegetable farming?*". Labour and a system supporting crop rotations (knowledge, seeds, incentives) are the most important resource in sustainable weed control. Robotisation of weed control was investigated as socio-technical solution to support organic production in the field. However, weeding robots are currently only in a piloting phase. Robotisation and the link with better data collection (mechanical robots embedding GPS and cameras) can overcome labour costs, ameliorate the working comfort, and increase economic efficiency of weed control. However, robot safety and legal data issues represent the main threats and need to be clarified and secured.

The LL in the Lake of Constance region (Germany) focused on the question: "*How has digitalisation contributed to the sustainability of fruit production in the Lake of Constance region?*". The fruit sector is facing strong challenges, which encompass both socioeconomic and environmental aspects. On one hand, protecting agricultural biodiversity and changing consumer behaviours are opportunities to valorise high-quality fresh produce. On the other, the climate change and dependence on foreign seasonal workers represent the main threat to the fruit sector in the region. Digitalization in this sector is fast speeding up, from farm to fork, and supply chain actors show high expectations for digital solutions.

One LL in Greece focused on the question: "***How*** have new digital services and functionalities based on utilising existing agricultural infrastructures and tools supported the economy and farmers' income in rural communities?" The LL addresses specifically on various elements of the digitalisation in the Greek tobacco sector. Strong policy and market changes have made tobacco cultivation risky, reflecting the dependency from EU subsidies and weak position of farmers along the supply chain. Digitalisation was investigated as mean to foster the transition to a diversified cropping system and rural economy, for instance, by improving knowledge and information sharing about new or diversified crops and upgrading the farmers' position along the supply chain.

The LL in the South-West of France focused on the question: "*How have digital technologies in the wine sector helped achieving the agro-ecological transition and competitiveness of farmers along the value chain?*". The LL focuses on digital innovations in both upstream and downstream sides of the value chain. The wine sector is affected by structural changes, low farmers' generation renewal, changes in the markets due to ICT tools (i.e. e-marketing, new marketplaces, digital enotourism). To exploit the benefits of digitalisation in knowledge exchange and information acquisition (i.e. traceability and transparency), the region needs to meet new digital literacy and connectivity requirements.

The LL in Centre Val de Loire and Auvergne-Rhône-Alpes of France focused on the question: "*How has digitalisation allowed companies in the French horticultural sector to remain competitive on the international market?*" The LL addressed digital solutions that can reduce the competitiveness gap with other agricultural sectors. Moreover, the current workforce shortages and the recent change in regulation (i.e. health legislation, rules for issuing plant passports), the development of new sustainable standards and labels (Blue Plants, Flowers of France, etc.) are challenging the vegetable sectors in the region. Digitalisation can become one of the tools to increase the economic and environmental performances of the sector, enhance competitiveness, reduce costs, inputs and labour requirements, and support better-informed decisions on the consumers' needs and demand.

The LL in the Adriatic Region of Croatian focused on the questions: "*How has digitisation contributed to strengthening the connections between farmers and tourists, and create a better position of the small* *family farms in the value chain?*" Living lab focuses on the emerging topic of interactive web applications technologies to improve (small) farmers' access to the new digital marketplaces. The Adriatic Region is experiencing a growing touristic demand, but this does not properly involve rural areas and farmers. Digitalisation represents an opportunity to digitalise the connection between agricultural and tourism sector. However, the lack of existing virtual or physical reflexive space requires an institutional change and the creation of a new and governance mechanisms and networks to improve (small) farmers engagement in touristic governance.

The LL in Latvia focused on the question: "*How have digital tools for quality recognition, traceability, and direct selling of beef meat improved market conditions for producers?*". The beef sector in Latvia is experiencing significant structural changes (drop in the production and development of organic beef livestock systems), a shift in consumer preferences (change in the dietary and reduction of domestic consumption) and a deep transformation of socio-economic and political context (i.e. reducing population). Digitalisation is an opportunity to improve the traceability of beef cattle meat and reaching new markets.

3.1.2 Forestry domain

The LL in Austria focused on the question: "*How has digitalisation supported the enforcement of the European Timber Regulation (EUTR) concerning imported round wood in Austria?*". The LL focuses on the role of digitalisation in the implementation of the European Timber Regulation and which role digitalisation plays. There is a long-existing forest law guaranteeing sustainability in Austria, but the growing demand for Roundwood has posed the threat of placing illegal deforested products on the European market. Digitalisation represents an opportunity to increase the transparency of the timber market, but the diffusion of digital solutions requires uniform legislation and the define of common standards to be adopted in global digital technologies.

The LL in Andalusia (Spain) addressed the question: "*How has digitalisation contributed to reduce the damage caused by wildfires and to make more effective firefighting and degraded land restoration?*". Forest fires are dramatically increasing in recent years, threatened by the reduction of the rural population, land abandonment, change in the ecology of the territory, and climate changes. Although digitalisation opened many opportunities (i.e. developments in telecommunications like 5G, spatial data techniques, availability of satellite information (Copernicus, Sentinel satellites), the current and the new policy framework encourages the adoption of digital technologies are the main obstacles.

The LL in Italy addressed the question: "*How has digitalisation supported the wood-energy traceability along the supply chain in conformity to the compulsory EU Timber Regulation (995/2010) in Italian forests?*". Illegal logging accounts for more than one-third of the global trade of timber. Although the European Timber Regulation prohibits illegal timber and requires specific information on the timber imported (i.e. country of harvest, tree species, quantity, supplier, trader and compliance with applicable legislation), its implementation is mainly based on desk audit based on paper-based approach. The availability of mature technology in other sectors and the possibility to implement traceability processes using wood DNA offer an opportunity to improve the monitoring of the logging.

3.1.3 Rural domain

The LL in Rhineland-Palatinate (Germany) focused on the question: "*How has digitalisation integrated citizens as well as other local actors into the local administration, by cope with the internal and external challenges of digitalisation?*" The restriction to Covid-19 pandemic has pushed for the transition towards digitalised services in public administration, such as telemedicine, education and schools, and e-commerce. The living lab area suffers from rural exodus and economic transformation, with the second sector losing its relevance. Therefore, there is a need to improve the current administrative and public services through the participation of citizens. Some digital tools exist and are accepted (i.e. DorfFunk), but organisation issues and lack of uniform digital literacy are opposing to that development

The LL in Trikala (Greece) focused on the question: "*How has digitalisation contributed to the better management of water resources for the benefit of both farming purposes and the everyday needs of the citizens?"*. LL operates in a region with adequate water availability to cover agricultural, industrial and citizen demands. However, the Water authorities would like to promote a long-term plan for sustainable water use. The roadmap towards sustainability requires the adoption and diffusion of digital tools to improve administrative coordination, e-governance, better dialogue with society. These aims would also increase citizens' awareness of the sustainable use of natural resources.

The LL in Aragon (Spain) focused on the question: "*How has digitalisation contributed to enhance the global attractiveness of the territory of Maestrazgo and Gúdar-Javalambre while taking care of their natural resources and environment?*" The LL operates in a rural area with significant depopulation and poor investments in rural infrastructures, making the urban-rural divide very significant (i.e. attractiveness; job and income opportunities). Although the Maestrazgo and Gúdar-Javalambre areas show a high tourist demand, rural areas do not benefit from it. Digitalisation can represent an opportunity to increase the touristic demand for rural areas and add value to agricultural production jointly with the communication of the conservation and sustainable use of biodiversity and ecosystems.

The LL in Finland focused on the question: "*How has digitalisation contributed to close the (organic and inorganic) loops in the Biovalley economy?*" The LL operates in the Central Ostrobothnia region of Finland, which is not very well developed with digital infrastructure compared with Other Finnish Areas. Moreover, the region shows a contrasting situation between rural and urban areas in terms of digital infrastructure, investment and opportunities of digital technologies and e-administration. This contrast has required the mobilisation of rural actors toward creating the Biovalley in Finland (BF), which tries to advance systemic changes towards circular bioeconomy. Digitalisation can offer new opportunities such as new predictions (i.e. predict problems with humans' and animals´ health before; predictive maintenance also applies to machinery; or increasing the capacities to monitor functioning and performance in large areas.

The LL in Bourgogne-Franche-Comté Region (France) addressed the question: "*How has digitalisation contributed to the emergence of innovations in favour of agro-ecological transition in agriculture?*". The LL focuses on emerging innovation with many policy implications in light of European Green Deal. Digitalisation can represent an opportunity to improve data collection to support the effective agroecological transition (i.e. digital culture, financial farm sustainability, types of product and location) and improve the knowledge sharing between actors involved in such transition. However, the infrastructure and the digital skills of non-young actors are the main obstacles.

The LL in Cloughjordan (Ireland) addressed the question: “*How has digitalisation fostered the collaboration between colleagues and partners, educators and students, and producers and consumers, in the context of a community enterprise centre in rural Ireland, and how can these changes contribute to local livelihoods, rural regeneration, local supply chains, and reducing carbon emissions?*” The LL is developed in the Cloughjordan Ecovillage and is active in sustainable rural regeneration. The Ecovillage shows a quite established digital process (i.e., FabLab, digital media studio, and Open Food Hub), and consider digitalisation as strategic tool for enlarging partnership, collaboration, and remote working.

The LL in North-Tuscany (Italy) focused on: “*How digitalisation has affected the communication and information flows among citizens, farmers, public administration, and other stakeholders to make ordinary land management in marginal rural areas more effective*”. The LL operates in very vulnerable mountain areas and with growing land and water management challenges due to increasing the extreme weather event and rural depopulation with its consequence of less fewer (ecosystem) services provided by the farmers’ activities (i.e. surveillance, preservation of soil erosion, forest control). Although past trials have demonstrated the potential of digital tools (WebGIS), some institutional and governance issues represent the main obstacles to developing digital solutions.

The LL in the Netherlands explored the following question: “*How has digital systems/platforms contributed to establish and maintain vibrant (short food supply chain) communities within Oosterwold and between Oosterwold and Almere city region?*”. The LL aims to establish a better functioning of short food supply chains in the region, making these alternative food systems more inclusive. Digitalisation could be developed to exploit the new narrative of organic grass-fed cattle farming as well as to improve the traceability of high-quality beef. Digitalisation can offer an opportunity to create a vibrant and committed community around short food supply chains.

The LL in the Poland addressed the following question: “*How has digitalisation enhanced the participation in rural planning and improved the involvement of local communities in spatial planning processes?*”. The LL operates in a context with an innovative approach to spatial planning. Digitalisation has a very high potential to enhance participation and transparency in spatial planning as can improve the inclusion of multifunctionality and non-productive functions in local economies and new lifestyles. Therefore, digitalisation was studied as tool to reinforce of social and territorial identity.

The LL in Scotland addressed the following question “*How has digitalisation promoted the opportunities for crofting communities in Wester Ross?*”. The LL operates in a context with dynamic changes in spatial planning that involves the involving digitalisation. Digitalisation was studied from the perspective of enhancing participation and transparency in spatial planning as well as improving the multifunctionality and non-productive functions in local economies. Research activities looked at the interplay between digitalisation and territorial identity, community cohesion, and fairer marketplaces. All this was studied in a context where an enabling digital infrastructure (broadband) and access to specific digital tools are still weak.

3.2 The level of digitalisation across the Living Labs

As part of the context analysis, the appraisal of the level of digitalisation (skills, use of technologies, digital infrastructure, etc.) is one of the first step to build a common knowledge base among stakeholders and assess their impacts on the subject of their focal question (e.g. weed control in Swiss organic farming). Given the lack of harmonised statistical data at lower administrative levels (e.g. DESI index), two questions of the DESIRA online survey were posed to the LL stakeholders to ascertain their perception of the current level of digitalisation. The first question was based on the DESI dimensions and asked stakeholders to rank their perceptions on the subject and area of their focal questions. The results were expressed on scale ranging between 1 to 7, with 7 being the highest (Figure 3).

Stakeholders gave a high average score of 5.55 for general digital connectivity in the geographical areas concerning their focal questions. Many stakeholders explained that although the level of connectivity is high, there are some problems of limited internet coverage in mountain areas, as well as low incentives for some business to adopt digital technologies.

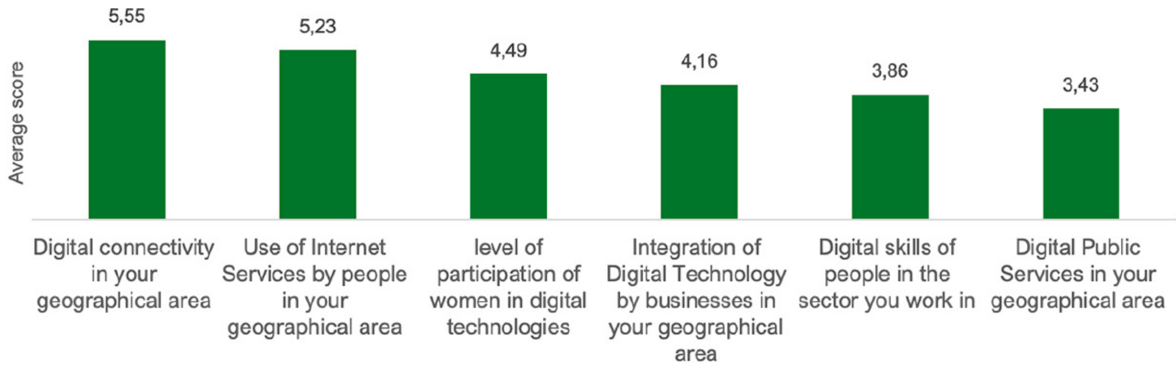
The score for the use of internet services by people in the geographical area is also high, but less than the score for general digital connectivity (5.23). Stakeholders explained that digital skills could be improved with adequate awareness of the opportunities that comes with this skill.

Stakeholders awarded an average score of 4.49 for women's participation in digital technologies. While there are opportunities for women to improve their participation in digital technologies, most stakeholders observed that many obstacles hindering women's active participation in the design and use of digital technologies (cultural, domestic, educational, professional).

A score of 4.16 was given for the integration of digital technologies in business. There is a general perception that wholesale business and supermarkets in the urban or peri-urban areas outperform rural business in the adoption of digital technologies.

Comparable lower scores were awarded to the availability of digital skills (3.86) and digital public services (3.43), indicating that these areas require policy attention. Generally, while digitalisation is perceived to be increasing, the usage among women and the application to business relevant to the stakeholders have lagged, and one of the factors leading to the lag could be limited digital skills in the communities.

Fig. 3: Average scores (from 1=low to 7=high) given by online survey respondents on the current level of digitalisation in the Living Labs' focal question? (N = 273)

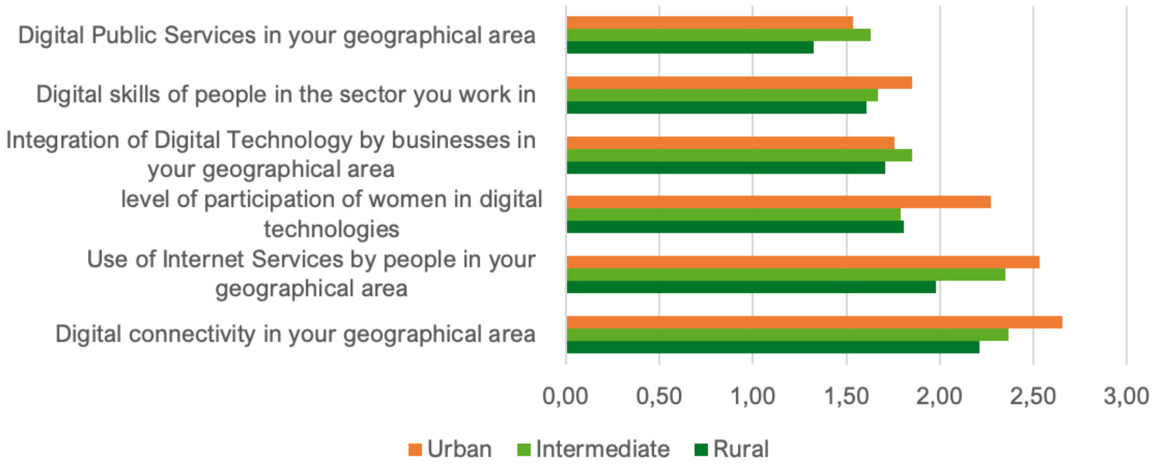


Source: own elaboration

The perceived divide between urban and rural is noticeable in digital public services, participation of the woman in digital technology and general use of the internet. The perception of the level of digital public services shows a low score for rural areas. Although the higher physical distances between the urban and intermediate areas suggest the opposite figure, digitalisation is not yet perceived as a tool to overcome it. This can be a consequence of the extent of informal knowledge exchange between rural communities or by low digital skills and infrastructures in these areas.

Although the woman's participation performs better than the level of digital public service, different type of stakeholders located in rural, intermediate, urban areas gave different scores (Figure 4). A digital divide between urban and the other areas can be linked to lower possibilities for woman entrepreneurship in these areas or contexts with little support to increase the overall digital literacy or develop proper infrastructure to make accessible services by all citizens.

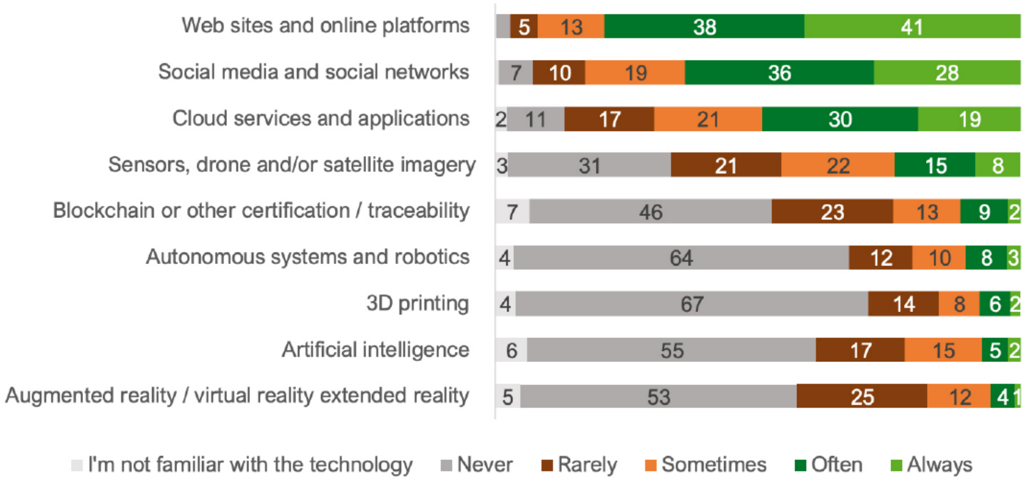
Fig. 4: Living Lab's stakeholders use of digital technologies in relation to the subject and areas of their focal questions (N=273)



Source: own elaboration

Another question from the online survey examined the level of use of different digital technologies in the LL stakeholders' working activities. Figure 5 shows the results expressed in percentages (i.e. number of stakeholders using the listed technologies over a total sample of N=273). Internet services such as websites and online platforms, social media, and cloud services and applications are the leading digital technologies the focal questions' stakeholders use in their working activities.

Fig. 5: Living Lab's stakeholders use of digital technologies in relation to the subject and areas of their focal questions (N=273)



Source: own elaboration

Websites and online platforms used by 79 percent of the stakeholders, followed by social media and social networks used by 64 percent of the stakeholders. Cloud services and applications are often or always used by almost 50 percent of the stakeholders. Several stakeholders also use advanced digital technologies applied in the production process. About 23 percent applies sensors, drones, and or satellite imagery, and 11 percent applies blockchain or other certification in their working activities. 3D printing, artificial intelligence, and augmented realities are the least applied, and they are applied by less than 10 percent of the stakeholders.

4. Overview of Socio-Cyber-Physical Systems

This chapter aims to answer the questions raised in the methodological section on how SCPS work, what are the differences or similarities, and what are the realms and the places where digital technologies have been mainly affecting relationships among socio, cyber and physical entities in agri-rural and forestry areas.

Based on LL descriptions, we aimed to look for main commonalities across SCPSs so as to identify a set of overarching and generic "agri-rural and forestry SCPS", where these three broad contexts (agriculture, rural and forestry) are strongly interrelated and interdependent and their boundaries are naturally blurred. Such an approach would help disentangle the natural complexity of strongly interconnected contexts, that a "stand-alone" approach would not be able to incorporate. However, at the same time, some residual peculiarities emerged from the specificities of the 21 focal questions.

As a general approach, synthetic visualisations of SCPS were built upon those provided by the 21 LLs (see Annex 8.4 for the list of SCPS visualised by each LL). Due to the nature of the information provided, a quantitative approach was used.

Thus, first we provided a description of both main common and peculiar macro entities at stake in the rural agro-forestry SCPS, followed by specific graphical visualisations. In both cases, emphasis was given to the description of how digital technologies (that is, cyber entities) had been impacting on (intra- or extra- domains) relationships among entities.

After the clustering of entities, attention was paid to synthetically map and describe main (intra- or extra- domains) relationships, that had been created, eliminated, modified by the interventions of digital artefacts in the last ten years. In doing so, a descriptive narrative was elaborated based on the concept of "digital(ised) milieux", which are environments where "*datafication of objects and objectification of data form networks across multiple domains*" (Hui, 2012).

4.1 Agri-rural and forestry SCPS: main entities

Agriculture, forestry, and rural areas were the three interrelated contexts underpinning the 21 NEI assessments. Each LL described and analysed specific SCPS by means of a mapping exercise. The different types of entities at stake were identified and their activities and relationships evaluated. The DESIRA's taxonomy and inventory of digital game changers was used to facilitate the mapping of digital technologies.

How did we identify the "agri-rural and forestry" SCPS?

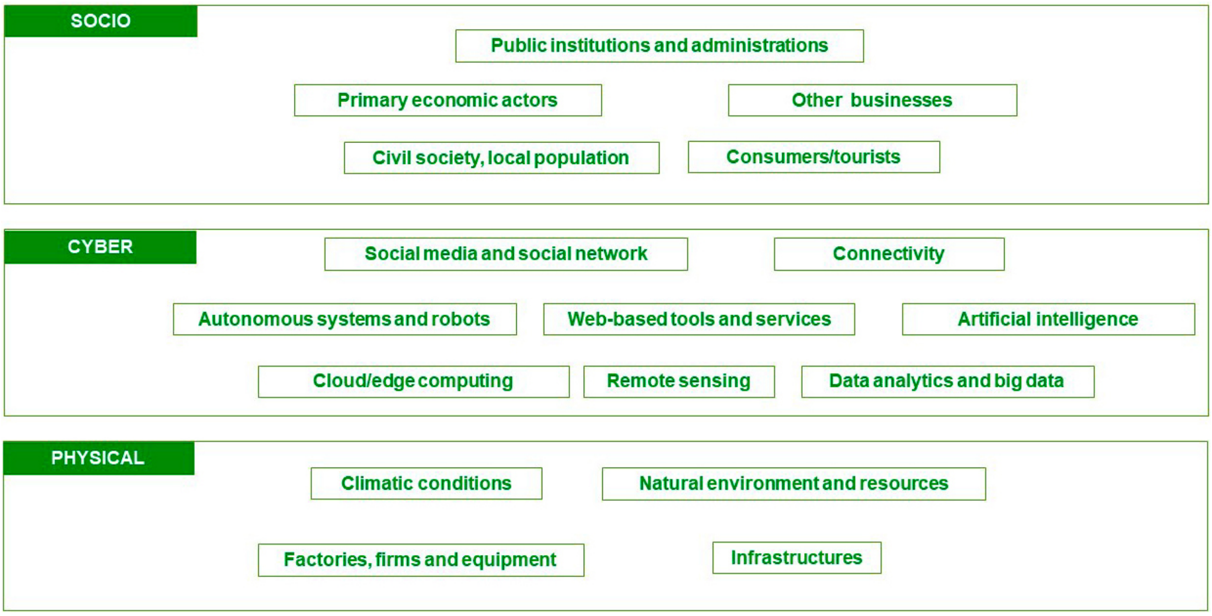
For the sake of simplicity, in order to avoid repetitions and proliferation of entities, these were aggregated in broad categories with common characteristics (macro entities), so as to map:

- actors, communities and institutions concerning the **socio domain**.
- digital constructs and artefacts including also data and algorithms concerning **cyber domain** following the taxonomy proposed by (Rolandi et al., 2021); and

- **natural or artificial elements and resources and (living or inanimate) physicality** concerning **physical domain**.

Despite the heterogeneity, many analogies emerged across SCPSs. This allowed for the identification of common entities and interactions across agricultural and forestry activities in rural areas. Based on these commonalities, Figure 6 summarises an overarching "**agri-rural and forestry SCPS**", whose components and relationships are common in all the domain under investigation.

Fig. 6: A schematic visualisation of an agri-rural and forestry socio-cyber-physical system



Source: own elaboration based on the 21 Living Labs' reports

In the social domain, the following common macro categories of entities were identified:

- **Public institutions and administrations** included their workforces, that firstly promulgate and then enforce rules and regulation at different territorial levels (European, national, regional and local). They are often also responsible for financing the provision of public services (such as health, education, research, social services), initiatives of public interests from private companies (by means of European Structural and Investments funds and similar).
- **Primary economic actors**, such as farmers and forest entrepreneurs carrying out farming, livestock and forestry (including their organisational arrangements, such as cooperatives, network, etc., and their associations) and workforces employed in these activities in rural areas, that use (material and immaterial) inputs to produce/provides goods (food, timber) and services (agritourism, ecosystem services).;
- **Other business actors**, such as input providers, banks, consultants, processors and manufacturers (e.g. sawmill), retailers, restaurants, hotels and so on;

- **Consumers in broad terms (including clients, end-users** and **tourists)** that buy agri-food and forestry products and benefit of local services, facilities and infrastructures in rural and internal areas;
- **Civil society**, that include **resident communities** stimulating public debate and collective actions and initiatives at local level as well as associations, environmental organisations, action committees, journalists and NGOs that animate rural and internal areas and small villages, thanks to bottom-up initiatives (e.g. Local Action Groups).

The cyber domain includes several digital technologies and skills whose uptake in an agri-rural and forestry SCPS is largely context-related, depending on economic but also socio-demographic and geographical and conditions. Below, cyber entities, standing alone or increasingly embedded in cyber bundles or digital ecosystems, that are common throughout our LL are listed:

- Connectivity, either fixed or mobile, that are infrastructures providing internet services (e.g. fiber optic network, WAN network, fiber broadband, 5G) also in peripheral and mountain areas such as Sigfox antennas;
- Social media and social network (Facebook, Twitter, and so on), including messaging platforms (WhatsApp and similar), collaborating tools such as Agricommunity, Cerdys, Miro, Loomio, Only Office, etc., traditional email and video conferencing platforms for interaction (Zoom, Teams, GMeet, Jitzi, Zoom etc.) as well as specific Apps/software used for traceability, communication (Smoke Sense for firefighting, DorfFunk to connect digital villages in rural areas in Germany, La Era Rural to boost young entrepreneurship in Spain, and the Oosterworld platform to foster online transactions not only related to agri-food products in The Netherland), logistics, resource sharing and commercial and promotional activities (advertising, purchasing group).
- **Web-based technologies**, IT portals, digital platforms and Apps to facilitate transactions, like accessing online public and private services (e-government tool such as E-loket in Flanders region and website of the municipal administration in Rhineland-Palatinate, the Intrastat and the specific Conlegno portal in the forestry sector in Italy, e-commerce tools such as QR codes or online marketplace in France, Latvia and Ireland, e-booking, weed and plot management, GIS services, data exchange, fires detections) or where data and information are safely stored in digital format (e.g. DJustconnect in Belgium and bg-aktuell.de in Germany).
- **Autonomous systems**, robots, such as automated field work in fruit production in the Lake Constance region, Naio technologies, autonomous tractor without cabin and milking systems in France, weeding robot in Swiss organic vegetable farming or Remote Piloting Aircraft Systems, that allow for the management of production or drive fire attack strategy thanks to real-time large sets flows of data and information, as well as drones embodying proxy-detection for plant diseases and weed control;
- **Cloud/edge computing**, for remotely storing resources and data in collaborative digital tools (such as Gdrive, Dropbox, Gdocs, OnlyOffice, SOBLOO, etc.);
- **Remote sensing**, which allows for the capture of data from different sources (satellites and manned or unmanned aircraft, such as MODIS, Landsat) providing an enormous amount of

information on the environmental, climatological and topographical conditions (such as digital mapping techniques for pest risk management in the LL FR Inno'vin, REDIAM in the Andalusia region containing relevant environmental information and humidity-irrigation sensors), as well as on water metering and diseases detection thanks to satellite imagery or machinery, in order to manage crop production or livestock (e.g. sensors on air scrubber in Flanders region, captors for cows to measure their health and wellbeing and tracking chip for flocks herds). Moreover, it can also provide accurate assessments of fire severity, offering valuable information for the design of restoration plans adapted to the real impact of the fire on the natural environment

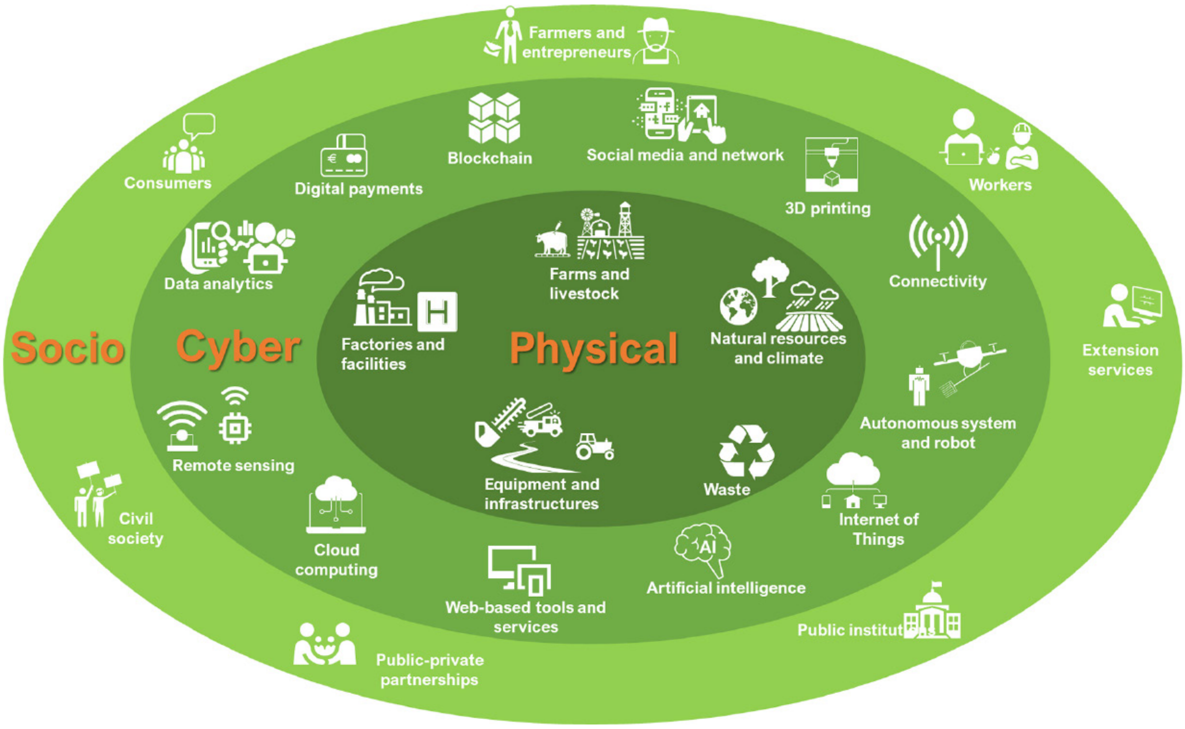
- **Data analytics software**, like search engines or predicting algorithms, used to collect and process **big data** and provide decision making tools (e.g. Loomio, Djustconnect, ecc.) for several purposes (real-time production monitoring systems, computer-controlled climate management and watering systems as well as managing phytosanitary treatments and irrigation in France).
- **Artificial intelligence and IoT** (e.g. machine learning), used to transform large amount of data into information for farming machinery, monitoring (e.g., IoT based smart water metering systems, GrainSense to analyze protein, moisture, carbohydrates and oil contents from crops) and building tools (e.g. digital callipers, laser levels).

In the physical domain, the following natural or artificial entities were identified:

- **Natural environment and its resources**, such as soil, air and water, raw materials, livestock and their emissions, forests, fields;
- **Climatic conditions**, affecting both production patterns (of crops, livestock and timber) and living conditions of local population (e.g. fire, droughts, floods) in rural and mountain areas;
- **Material infrastructures** in rural and mountain areas, that include roads, pump stations, roads, power line, etc. as well as public facilities (offices, hospitals, schools, and so on);
- **Factories, firms** and their **equipment, physical investments, inputs,** that are used in farming, forestry and related activities (e.g. animals, seeds, plants, fuels, tractors, sawmills, machineries, pesticides, offices, agritourisms, solar panels for energy sourcing and so on) as well as their **final outputs and by-products**.

Figure 7 provides a graphical visualisation of all the entities involved in an agri-rural and forestry SCPS as reported by LL. However, individual representations made by each LL are included in Annex 8.5.

Fig. 7: A graphical visualisation of an agri-rural and forestry SCPS and its entities



Source: own elaboration based on the 21 Living Labs' reports

4.2 Agri-rural and forestry SCPS: digital(ised) milieux

In order to understand whether and how cyber entities have mediated and affected activities, transactions, and, in some cases, the relationships among entities in the agri-rural and forestry SCPS, we identified seven digital(ised) *milieux*, already defined as environments where "datafication of objects and objectification of data form networks across multiple domains" to perform different functions.

What are digital(ised) milieux?

In digitalised milieux, the boundaries between socio, cyber, and physical entities diminish and get blurred. They represent everyday life's places/realms in agri-rural and forestry SCPS, where digital technologies affect and mediate relationships among entities in order to perform a vast array of functions in several "application scenarios".

Following Bacco et al. (2020), in turn, these scenarios are "*contexts where a given goal can be accomplished by using digital tools, setting the technical requirements around which these solutions should be designed, and defines the objective to be achieved*".

Figure 8 presents the digital milieux emerged across the 21 LLs: communities, public administrations and related facilities, agro-forestry ecosystems, business, markets and organisations and workplaces. Each *milieu* represents an "everyday life" environment that has repeatedly occurred in SCPSs descriptions provided by LL and, therefore, is deemed as highly significant for inhabitants of rural areas and those who deal with agri-food or forestry activities.

As a general remark, it is worth focusing on some prerequisites that make these digital milieux indeed operative and functional, according to LL descriptions. First and foremost, digital technologies require the presence of **physical infrastructures and resources** (servers, powerlines, hardware, and so on, that may be also negatively affected by cataclysms such as fire) and, moreover, their functioning depends on **sources of energy.**

Connectivity in internal and rural areas (that is the availability of infrastructures providing internet) is certainly a precondition in order to access web resources as to allow the use of a **large set of interconnected digital tools**, whose purposes are manifold for agricultural and forestry activities. Moreover, it allows to **remotely synchronise data and resources** across apps, (messaging) platforms and devices (smartphones, tablets, laptops, smartwatches as well as drones, sensors) as well as to geolocate objects, photos, data as well.

Likewise, **broadband availability and coverage is essential** to allow storing data and information in both private and public platforms and portals, using digital solutions for payments of goods and service, releasing and acquiring information related to farming, livestock and forestry activities. Figure 8 Digital(ised) milieux in an agri-rural and forestry SCPS

Fig. 8: Digital(ised) milieux in an agri-rural and forestry SCPS

Henceforth, a synthesis of the analyses provided by 21 LLs in the identified digital(ised) *milieux* is reported.

COMMUNITIES

Communities were central in many Living Labs, like Cultivate (a national NGO and Civil Society Organisation held on the Green Enterprise Centre in Cloughjordan Ecovillage, in Ireland), the Biovalley Finland hub in Central Ostrobotnia; the groups of crofters and fishers in remote Scotland; or the clubs and church congregations in Rhineland-Palatinate. In many instances, LL reported that local members are able to interact more with public institutions and their administration thanks to apps and digital platforms (i.e. early warning to public offices in case of fires in Andalusia region and guaranteeing safety in evictions).

Citizens and community groups can put pressure on decision-makers by means of social media campaign (e.g. advocacy activities of associations, NGOs for a participatory territorial planning through GIS tools and a sustainable management of both livestock emissions, such as in Flanders region, and natural resources, such as in the Austrian timber sector).

Did you notice that…?

As result of the COVID-19 pandemic, urban inhabitants looked for houses in small and amenable rural villages to benefit from remote working and improve their lifestyle, thus enhancing the likelihoods to interact with more remote, sparsely populated villages. In turn, this trend is affecting mobility and housing market in rural communities.

However, the increase of digitally mediated interactions and online social media has led to less direct and face-to-face relationships in rural communities. For instance, some automated and/or remotely controlled processes or routines have replaced/displaced/changed relationships within these social aggregates. As a consequence, people in several contexts (families, workplaces, associations, public offices, neighbourhood, ecovillages and so on) and with different roles interact also (if not only) by means of digital devices or services (social network, messaging platforms) to access and share information, experience and knowledge.

PUBLIC ADMINISTRATIONS

In public administrations and related facilities (including municipalities and their unions, regional and local authorities, managing authorities, prefectures, reclamation consortia, Ministries, etc.), digital technologies are increasingly displacing hard copies for digital files that can be stored and shared in platforms and databases.

This process of 'digitisation' is accelerating the provision of e-government services to remote rural areas, farms, and forest operators.

From e-government services…

Civil society and businesses in rural areas increasingly interact with public facilities through e-government apps and/or digital platforms in order to share documents, data and information by means of digital platforms (such as Intrastat and Metsaan, respectively, in the Italian and Finnish forestry sectors, E-loket tools in Flanders).

… to digital villages…

LL DE in Rhineland-Palatinate show that some "digital villages" implement platforms and service apps within the collective municipality of Betzdorf-Gebhardshain in Germany. As a result, mutual understanding and reconciliation among social entities arise.

Another example comes from the Greek municipality of Trikala, where the central platform city monitoring has been implemented, integrating sensors and controllers for smart public lighting and parking as well as an IoT-based smart water metering system.

…passing through citizen-led monitoring.

Lastly, the interaction between citizen-led monitoring and public service provision is also boosted by digital tools. This is the case of the forestry areas, where LL ES Andalucia reported that digital tools allow local inhabitants to interact with public offices and firefighters to spread real-time warning alarms in case of cataclysms as well as to design smart landscapes to the advantage of mountain population in case of fire. An example is Cybertracker, a free software to develop a worldwide environmental monitoring network by means of field data collection.

With the growing digitalisation of public administration, Living Labs raise numerous concerns on the increasing risk of cyber-attacks and data breaches that, in turn, entail the recruitment of data protection officers. Conferencing and messaging platforms and emails sometimes replace the direct relationships between employees and users in public administration, while on the other hand new interactions among offices, units or departments (that scarcely interacted in the past so as to real-time generate, collect, manage and share information and data) flourish.

BUSINESS

Looking at businesses, we observed the same trends with 'datafication' that are characterising other economic sectors. The various 'things' involved in farming, forestry management, or logistics operations are becoming sources of large volume of data. Data capturing along the forestry or food supply chains are feeding the creation and provision of new services (e.g. nutrient, pest, or water management decision support), whose value however is not always captured and shared with data providers (e.g. platforms users, farmers, public authorities).

Digital tools often replace/substitute practices used in agriculture and rural areas, making them obsolete or outsourced. For instance, in the LLs dealing with farming and agriculture, sensors and drones were connected to insect traps (such as in LL FR Inno'vin), management tools for pest and disease treatments and irrigation (LL CH and LL FR AgrOnov) as well as technical management software (LL FR Inno'vin). New services based on real-time data and prediction models are being offered to farmers (i.e. outsourcing farming activities to specialised companies). More digital tools mediate the relations between farmers and crops/orchards/timber growth or livestock development. They allow to monitor both input and output quantity and quality (included sensors on air scrubbers to limit airborne livestock emissions in Flanders region and portable near-infrared devices that analyse protein, oil contents and humidity from crops developed in Finland).

Sensors directly interact with machineries (digital mapping techniques), facilities (magazines with controlled atmosphere and artificial intelligence applied to processing machines in cellars in France). Sensors are also applied to autonomous robots in forestry and agricultural activities (livestock and crops). LL provided several examples of applications in this regard: weed control in French vineyards, milk production in Finnish cowsheds (along with RFID technology and visual scanners), organic farming in Switzerland and orchards in Germany.

Likewise, data (collected and processed by means of IoT, AI and proprietary platforms, software and packages that implement machine learning techniques) are used for farming and livestock production planning. In agri-food companies, sensors and machine vision techniques allow processors and retailers to get information on products' characteristics and their carbon and water footprint, whereas digital ledgers are used for labelling and certification purposes, and, lastly, digital maps (used, for instance, by courier services in Croatia) simplify interactions within the surrounding rural and urban environment allowing easier logistics for landscape management (as emerged in the LL IT Toscana Nord) and transportation/delivery of agri-food products and equipment.

Moreover, digital technologies free up time for real-time exchanges of information among stakeholders (farms, support structures and other related activities) and to develop tighter (remote and/or direct) cooperative interactions along agri-food supply chains to share information (as in La Era Rural, a network of young entrepreneur in Spain) as well as to pool resources, facilities, energy, services and logistic infrastructures (such in French horticulturists' collectives and among Scottish crofters). The other side of the coin is that direct (i.e. personal) relationships are less frequent in business since the interaction between employee and employers are increasingly mediated by digital technologies.

Likewise, interactions between crops/animals, on the one hand, and farmers/breeders/workers, on the other hand, have been reported to be weakened or more distant by the mediation of digital tools in farming and livestock activities. The same applies to the interaction between farmers and machineries/equipment that tends to decline in presence of remote-control solutions. Digital solutions and use of robots and automated machines also displace some manual (or in person) work activities (such as in milk production in Finland) in favour of more skilled workforce, as well as some intermediation activities such as those played by middlemen selling and buying agricultural products, replaced by direct B2C relationships (as emerged in the beef sector in Latvia).

Digital data ownership: a lesson from a LL

Worries about farmers' dependency on tech companies due to power relationships and data handling issues emerged, such as in the LL CH and LL FI Central Ostrobothnia. Moreover, among farmers, there is clear distrust to other stakeholders (mainly input providers, such as feed company, and tech companies) regarding data ownership.

In the Flanders region, the platform DJustconnect allowed everybody in the agricultural food chain (farmers, data providers, etc.) to control the use of to their own data.

MARKETS AND ORGANISATIONS

In markets and other forms of organisation of transactions, the uptake of digital technologies has paved the way for new ways of interaction between providers of public goods and services, management agencies and consumers/clients. Such a process certainly affects a vast array of transactional activities by reducing related costs: this is the case of (multifunctional) farmers.

Multifunctionality and digitalisation

Farmers adopted digital tools to sell local food to private and public clients (such as schools, hospitals, canteens) in rural France and in Croatia. In Scotland, the "Green Bowl" platform allowed crofters to sell their local products). In the Netherlands, the Platform Oosterworld allowed to promote goods and services also in urban areas.

On the other hand, as emerged in the LL HR, consumers use social media, instant messaging, digital and e-commerce platforms and e-mails to get more information on agri-food and forestry products, services, rural places, lifestyle (e.g. healthy diets, amenable villages, agritourisms, caterers, etc.). Moreover, they use apps and websites to interact with producers by giving feedback based on their purchasing experiences. At the same time, social media and messaging platforms create new occasions for interaction and real-time exchanges of information among consumers to establish and coordinate buying groups as well (as emerged in the LL LV).

Web services, social media and digital portals are also increasingly used to attract tourists that look for space rentals or people in search of secondary residencies in rural areas (as emerged in the LL Scotland). However, as a result of the ongoing digitalisation process, relationships mediated by intermediaries along the agri-food supply chain tend to decrease whereas, on the other hand, transactional relationships between new digital users (businesses, freelances, families, public administration) and producers/providers of digital devices emerge.

AGRO-FORESTRY ECOSYSTEMS

As far agro-forestry ecosystems are concerned, telecommunication systems, digital mapping techniques, remote sensors (which allow information to be taken from satellites such as Landsat, MODIS, Sentinel and manned or unmanned aircraft), software and apps with processing capacities of large volumes of information exploring data science techniques are used in agricultural and forestry activities. They aimed to monitor weather conditions, fires, input use (pesticides and fertilisers) and natural resources (atmospheric, soil and water parameters).

Digital technologies foster a data-driven interaction with plants and trees growth and livestock development that, in turn, affect the relationships with and the use of natural resources (water, soil and so on). In practice, modern decision support systems used to manage farm/forestry activities and performance are increasingly based on robots interacting with land parcels, livestock emissions and crops and sensors allowing machines to set and adapt doses of nutrients and pesticides to real-time needs of crops and livestock, so that the tie between entrepreneurs, workers and the surrounding agro-ecosystems are bound to lose.

On the other hand, digital technologies may strengthen the remote control of the environmental effects generated by economic activities in agroecosystems in order to foster a different (evidence-based) management and allocation of resources and waste.

Digital tools to fight fires

Digital tools are also deployed by public institutions to deter malpractices and foster best practices towards an ecological transition. In this regard, digital tools are changing the firefighting scenario, since remote sensing and spatial techniques permit both an updated knowledge of the forest status (vegetation index, fuel index, humidity level) and remote piloting of aircrafts which solve communication problems in firefighting.

WORKPLACES

The ongoing process of digitalisation is deeply affecting workplace nature as well. As widely observed during the COVID-19 pandemic, there is a decreasing level of direct interaction among co-workers and between employers and employees in public and private workplaces due to the uptake of proprietary digital tools (cloud computing, instant messaging, conferencing platforms and so on). All these technologies have certainly made remote (or agile) working widely possible, with direct consequences on commuting as concerns the use of means of transportations to the advantage of rural inhabitants as clearly emerged in rural Ireland and Scotland.

This process may also reduce interactions among social entities in workplaces (e.g. reducing the use of manual workforce in economic activities replaced by digital machines/devices or more skilled workforce) or modify the relationships between people and the surrounding environment, due to blurring boundaries between traditional living, working and recreational spaces with unknown psycho-physical effects as a result. As a whole, new relationships between people and their workplace emerge, so that the concept of workplace itself becomes more “liquid”.

KNOWLEDGE AND EXTENSION ORGANISATIONS

Lastly, as a result of such a constant and increasing uptake of digital tools, including in rural and remote areas, **knowledge and extension organisations** are also greatly involved in the process of digitalisation (as particularly emerged in the LL BE Flanders, LL CH, LL FI Central Osthrobotnia, LL EL and LL EL Trikala). In this regard, it is worth noticing that civil society (that is, local population, associations), economic actors (such as farms and other business in rural areas) and public administrations, all have started relying on (public or private) advisory and/or extension services for digital training, and e-education and field visits to pilot projects. In doing so, relationships between educators (such as technical school, Universities, etc.) and learners in agricultural knowledge and innovation systems are, in turn, mediated by video conferencing platforms and interactive digital tools (such as hi-tech farming platform and cloud-based databases of American Farm School in Thessaloniki, Greece).

In conclusion, with the caveat that SCSPs descriptions provided by 21 LLs have been decisively affected by their specific focal questions, what emerged is that digital technologies have become pervasive and transformative elements in agri-rural and forestry domains, affecting everyday actions and inter-actions/trans-actions among socio and physical entities in specific environments (*milieux*) for a multitude of purposes and functions.

4.3 Agri-rural and forestry SCPS: main needs

In relation to each focal question, LL coordinators synthesised the main stakeholders' needs, which can be distinguished in digital needs and development needs. The development ones are related to the broader social, economic, and environmental needs of the stakeholders and their area. Digital needs are strictly concerning digitalisation and are instrumental to meet the development needs. Table 1 presents some examples of the needs identified by Living Labs.

Tab. 1: Examples of development needs identified by the Living Labs in relation to the digital milieux

Digital milieux	Living Lab	Example of need reported by the Living Labs
Agro-ecosystem	Flanders (BE)	Reducing livestock emissions near rural populations and nature reserves
Agricultural Knowledge and Innovation System (AKIS)	Végépolys (FR)	Investing in independent Research and Development (field tests, cooperation) for farming practices and knowledge truly adapted to the specificities of various farm size and typologies, while reducing farmers' financial dependency on technology.
Business operations	Switzerland	Increasing cost efficiency in weed control
Community	Andalucia (SP)	Increasing awareness about the impact and danger of wildfires; how to proceed in case of an event and how to contribute to its prevention.
Local Development	Cultivate (IE)	Creating opportunities and conditions for people to work remotely in marginalised, rural areas
Markets	Latvia	Building capacity among farmers to reach consumers with appealing stories to convey to their target audience.
Policymaking	Poland	Improving spatial and land use planning within municipalities and neighbouring borders.

Digital milieux	Living Lab	Example of need reported by the Living Labs
Public Services	Trikala (EL)	Providing clean water to end-users through municipal network
Workplace	Lake of Constance (DE)	Reducing hard manual labour

Agroecosystem-related needs are related to the possibility of managing the agro-ecosystem, as in the case of water, pest management, soil. **AKIS**-related needs are related to the need of specific actors that can support processes of adoption of digital technologies. **Business**-related needs refer to efficiency, added value, profitability of firm operations such as production, processing, selling, logistics. **Markets**-related needs are related to the possibility to shape market configurations differently and to redistribute the power in the supply chains. Traceability or apps that connect farmers to consumers are examples. **Community**-related needs are especially felt in the case of rural application scenarios, where the role of social capital and a strong cooperation between rural population and public administrations is essential. In some Living Labs (as in the case of Andalusia and in Tuscany, Italy) social capital is necessary to important public goods as fire prevention or water-related risks.

Table 2 shows the digital needs identified by Living Labs, with examples. The fulfilment of digital needs can represent a mean to fulfill of development needs. In other cases, like respecting good agronomic and environmental conditions in agriculture, other non-digital needs must be fulfilled (e.g. access to seeds, tools, and knowledge to design and implement multiannual crop rotations).

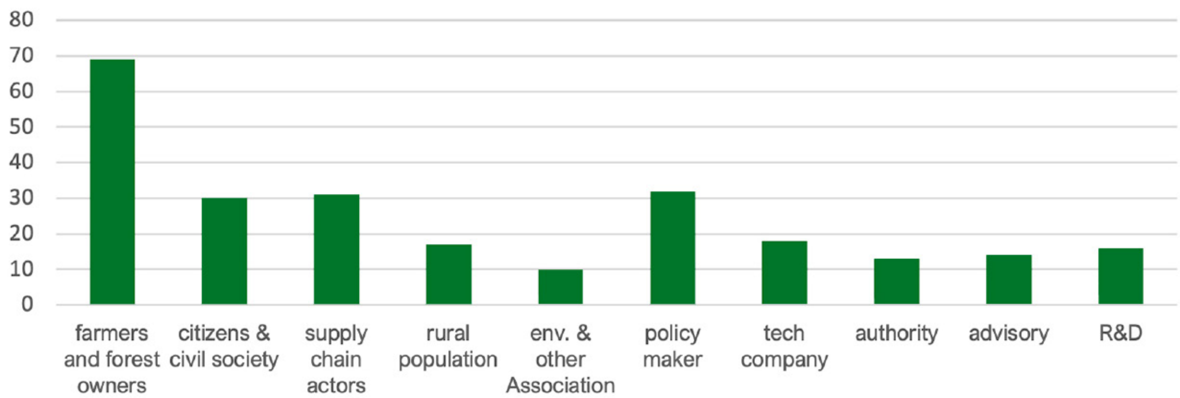
Digital needs can be represented as a hierarchy, as to fulfil needs of higher level other basic conditions are needed. **Digital skills** are at the basis of this hierarchy. They can be basic skills (computer literacy) or more advanced skills (related to the operation of digital systems, as for in the case of precision farming). **Connectivity** is another basic need: without it, most advantages of the 4th revolution cannot be grasped. **Digital services** - namely, on the cloud - represent the third level of the hierarchy. For example, farmers need internet-based services to put them in contact with tourists (as in the Croatian case). **Data availability** is complementary to digital services in a chicken-egg situation: without data, services are not available, and without services, data are useless. **Data security** is felt as another important need, as stakeholders, and especially farmers, are reluctant to share their data because they are concerned about potential use against them. Finally, **interoperability** is felt as a need in more advanced contexts, where the first steps of digitalisation have already been made.

Tab. 2: Examples of digital needs identified by the Living Labs

Digital needs	Living Lab	Example of need reported by the Living Labs
Access to information	Rhineland-Palatinate (DE)	Improving the access to spatial data both through the website of local communities as well as through the official public information portal and with the use of uniform terms.
Connectivity	Scotland	Improving the access to the internet for the entire community. A basic need for 12 MBPS and a shared feeling that it does not always need to be super-fast, but reliable. 30 MBPS preferable. The community broadband service is also very costly compared to Internet Service Providers in less remote regions.
Data availability	Andalucia (ES)	Improving data collection on the vegetation stage of crops, water deposit's location, firebreak areas, perimetric strips, new roads, etc.
Data security	Switzerland	Setting up clear rules on data ownership and use. Farmers are reluctant to share their data as regulations on data use and ownership is not clear.
Digital services	Croatia	Developing (faster) service delivery to be more efficient and cheaper.
Interoperability	AgrOnov (FR)	Improved communication between digital objects to promote their uses and the exploitation of the data collected.
Skills	PEFC (IT)	Improved use of innovative tools aimed to ensure traceability of wood and biomasses for energy purposes.

Finally, the analysis of '*who needs what*' shows that these needs are relevant for farmers and forest owners, policymakers, technology companies, advisory services, citizen and civil society, supply chain actors. Figure 9 shows the distribution of the reported needs associated to various social entities.

Fig. 9: Distribution of needs across Living Labs' stakeholders (N=61)



Source: own elaboration

5. Impacts of digitalisation in agriculture, forestry, and rural areas

5.1 Digitalisation and socio-cyber-physical activities

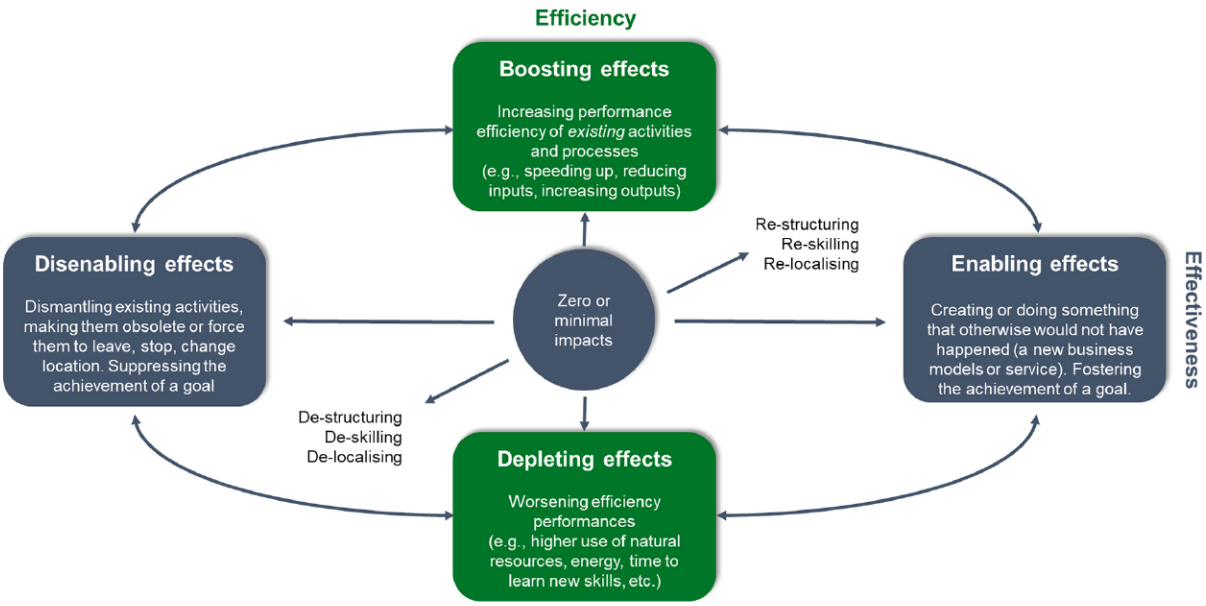
This chapter summarises the impacts of digitalisation on SCPS activities, here understood either as individual performances (e.g. booking a service, completing a payment transaction) or a set thereof (e.g. processes like supply chain management). The comparison across the 21 NEI assessments revealed that activities are generally affected along two main performance measurements (Fig 10):

- **Effectiveness, i.e. ability to achieve (or not) a desired goal or demand, or capacity to successfully execute an activity or process.** This concerns the accomplishment of new tasks, the creation of new services and values, the achievement of undesired goals.
- **Efficiency, from a pure performance point of view, refers the ratio of resource/output of an activity** in a given time.

The impacts of digitalisation on efficiency and effectiveness emerged as interrelated and complex. In other words, digitalisation creates trade-offs as traditional activities are mediated by cyber-entities. *Efficiency* gains like saving time, streamlining procedures, or rationalising complex relations can influence the *effective* achievement (or not) of a goal, activity or a system's modus operandi (e.g. in a corporate vs collective manner).

Along these two measurements, the impacts identified by the LL were qualitatively clustered under **enabling and disenabling effects** (effectiveness), **diminishing and boosting effects** (efficiency).

Fig. 10: Impacts of digitalisation on the SCPS activities in agriculture, forestry, and rural areas



Source: own elaboration

The quantification of the exact magnitude or extent of these effects was beyond the scope of this participatory assessment. LL were limiting their analysis to 'identifying' the impacts (what, how, why, who), rather than measuring 'how much'.

However, it is worth highlighting that some LL reported the situations where no or zero impacts were found for various reasons. In some cases, digital technologies were still at their piloting or early adoption stage, in others, effects were minimal simply because effects take time to appear. Zero or minimal effects emerge also as result of **deviations between digitalisation and identified needs** of stakeholders in a given (organisational, temporal and spatial) situation. Chapter 5.4 sheds more lights on the way through which digitalisation generate impacts ('how').

While digitalisation is pushing processes and activities towards both the efficiency and effectiveness lines, the NEI assessments brought up a wealth of experiences and insights from the ground, showing that **digitalisation is affecting also intangible and tangible properties of a process**, like knowledge, physical location, governance structure, or business models. This chapter unfolds the deeper and more complex implications of digitalisation in terms of re-skilling/de-skilling, re-localising/de-localising, re-structuring/dis-placing people, businesses, institutions, or natural resources. Here a summary of what the LL reported.

5.1.1 Boosting effects

By using digital integration within the existing activities, production lines or services, some LL's stakeholders pointed out that companies, consumers, citizens, workers, producers or public authorities are reaching a higher level of efficiency and allocation of resources. Risks of human errors and duration of processes are being reduced.

> As result of complex interactions between digital and socio-physical systems, **boosting effects refer to efficiency improvements** brough by digitalisation on existing activities and processes performed by socio-cyber-physical systems.

BOOSTING EFFECTS IN AGRICULTURAL ACTIVITIES

At *field level*, some LL reported that robots and precision machinery are **decreasing** hard and manual labour, which result in higher productivity, more comfortable and attractive working conditions (DE Lake of Constance, CH, FR AgrOnov), especially for new entrance and young farmers (FR Végépolys Valley). For instance, the recognition/detection of weeds was considered less fastidious and time consuming when using the weed detection apps as compared to the 'traditional' books (CH). Real-time tracing and tracking tools are **optimising** quality controls, management decisions, traceability, and transparency, for instance in the dairy livestock sector (FI Central Osthrobotnia). The setting up and upgrade of more precise data collection systems in irrigation or pest control is **reducing** water loss (EL Trikala) and pesticide use (DE Lake of Constance, EL Greece, FR AgrOnov).

At businesses level, digitalisation is **simplifying and accelerating** business transactions, by making marketing, ordering, payments, or delivering more automatic (HR, FR Végépolys Valley). Digital transactions are **cutting the risks** for human-errors and hassles in business operations. Direct selling promoted via digital marketing are **boosting** regional or local sales vis-á-vis supermarkets and big retailers (LV, NL Flevoland). Higher visibility and transparency can lead to higher prices and output values (DE Lake of Constance). By collecting data beforehand through online order forms, producers are **spending less resources** on in-person sales (e.g. local markets), thus making their direct supply chain more efficient. Time, energy, and/or staff costs involved in attending physical markets are decreasing, leaving producers free to focus on production (Cloughjordan). At the same time, digital order forms are helping reducing food waste by better planning of daily supplies (unsold perishables at the end of a market day) (DE Lake of Constance, Cloughjordan).

The digitisation, archiving, and processing of paper documentations and controls have improved in terms of time, costs, or handling over responsibilities, both within and between enterprises. In some cases, the communication with public authorities has become faster and easier when it comes to tax declarations, certification transfers for safety and sanitary, and other requirements.

Concerning agricultural knowledge and information exchanges, digital platforms for matching supply and demand, by lowering transaction costs in finding and purchasing inputs, are enhancing farmers' access to plant protection products, fertilisers, machinery, and other input. Market prices, field observations, administrative documents, accountancy records can be more easily retrieved, stored, transferred, and compared in various formats: dashboards, videos, podcasts, etc. Whether they are applied or not, digitalisation has accelerated and increased the sharing of educational and vocational materials, e.g. for sustainable water management (EL Greece), grapevine and wine production (FR Inno'vin).

BOOSTING EFFECTS IN FORESTRY ACTIVITIES

When it comes to *risk prevention and control* in forestry areas, decision making processes are **more informed, accurate, and immediate** (ES Andalucia). The damage to ecosystems and people has decreased thanks to more risk alerts, rapid reaction capacities, and better communication among operators during their interventions. Digital tools and data-driven processes are simplifying land planification, forest and ecosystem management in the region Andalucia. Software and comprehensive real-time analytics are enhancing the monitoring of working factors (heat, wind, temperature, etc.), which results in higher safety level for firefighting brigades.

As concerns *public administration*, the continuous digitisation and availability of forestry information is **saving time and resources** deployed by the competent authorities (Austria), which otherwise would have been spent to conduct on-spot, additional research and networking. Digital platforms and electronic invoice services are **reinforcing the payment traceability and structuring of information flows** among managing authorities implementing the EU Timber Regulation, forestry holdings, and forestry operators involved in the production of biomass for energy uses (IT PEFC). Documentary checks related to compliance with EU Timber Regulation are faster, and the transparency in administrative decisions is enhanced.

Forestry business operations have also been affected. Instant messaging platforms are **speeding up vertical and horizontal communications** (e.g. scanning and transferring of paper documents to buyers or sharing geo-location with colleagues). The transparency in business relationships is overall enhanced. Women are taking up more roles and responsibilities in managing administrative and management tasks within family forestry holdings (IT PEFC).

BOOSTING EFFECTS IN RURAL AREAS' ACTIVITIES

The provision of *public and administrative services* in rural areas are becoming **faster, more convenient** (independent from time/place) and **using less paper** for ordinary administration (DE Rhineland-Palatinate). Paper costs and travel costs for meetings are being reduced (ES Aragon).

The *collective management of agro-forestry ecosystems* has also been impacted, like in Toscana Nord (Italy). The establishment of an e-alert systems and digital communication channels among actors (farmers, citizens, land management consortium, managing authorities) are **speeding up restoring interventions** (e.g. site clearing, repairing a slope after a landslide), **adjusting their targeting, enhancing coordination** among operators, **increasing precision** of on-site inspections planning, and reducing the number of risky on-site inspections.

Workplaces in rural areas are becoming increasingly digitalised and wireless. This is enabling new working opportunities (see chapter 5.1.3). At the same time, tele-working is affecting efficiency too. As reported by LL Cloughjordan, remote working is **reducing greenhouse gas emissions** from daily commuting and flying to international conferences.

Communities can perform joint activities in a cheaper and faster way through digital means, like for collaborative online purchasing among crofts and households (Scotland). Community gatherings and actions are facilitated, bringing some environmental gains through less commuting and better planning.

5.1.2 Depleting effects

Efficiency gains can come at the expenses of other aspects that deserve careful consideration, such as: material resources, energy, repairing and maintenance, and waste disposal of digital devices, smart machinery, and data flows. Knowledge, skills, power, values, trust in relationships are also part of the equation, especially because of the invasive and immersive socio-economic and organisational adaptations required by the digital transformation. In other words, digitalisation comes with (material and immaterial) costs and benefits, and its ultimate effects – in the short or long run period – might be *depleting* instead of *boosting* performance efficiency.

> As result of complex interactions between digital and socio-physical systems, **depleting effects refer to efficiency worsening** brought by digitalisation on existing activities and processes performed by SCPS.

DEPLETING EFFECTS IN AGRICULTURAL ACTIVITIES

Digital farm advisory services are **increasing farmers dependency** on technology and external input providers, reported various Living Labs (LL EL Greece, CH, FR AgrOnov). The abundant amount of videos, decision supporting tools, and solution advertisements accessible online is creating '**information**

congestion' as farmers and advisors are often left alone, lack research and testing equipment, or have little time to digest, apply, and make their own judgment about the quality of information, its risks, and real benefits. Moreover, data-driven farming methods have been associated with the **loss of farmers' know-how** and **increased smallholders' upgrading costs** to keep up with digitalisation developments (LL DE Lake of Constance, EL Greece, CH).

The *digitalisation of business activities*, like promoting and selling food from farm to fork via specialised online platforms or general social media, is **adding farmers' stress and mental tension** for being constantly connected (LL FR Végépolys Valley). More purchasing options offered by digital selling channels can overlook the logistics constrains and delivery costs, thus **leading to selling volumes or price, while increasing the environmental footprint** in short food supply chains (HR). At the same time, fewer personal contacts and meetings in digital food markets is **reducing consumers' fidelity and sociability** with primary producers (HR), especially for those who see food purchasing as an 'experience' and social relation, rather than a pure transaction.

LL DE Lake of Constance reported also that farmers are **bearing higher financial and management costs** to buy, learn, adapt, run, add inputs, delegate, maintain, or repair digital devises, data-driven machinery, cloud computing systems, digital platforms, and software that were not foreseen in their farming practices and business models.

DEPLETING EFFECTS IN FORESTRY ACTIVITIES

Increased costs connected to digitalisation have been reported also by the LL in the forestry areas (AT, IT PEFC, FI Central Osthrobotnia). Forestry holders and operators were confronted with new e-invoicing procedures, which entailed the acquisition of new devises and skills. Similarly, the proliferation of multiple webservices and data portals, with poor interoperability among them, is leading to **longer and larger volumes of data collection**. Data interpretation of complex information (e.g. satellite imaginary of forestry parcels) can **raise new risks and demand different skillsets** in decision making processes in fighting fires and forestry planning.

DEPLETING EFFECTS IN RURAL AREAS' ACTIVITIES

Socialisation through face-to-face, personal meetings are important blocks of community cohesion and resilience. The widespread use of social media, web archives, e-governance services, and online communication have helped with building cohesion and carrying on interactions among rural dwellers during the COVID-19 pandemic. However, **risks and related costs to recover can also increase** when rural activities become digital. A plan B needs to be prepared for technological problems (e.g. hacking, power cuts, etc.) that can disrupt online community gatherings (ES Aragon), tele-work or food supply chain (IE Cloughjordan).

As reported by IE Cloughjordan and ES Aragon, fibre optic broadband expansion allowed people to work from rural areas, but tele-working **impacted working hours** (backpain from spending long periods of time at computer), **overloaded and overlapped personal with professional lives** due to the growing number of videoconferences and online meetings with colleagues across different time zones, as well as **hindered the possibility of focusing on priorities**, due to the increasing expectation to be always available 'online' for private and professional life.

The proliferation of websites, mobile apps, and digital communication tools with public authorities (instant messaging platform, social media) is **increasing the likelihood of discords and inconsistent information** (DE Rhineland-Palatinate). Data-assisted decisions taken off-sites from public authorities (e.g. land management) are still requiring on-site inspections to ensure the effective implementation of desired actions, therefore creating some additional steps or information short-circuits (IT Toscana Nord).

From an energetic and material point of view, LLs remarked the increased **energy use and mineral extraction** required by digital devises and data power infrastructures (FR Végépolys Valley, Cloughjordan), as well as the increased pressure on waste displacement and recycle (e.g. 3D printing technologies, microchips).

5.1.3 Enabling effects

"*Nothing is lost, nothing is created, everything is transformed*" said the French chemist Antoine Laurent de Lavoisier in relation to the conservation of mass. Whether these wise words will also be true for fast-paced digital transformation needs to be seen in long-run period from both anthropological and planetary point of views. Certainly, for many years, digitalisation has modernised the way through which value is generated and captured from data and labour, by providing new services, and perform brand-new activities like controlling a farm remotely or creating digital twins.

Datafication and connectivity between people and things are at the core of this process, which involve more than just digital skills, natural resources, technological engineering (e.g. modularity, interoperability). Data is being exploited – sometimes not equally by all actors in the **data value chain** – to optimise existing activities as much as to generate and capture **added value**, either by creating new services ('servification'), enriching existing ones, or simply by aggregating and selling data to third parties.

By reducing transaction costs, saving time, or streamlining procedures, digitalisation is indirectly enabling businesses, authorities, and citizens to do things that maybe already existed in other contexts, but could not be performed before. As reported by numerous LL, digitalisation can enable the diversification of work activities and offer different options to live and work in rural areas.

As result of complex interactions between digital and socio-physical systems, **enabling effects refer to the creation of new activities, products and services that serve a specific function or a given goal, as well as the ability offered by digitalisation to do things which otherwise could not be performed.**

As indicated by the online survey results, in general, **digitalisation has also affected the diversification of working activities** for most of the consulted stakeholders in agriculture, forestry and rural areas. More than half of the stakeholders (62 percent) consulted in the online survey agreed that digitalisation led to the diversification of working activities. Saved time may be one of the indirect factors to enable new productive or non-productive activities, as well as to focus on deepening existing core businesses.

Other factors leading to diversification were the versatility and remote working, more possibilities for professional communication and interactions, higher access to information and knowledge for better decision making, and the demand for new jobs and functions.

Here below more examples of enabling effects in the different domains.

ENABLING EFFECTS IN AGRICULTURE

Concerning *farming practices*, LL reported that sensors, cameras, Radio Frequency Identification (RFID), and other 'data capturing devices' are enabling the **monitoring and control** of agronomic and productivity variables (EL Greece), or the **surveillance** of holding assets security from robbery or burglary. In terms of **automation and precision**, thanks to camera-assisted technologies, LL CH reported that equipment can work closer to plants during hoeing, thus making the weeding more effective. Digital videos and communications are **revamping the poor appeal** of labour intense crop systems (horticultural production) towards young workers. From a common-pool resource management point of view, public authorities can **publish accurate figures** about the agricultural water consumption in relation to other water uses (EL Trikala).

When it comes to *agricultural work* and *carrying out other gainful or non-gainful activities*, digitalisation is facilitating **on-farm** and **off-farm employments** opportunities (LL EL Greece, HR, FR Végépolys Valley). Some farmers with limited material, time, and human resources can **create their own farm digital profiles**, manage **multiple business activities** and **digital marketing channels**, and **capture the added value** through simple digital tools like a webpage, cloud service, instant messaging platform, and web delivery services. New real time data and long-term data analytics are offering the opportunity to exploit **new marketing tools (i.e. searchandising)** that enable farmers, food business enterprises, logistic platforms to examine web browsing histories, classify products according to multiple criteria (harvesting day, stock availability, distance, etc.), and reach out new consumers, even though physical distance/proximity plays still a major role in remote rural areas. Small scale producers can **pool their stock** through dedicated platforms, and consequently respond to bigger orders in cooperation with other producers (FR Végépolys Valley). Finally, some LL reported that digitalisation assisted the **lifelong learning** of farmers who are interested in acquiring new skills and capacities in a context of limited time, remoteness, and financial resources (LV, FR Inno'vin).

ENABLING EFFECTS IN FORESTRY

The increasing generation of data from operations in the forestry sector is enriching existing services and creating new opportunities for policy planning, public research, and business operators (AT, IT PEFC, AT). For instance, traceability to contrast illegal practices along the energy-wood supply chain is enhanced through the tracking of online payment transactions. Increased data availability concerning carbon storage and footprint (FI Central Osthrobotnia), deforestation and fire risks (ES Andalucia), timber quality (LL AT), are providing authorities, forestry operators, manufacturers, and citizens with new accurate diagnostic tools to avoid fraud, illegal operations, and unstainable practices.

ENABLING EFFECTS IN RURAL AREAS' ACTIVITIES

By depriving most of the population of the possibility to live in the socio-physical sphere outside their homes, the COVID-19 restrictions demonstrated many of the enabling effects that digitalisation brought to rural areas when it comes to **remote working, e-health, e-governance, online rituals, long-distance relationships, and more**.

Real-life collective practices have been made possible thanks to virtual communities in the field of art, political activism and social movements, music, food, solidarity. The world-wide connection to ideas, people, information, projects enabled the design of socio-economic innovations (IE Cloughjordan). Web-archives provided access to information and historical sites (ES Aragon) that would have been otherwise neglected. Online platforms are acting as entry points between authorities, associations, and citizens. This is creating **new ways to collaborate** (DE Rhineland-Palatinate), **execute interrelated tasks** (e.g. obtain insurance permissions, transfer documents, troubleshooting), or simply **connect multiple administrative, private and public services** (e.g. e-alerts on mobility or events; searching for rural accommodations or agri-tourism options).

5.1.4 Disenabling effects

As demonstrated elsewhere outside the EU (Pfeifer et al., 2020), the deeper socio-political forces shaping digitalisation (colonialism, corporatism, or patriarchism) can also dismantle activities and practices, for instance community based mapping or collective land ownership. Digital tools might threat human rights or disempower people from their social or political role (like women or minority groups).

Noticeably, path dependency and lock-in effects can emerge from the mainstreaming of digital logics over standardised, capital-intense, mechanised farming methods. When biological and ecological principles are overlooked, it follows that precision farming technologies might disrupt the already fragile social relations between human, animals and plants. Digitalisation can endanger the number and variety of animal breeds, seeds, or plant species suitable for precision farming technologies, hence destroying biodiversity. Instead of fostering links between humans and animals, the objectification of animals through digital means (as if they were "things" to extract data from) can take out their social agency despite their important role in agriculture and rural areas (e.g. social farming, compassionate farming).

Social norms, values, manners, shared beliefs, customary practices, hence referred as '**rural codes**' **can be displaced by 'digital codes'** such as adding "virtual likes, comments, stars, shares" when social interactions were generally more colloquial, in-depth, and sensitive of the context (e.g. online booking platforms rating rural and farm-stays on the same rating parameters for urban accommodation). The rational approach of video surveillance, quality traceability (QR codes), or online booking systems interfere with trust-based, screen-free, long-term, informal, and spontaneous interactions that can be built between open farms, farmers, village dwellers and consumers.

Disenabling effects should not be seen necessarily as negative ones. As reported by some LLs, digitisation along long value chains (e.g. wood-energy), can dismantle fraudulent practices, corruption, or environmental dumping too.

As result of complex interactions between digital and socio-physical systems, **disenabling effects refer to the dismantling of existing activities that serve a specific function or are used to achieve a given goal, making them obsolete or force to leave, stop, change location**.

DISENABLING EFFECTS IN AGRICULTURE

As reported by FR Inno'vin, wine producers who are not selling their wine online or not using social networks to promote their products, increasingly risk losing market share and competitiveness. Dairy cooperatives or corporations can further strengthen their competitive market position through integrated management systems, or absorb most public funds available for Research, Development and Innovation, thus forcing small and independent dairy farmers to quit or adapt (FI Central Osthrobotnia). Farm automatization and mechanisation is **displacing workers and manual jobs in rural areas**, while other LL pointed out that digital farm mechanisation is also reducing the dependency of fruit producers on seasonal workers (DE Lake of Constance) and relieving tedious practices like weed control from the manual labour (CH).

Precision farming activities, like the sensor-controlled hoeing machinery studied in the lettuce production (CH), can bring savings in terms of time and human labour in organic farming, but can also have negative consequences on the effective maintenance of **good agronomic and environmental conditions (GAECs)** due to the weight of machinery (e.g. soil compaction) or the displacement of effective crop rotation practices. Higher transparency offered by social media can have an adverse effect on consumer perception. For instance, this was the case reported by DE Lake of Constance about organic farming sometimes misunderstood by social media users as 'completely free' from *organic* plant protection products or organic fertilisers. Less or no work opportunities are offered to farm advisors if farmers continue to rely on automatised decision supporting tool (DE Lake of Constance).

The privileged and multi-functional link between agriculture and the environment can lose its meaning when mediated by digital technologies. For instance, as expressed by a social farmer interviewed in Italy, digital media (Instagram or Facebook pages), instead of enhancing, can lead to the homogenisation or virtual fabrication of the countryside experiences.

DISENABLING EFFECTS IN FORESTRY

Common transparent rules limit environmental dumping (unfair price competition) from sources that do not publish their data or hide them behind unclear counting measures (FI Central Osthrobotnia). More accurate data collection, reporting and transparency can lead consumers, policy makers, or companies to rethink their decisions and disincentive unsustainable practices. Tax evasion can be contrasted through more tracked payment transactions (IT PEFC).

DISENABLING EFFECT IN RURAL AREAS

IE Cloughjordan found that, increased digitalisation in general has moved consumer habits away from local businesses, and towards tech giants (like Amazon). Social interactions at markets are being lost (although distribution hubs may also be social spaces).

Internet connectivity and COVID-19 together have encouraged the 'néoruraux movement' in many parts of the EU, e.g. urban citizens and workers moving to and setting up in rural areas. However, the rapid installation of workers from city-offices to rural areas created an inflation of real estate property costs (IE Cloughjordan). The inflated prices from increased demand can drive out previous rural dwellers from the housing market.

Moreover, the rapidity with which people move from urban to rural areas in search of a second home or better environment for remote working can deviate from an assumed 'rural revitalisation'. Social class conflicts and tensions might continue. Cohesion needs the time and social structure to ensure the integration between urban and rural dwellers in a sustainable and long-term community development. On the contrary, IE Cloughjordan reported that incomers disenabled stagnant negative community relations by facilitating interactions among community members that did not interact with each other up to then.

Among the trade-offs, the digitalisation of private and public services like village post offices, banks, labour law advisors, accountant, etc. has contributed to their de-localisation, de-funding of human resources, and the loss of in-person interactions between citizens, advisors, local councillors, and other public and administrative services (IE Cloughjordan, DE Rhineland-Palatinate). On the other hand, without neo-rural incomers harnessing tele-working opportunities, these services might have closed much earlier.

5.2 Digitalisation and socio-cyber-physical entities

As part of the NEI assessments, LL paid particular attention on the entities impacted by, or playing an active role along the digital transformation analysed in the 21 focal questions. **Winners** are understood here as those entities that gain benefits from the change. For instance, some type of farmers will see their productive role strengthened with precision farming systems, while others might see their socio-professional role undermined, oppressed, or narrowed down to a productivist, state-supported project of modernisation. **Losers**, far from being a term to stigmatise, are those entities who become marginalised by the change brough by digitalisation, bear the costs, or do not gain any benefits. Nature, culture, folk habits, social relationships and other intangible elements can also be affected, therefore win or lose as result of the digital transformation.

Digitalisation does not happen alone, nor in a socio-economic or political vacuum. **Proponents** are specifically those entities who support or advocate for the digital transformation, whereas are those who resist, defend themselves, or take a position against the use and effects of digitalisation.

Annex 8.4 provides a summary of the winners, losers, proponents, and opponents identified by the 21 Living Labs. It explains also under which conditions (how and why) certain entities can lose or win, propose or oppose. The box below presents an in-depth case-study in the field of farm diversification.

Box 1 Case-study: A digital milieu around on-farm diversification activities

Agriculture goes beyond producing market commodities. In an enabling socio-economic, geographical, and political context, farmers are engaged in other gainful activities that go beyond producing agricultural products, like social farming, food processing, direct selling, agritourism, energy production, etc. Here below, some examples of winners, losers, proponents and opponents are outlined in an increasingly integrated SCPS around on-farm diversification.

Box 1: Case-study: A digital milieu around on-farm diversification activities

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Examples of Digital tools applied in On-Farm Diversification Activities

- Online selling platforms and software (e.g. Gasdotto.net for Solidarity Purchasing Groups in Italy).
- Farm Accountability software
- Online booking channels
- Online banking, payment systems & devises for point of sales
- E-governance platforms (e.g. transmitting permissions, downloading certificates)

- Tourism and cultural event platforms
- Online maps for geolocation and business registration
- Social media and analytics
- Farm photo gallery
- Instant messaging platforms
- Collaborative working platforms (e.g. cloud storing, project software)
- Canvas software to produce flyers, leaflets, promotions.

Examples of Digital skills applied in On-Farm Diversification Activities

- Scanning, storing, sharing (documents, images, ideas)
- Classifying (transactions, clients, products)
- Tracing (orders, visits)
- Visualising (images, stories)
- Geotagging (businesses, touristic points)
- Detecting (free riding behaviours, financial loss)
- Managing remotely (e.g. collaborative teams via online platforms)
- E-learning (complementing audio-visual to on-spot farmers' trainings).
- Optimising (reducing errors in booking transactions, online orders)
- Recommending (memberships fees, new products, services)
- Evaluating (dealing with consumer reviews on social media)
- Protecting (data protection from cyber-attacks)
- Troubleshooting (repairing software or hardware damages)
- Digital planning (envisaging a digital strategy with clear objectives and ethical considerations).

Example of digital infrastructure needed in On-Farm Diversification Activities

- Internet connectivity (speed, stability, price, coverage)
- Computer and ergonomics
- Mobile devises (smart phone)
- Electronic cash registers
- Monthly membership fees (shared clouds, advance social media features, collaborative platforms)

Who wins, loses, proposes, or opposes in digitalised farm diversification?

Winners

- **Farmers with medium-high level of digital skills**: e.g. by managing multiple tasks with better control; enriching offer with new services (e.g. on-farm co-working spaces), interacting with several physically remote actors (e.g. certifying bodies, health insurances); gaining access and control on data; planning of stocks and delivery.
- **Agriculture**: e.g. strengthening the multifunctional role of farmers and integrating their food production role into the wider society, economy, and territory.
- **Consumers**: e.g. more convenience in services; faster access and lower consumption barriers; etc.
- **Tourist and cultural operators**: e.g. easier promotions activities and more possibilities to create integrated tourism services and experiences with farms.
- **Public administration**: smoother flows of documents, more precise accountability and control.
- **Fiscal and insurance organisations**: faster controls, smoother sales of insurance services (e.g. online bike insurances)
- **Children and people with disabilities**: smoother administrative tasks can encourage farmers to engage themselves in educational and inclusive activities.
- **Online business platforms**: earning a share from payment transactions in rural services (farm stays' bookings, direct selling payments, etc.)

Losers

- **Farmers with low digital skills and human resources**: e.g. time and resources to invest to change arrangements and adapt procedures to public and consumers demands without capturing additional revenues.
- **Farmers with a strong socio-economic position in offline environments**: e.g. digital pressure to change local markets habits, undermining historical and in-person ties with surrounding community, converting cash into digital transactions, lost of farms as 'internet disconnected' socio-ecological spaces.
- **Agritourism with high farming and nature value**: mainstream booking platforms and urban-adapted consumption habits/reviews can undervalue rural specificities (e.g. seasonality, narrower options of on-farm food compared to supermarket-procured food, less electronic equipment, dry toilets in farm camping sites, remote locations).
- **Family members used to have a more front-end position** (hosting people, walking them through the farm, in-person presenting and selling farm products) **might take up more back-end role and responsibility** (dealing with online orders sitting behind a computer).
- **Farms excluded by online maps, tourist platforms, and mobile tour planners.**
- **People looking for digital disconnection and less rational approaches to human-nature relationships** (farmers, consumers, children).
- **Consumers who fully rely on outdated digital information on farms** (e.g. opening hours, booking availabilities, pictures).

Proponents

- **Digital natives**: people who master digital skills and have fully adopted digital habits (e.g. searching online instead of talking to locals)
- **Public administrations**: to streamline procedures, accelerate reporting to funders, etc.
- **ICT experts and organisations in the online platform sector** (e.g. Google, Shopify, Open Food Network, etc.)
- **Organisations in collateral services** (banking, delivery, insurance, tourism)

Opponents

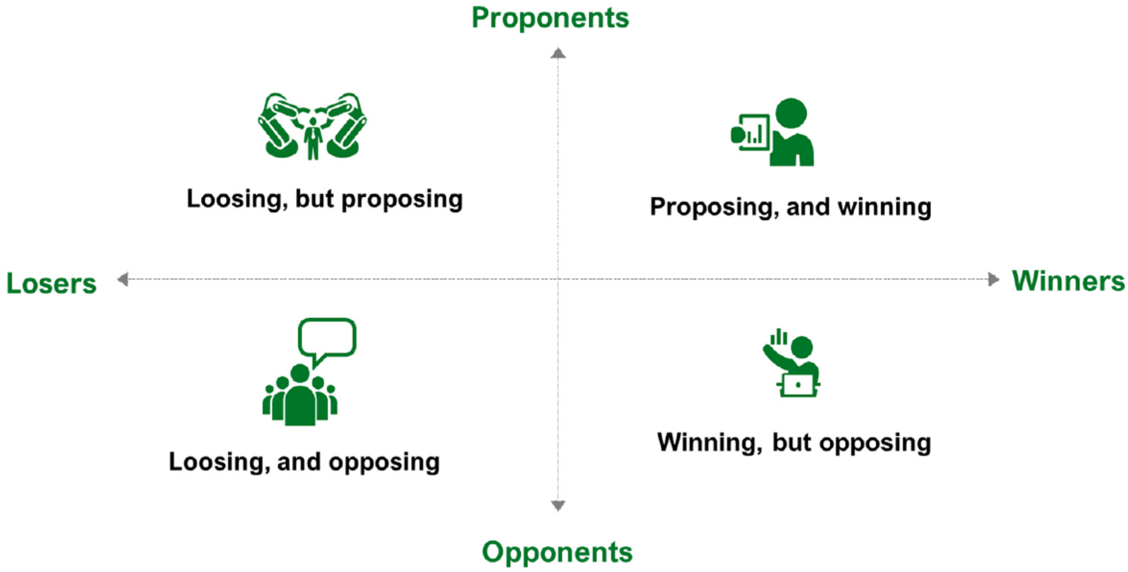
- **Farmers with low digital skills, financial, and human resources** who have estimated that the socio-economic and environmental return of investment is not worth changing for.
- **Rural stakeholders who reject tools, standards, and working methods coming from other classes of society** (e.g. urban, office-based, business oriented).
- **Rural stakeholders who refuse to spend money on digital devises, or to concentrate most of their time on screens and virtual connections.**
- **Public administrations**: lack of adaptation to simplify and integrate procedures.

As presented in this case, the same actors (e.g. farmers) can be winner or losers depending on many circumstances. Attitudes and stakes towards digital systems are complex and evolving, therefore this categorisation is obviously weak, if not problematic from the normative point of view. In between these extremes, there are a lot of nuances and additional cases (entities who simply ignore, rather than oppose or propose).

Therefore, this analysis reveals that simple conceptual tools like these can help to take a photograph of a given situation in time, as well as stimulate collective reflections on the underling conditions and circumstances under which success or failure happen, acceptance or rejection occur, and so on and so forth.

From a policy, market, science, or civil society point of view, mapping different entities also help thinking about different strategies and actions for shaping a just digital transition, like facilitation, adaptation, regulations, development, or reconciliation between proponents and opponents, winners and losers (Figure 9). Here below some examples.

Fig. 11: Digitalisation and entities: strategies and actions for a just digital transformation



PROPOSING, AND WINNING

As emerged in the Living Labs' NEI assessments, a wide range of actors are harnessing the potential of digitalisation in their everyday life and business. Some of them are leading this process, like agri-tech companies, research and development institutions, software engineers, or developers of data capturers. Others are trying to adopt and grasp the benefits of digitalisation, from private initiatives (e.g. apps for food delivery) to public ones (e.g. Big Data and algorithms for the monitoring of agri-environmental and climate measures). Understanding the key elements of these successful practices and make their underlying interests, purposes, costs-benefits more explicit to all is crucial. In a just digital transformation, specific arrangements must be envisaged to distribute profits and benefits, encourage improvements, reduce entry barriers, and prevent negative side effects.

WINNING, BUT OPPOSING

Despite the increasing use of digital solutions, some entities are deeply concerned about a number of issues, like data-driven market concentration, surveillance, privacy, or privatisation of public goods. This is especially the case for entities facing job-replacing technologies, like workers in rural areas who value the complementary value of digital tools for their work (e.g. in firefighting, farm advisory, health monitoring), but refrain from pushing digitalisation further for the fear of being fully replaced by cameras, artificial intelligence, machine learning, or tech devices for surveillance. Entities who see the benefit from digitalisation (e.g. remote working, online banking) can still distrust it for the potential legacy it has with privacy, autonomy, corporatism, or the dehumanization of socio-economic activities.

In social science theories, reflexivity or reflexive modernisation (Beck et al., 2016) can provide useful analytical lenses to understand the contradicting position of *winners but opposers*. Rather than enjoying the success brough by digital artefacts and arrangements, these entities critically question the foundations of digitalisation, e.g. in terms of mineral extractions and (lack of) climate action behind a digitalised growth and corporatist society. Understanding these trade-offs and solving deeper tensions become key in addressing the indirect consequences of digital impacts on winners and losers.

LOSING, AND OPPOSING

Higher traceability, transparency, accountability or precision is meant to reduce human errors, dismantle illegal or unsustainable practices like those emerged in various LLs' NEI assessments (e.g. illegal forest logging, food waste, water overuse, etc.). In these cases, digitalisation can disrupt arrangements that harm or are of detriment for the society as whole. In other cases, digitalisation can actively damage or marginalise some entities (e.g. rendering tasks and competences obsolete). Corrective actions in this area might entail listening to concerns or estimating the benefits versus the loss from a public good perspective. Other adapting strategies can include compensations or the creation of alternative scenarios, with and without digitalisation. Rather than driving deregulation (e.g. New Genomic Techniques), stricter rules can be established to safeguard biodiversity, workers' rights, or to use digital tools for a more effective and efficient enforcement of legislations and public policies.

LOOSING, BUT PROPOSING

Differently from 'winners, but opposers', some entities might not even be aware of the costs, or long term trajectories pushed by digitalisation in relation to their privacy, autonomy, creativity, attention, social skills, financial independency, and more to respect fundamental human rights and freedom. Nevertheless, those who are implicitly losing out, might be locked-in and advocate for more of the same. To break this vicious cycle, awareness-raising on the implicit consequences of digitalisation and its societal costs becomes key. Other initiatives include setting up regulatory framework and providing substantial resources and socio-technical means to get out of digital technological traps.

5.3 Digitalisation and socio-cyber-physical relationships

The relations between human, animals, nature, objects, and values are changing not only in urban contexts, but also in agriculture, forestry, and rural areas. Previous chapters touched already upon the various ways in which digitalisation is impacting the connection between two or more people or things, as well as the state of being (dis-)connected. Section 4.2 elucidates the different examples collected from the socio-cyber-physical systems mapped out by the Living Labs and shows how the relations among these entities coagulate in one integrated system of rules and standards (digitalised milieux). Section 5.1 presented some examples of how digitalisation is impacting the effectiveness and efficiency of processes and activities, thus also strengthening, weakening or dismantling existing relations between consumers and producers, farmers and animals, citizens and public administrations, enterprises with other enterprises.

Each relation is governed by rules, powers, interests, and can be affected in various dimensions, like:

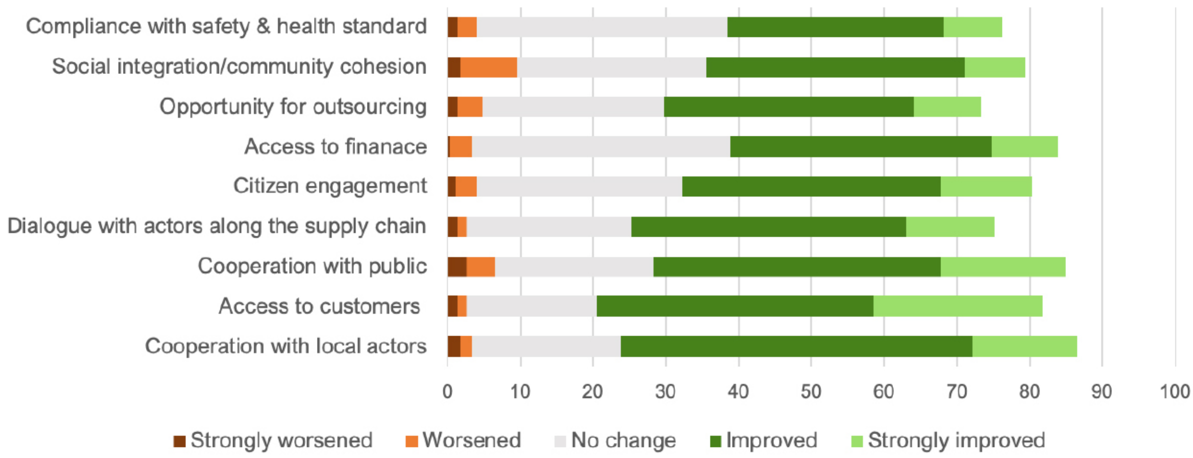
- More vertical vs horizontal **integration** (e.g. from farm to fork);
- Stronger or weaker **social agency** and freedom (e.g. between human and animals, women and man, farmers and consumers);

- Higher or lower **rationality** (e.g. for socialising, asking advices, interacting with public administrations, learning competences), and more aspects, like trust, reciprocity, solidarity.

The subjectivity and context-dependency are important considerations to study the implication of digitalisation on each relation existing in food environments, forestry, and rural areas.

An online survey was sent to the Living Labs' stakeholders to collect their general perceptions on the impact of digitalisation over some aspects of these relationship (**Figure 10**). Over 273 total respondents to the online, less than half gave a score to a Linkert-scale. The remaining ones either did not answer or considered the question not applicable. The number of respondents who expressed their opinion suggests that digitalisation is more frequently improving, rather than worsening some relations between public authorities, community, business partners, input providers, etc.

Fig. 12: Impact of digitalisation on relationships in agriculture, forestry, and rural areas (N=273)



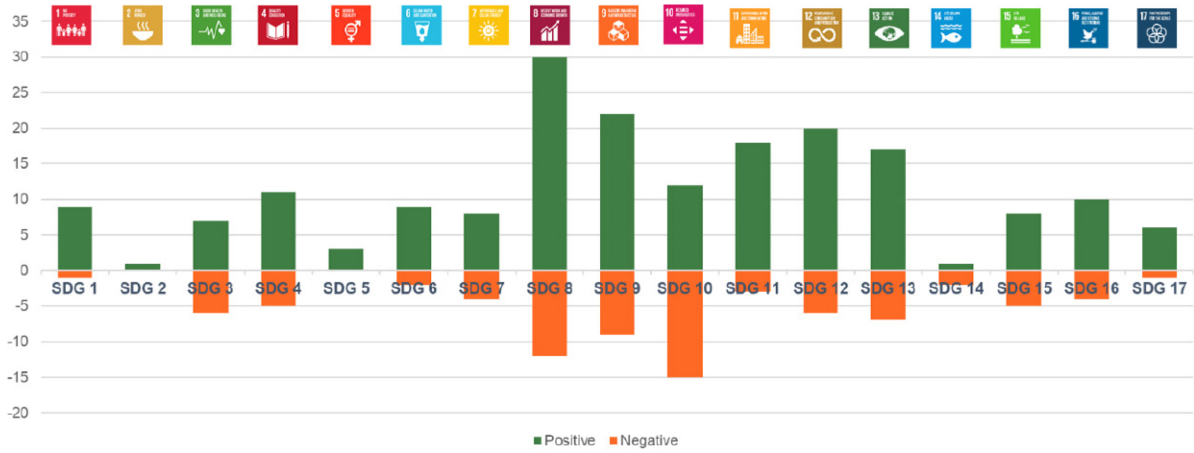
Source: DESIRA online survey

A high number of respondents considered that digitalisation was so far neutral for the relations existing in their focal questions. More insights on the digital impacts on relationship can be found in other chapters of this report as outlined above (e.g. Chapter 4.2, 5.1, 5.2).

5.4 Digitalisation and socio-cyber-physical expectations (UN SDGs)

Figure 11 shows the links identified by the Living Labs between digitalisation and the 17 SDGs. Instead of quantifying the extent of these contributions towards the goals, the links shows the frequency of general perceptions expressed by the LL stakeholders as result of focus group discussions and interviews. The green bars indicate the number of positive links that were found across the 21 LLs between the digital transformation and the achievement of the SDGs, whereas orange bars represent the opposite (negative links).

Fig. 13: Positive and negative links identified by the Living Labs' between digitalisation and SDGs



Most of the links found with the SDGs were positive, especially for the "productive" goals, like SDG 8 (Decent work and economic growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 12 (Responsible consumption and reproduction). These SDGs (8, 9, and 12) were also among those with the highest number of negative links, thus suggesting the presence of pervasive trade-off effects and negative externalities, e.g. in SDG 3 (Good health and well-being), SDG 4 (Quality of education), SDG 10 (Reduced inequalities) and SDG 13 (Climate action).

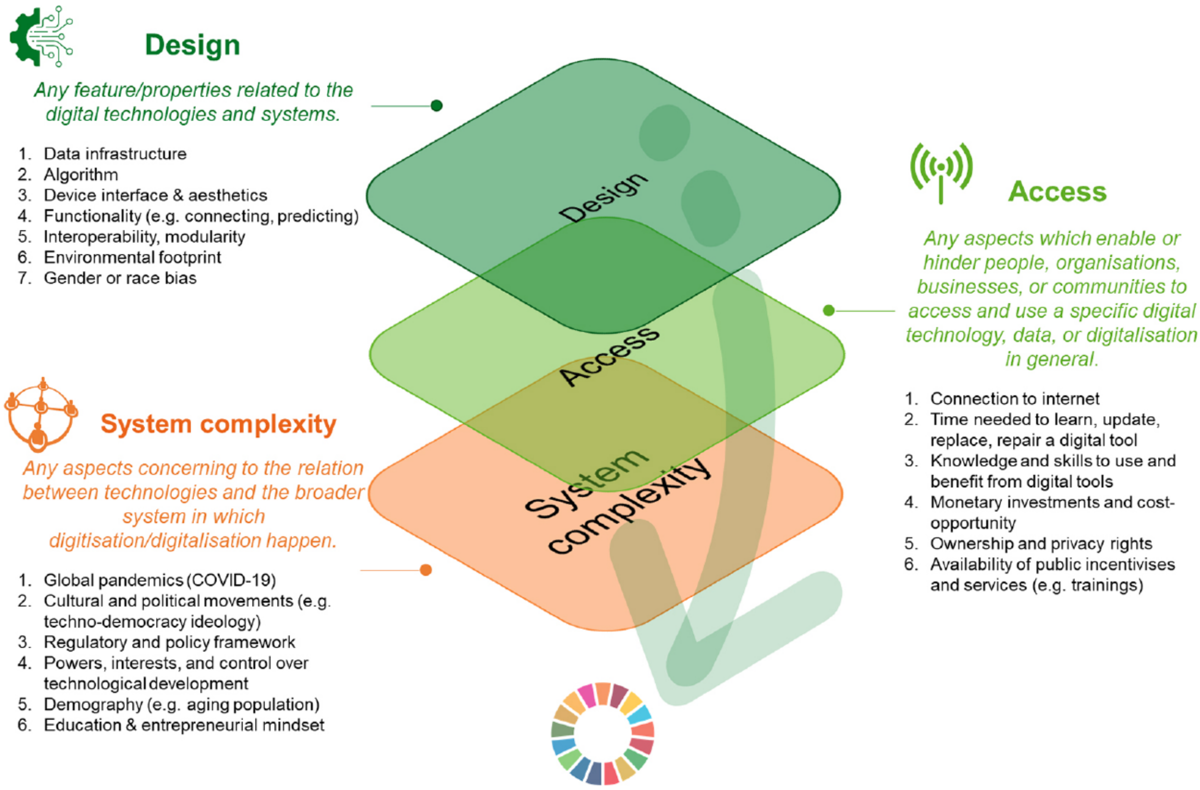
Except for climate action (SDG 13), less positive and negative links were identified between digitalisation and environmental goals compared to socio-economic ones, like SDG 6 (Clean water and sanitation), and SDG 7 (Affordable and clean energy), SDG 15 (Life on land). This observation might be due to the topics addressed by the LL focal questions, predominantly concerned on labour, growth, trade, community, consumption and production (e.g. SDGs 8, 9, 10, 11, 12).

SDG 2 (Zero hunger) and SDG 14 (Life below the water) were the least addressed, probably because of the little relevance for the LL's focal questions, although water pollution and scarcity, as well as access to food are big concerns also in the European context. The links found between digitalisation and SDG 5 (Gender) were also poor.

The achievement of the SDGs cannot be attributed only to digital technologies, skills, data infrastructures and flows. *Access* to digitalisation, as well as other *socio-economic, environmental or cultural factors* (system complexity) mediate the attainment of the SDGs. Figure 12 presents a generic overview of how digitalisation can impact these SCPS needs and expectations, in this case, the SDGs were used as policy framework.

Based on three impact pathways (i.e. mechanisms explaining how digitalisation generate impacts), the section presents the specific explanations provided by the LL for main SDGs involved in their participatory activities. This shows the existing trade-offs between positive and negative contributions of digitalisation to SDGs.

Fig. 14: Impact pathways through which digitalisation can impact needs and expectations (UN SDGs)



Source: own elaboration

DG 1 NO POVERTY AND SDG 2 ZERO HUNGER

Negative contributions		Positive contributions
• If other economies decline too, labour automation in agriculture can displace workers from rural areas, affecting rural livelihoods, and alienating farmers from food production.	System Complexity	• Community-owned, but digitally managed and controlled resources (land, water, seeds) and services (farm advisory) can ensure workers and communities are not displaced and alienated by commercial Interests.
• Digital barriers in donation and solidarity purchasing groups might exclude the most vulnerable people from basic food rights.	Access	• Access to internet, digital equipment and skills can offer new on-farm and off-farm income opportunities for communities, farmers, business entrepreneurs in remote rural areas
• Highly standardised software used by private risk insurance schemes are not designed to include diversified poly-crop systems in small-scale farms (e.g. 50 varieties in less than 6 ha).	Design	• An efficient ordinary land management organised through multi-stakeholder online platforms reduces the vulnerability of local communities to extreme climatic events.

SDG 5 GENDER EQUALITY AND SDG 10 REDUCED INEQUALITY

Negative contributions		Positive contributions
• A patriarchal system might delegate skilled women to undertake mainly administrative and repetitive digital tasks, instead of empowering their decision-making role in domestic, business, and public spaces.	System Complexity	• Women, who often bear the burden of carrying out multiple tasks, can be facilitated by the online working tools to grasp job opportunities that normally would have not been accessible.
• High price, as well as low cost-opportunity offered by digital equipment and tasks can be imposed on farmers, and possibly exclude them from centralised markets	Access	• Access to online and more transparent databases (e.g. local banks for lands and houses) can reduce information barriers and offer everyone the opportunity to apply and install their (OF WHOM?) farm or life in rural
• More technical, standardised, and ICT-based education systems further marginalise those young or adult students with lower digital skills and special social-cognitive needs.	Design	• Online administrative software and cloud systems can simplify the multiple bureaucratic tasks of social farmers and facilitate the inclusion of people with disabilities in rural life.

SDG 3 GOOD HEALTH AND WELL-BEING; AND SDG 8 DECENT WORK AND ECONOMIC GROWTH

Negative contributions		Positive contributions
• Widespread use and incentives to use digital decision support tools are increasing farm dependency on tech companies and industrial farm advisory services.	System Complexity	• COVID-19 regulations challenged the arrival of seasonal workers and demonstrated the dependence of local economy on seasonal workers or more automatised farming systems, as well as the benefits of a local food chains.
• The higher accessibility due to digitalisation leads to a lack of boundary between work and personal life. Less face-to-face interactions and increased computer-based time.	Access	• Internet connectivity in remote rural areas allowed tele-working and the reduction of travel costs and time.
• Automatised tools and robots, to replace field work, need to be able to deal with variable physical parameters such as slopes and rocky/heavy soils.	Design	• Data-driven mechanic weeding technologies can decrease hard manual work and play a role in the increase of farm productivity

SDG 4 QUALITY EDUCATION AND SDG 11 SUSTAINABLE CITIES AND COMMUNITIES

Negative contributions		Positive contributions
• An excessive dependence on public institutions and the primary sector can limit communities in seizing the job and education opportunities available in a digitalised society and economy.	System Complexity	• Social and climate justice movements can drive the design and widespread use of simple digital tools (e.g. order forms, instant messaging groups) to support solidarity economy in cities and rural villages.
• Time and investments to use digital tools are taken away from learning and transmitting competences with lower social and environmental leakages (e.g. pruning traditional olive groves with local varieties)	Access	• Access to high quality mobile or fixed connectivity can offer new options for jobs and workers in remote rural areas and depopulated territories
• Dominant booking platforms with standardised rating criteria and filters (e.g. air conditioner) might penalise rural and farm accommodations or force them to adapt to urban standards.	Design	• Modular and interoperable online or mobile platforms with open interfaces allow the context-sensitive integration of services in communities, villages, and regions (agri-tourism, culture and events)

SDG 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE AND SDG 12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Negative contributions		Positive contributions
• Increased value chain risks due to higher dependency on digital technologies (e.g. power disruption or hardware problems).	System Complexity	• More data collection for traceability, together with tightening legislations and new consumers' expectations are pushing producers to adopt more sustainable practices
• Access to internet and online purchasing platforms give space to commercial advertisements, which increases consumption and create new consumption needs.	Access	• By reducing information asymmetry, digital media and databases can foster the uptake of new production practices and innovations.
• Lack of transparency on data ownership rules can disengage farmers to cooperate in collective resource and value chain management.	Design	• Field sensors to collect, LoRaWAN Network to exchange, and Internet Cloud to store and process data can help to constantly monitor and control natural resources at farm level.

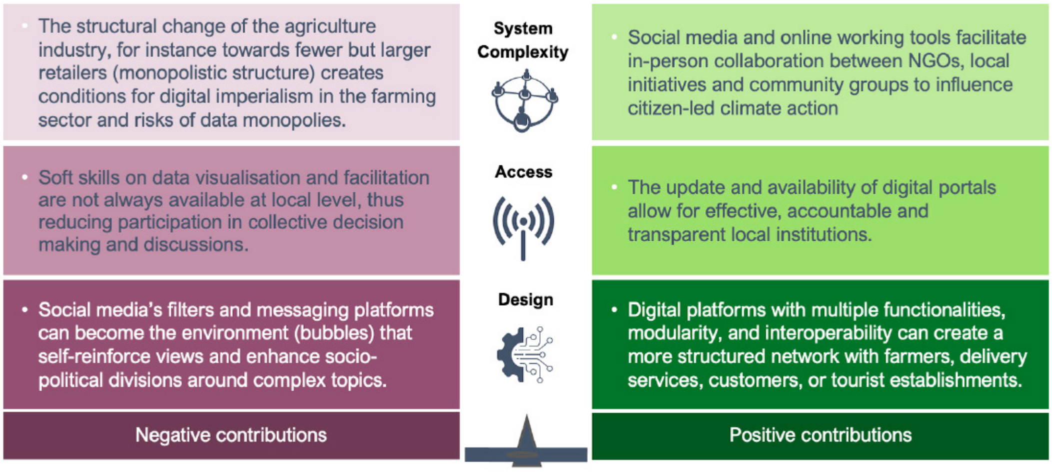
SDG 6 CLEAN WATER AND SANITATION; SDG 7 AFFORDABLE AND CLEAN ENERGY; SDG 13 CLIMATE ACTION

Negative contributions		Positive contributions
• Clandestine activities are established drivers of economic growth and energy provision; they are hard to uncover and tackle through digital solutions.	System Complexity	• Legislators, scientists, and policy makers can use large volume and long-term data from satellite, drones and other spatial technologies to build knowledge and raise awareness on climate change mitigation and adaptation.
• More affordable and connected digital devices (e.g. wearable sensors, field sensors, tablets) can increase extraction of natural resources in conflicting areas, as well as increase energy demands of socio-economic activities	Access	• Open access to the smart watering system, web-based applications and IoT tools create a unified water data infrastructure, facilitating the common water management in the region.
• Digital technologies' dependency on scarce natural resources and energy sources (CH) • IoT involves greater use of batteries and micro-chips	Design	• Simple and easy interfaces (dashboards, mobile apps) can increase traceability, accuracy, and stop illegal tree logging for energy purposes.

SDG 14 LIFE BELOW WATER AND SDG 15 LIFE ON LAND

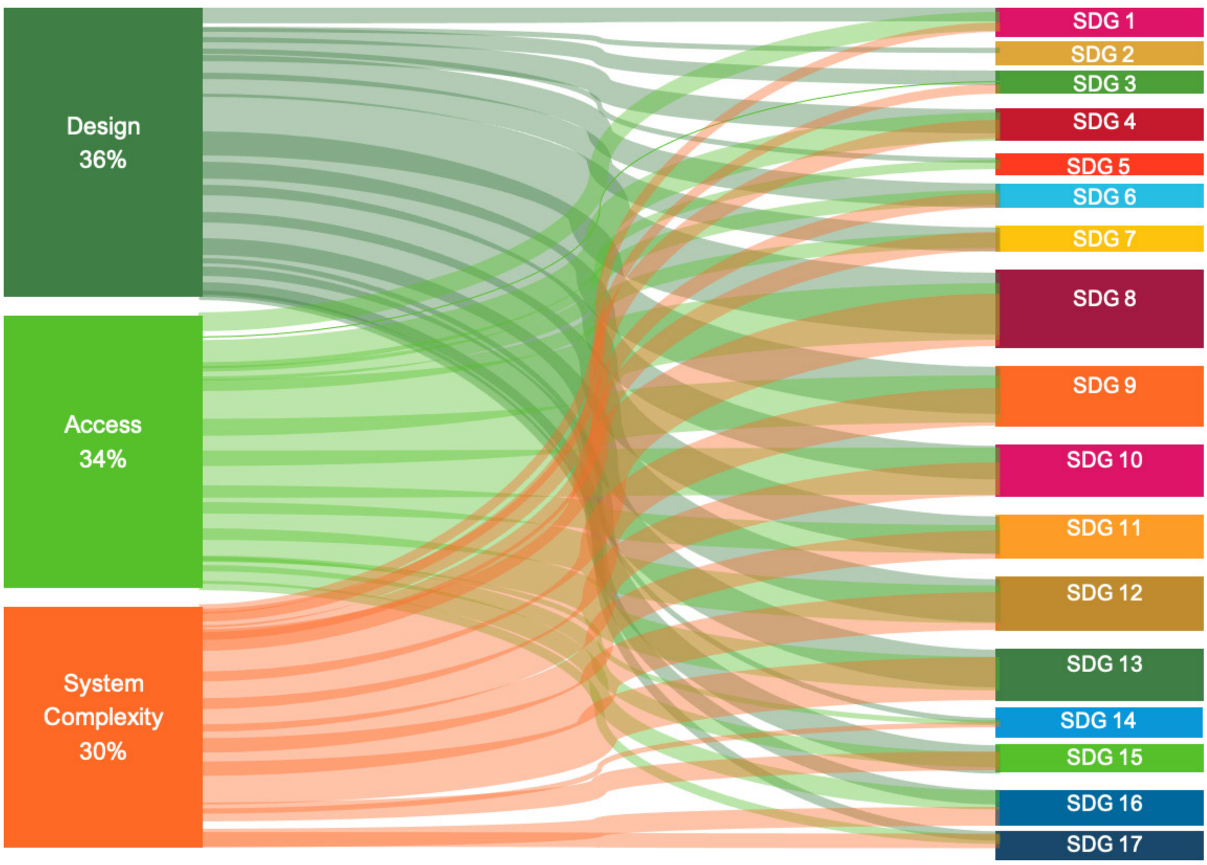
Negative contributions		Positive contributions
• (Lack of) harmonisation among regional forestry regulations to authorise forest logging activities and high amount of data required reduce possibilities to operate in forestry areas.	System Complexity	• Increased societal and political demand for organic farming pushes research and innovation investments to design and implement more digital solution.
• The widespread access to instant messaging platforms allows land restoration workers to delegate decision to their chief. Decision taken off-site can reduce the timely protection and restoration of degraded lands.	Access	• Access to geo-physical and longitudinal databases allow forestry policy makers to monitor and make more informed decisions about logging permissions.
• New genetic engineering techniques aimed at increasing animal productivity or plant resistance in the short run period can drive biodiversity loss and put pressure on endangered breeds and varieties.	Design	• Photos, geo-location sharing, sensors and early warning systems for forest fires can alert both the administrations in charge of firefighting and the population affected.

SDG 16 PEACE AND JUSTICE STRONG INSTITUTIONS AND SDG 17 PARTNERSHIPS TO ACHIEVE THE GOAL



Finally, based on this analytical framework (design, access, and system complexity), **Figure 13** clusters and counts the explanations given by the LL for each link found between digitalisation and the SDGs. This illustration is only meant to give a broad and generic overview of the weight that each impact pathway has in terms of frequency, rather than statistically prove the causality.

Fig. 15: Impact pathways identified by the Living Labs between digitalisation and SDGs (N=253 links clustered in design,



Source: own elaboration

6. Conclusions and recommendations

Digitalisation, as process entailing both digital technologies, as well as digital skill-sets, culture, and infrastructures, is transforming entities, relationships and activities in agriculture, forestry, and rural areas. These impacts are both positive and negative. Trade-offs exist in the way digitalisation is contributing towards the achievement of the United Nation's Sustainable Development Goals. This generates winners and losers in a context where social entities can act in favour (proponents) or against (opposers) this transformation.

There are different working areas to harness the potential of the digitalisation transformation in breaking vicious cycles and driving the sustainable and resilient development of agriculture, forestry, and rural areas in a European and global context.

The following section raises some of the main questions to be addressed at level of technological design, access, and system complexity. The key points summarise the main working areas and issues that can be subject of reflections for policy making, technological development, future monitoring and evaluations.

DESIGN: ANY FEATURE AND PROPERTY RELATED TO THE DIGITAL TECHNOLOGIES AND SYSTEMS

Some of the main questions to be addressed

What functionalities can rural dwellers, farmers, advisors, or forestry operators deploy to overcome technical or more persistent challenges like low remuneration of agricultural products, illegal logging, etc? How can farmers rely on digital tools (metrics, decision supporting tools, etc.) that are adapted to the changing climate and agri-environmental conditions (e.g. temperature, slope, varieties, water resources)? What properties of digital systems need to be maintained to safeguard the public nature of data (e.g. non-rivalrous and non-excludable)? What socio-technical aspects need to be considered when investing private or public resources into digital technologies or more complex data systems?

Key points to be addressed in formulating policies and actions:

- **Functionality**: the total range of range of operations that can be run by the digital technology or system to meet the intended purposes (e.g. predicting, connecting, storing, sharing, filtering, comparing, collecting, matching, verifying, etc.)
- **Flexibility**: the capacity of a digital solution to be used for different purposes without totally modifying its main settings. This also includes any design properties like modularity and interoperability that enhance the flexibility and integration of digital technologies, like adding new functionalities through application programming interfaces (API) or Software Development Kit (SDK).
- **Adaptability**: the capacity of users to modify the rules and design of digital technologies and systems in negotiation and agreement with other stakeholders.

- **Transferability**: the capacity to transfer all the data infrastructure or assets (e.g. privacy consents) to another operator or digital system.
- **Scalability**: the minimum threshold of users needed to perform the functionalities (e.g. matching demand and offer), meet the intended purposes (e.g. reduce information barriers, capture money from each business transaction) and achieve the intended benefits (e.g. economy of scale).
- **Control**: structures and mechanisms used to govern the functionalities of digital technologies or systems (centralised, de-centralised, distributed like peer-to-peer).
- **Internal biases**: the embedded biases in the software and hardware components (e.g. bubble filters, profiling) that influence data collection, analysis, and final service and value capturing.
- **Security and compliance with data protection regulation.**
- **Copy-rights and licenses** (open source, free software, etc.).
- **Data infrastructure**: material centers with energy consumptions that support immaterial data
- **Material requirements**: material equipment and devises needed to use a give digital service or system (e.g. devises for Point of Sales, cameras, micro-chips, smart phones, PC, wearable devises, card readers, tractors).
- **Reparation and recycling**: the easiness and costs by which digital tools or systems associated to physical objects can be repaired or recycled in case of hassles, breakdown, depletion, or cyber hacking.
- **Value-creation, capturing, distribution**: who and how monetary or non-monetary value is generated, captured, and distributed (e.g. share take from each payment transaction, data pooling services, public provision of a data infrastructures to generate new innovations and services).

ACCESS: ANY ASPECTS RELATED TO ACCESSING AND USING DIGITAL TECHNOLOGIES, SKILLS, INFRASTRUCTURE.

Some of the main questions to be address

How can digital systems and technologies reach a critical mass (minimum threshold of users accessing and using it) to achieve the intended benefits? What material and immaterial factors hinder or force the adoption of digital technologies? What do society need to give up in terms of privacy, autonomy, skills, costs, and so forth, in order to access digitalisation (connectivity, data infrastructure, technologies, etc.)? What are the positive and negative sides of who decides or gets inevitably excluded in a society and economy increasingly connected? How can rural areas preserve its spaces of 'digital disconnection'?

Key points to be addressed in formulating policies and actions:

- **Ownership**: ownership agreement on data infrastructure, intellectual property rights, access (public, private, mixed).

- **Quality of connectivity**: speed, cost, stability, coverage, ownership, mobile vs fixed internet connectivity.
- **Opportunity costs of learning**: individual and collective opportunity costs to acquire new competences instead of using existing ones.
- **Easiness of mastery**: time, knowledge, human resources and skills needed to master digital technologies.
- **Opportunity costs of running**: time, human and natural resources, skills needed to run, monitor, upgrade a digital technology or system in the long-run period (e.g. from data capturing to delivering the final services in the long run period).
- **Purchasing capacity**: ability to pay for the immaterial and material requirements to use digital services or products.
- **Transparency and data sharing code of practices that enable an open data society**
- **Socio-geographical entry barriers**: gender bias, education, class, race, political background, as well as geographical conditions (e.g. mountainous, windy, rainy, arid conditions)
- **Anthropological, political, and cultural considerations**: beliefs, customary habits, values that can conflict with the implicit standardisation and rationalisation of data systems and technological solutions.

SYSTEM COMPLEXITY: ANY ASPECTS CONCERNING THE RELATION BETWEEN DIGITAL TECHNOLOGIES AND THE BROADER SYSTEM IN WHICH DIGITISATION/DIGITALISATION HAPPEN.

Some of the main questions to be address

How do we close the gap between designers and users? How can more data be translated into better means to solve societal and ecological tensions over natural resources and climate action? How can the standardisation required and brought by digital systems meet the particular conditions and enhance the diversity of agri-food systems, forestry, and rural areas (demography, crop varieties, environmental conditions)?

How can human rights be protected for labour, food, water, land in a more virtualised and data-driven context? How investments and initiatives supporting digitalisation can avoid de-funding, de-localising, de-skilling, de-humanising practices, services, and businesses?

Key points to be addressed in formulating policies and actions:

- **Advisory and innovation-risk bearing systems**: creating and supporting an enabling environment (cooperation, incentives, innovation support) to help farmers, local administrations, forestry operators, and more actors to be part of the needs assessments, co-designing, piloting, and implementation of new digital tools, or adoption of existing ones applied for the first time in other context.

- **Official protocols and standards to design and commercialise digital technologies**: e.g. work security standards for workers using robots or unmanned technologies, eco-efficiency parameters to be respected, etc.
- **The power-political context**: structures and mechanisms to prevent digitalisation from perpetuating and exacerbating existing trends in European agri-food systems, forestry and rural areas, like: corporatism, consumerism, misrepresentation of farmers by agri-business corporations, sexism and transphobia, privatisation of means of production, xenophobia and racism.
- **Technological path dependency**: regulatory and policy framework that prevent digititalisation to contribute towards de-humanised, capital-intensive, polluting, and natural-resource depleting agri-food systems, forestry and rural areas.
- **Cooperation among actors involved in data systems and technology providers**: e.g. managing authorities, research institutes, business platforms, international and local statistical organisations, users, etc.
- **Socio-physical inter-dependency**: material and immaterial inter-dependency between a digital technologies and other socio-physical conditions (e.g. food quality, solidarity, social life, etc.)
- **Regulations, policies, and collective actions to prevent gender security (gendersec) in rural areas**: violence and discrimination facilitated by digital technologies towards women, children, non-binary and transgender in rural areas.
- **Initiatives for inclusive and open digitalisation**: participatory platforms to disseminate and promote local actions for a collective uptake of digital tools around the management common goods (e.g. natural resources).
- **Data privacy and protection**: legislative solutions to limit unfair practices (e.g. unclear contractual clauses) that pave the road for technology providers in order to exploit/monetise sensitive and personal data for marketing purposes.

RECOMMENDATIONS FOR FUTURE EVALUATIONS OF DIGITALISATION

Some of the main questions to be address

How can evaluation of digitalisation demonstrate evidence about its assumptions (e.g. lower pesticides thanks to precision farming) based on strong counterfactual analysis with comparable (e.g. conventional farmers with and without precision farming tools) as well as across alternative scenarios (e.g. conventional, organic, agro-ecology). How can evaluations consider the energetic and material costs for building and running digital system, as well as their recycling? Which methodological approaches or mix thereof can reduce biases and bring more clarity on the contested drivers and effects of digitalization (e.g. surveillance, domination, control, rationalisation)?

Key points to be addressed in future evaluations:

- **Life-cycle assessments considering biological, material and energetic consumptions** of digitalised farming machineries, food supply chain systems, and other devises or systems designed in agricultural, forestry or rural environments.
- **Build more update and interoperable statistical databases at lower levels (e.g. NUTS3 or 4) on the multiple dimensions of digitalisation**: connectivity, skills, use of technologies, gender, and more.
- **Framing research questions**: understanding the differences between past, present, and future timespan when assessing the level and impacts of digitalisation on a given topic or unit of analysis.
- **Verifying assumptions, hypothesis, and conclusions**: by using robust datasets, posing reflexive questions on the limits of the selected research approach, or collecting people's experiences on the ground to double check any qualitative or quantitative information.
- **Go beyond simple cost-benefits analysis at technological level**: explore the deeper and immaterial requirements and consequences of a digital technology or a bundle thereof, for instance, on digital pollution (emissions, farm operations on soil qualities, etc.), community socialisation, solidarity, transmission of competences, autonomy, diversity of crop and breed varieties.
- **Involvement and empowerment of "users"**: include farmers, rural dwellers, local administrations, and any relevant stakeholders in setting up research and innovation agendas for digitalisation, as well as its evaluation, dissemination, and validation of findings.

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8. Annex

8.1 Overview of the 21 Living Labs' focal questions

Living Labs	Focal questions
1. Austria	How can digitalisation support and enforce the adoption of the European Timber Regulation (EUTR) concerning imported round wood in Austria?
2. West Flanders, Belgium	What is the impact of individual farm based airborne monitoring of emissions of ammonia, particulate matter, and odour, in the intensive livestock sector for agriculture, policy, and society in Flanders?
3. Switzerland	How to control weeds effectively and efficiently in Swiss organic vegetable farming?
4. Lake of Constance, Germany	How can digitalisation contribute to the sustainability of fruit production in the Lake of Constance region?
5. Rhineland-Palatinate, Germany	How the local administration can cope with internal and external challenges of the digital transformation and integrate citizens as well as other local actors into this process?
6. Greece	How to develop new digital services and functionalities for rural communities based on utilization of existing agricultural / data infrastructures and tools. How can these infrastructures be used to further support the economy and farmers' / citizens' income in rural communities?'
7. Trikala, Greece	How to better manage water resources for the benefit of both, farming purposes and the everyday needs of the citizens?
8. Andalucia, Spain	How can digitalisation contribute to reduce the damage caused by wildfires and to make more effective firefighting and degraded land restoration by 2030?
9. Aragon, Spain	How can digitalisation contribute to enhance the global attractiveness of the territory of Maestrazgo and Gúdar-Javalambre?
10. Central Osthrobotnia. Finland	How can digital systems contribute to advancing bioeconomy and circular economy in Central Ostrobothnia in 2030?
11. Inno'vin, France	What is the current state of the level of digitalisation within the wine sector's value chain and how these technologies can help achieve the agro-ecological transition of the wine sector while strengthening its competitiveness?
12. AgrOnov, France	How does digital technology contribute to the emergence of innovations in favour of agro-ecological transition in agriculture?

Living Labs	Focal questions
13. Végépolys Valley, France	* How can digital technology enable horticultural companies to increase their productivity and reduce costs, while reducing their environmental impact? * How can digital technology enable horticultural companies to have a better knowledge of the offer, to better appreciate the market and the real needs of end consumers, but also to diversify the sales methods?
14. Croatian Adriatic Region, France	• How can digitisation contribute to availability of local products, recognition, flexibility and standardization of local traditional small-scale products and services? • How can digitisation contribute to strengthening the connections between farmers and tourists, and create a better position of the small family farms in the value chain?
15. Cultivate, Ireland	How can digitalisation support local livelihoods that contribute to rural regeneration and assist in the transition to a low carbon society?
16. Tuscany Nord, Italy	How can a better communication among citizens, farmers, public administration and other stakeholders make ordinary land management in marginal rural areas more effective? And how can digitalization facilitate the information flows between actors/tools involved in this process?
17. Programme for the Endorsement of Forest Certification schemes, Italy	How to strengthen the adoption of digital tools to support the wood-energy traceability over the whole supply chain in conformity to the compulsory EU Timber Regulation (995/2010) in Italian forests
18. Latvia	To develop an innovative support system with the use of digitals tools for the recognition and traceability of beef cattle meat in order to improve and extend markets (e.g. digital marketing strategy aimed at communicating the characteristics of Latvia's beef to consumers and farmers).
19. Flevoland, the Netherlands	How can digital systems/platforms contribute to the exchange of knowledge of short food supply chains?
20. Poland	How to enhance participation in rural planning? And how can digitalisation improve the involvement of local communities in spatial planning processes?
21. Scotland	How can digital technologies promote opportunities for crofting communities in Wester Ross?

8.2 Common structure of online survey and respondents statistics

Digital technologies can have positive or negative impacts depending on a range of factors including accessibility, affordability and ease of use. DESIRA would like to explore the socio-economic impact of digital transformation in rural areas. Digital transformation may generate winners (those who benefit from the change), but also losers (those who are marginalised by the change), as well as opponents (those who resist change) and proponents (those who support or advocate change). This survey explores these aspects of digital transformation in rural areas.

1 PRIVACY STATEMENT

The research participant has been informed that: Data is being collected as part of the EU H2020 Project DESIRA. Data collected, audio recording, video recording and photos may be taken and used for research, dissemination and communication purposes. Data will be analysed by members of the DESIRA project, and in some cases may be analysed by project members other than the interviewer. Participation is voluntary. Consent can be withdrawn at any time without reason. Participants can access personal data at any time without reason. Data will be anonymised if possible. In cases in which the data cannot be anonymised, any publications will be shown to identifiable participants for further consent for publication. Data will be safely stored in certified repositories for long term preservation and curation.

YES / NO

2 RESPONDENT PROFILE: DESCRIPTIVE INFORMATION OF THE RESPONDENT

1 Age

Younger than 30
30-40
41-50
51-65
Older than 65
prefer not to say
Other

2 Gender

Female
Male
non-binary
prefer not to say

3 Country

4 How would you describe the area in which you live?

Predominantly rural
Intermediate
Predominantly urban

5 What is your highest level of education?

Primary school
Secondary school
University degree (Bachelor, Master, PhD)
Other

6 if other please specify

7 Do you have a specific educational qualification in one of these fields?

agriculture
food science
forestry
sustainability
digital technology (e.g. informatics, electronic, engineering diploma, or degree)

8 if other please specify

Txt

9 How would you describe your role in the community? (multiple choice)

Crofter
Forestry manager
Farm advisor
Agricultural union/ farmers organisation
food value chain sector (i.e. processing, logistics, retailers)
IT or digital expert
Consultant
administration worker,
Researcher
Educational institute
Marketing Expert/Trader
Technology developer
citizen group
local community group
Volunteer
Charitable trust
No professional status (resident, inhabitant etc.)
Other

10 if other please specify

11 Which sector do you work in? (multiple choice)

Private
Public
Public-private
Civil society
OTHER

12 if other please specify

3 THE LEVEL OF DIGITALISATION AND ITS IMPACTS IN RELATION TO THE FOCAL QUESTION

The section investigates the adoption of past and present digital technologies and its main socio-economic impacts.

13 How often do you use the following digital technologies in your working activities?

Digital Technologies	never	rarely	sometimes	often	always	I'm not familiar with the technology
social media and social networks (social tools for interaction or access to services).						
web sites and online platforms (web tools for interaction or to access/offer services).						
cloud services and applications (services available through mobile applications, web platforms, or other systems (for instance, image analysis for disease / pest recognition by sending pics).						
sensors, drone and/or satellite imagery (use of sensors in the field or drone / satellite imagery to collect data).						
blockchain or other certification / traceability (services to certify products, processes, etc. or to trace products).						
augmented reality / virtual reality extended reality (techniques for training, education, or other purposes).						
3D printing (production of 3D objects through a printing-like process).						
artificial intelligence (use of AI to analyse data or to suggest actions / decisions).						
autonomous systems and robotics (robots like milking robots or other systems performing actions autonomously).						

14 How has the adoption of digital technologies impacted the following areas of your work in the last 5 years?

	Strongly worsened	Worsened	No change	Improved	Strongly improved	don't know	Not applicable
Access to new tools.							
Number of employees.							
Working conditions.							
Access to financial resources.							
Capacity to take initiative.							
Technical means and equipment.							
Operational costs.							
Access to customers.							
Quality of existing products.							
Access to new products in local markets.							
Export/find new markets abroad.							
Compliance with safety working and health standards.							
Citizen engagement.							
Dialogue with actors along the supply chain.							
Social integration/ Community cohesion.							
use of agricultural inputs (water, pesticides, fertilizers).							
Other							

15 if other, please specify

Txt

16 Have digital technologies affected the diversification of working activities in your job?

Yes / No

17 If digital technologies have affected the diversification of working activities in your job (displacing, maintaining, creating new types of activities, etc.), can you briefly explain how?

Txt

18 In relation to your focal question, what do you think is the current level of

	1 (low) _______________7 (high)
Digital connectivity in your geographical area (referring to the deployment of broadband infrastructure and its quality).	
Digital skills of people in the sector you work in (skills needed to take advantage of the possibilities offered by digital).	
Use of Internet Services by people in your geographical area (accounts for a variety of online activities, such as the consumption of online content (videos, music, games, etc.) video calls as well as online shopping and banking).	
Integration of Digital Technology by businesses in your geographical area (digitisation of businesses and e-commerce).	
Digital Public Services in your geographical area (digitisation of public services, focusing on eGovernment and eHealth).	
Level of participation of women in digital technologies	

19 How do you think the use of the following technologies in your working activities will change in the next 5 years?

	Strong reduction	Reduction	No change	Increase	Strong increase	Not applicable
social media and social networks (social tools for interaction or access to services)						
web sites and online platforms (web tools for interaction or to access/ offer services)						

	Strong reduction	Reduction	No change	Increase	Strong increase	Not applicable
cloud services and applications (services available through mobile applications, web platforms, or other systems (for instance, image analysis for disease / pest recognition by sending pics)						
sensors, drone and/or satellite imagery (use of sensors in the field or drone / satellite imagery to collect data)						
blockchain or other certification / traceability (services to certify products, processes, etc. or to trace products)						
augmented reality / virtual reality extended reality (techniques for training, education, or other purposes)						
3D printing (production of 3D objects through a printing-like process)						
artificial intelligence (use of AI to analyse data or to suggest actions / decisions)						
autonomous systems and robotics (robots (like milking robots) or other systems performing actions autonomously)						

20 What are the main obstacles to the adoption of digital technologies in your working activities?

Obstacles	Not at all important	Slightly important	Moderately important	Very important	Extremely important	Not applicable
Adjustment of company's organisation.						
Recruitment of highly skilled ICT staff.						
Development of ICT skill among staff.						
Level of Connectivity and digital infrastructure.						

Obstacles	Not at all important	Slightly important	Moderately important	Very important	Extremely important	Not applicable
Cost of development/ implementation.						
Regulation and legislation.						
Identification of opportunities presented by digital technology.						
Cultural distrust on new technology.						
Social Acceptability.						
Ethical aspects.						
Perceived benefits.						
Other.						

21 if other, please specify

Txt

4 SOCIO-ECONOMIC SUSTAINABILITY INDICATORS[2] (PRE-SELECTED BY THE LIVING LABS COORDINATORS)

In the following questions, we would like to know how digital technologies can help to reach sustainability targets, which would promote opportunities for crofting communities in Wester Ross.

22 How can digital technologies help to reach the following sustainability targets?

Please indicate if and how digital technologies will impact the below areas

Sustainability Targets		strongly decrease likelihood of reaching target	slightly decrease likelihood of reaching target	neither increase or decrease the likelihood of reaching target	slightly increase likelihood of reaching target	strongly increase likelihood of reaching target	No answer
1	increased volume of production per labour unit by classes of farming/pastoral/ forestry enterprise size (Would digital technologies increase productivity?)						

2 This section of the online survey was adapted for each focal question. Living Labs coordinators were invited to select the most relevant targets from a list or add their own ones.

Sustainability Targets		strongly decrease likelihood of reaching target	slightly decrease likelihood of reaching target	neither increase or decrease the likelihood of reaching target	slightly increase likelihood of reaching target	strongly increase likelihood of reaching target	No answer
2	added value to end-product. (Would digital technology add value to the end-products?)						
3	increased proportion of small-scale industries in total industrial value added. Can digital technologies increase the proportion of small-scale industries among all industries?						
4	new technology has a positive contribution to income. Could digital technology increase profit?						
5	increased land use efficiency. Would digital technology increase the efficient land use?						
6	reduced person hours of production. Would digital technology save labour/time?						
7	improved image of a subject or product. Would digital technology enhance the product image, make it more appealing?						
8	improved marketing of a product. Would digital technology improve the marketing of products?						
9	increased public awareness. Could digital technology be used to make the public more aware of issues?						

Sustainability Targets		strongly decrease likelihood of reaching target	slightly decrease likelihood of reaching target	neither increase or decrease the likelihood of reaching target	slightly increase likelihood of reaching target	strongly increase likelihood of reaching target	No answer
10	increased cooperation between different institutions and citizens. Could digital technology be used to enhance relationships between individuals and institutions ?						

23 If other sustainability targets should be considered, please list them below and provide a short justification

Txt

24 Please identify the 5 targets you value to be the most important/critical of the 10. To identify them, please rank them from 1 to 5, with 1 being the most important.

		(1= most important,	2	3	4	5= least important).	Not important
1	increased volume of production per labour unit by classes of farming/ pastoral/forestry enterprise size.						
2	added value to end-product.						
3	increased proportion of small-scale industries in total industrial value added.						
4	new technology has a positive contribution to income.						
5	increased land use efficiency.						
6	reduced person hours of production.						
7	improved image of a subject or product.						
8	improved marketing of a product.						
9	increased public awareness.						
10	increased cooperation between different institutions and citizens.						

5 IMPACT OF COVID-19

In addition to serious implications for people's health and healthcare services, (COVID-19) is having a significant impact on businesses activities. In this section we aim to collect stakeholders' opinions about how COVID-19 has affected the adoption of digital technology as well as on working activities.

25 Has covid-19 affected the adoption of digital technology in your job or community?

Yes / No

26 28 If covid-19 has affected the adoption of digital technology, can you briefly explain how?

Txt

27 29 Has covid-19 impacted on your working activities?

Txt

28 30 If covid-19 has impacted on your working activities, can you briefly explain how?

Txt

6 COMMENTS AND SUGGESTIONS

Respondents statistics

A total number of 273 Living Labs' stakeholders responded to the online survey across the 21 focal question. The stakeholder demographic characteristics show that most are middle-aged, educated people who could use digital technologies in their businesses and lives. About 32 percent are below 40 years, while 68 percent are above 40 years. The majority of the respondents are male (71 percent), and 29 percent are female. Most of the respondents attended university (79 percent), 11 percent attended secondary school, 3 percent attended primary school, while 7 percent hold other types of degrees. About half of the stakeholders reside in predominantly rural areas, 34 percent reside in intermediate areas, and 16 percent resides in predominantly urban areas. There is, therefore, a substantial diversity across the stakeholders, and this is important to gain varied and comprehensive responses.

Besides being very educated, most stakeholders have specific training and qualification in agriculture and digital technology fields, which help them play their roles in various sectors. The majority (41 percent) have a specific qualification in agriculture, 18 percent are qualified in forestry, another 18 percent are qualified in digital technologies, for example, informatics, electronic, and engineering. Twelve percent are qualified in sustainability, while 4 percent have a specific qualification in food science. This result indicates that the stakeholders are both educated and qualified in relevant subject matter and can provide valuable responses to the survey.

The stakeholders play multiple roles in the community, and a majority are consultants, farmers, members of agriculture organizations, IT experts, or technology developers. About 27 percent are consultants, 23 percent are farmers, 18 percent are members of agriculture organizations, 18 percent are farm advisors, 17 percent are administrative workers, 13 percent are IT experts, and 10 percent are technology developers. Other stakeholders' roles include employees of education institutes, volunteers, researchers, marketing experts, food-value-chain workers, members of local community groups, citizen groups or charitable trusts, and forest managers. Only 2 percent of the respondents said they do not play any role in a professional capacity in the community. This group is classified as residents in the community.

The stakeholders equally work in a wide range of sectors bringing different experiences to the survey. Half of the stakeholders work in the private sector, 23 percent work in the public sector,

12 percent work in the public-private sector, and 8 percent work in civil society or NGOs. Another 6 percent work in other sectors that do not fit these categories.

8.3 Data collection tool to assess impacts on activities

Intervention logic used by the Living Labs' participatory impact assessment

What has been digitalised? Which digital technologies and skills are involved?	What outputs has digitalisation produced?	What are the effects (consequences) generated by digitalisation on Socio-economic-environmental dimensions of the focal question?		How does this effect contribute positively or negatively to the SDGs?
		Direct		
		Indirect		

8.4 Winners, Losers, Proponents and Opponents in the NEI assessments

Entities	Winners	Losers	Proponents	Opponents
Wide society in rural areas (Citizens, workers, civil-society groups, tourists, consumers, researchers, market operators, associations, and public authorities)	• Common resources (water, land, education) can be potentially used more accurately, with more data available for planning, distributing, monitoring, etc. • Increase security (firefighting, crime prevention, etc.) • More opportunities to work remotely, innovate and change practices and habits. • Enabling women to access work opportunities remotely – i.e. flexibly in a way that fits around other responsibilities at home including childcare	• A specific stratum of society without access to digital skills, devices, connectivity. • People affected by anxiety, stress, and hypoconnectivity. • People who cannot access the elements to deal with information overload (community, in-person dialogue, individual and collective capacity to filter and process information) • Micro SMEs lacking the necessary skills and resources to incorporate new tools into their daily businesses • Communities that may lose the social benefits of face-to-face markets • Local community, especially young people, excluded from local housing market, because digital platforms extend market for houses, raise awareness of beautiful location to more people outside of the community	• Data can bring more elements to objective and evidence-base debates and decision-making process (consumption, regulation, trade, etc.) • Community members advocating for improved broadband services • Increasing distance to local producers (both geographically and in terms of intermediators), as well as interests on the quality aspects (e.g environmental, ethical, organoleptic properties) call on digital solutions to ensure transparency and gain more information about agri-food and forestry products.	• Actors concerned on data-driven market concentration, surveillance, and privatisation of public goods • Workers replaced by cameras or tech devices for surveillance • Those who distrust for the ownership and use of data. • Individuals fearing change, feeling that new tools might bring dehumanization and may lead to cyber-attacks. • Food consumers and citizens who understand that often digitalisation is associated to corporate agri-food systems. • Those questioning the ethics of the minerals and materials extraction needed for further digitalisation

Entities	Winners	Losers	Proponents	Opponents
Governmental and para-governmental organisations	• More precise, rapid, accurate and long-term datasets are available for policy making, accountability, evaluation, and learning • Costs and time are saved for inspections, cross-compliance checks, rewarding and penalties, judicial proceedings (e.g. by relying on a mix of satellite images and on-site checks). • More fluid procedures between public, business, and civil society actors.		• The use of new auditing and monitoring tools can increase transparency and speed data collection processes	• Rigidity of the regulation • Lack of sufficient budget and staff to adapt new technologies
Farmers involved in high-capital intensive agriculture (large farm size, medium-high digital skills, high use of external inputs)	• Farm assets and inputs can be used more efficiently; higher productivity rates; higher capitalisation of acquired equipment, land, livestock, digital skills. • Labour inputs and dependencies are reduced. • On-farm or off-farm income diversification opportunities can be grasped with time-saving technologies.	• Higher dependency on third parties and external know-how providers to solve technical issues (e.g. problem with GPS signals)	• Interest in, and capacity to attract public and private funds for research and technological development in the field of smart farming.	• Farm data or new data collection tools (e.g. satellites, models) can be used for analysis and regulatory purposes by governmental or non-governmental organisations to change environmental performance (GHG emissions, odours, water quality, etc.).

Entities	Winners	Losers	Proponents	Opponents
Farmers involved in diversified and traditional farming based on the minimal use of external resources	• Integration of farm services and products into wider platforms (e.g. tourism, events, solidarity purchasing groups) • Small scale producers who can sell directly to customers without spending entire days at markets • Farmers involved in high-quality food production have more possibilities to tell the story and communicate the product values.	• Time and investments must be made to meet new digital requirements, without receiving proportional compensations from food provision (e.g. paying an official email, create several digital profiles and accounts, purchasing digital devises).		• Identity loss when farmers' labour is replaced by, or must increasingly rely on capital, data, and standardised knowledge and competences. • In-person relationships and traditional competences like dealing with animals, plants, territory, people in multiple tasks (e.g. on-farm cheese making, direct selling with face-to-face markets, etc.) are under threat by more rational and automatised solutions designed for a particular model of agriculture. • Opportunities do not overcome costs. • Rejection to adapt the agro-ecological farming model to those designed by agri-tech companies, financial insurance companies, seed and livestock breed engineers privatising genetic diversity, etc.

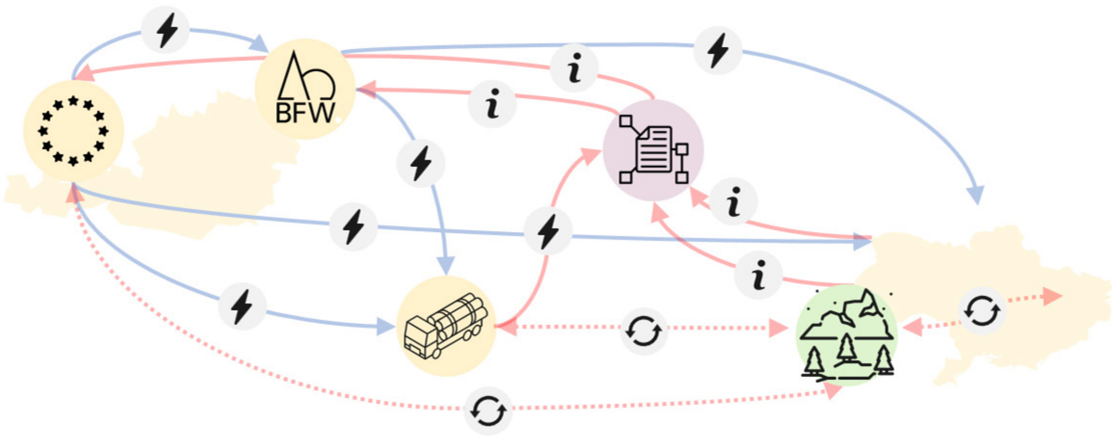
Entities	Winners	Losers	Proponents	Opponents
Manufacturers of agricultural machinery; input providers, agri-tech companies delivering digital tools and services	• Profits seeking is possible through the offer of new services and products. • Gaining access to a large volume of unstructured or structured (e.g. meta-data) to capture monetary value, personalise services, or strategizing market investments.		• Fertilisers and pesticide providers recommend using their decision supporting tools or platforms to gain data, or send commercial offers to meet agricultural demands.	• Input providers concerned with sharing commercial data, as well as losing market sales through digital advices.
Food logistics, delivery and intermediators (wholesalers, supermarkets, etc)	• For the sake of transparency and traceability, large data volume become available. Analytics tools allow to personalise services and products to consumer demands; control and influence quality parameters at farm level; predict and plan markets. • Through online platforms, added value is captured by users, data, advertisements, and transactions (e.g. share of payments taken for each online food purchase).		• New services for business and consumers are offered to facilitate the matching of supply and demands.	

Entities	Winners	Losers	Proponents	Opponents
Private and public operators working in unlawful practices (e.g. illegal logging, free riding)	• Information is uncovered on illegal practices leading to deforestation or corruption over public goods.	• Higher transparency and more controlled authority's permission procedures for private operators	• Public authorities responsible for authorizing and monitoring forest cutting since they could benefit from data generated by digital payment technologies	• Individuals who are benefitting from the lack of control and monitoring of water usage in the region and exploit the current state by avoid bearing costs proportionate with their water usage. • Forest micro-enterprises that have no interest in complying with EUTR, investing in digital tools and sharing their data (indirectly benefitting from high costs for EUTR enforcement) • Economic actors of the forest supply chain who operate in the black economy, (being sometimes supported and protected by local policymakers)
Researchers, practitioners, advisors	• More data and efficient tools are available to manage existing projects or develop new ones (e.g. digital marketing advisors for direct selling).	• Clients (e.g. farmers, rural dwellers, forestry operators) might opt to rely on free information online instead of paying for an expert advice or deeper analysis, as well as to learn to do things independently (e.g. tax declaration, accountancy, etc.)	• Different options are proposed to clients or research participants to deliver services or collect data for advisory and research purposes (video, audio, image capturing and sharing).	

8.5 Overview of the visualisations of the Living Labs' SCPS

LL in Austria, focusing on wood traceability

Fig. A1: LL Austria. Simplified visualisation of SCPS (main entities and detailed interactions)



i .... a flow of information

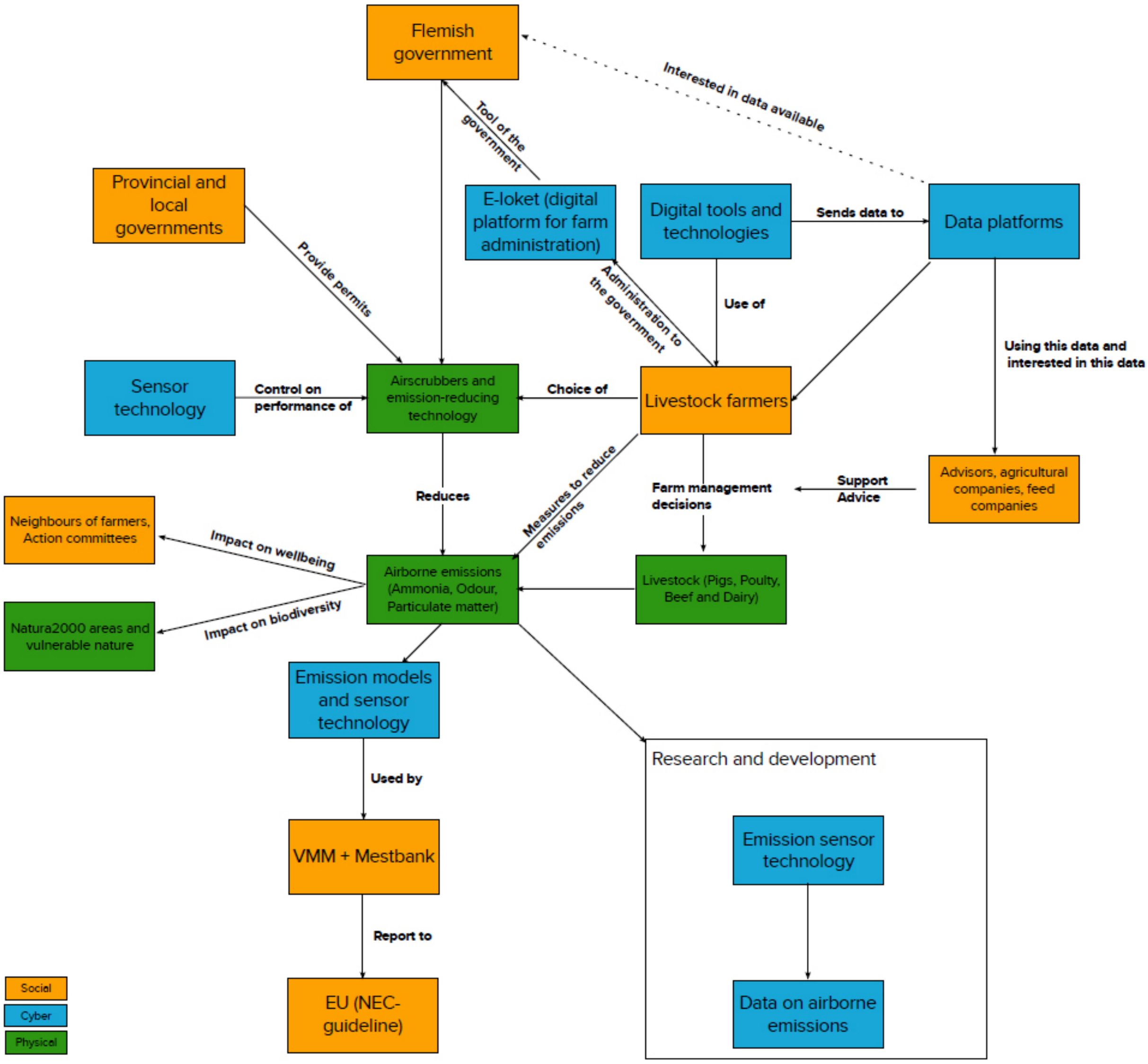
.... "power", "influence" of one entity over another

.... mutual influence

Exemplary visualization of entities and interactions:
Socio (yellow) – trading countries (Ukraine); Policy (BFW); European market (Austria and European stars)
Cyber (pink) – digital document (DDS documents)
Physical (green) – Forests (e.g., Carpathians)
Intradisciplinary – blue / Interdisciplinary – red
Two-way interactions – dotted double arrows

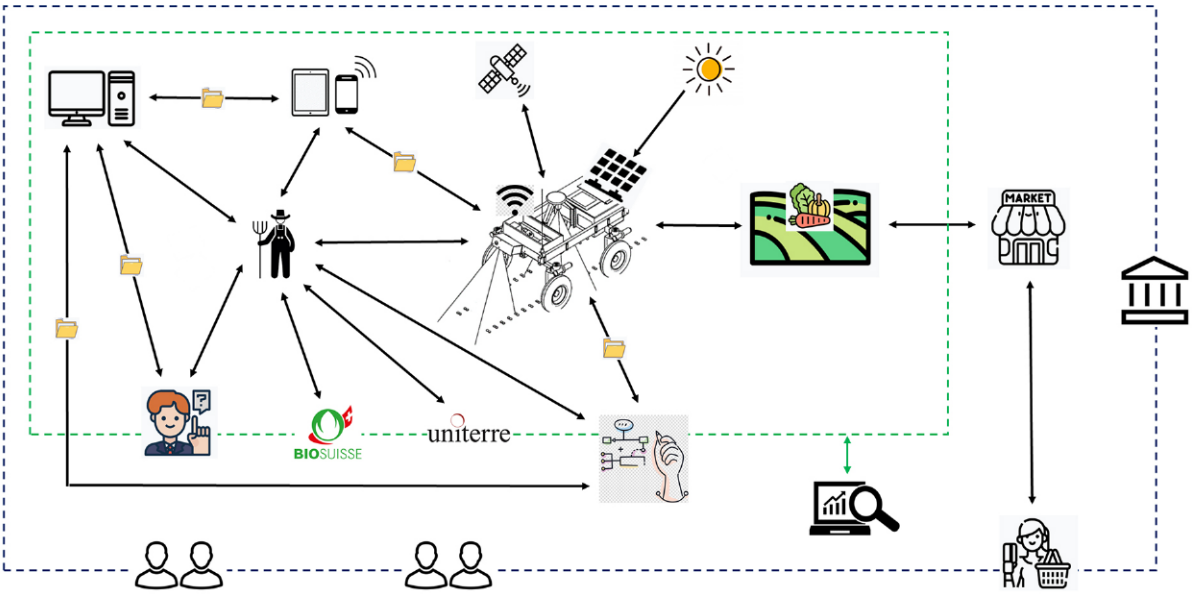
LL in Belgium (Flanders), focusing on ammonia emissions monitoring

Fig. A2: LL Belgium (Flanders). Visualisation of SCPS related to sensor technology to measure livestock emission on the individual farm-level



LL in Switzerland, focusing on weed control in organic farming

Fig. A3: LL Switzerland. Visualisation of SCPS related to the introduction of weeding robots in Swiss organic vegetable farming



Farm advisers

Tech companies dealing with weeding robots

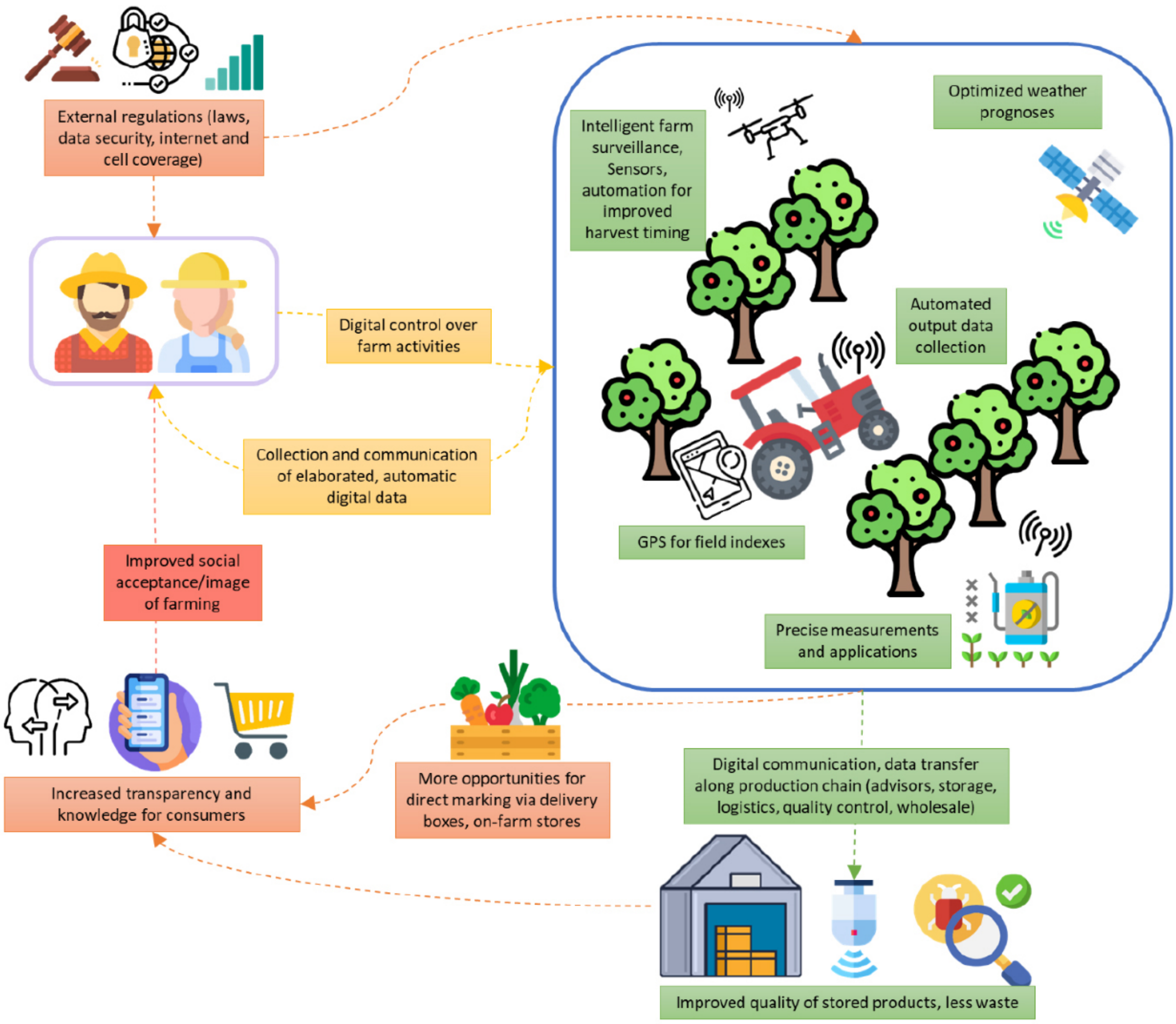
Research institutions

Quite direct interactions with the inner circle

Outer circle of the SCP system

LL in Germany (Lake of Constance), focusing on fruit production

Fig. A4: LL Germany (Lake of Constance). Visualisation of SCPS related to the impact of digitalisation on the sustainability of fruit production in the Lake Constance region



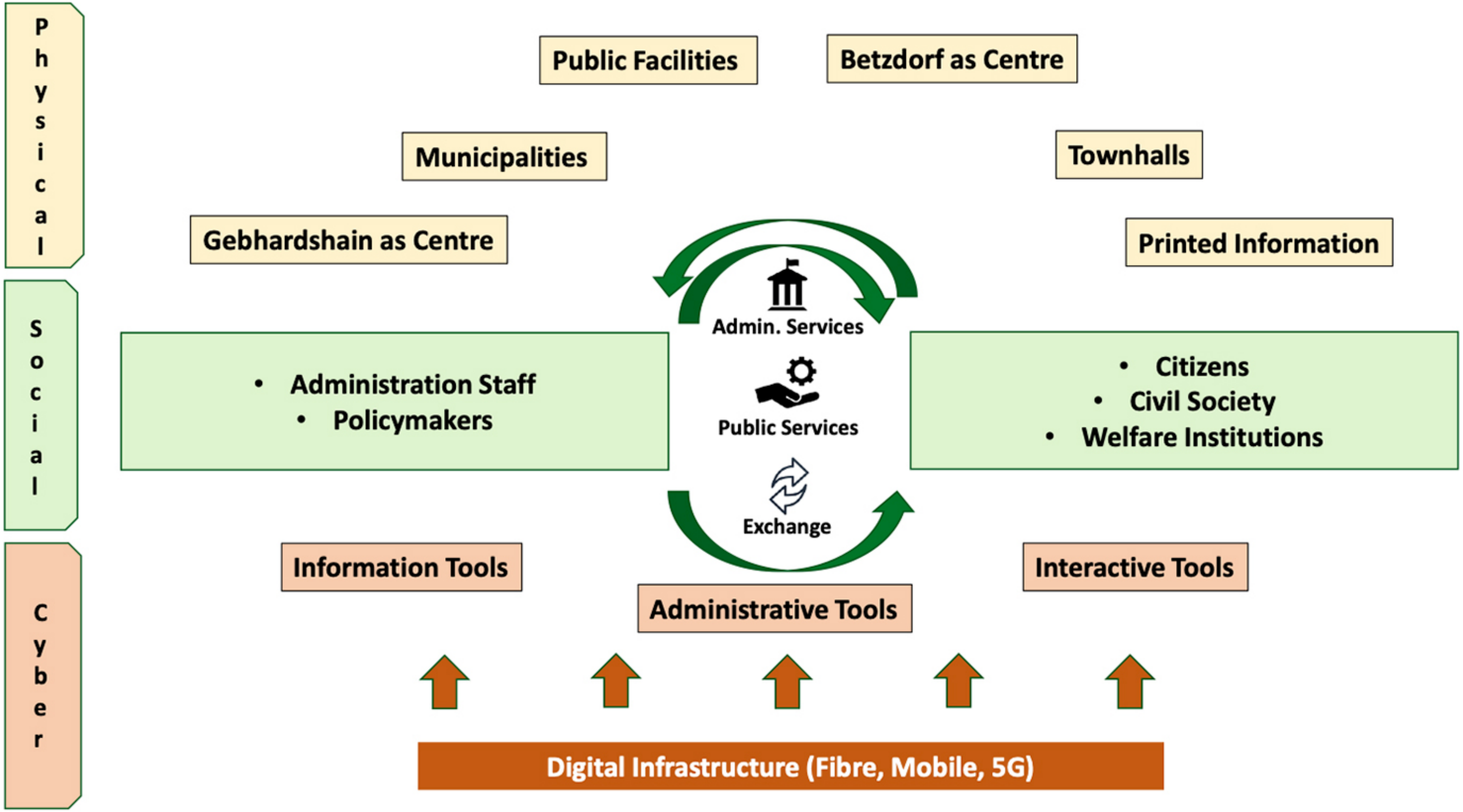
<div>Icons made by Freepik from www.flaticon.com></div>

Legend

Social | Social-Cyber | Cyber | Cyber-Physical | Physical | Social-Physical

LL in Germany (Rhineland-Palatinate), focusing on digital village

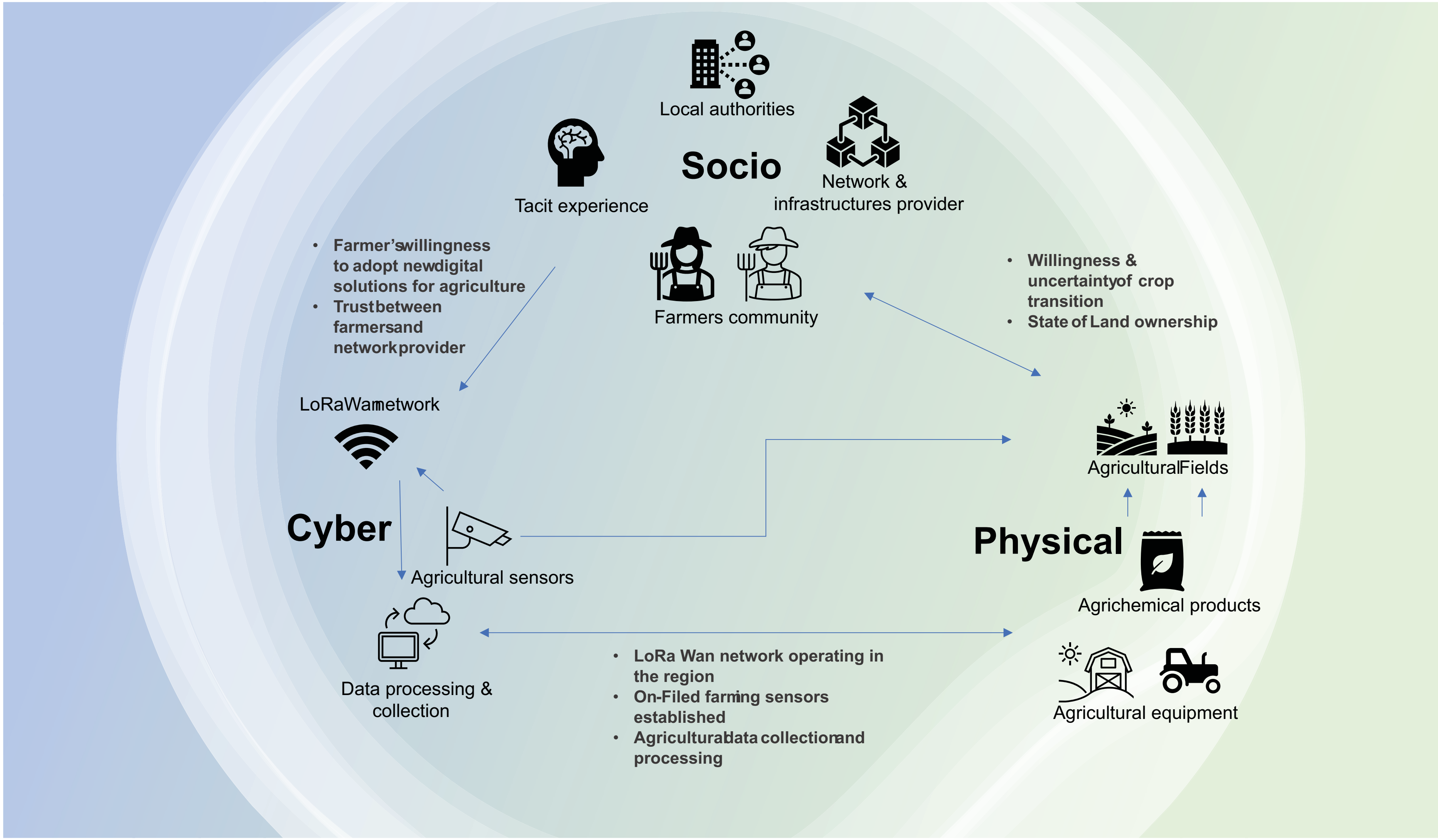
Fig. A5: LL Germany (Rhineland-Palatinate). Visualisation of SCPS related to the exchange of public and private actors in Betzdorf-Gebhardshain



(The dark green arrows represent interaction among social entities. Note, that in the cyber domain this process is predominantly unidirectional.)

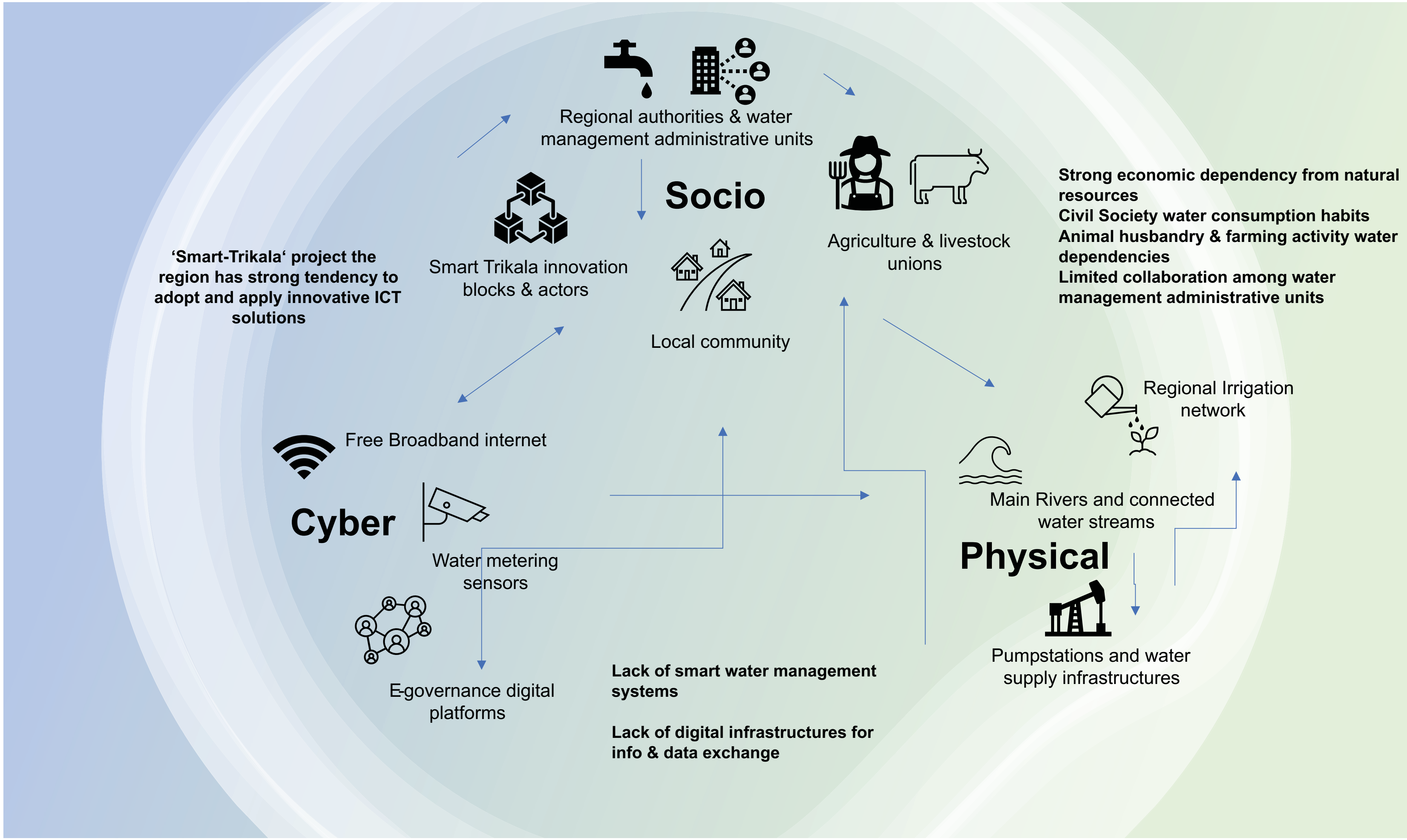
LL in Greece focusing on smart rural communities

Fig. A6: LL Greece. Visualisation of SCP system related to the development of new digital services and functionalities to support the farmer's income



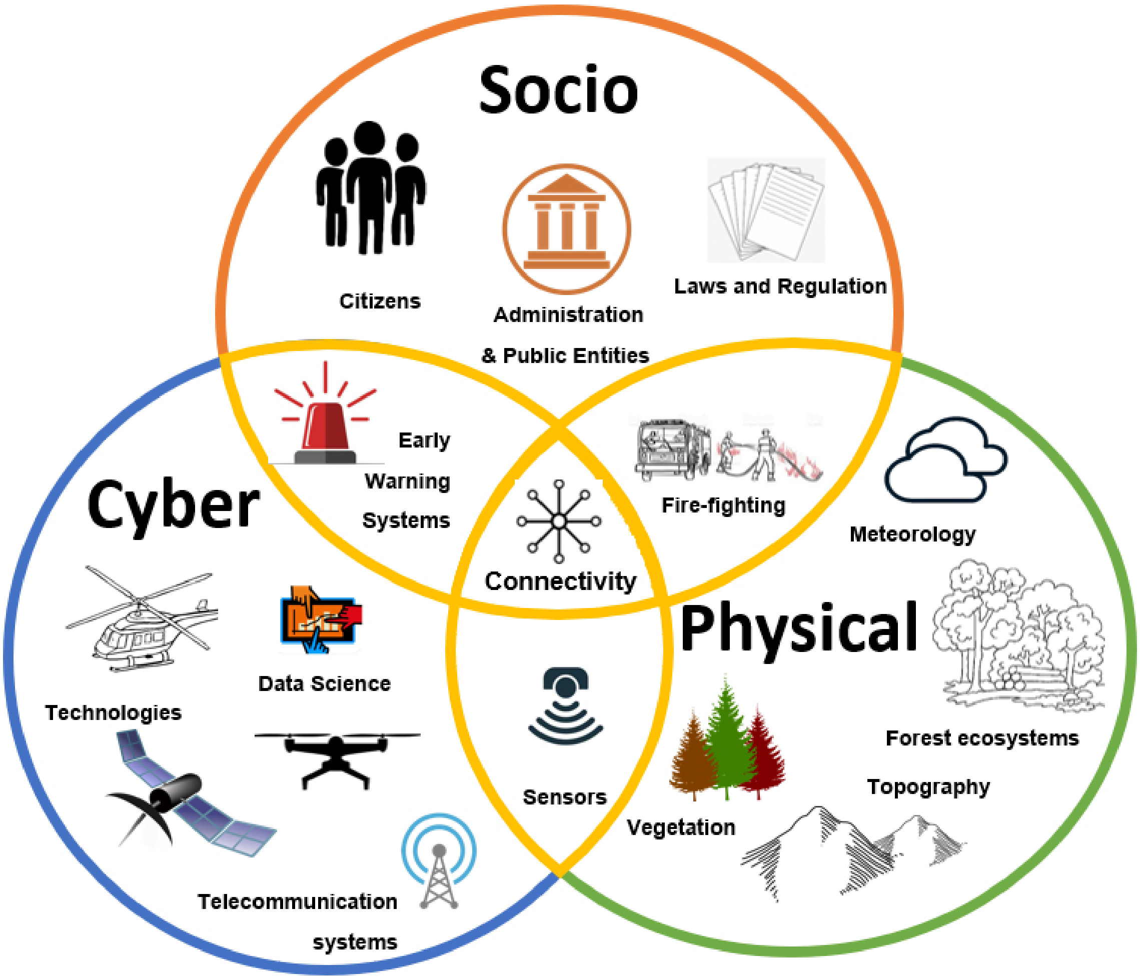
LL in Greece (Trikala), focusing on water management

Fig. A7: LL Greece (Trikala). Visualisation of SCPS related to sustainable water management practices in Trikala region



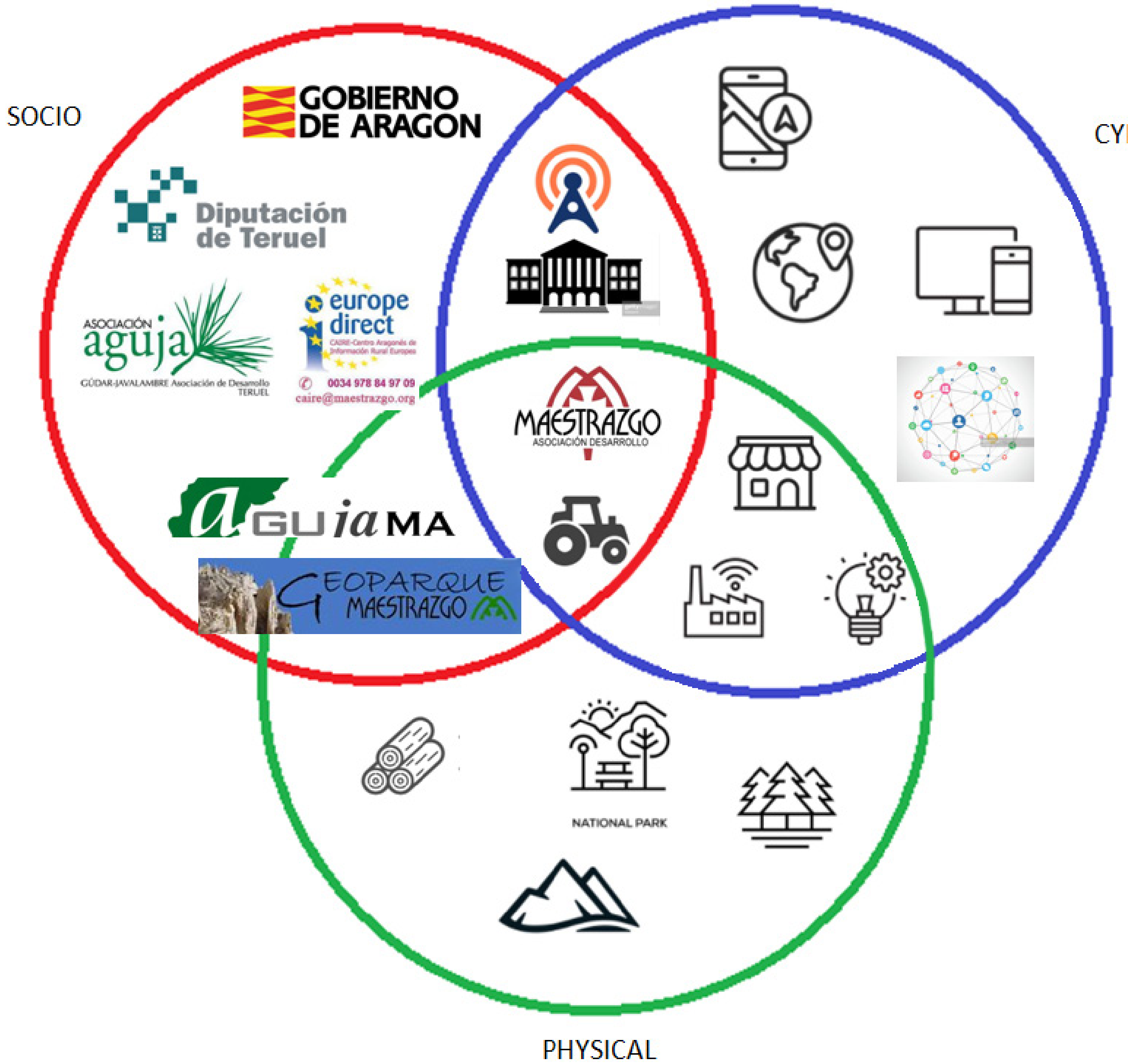
LL in Spain (Andalusia), focusing on contrasting forest fires

Fig. A8: LL Spain (Andalusia). Visualisation of SCPS for forest fires



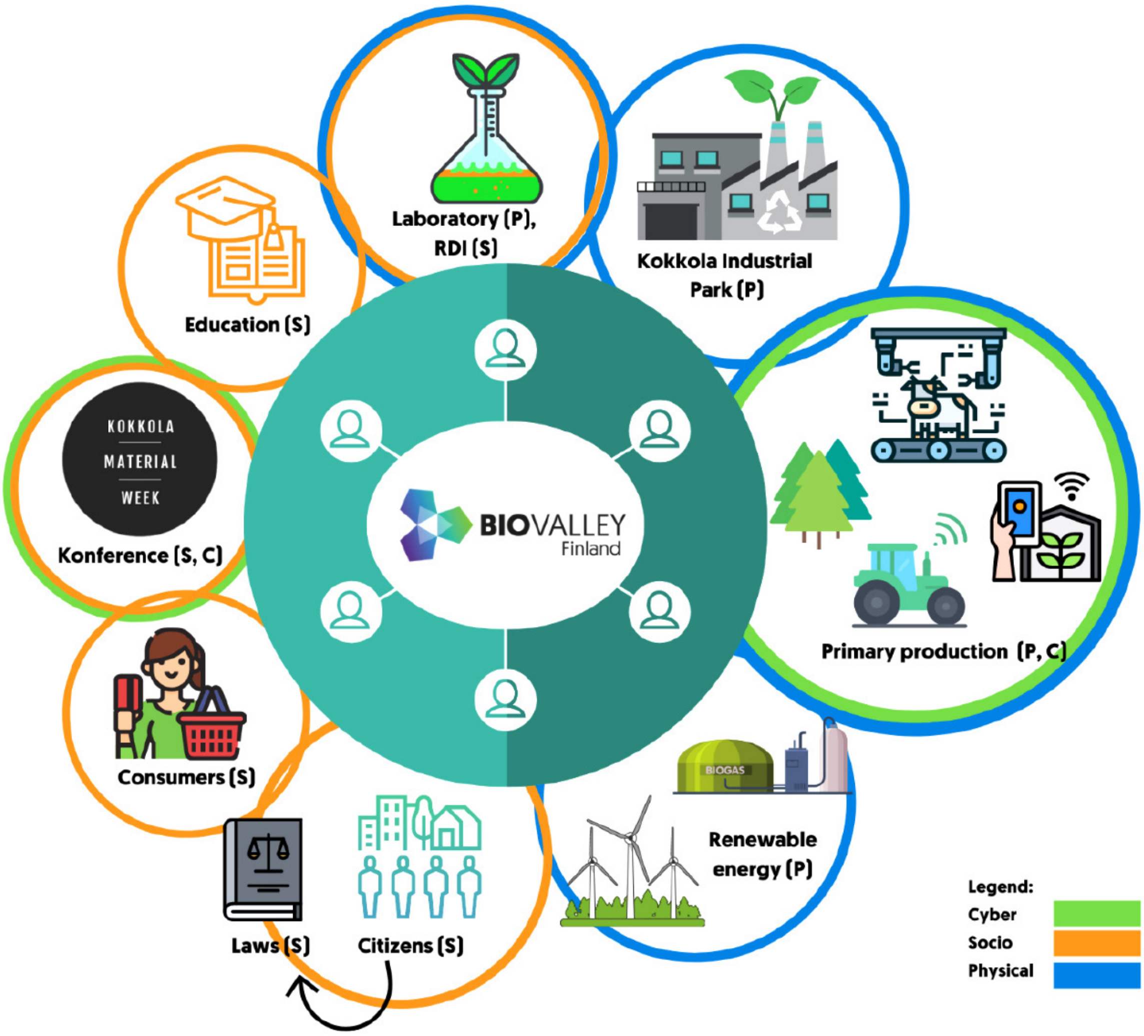
LL in Spain (Aragon), focusing on territorial attractiveness

Fig. A9: LL Spain (Aragon). Visualisation of SCPS



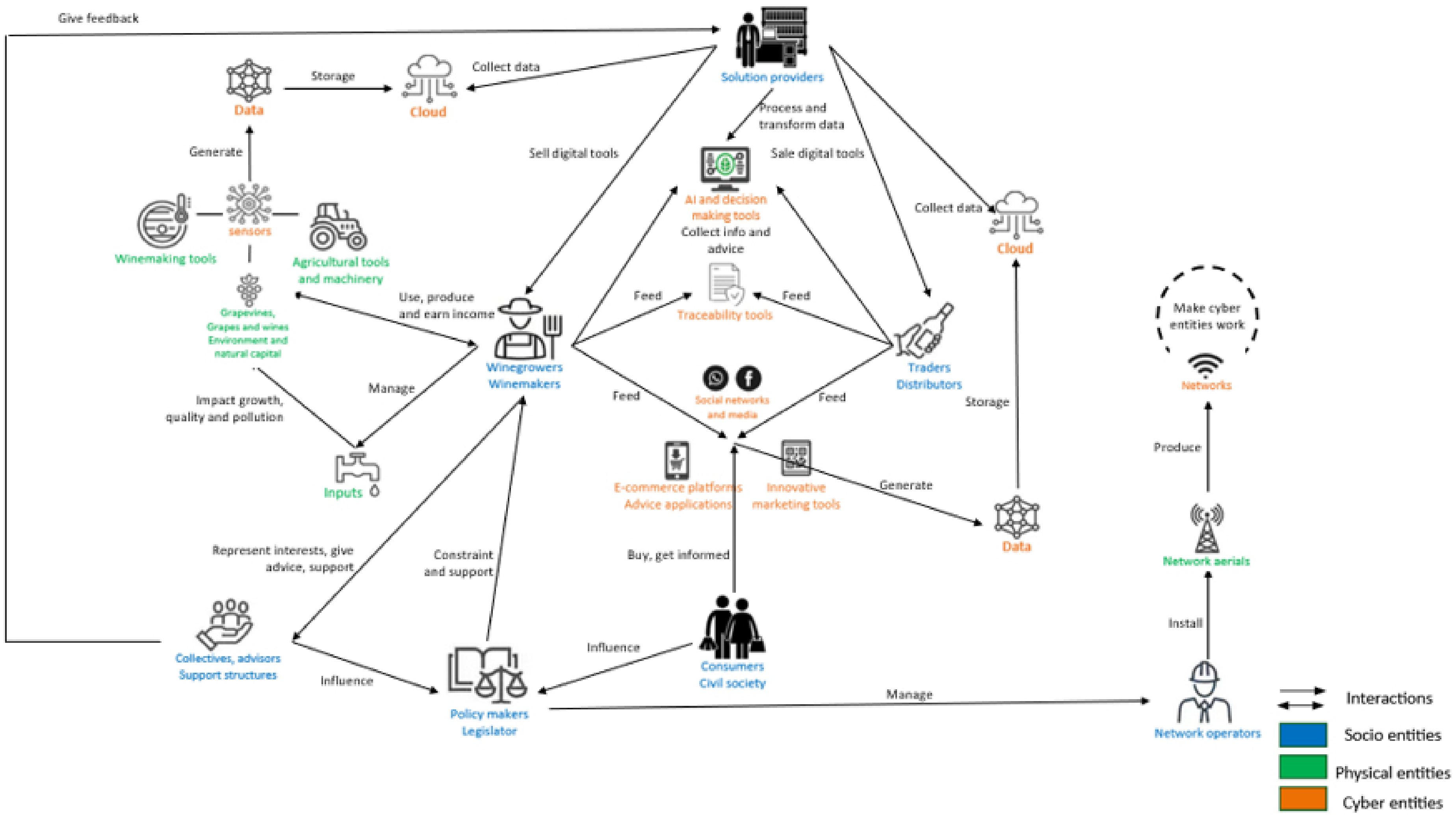
LL in Finland (Central Osthrobotnia), focusing on bioeconomy

Fig. A10: LL Finland. Visualisation of SCPS related to using digitalisation to advance bioeconomy and circular Economy in Central Ostrobothnia



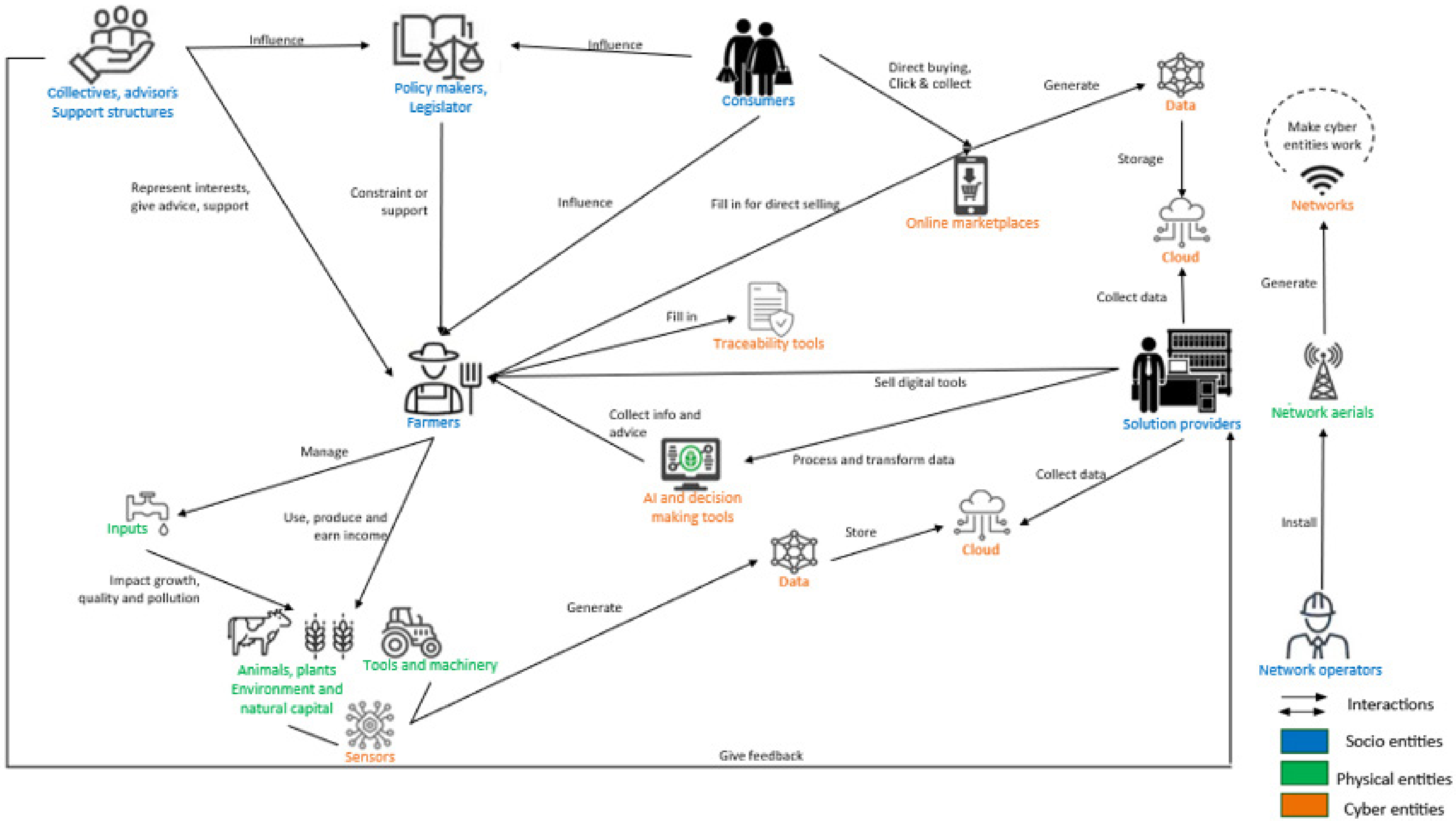
LL in France (Inno'vin), focusing on the wine sector

Fig. A11: LL France (Inno'vin). Visualisation of SCPS



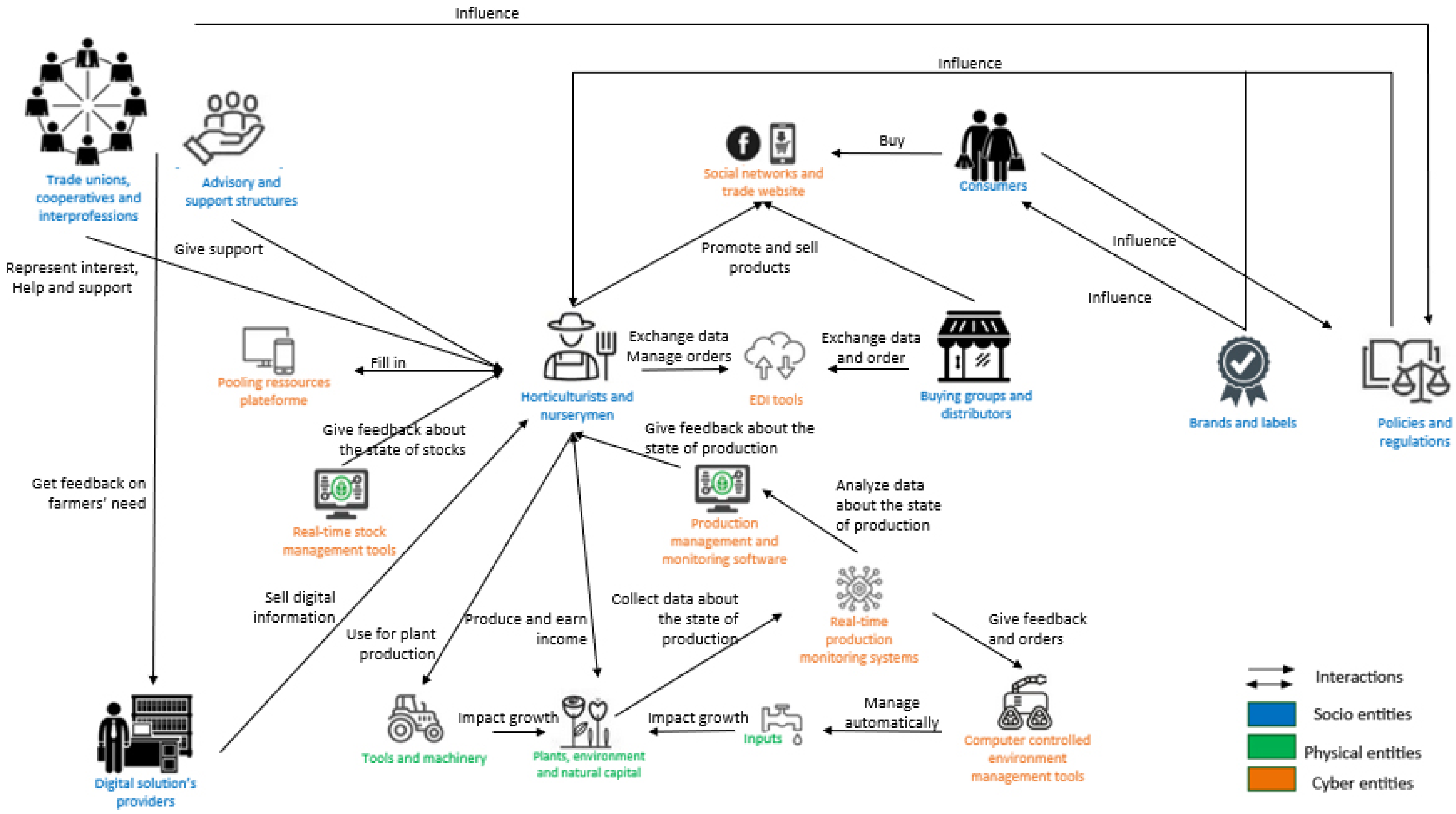
LL in France (AgrOnov), focusing on the agro-ecology transition

Fig. A12: LL France (AgrOnov). Visualisation of SCP system related to the contribution of digital technology to the emergence of innovations for agro-ecological transition in agriculture



LL in France (Végépolys Valle), focusing on horticultural companies

Fig. A13: LL France (Végépolys Valle). Visualisation of SCP system related to the competitiveness of the French horticultural sector



LL in Croatia, focusing on farm diversification like direct selling

Fig. A14: LL Croatia. Visualisation of SCPS related to DigiFarmTour

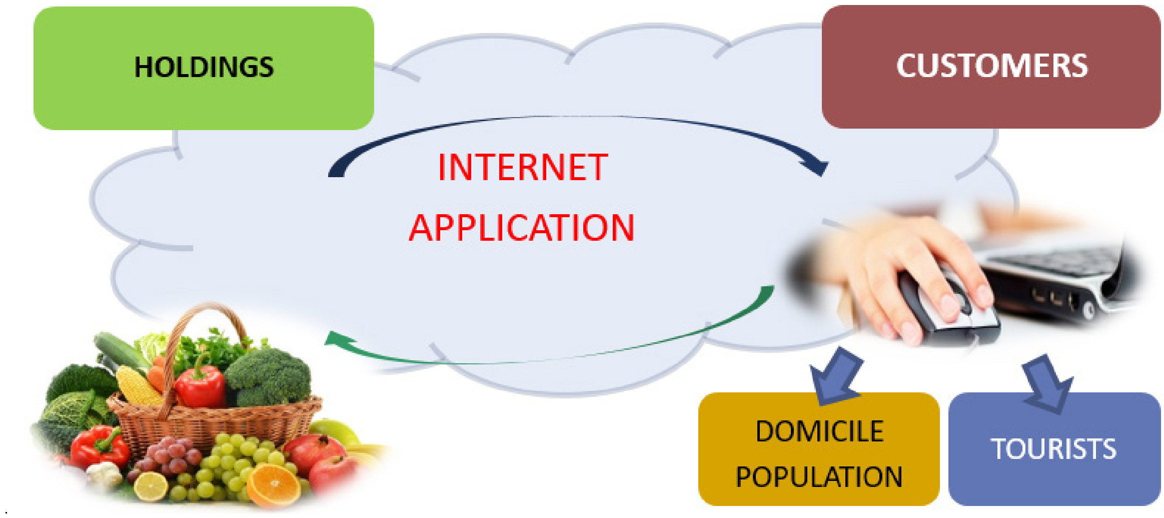


Fig. A15: LL Croatia. Visualisation of SCP system related to DigiFarmTour – linkages with the tourist sector

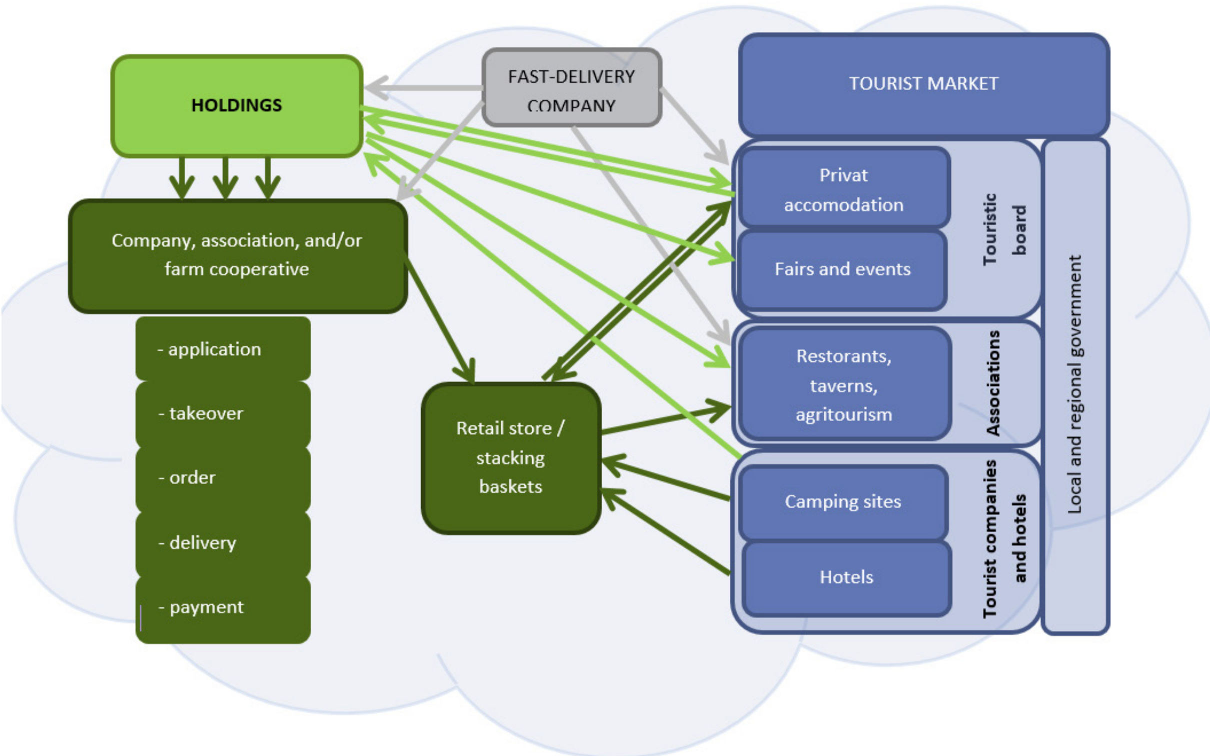
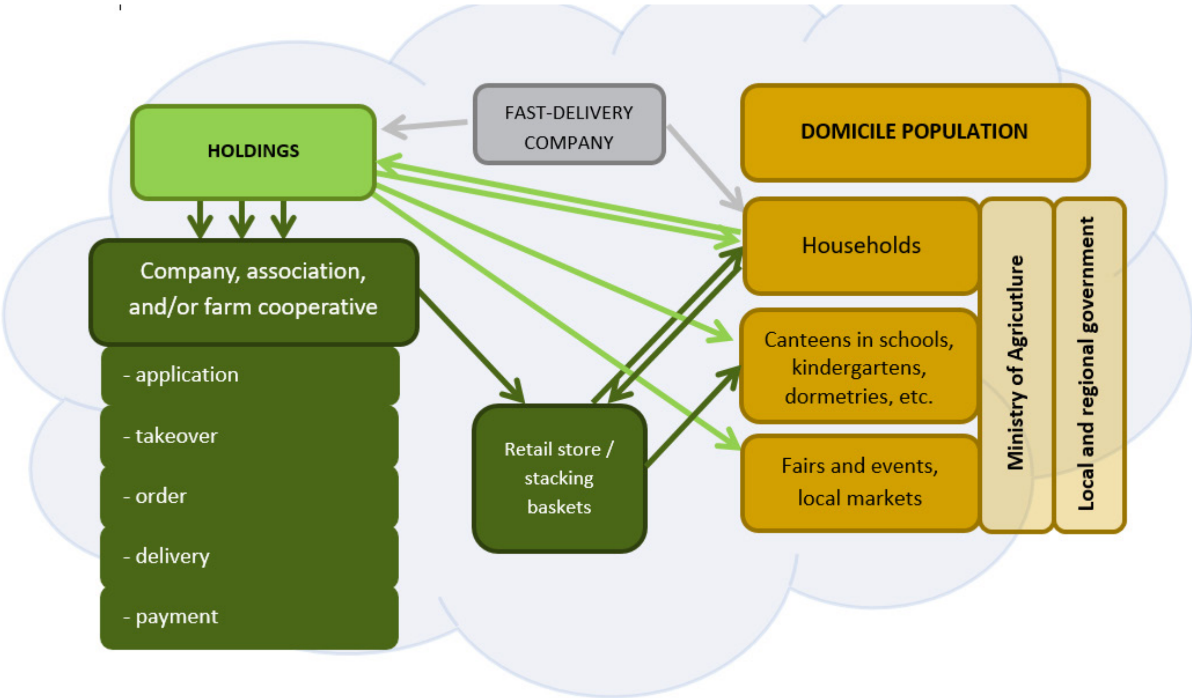
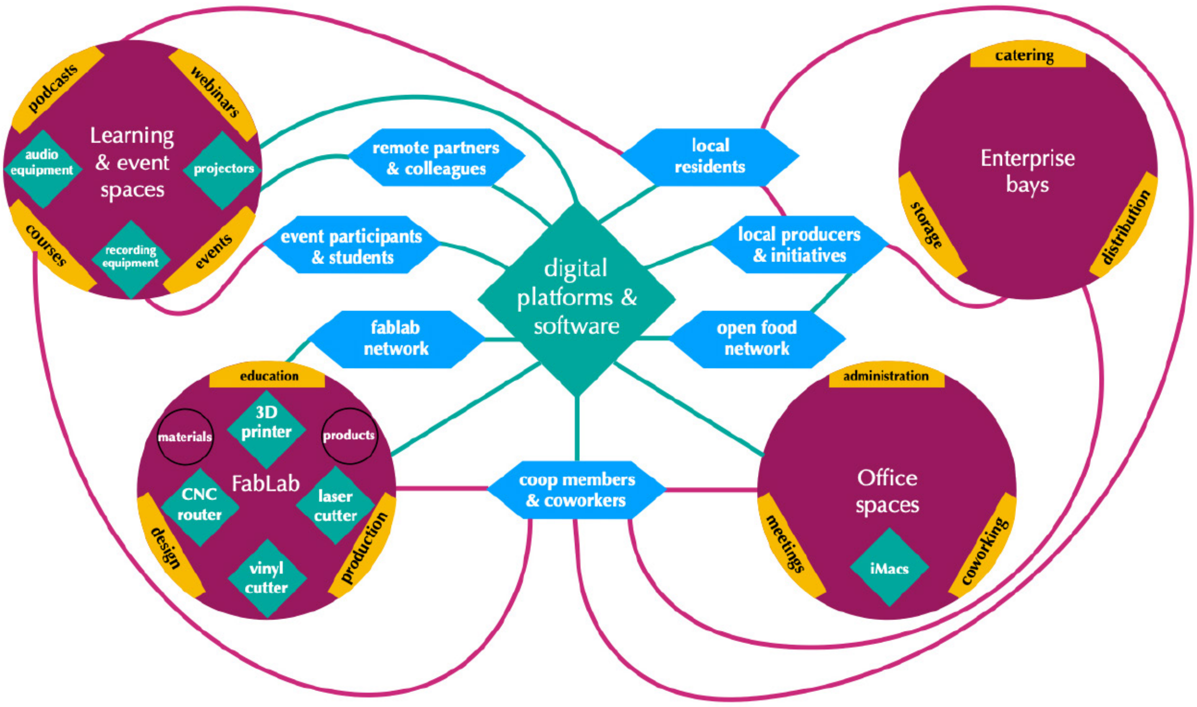


Fig. A16: LL Croatia. Visualisation of SCPS related to DigiFarmTour – linkages to domicile population



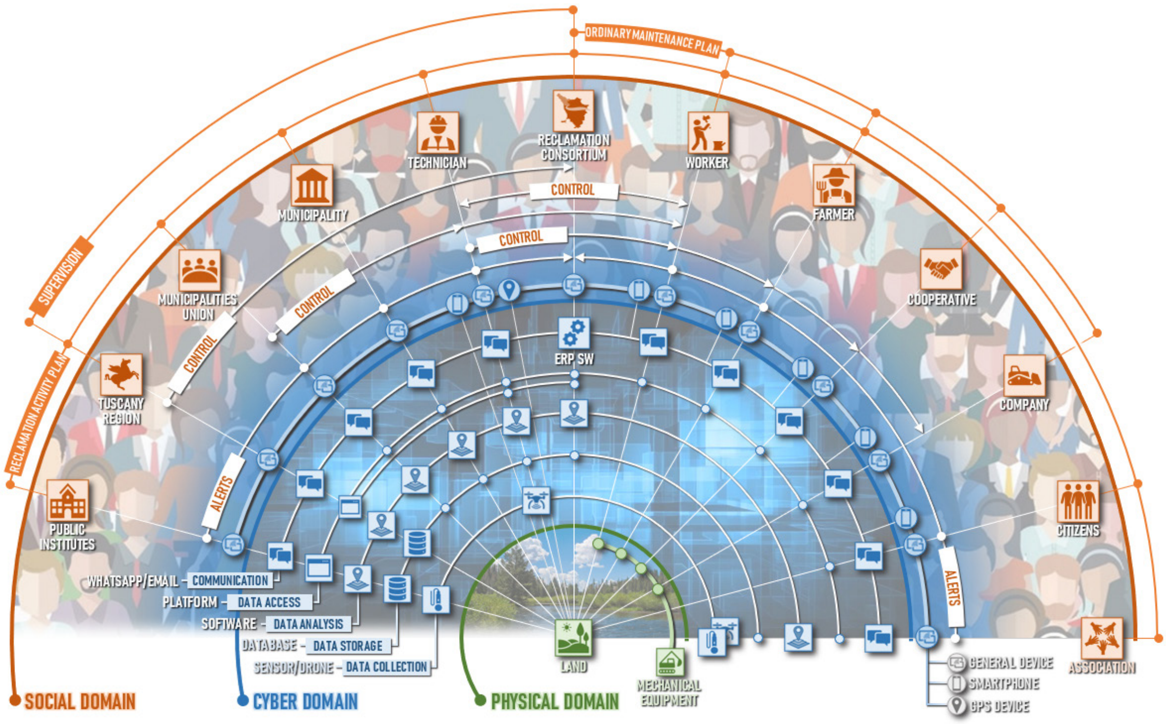
LL in Ireland, focusing on local livelihoods and low carbon societies

Fig. A17: LL Ireland. Visualisation of SCP system related to local livelihoods that contribute to rural regeneration and assist in the transition to a low carbon society



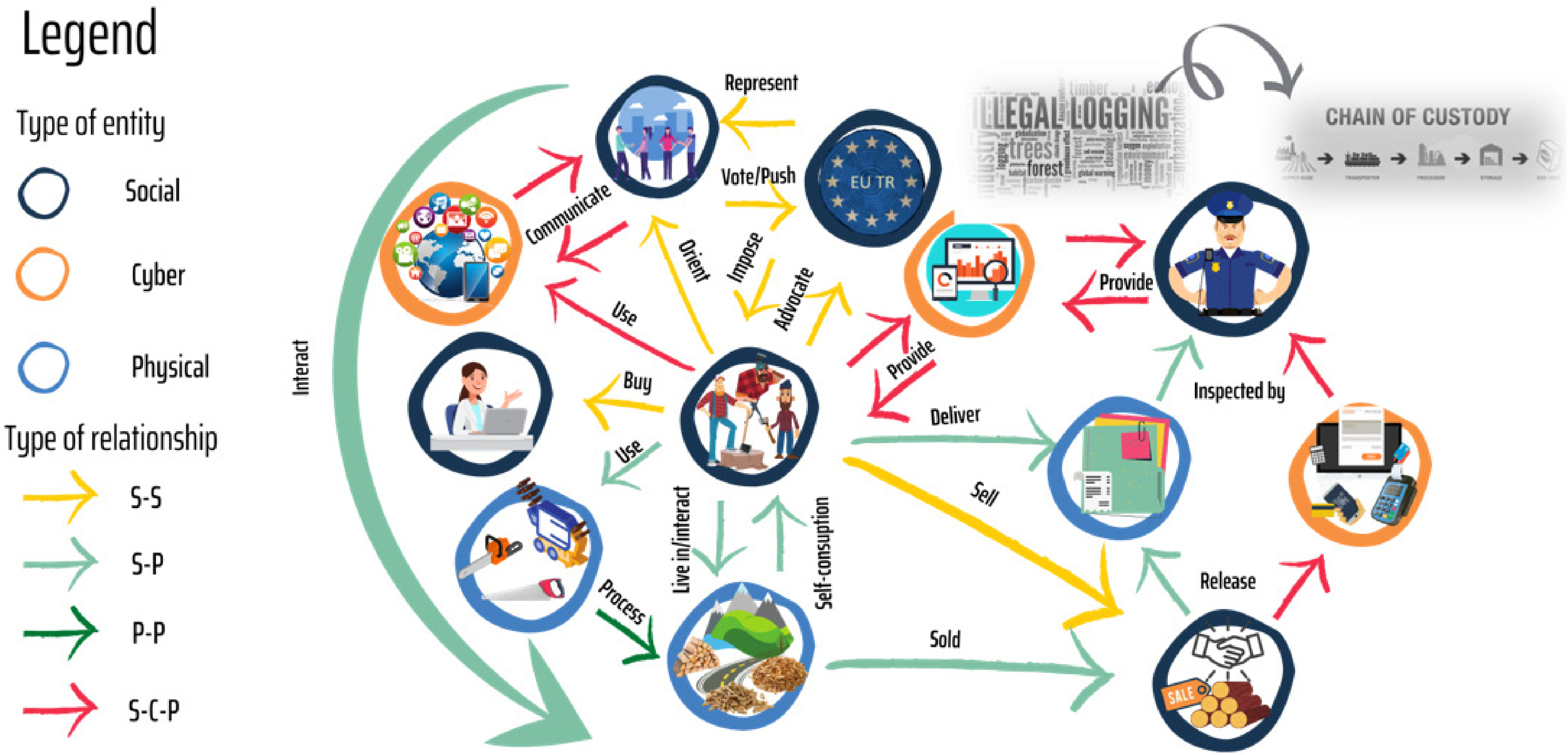
LL in Italy (Toscana Nord), focusing on community and land management

Fig. A18: LL Italy (Toscana Nord). Visualization of SCPS



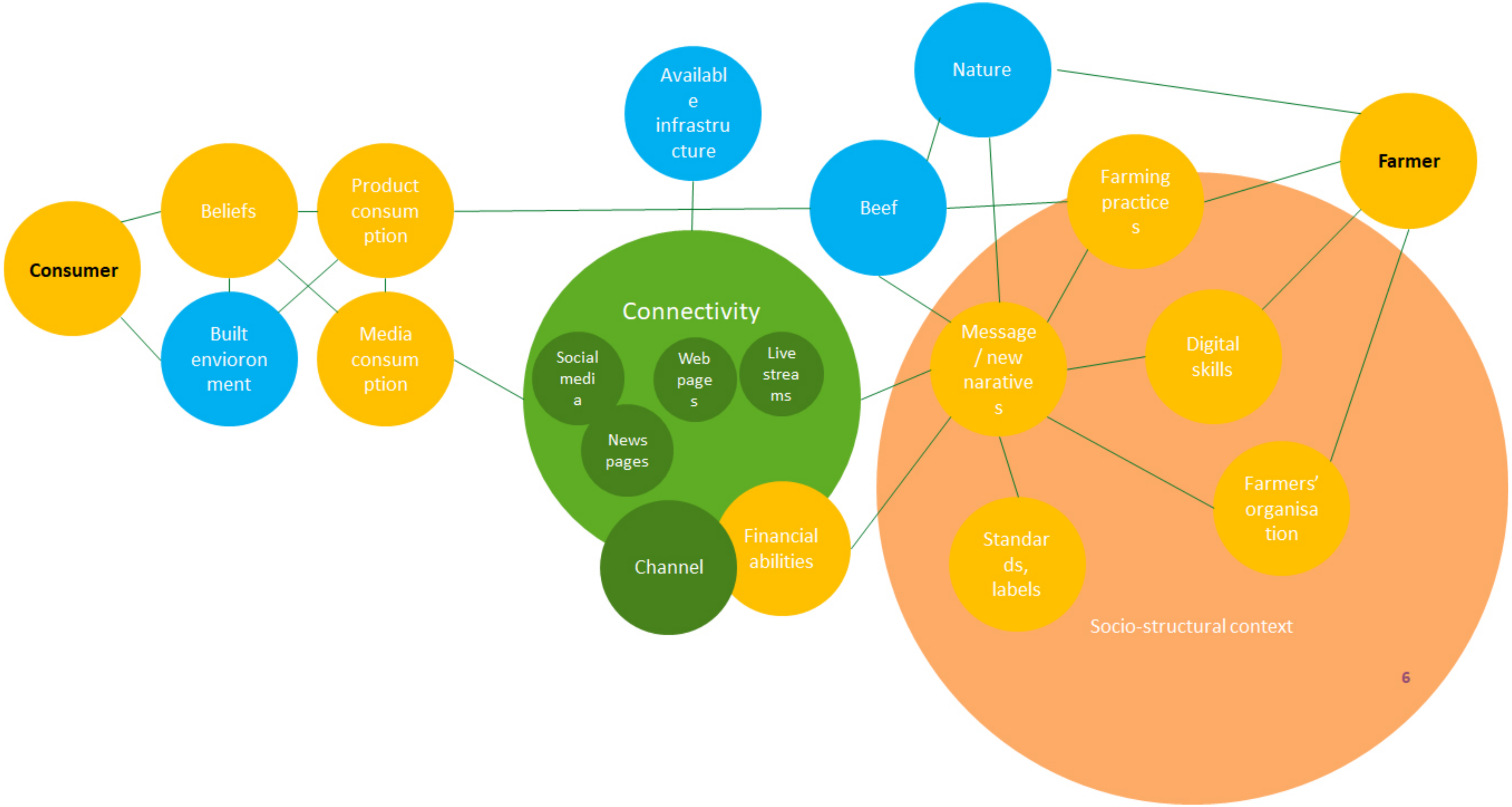
LL in Italy (PEFC,) focusing on wood-energy traceability

Fig. A19: LL Italy (PEFC). Visualisation of SCP system related to the adoption of digital solution to ensure traceability in the wood-energy sector for energy purposes in compliance with the EUTR



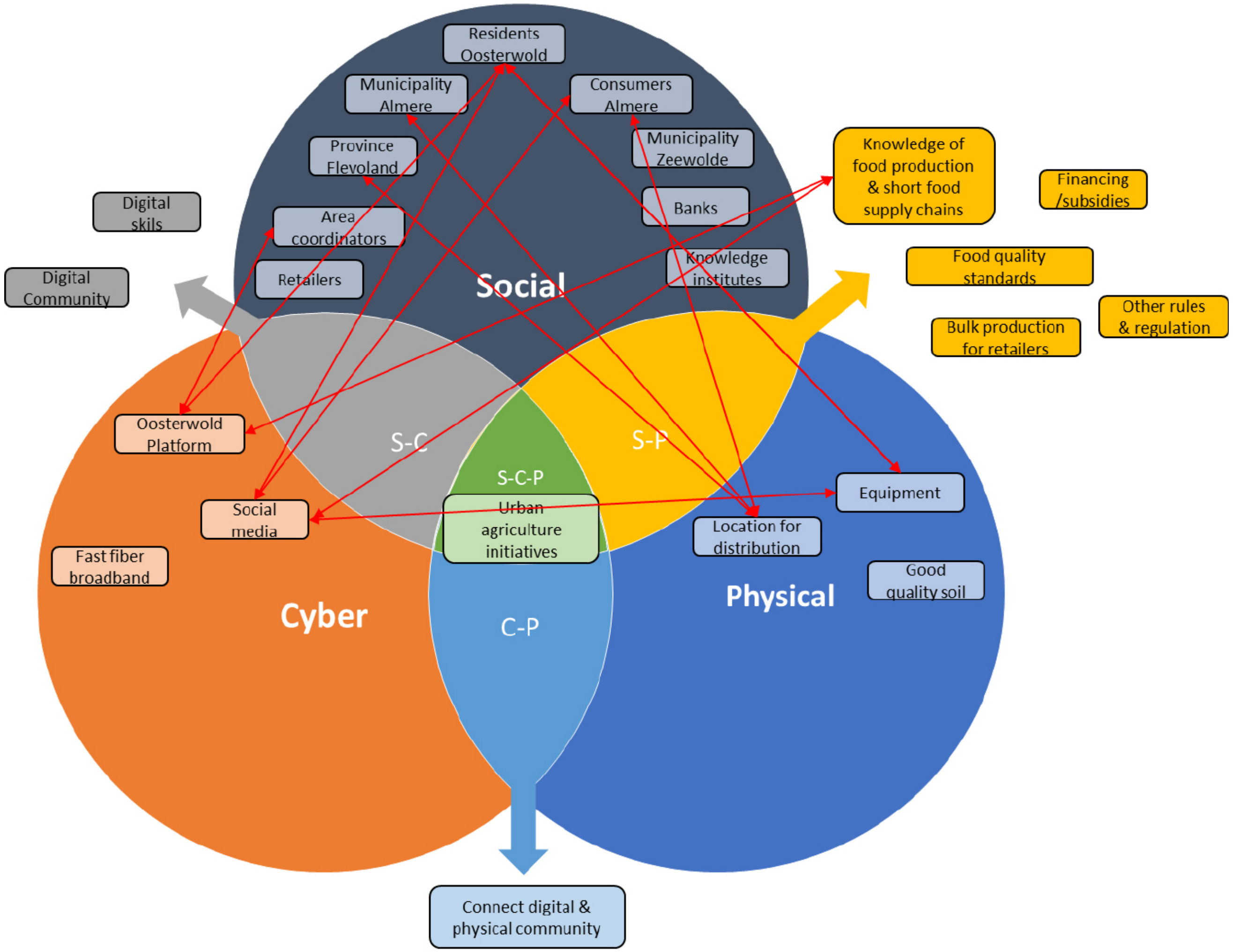
LL in Latvia, focusing on digital marketing of beef meat

Fig. A20: LL Latvia. Elements of SCPS allowing high quality beef farmers to engage in digital marketing (different colours represent different domains: yellow - socio domain, green - cyber domain, blue - physical domain)



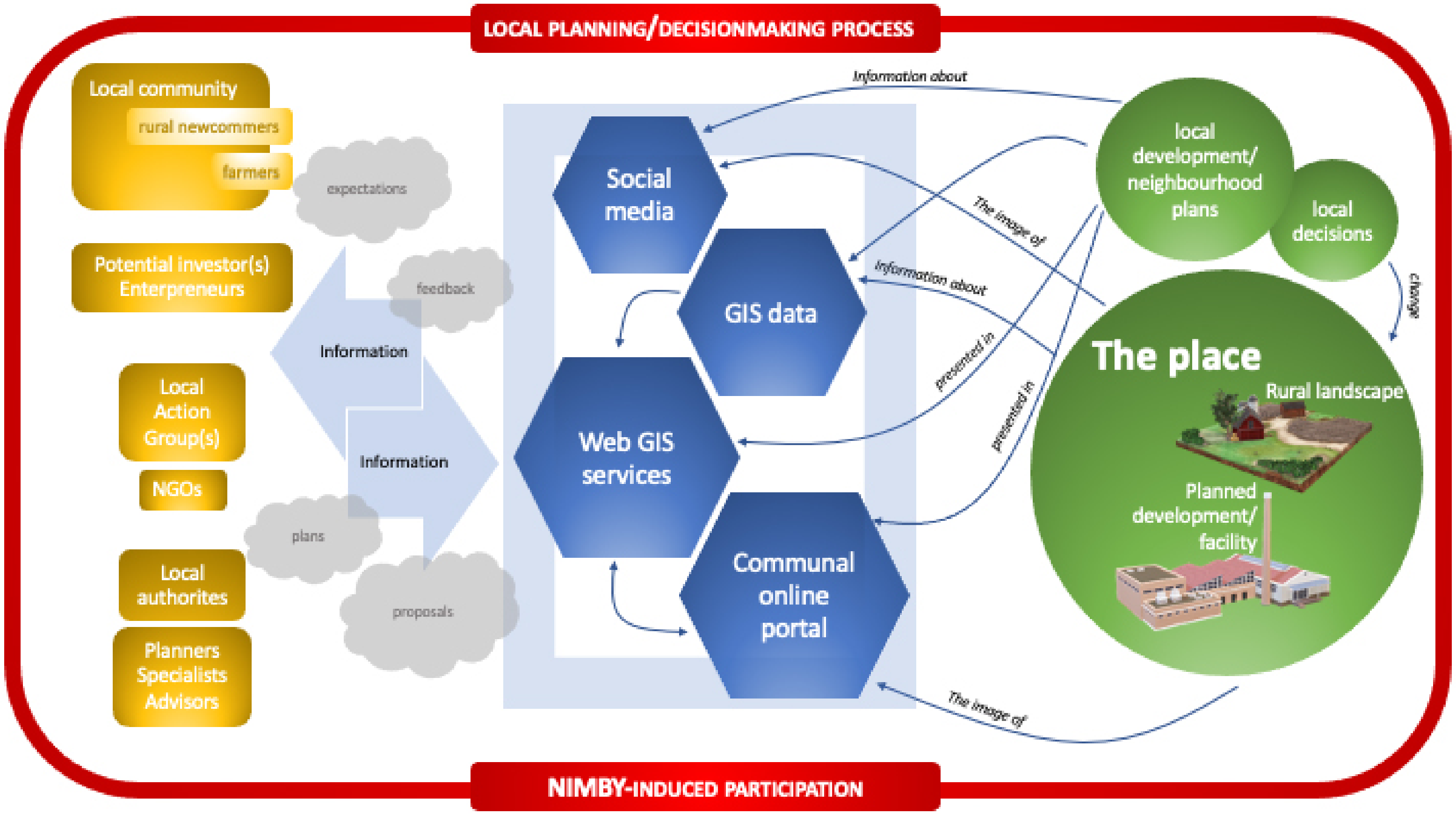
LL in Netherlands (Flevoland), focusing on digital short food chains

Fig. A21: LL in The Netherlands (Flevoland). Visualization of SCPS related to Oosterwold



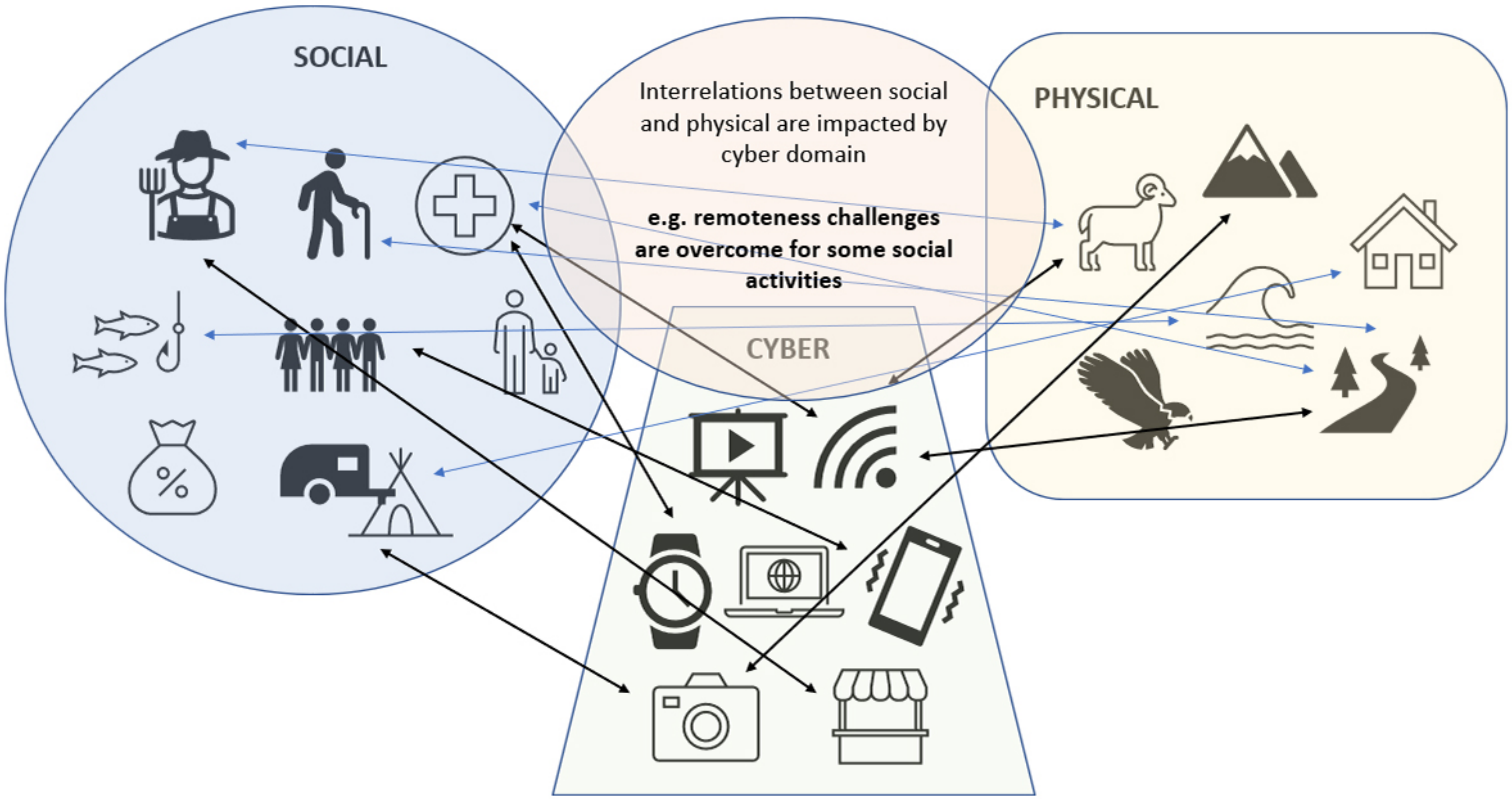
LL in Poland, focusing on enhancing participation in rural planning

Fig. A22: LL Poland. Visualisation of SCPS related to the impact of digitalisation
on the participation's enhancement in rural planning



LL in Scotland, focusing on crofting communities

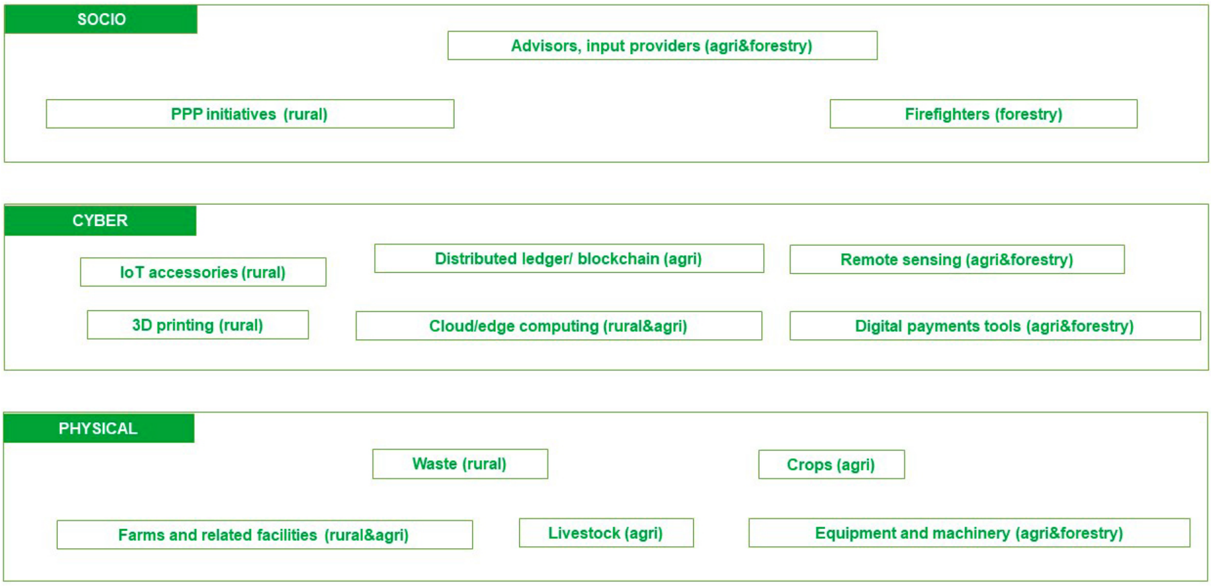
Fig. A23: LL Scotland. Visualisation of SCPS with examples of interrelationships



8.6 Visualisations of SCPS in agricultural, forestry and rural domains LLs' SCPS

Since SCPSs descriptions were oriented towards 21 specific focal questions referred to different contexts, some peculiarities emerge that are worth mentioning. Figure A24 allow to visualize idiosyncratic macro-entities that certainly represent distinctive elements of agricultural and/or forestry and/or rural contexts.

Fig. A24: Visualisation of peculiar entities of SCPS in agricultural, rural and forestry domains



Source: own elaboration on LL reports

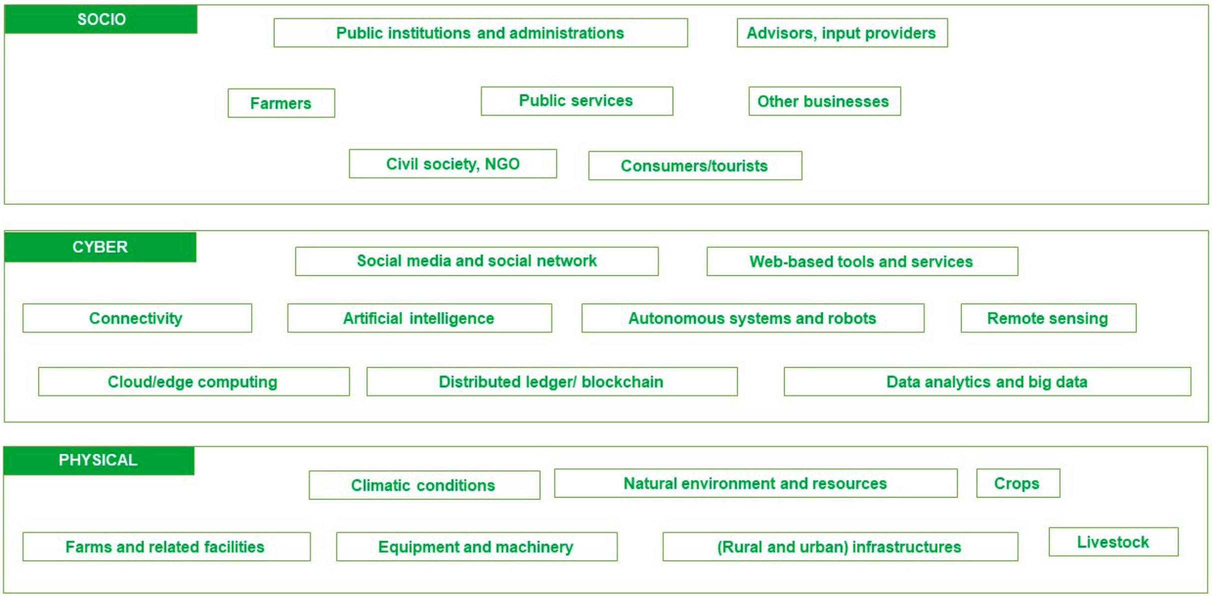
The following elements emerged that is worth describing in detail as follows:

- With regard to the socio domain, whereas **fire brigades** play a fundamental role as responsible for firefighting management in forestry areas in Andalusia (Spain), **input providers, advisors, extension and advisory services** are particularly relevant in agriculture and forestry context (as emerged in Flanders, Greece, Switzerland and France), to provide support for communication managements, digital technologies, and assistance to comply with regulation requirements, protocols, procedures. In rural areas, **public-private-partnerships** (P
- As for the cyber domain, while **remote sensing** has gained momentum in agricultural and forestry activities and **cloud/edge computing** in agri-rural contexts, the uptake of **digital tools for payments** used for the commercialization of food, timber and biomasses for energy purposes in Italy (slightly) enhanced traceability in the agricultural and forestry sectors, also thanks to some preliminary and experimental application of the **blockchain** technology. Lastly, some applications of **IoT** and **3D printers** related to housing activities emerged in rural areas as revealed by Cloughjordan Ecovillage in Ireland.
- In the physical domain, in addition to the classical role played by living organisms such as **crops** and **livestock** in agriculture and **forests** in mountain areas, fixed investments such as **equipment**

and **machinery** are central in farming and forestry activities as well as the presence of physical assets (such as facilities and factories) in rural areas. Lastly, both production and consumption activities in rural areas (not necessarily related to agri-food or forestry sectors) are responsible for **waste** generation that in some cases can be used as by-product and converted in recycled material or energy sources, as emerged in Finland Biovalley.

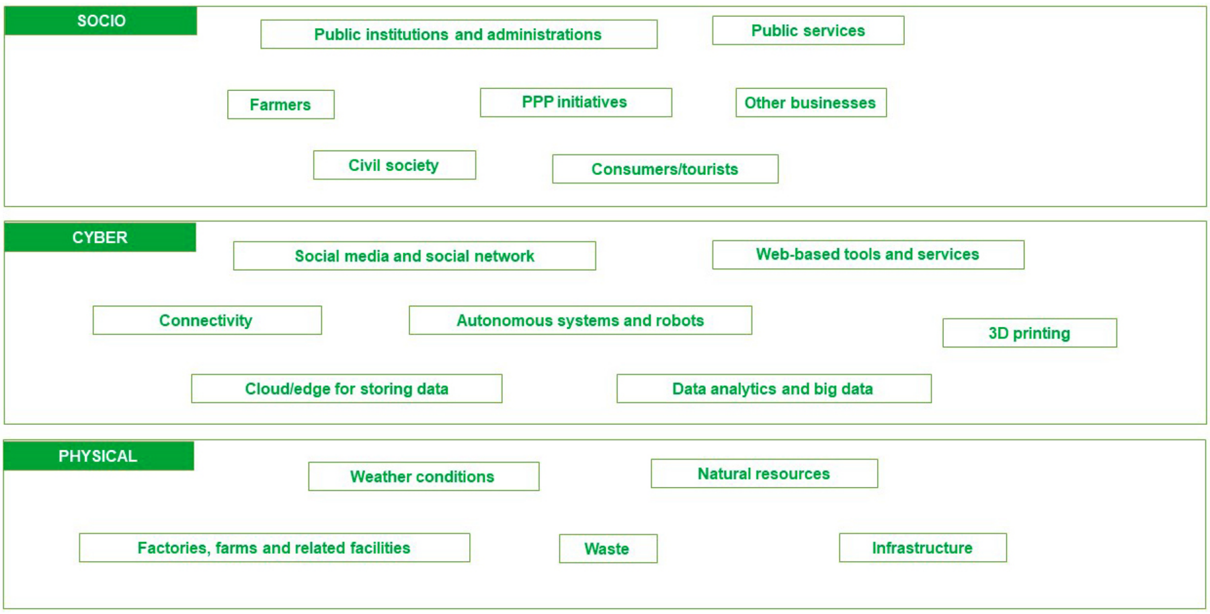
Lastly, synthetic visualisations of SCPS provided by LL, containing common elements referred to agriculture, forestry and rural areas, are reported in figures A25, A26 and A27.

Fig. A25: Visualisation of a SCPS for agriculture



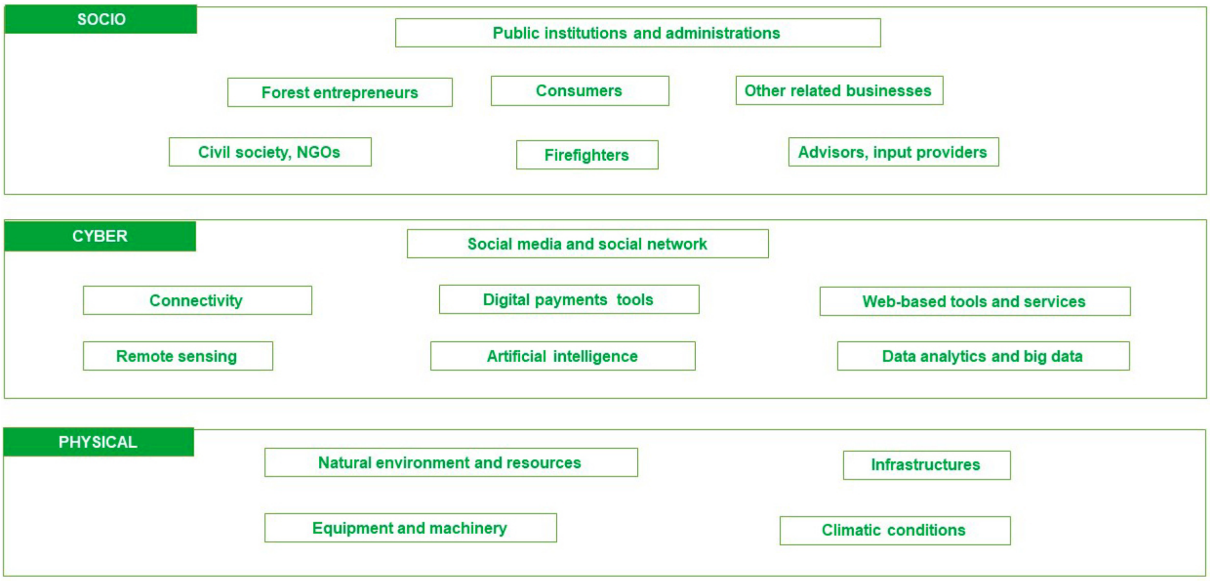
Source: own elaboration on LL reports

Fig. A26: Visualisation of a SCPS for rural areas



Source: own elaboration on LL reports

Fig. A27: Visualisation of a SCPS for forestry



Source: own elaboration on LL reports

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