DIGITISATION: ECONOMIC AND SOCIAL IMPACTS IN RURAL AREAS

DELIVERABLE 1.3

SYNTHESIS REPORT ON THE TAXONOMY AND INVENTORY OF DIGITAL GAME CHANGERS

SEPTEMBER 30, 2020

BACCO F. MANLIO (CNR), BARSOCCHI PAOLO (CNR), BRUNORI GIANLUCA (UNIPI), DEBRUYNE LIES (EV-ILVO), FERRARI ALESSIO (CNR), GOTTA ALBERTO (CNR), KOLTSIDA PANAGIOTA (ATHENA), LEPORE FABIO (UNIPI), ORSINI ALESSANDRO (UNIPI), ROLANDI SILVIA (UNIPI), SCOTTI IVANO (UNIPI), TOLI ELENI (ATHENA)

DESIRA receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818194.

Synthesis Report on the Taxonomy and Inventory of Digital Game Changers

Project name	**DESIRA | Digitisation: Economic and Social Impacts in Rural Areas**
Project ID	818194
H2020 Type of funding scheme	Research and Innovation Action (RIA)
H2020 Call ID & Topic	H2020-RUR-2018-2 / RUR-02-2018 Socio-economic impacts of digitisation of agriculture and rural areas
Website	www.desira2020.eu
Document Type	Deliverable
File Name	Synthesis Report on the Taxonomy and Inventory of Digital Game Changers
Status	Final
Authors	BACCO F. MANLIO (CNR), BARSOCCHI PAOLO (CNR), BRUNORI GIANLUCA (UNIPI), DEBRUYNE LIES (EV-ILVO), FERRARI ALESSIO (CNR), GOTTA ALBERTO (CNR), KOLTSIDA PANAGIOTA (ATHENA), LEPORE FABIO (UNIPI), ORSINI ALESSANDRO (UNIPI), ROLANDI SILVIA (UNIPI), SCOTTI IVANO (UNIPI), TOLI ELENI (ATHENA)
Work Package Leader	EV-ILVO
Project Coordinator	UNIPI

Table of contents

1. Executive summary

This document describes a toolkit designed within the DESIRA project to support the work in the 20 Living Labs. This toolkit is composed of several parts: the inventory of digital tools, the set of application scenarios as derived from the inventory, a list of digital technologies with the potential of being digital game changers (DGCs), and a map of plausible socio-economic impacts associated with the selected potential DGCs. Several experts' interviews have been performed to enrich and support the toolkit.

The toolkit leverages a multi-level taxonomy. Firstly, building on the cyber-physical system (CPS) conceptual model, digital technologies can be classified according to the purpose they serve (i.e., monitoring and actuating layer, connecting layer, computing layer, and intelligence layer) as shown in this document. Secondly, digital technologies are exploited by digital tools, as those DESIRA has collected through an internal survey to feed the inventory, to offer specific functions (i.e., applications and services) to actors in agriculture, forestry, and rural areas; the digital tools can be grouped and classified into application scenarios, which can be defined as different contexts in which a given objective can be achieved by using the digital tool(s). The context of an application scenario takes into account the technical requirements around which a digital tool is designed, and defines the function served by the digital tool. Then, a set of technologies having the potential of being DGCs - i.e., able to deeply reconfigure routings, rules, actors, and artefacts of social and economic life – has been selected through a literature review and several experts' interviews. Both experts and the literature consider as potential DGCs the technologies today deemed as enablers for Industry 4.0, with the notable addition of Internet connectivity still lacking in certain rural areas. Once this set of DGCs has been identified, and in order to also take into account the social, economic, and environmental effects that those DGCs may produce, the last point of view of the taxonomy proposed herein is based on a map highlighting plausible impacts of the selected DGCs as found in the literature. Figures 1 and 2 graphically depict this process, the former highlighting how DGCs are connected to the three domains (agriculture, forestry, and rural areas) through digital tools used in different application scenarios, and the latter depicting the impacts, which can be positive or negative, that the use of DGCs may generate.

As anticipated, a key concept presented in this document is the CPS conceptual model, which is extended in DESIRA CAF to also consider the social component, thus redefining it as the socio-cyber-physical system conceptual model. Such a choice is based on the fact that the CPS model is well suited to characterize the so-called *physical-digital-physical (PDP) loop*, the very basis of the digitisation process. Data from the physical world are collected and transformed into digital data (*physical-to-digital*) and used to extract information that can be used to e.g. provide support to users or assist into the decision process that leads to an action, or automatically perform that action, thus operating on the physical world (*digital-to-physical*) and closing the PDP loop.

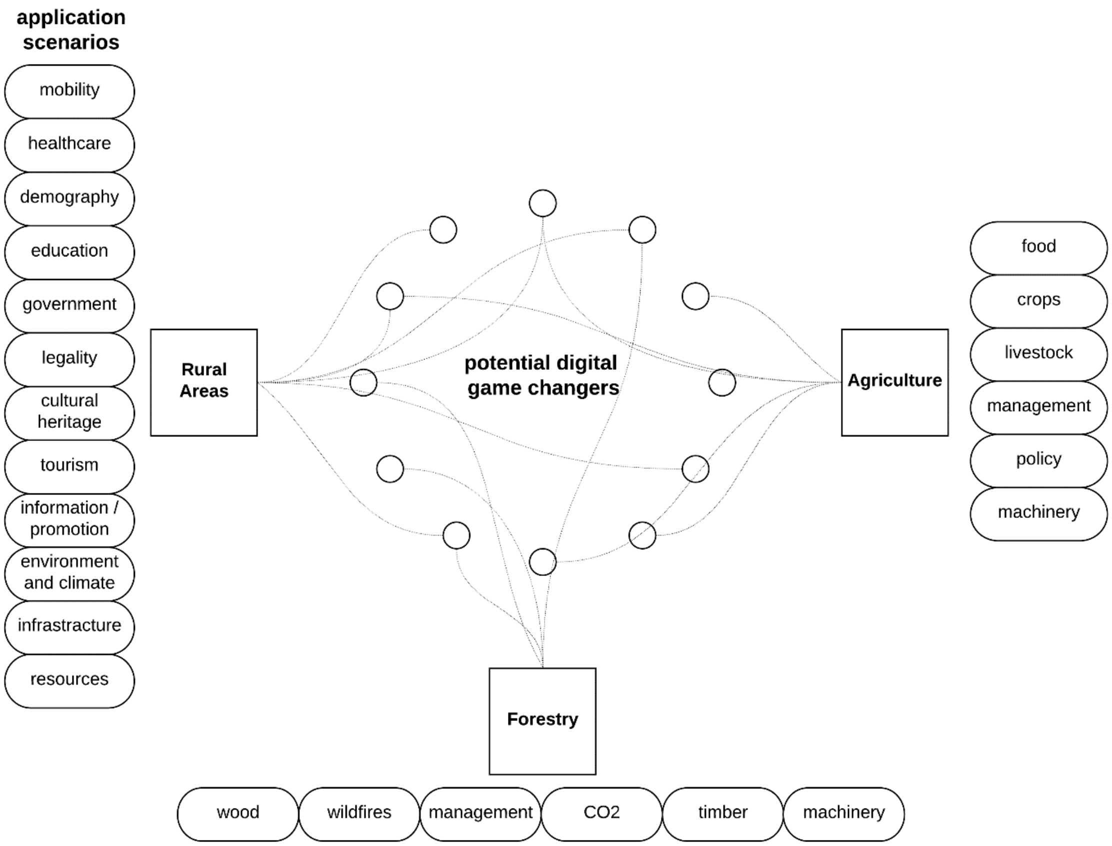


Figure 1: the three domains and application scenarios therein linked with potential digital game changers.

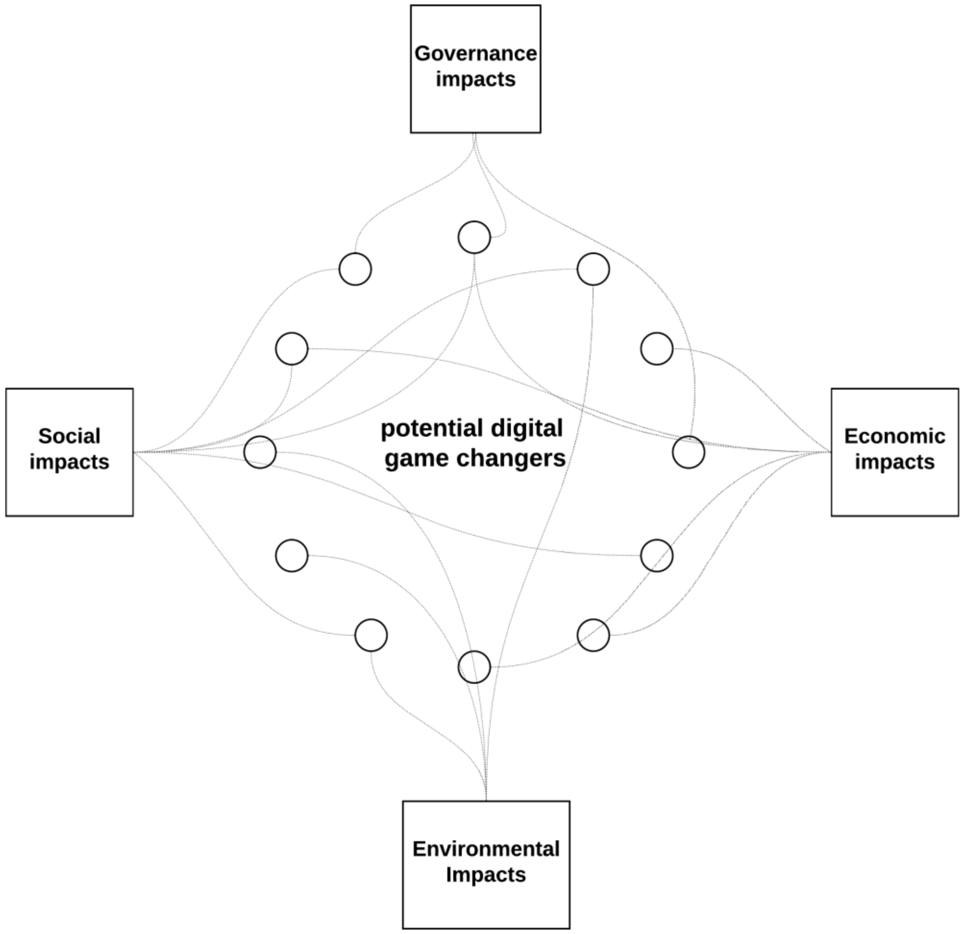


Figure 2: areas of plausible impacts that the use of DGCs may generate.

The rest of this document is organized as follows: Section 2 discusses digital technologies and their functions, and introduces CPS as the reference conceptual model. Section 3 introduces the inventory of digital tools collected through an online survey within DESIRA, and then shows the set of application scenarios derived from the collected digital tools. Section 3 also reports the experts' interviews performed to support the identification of digital technologies with the potential of changing the game. Section 4 discusses the digital technologies identified as potential digital game changers, and then provides a map of plausible impacts of the identified potential game changers. Finally, Section 5 provides short examples of use of the proposed toolkit to analyse digital tools; the same methodology has been used to compile the practice abstracts presented in DESIRA report D1.4 "First Set of Practice Abstracts".

2. Digital technologies and their functions

This section defines what is intended as digital technology and as digital tools, then the conceptual model of cyber-physical systems is described, highlighting its relevance to describe digitisation processes and how it can be used to classify digital technologies.

2.1. Digital paradigms, digital technologies, and digital tools: definitions

In this section, some necessary distinctions are made to carefully take into account the difference among what should be considered as pure digital technologies and what digital paradigms instead.

A **digital technology** can be defined as a combination of hardware and software making use of data in the form of digital data (numeric codes). A **digital paradigm** can be defined as the convergence of multiple digital technologies, which amplifies their joint effects. A **digital tool** is a physical and/or virtual instance relying on digital technologies (or on a set of those, as in a digital paradigm) having a given function as defined in its design phase.

Exemplary case

Internet of Things (IoT) should not be considered as a technology per se, rather a paradigm that exploits multiple digital technologies that converge for a given purpose. An IoT system, as the name suggests, is characterized by multiple logical parts, each able to meet a specific task, as for instance:

- **sensing** the environment by means of e.g. temperature and humidity nodes;
- **transmitting** data by means of e.g. a wireless interface, such as Wi-Fi, ZigBee, or Bluetooth;
- showing the status of the system and offering an interface for interactions with humans or other systems by means of an **application**, i.e., through components interacting via human-machine interfaces (HMI) or through machine-to-machine (M2M) communications.

The same logic must be applied to other cases, or at least it should be clear what we refer to when considering specific digital technologies. For instance:

- *blockchain:* the confusion between the technical solution (a distributed database organized in the form of an encrypted chain of linked data blocks preventing modifications to stored data) and the applications or scenarios it enables, such as traceability, payments, and others. With blockchain, we refer to the digital technology in this document;

- *artificial intelligence:* similarly to IoT, AI should be considered an umbrella term [1] comprising machine vision, natural language processing (NLP), process automation, machine learning; only narrow AI is considered in this document, thus excluding general intelligence;
- *robotics:* the use of robots to perform given tasks. The task can be performed in an autonomous manner (autonomous robots) with some degree of intelligence (advanced robotics), or in a simple repetitive manner (robotics). Advanced robotics is considered in this document. A robot is composed of sensing, actuation, and locomotion subsystems, for instance, thus it must be considered a complex system able to sense the environment and interact with it, exchange data via communication interfaces, storing on-board data and implementing a control system, having a given purpose and interfaces to interact with humans or other systems.

On the other hand, cases in which digital technologies can be classified rather precisely exist. For instance:

- *Big Data*: it refers to the case of very large datasets whose volume increases at high velocity, comprising a large variety of different data. Those cannot be analysed with classical data analysis tools, instead requiring different approaches for *making sense* of data[1]. In order to analyse such datasets, large computing power is needed to store and efficiently access such a large volume of data[2]. According to the classification in Section 2.2, Big Data fall into computing. For the sake of clarity, data sources (sensing), networking medium (transmission), and services and applications are excluded.
- *5G*: the fifth generation of cellular networks (5G NR) refers to the network infrastructure being put in place as an evolution of 4G networks. It is considered a fundamental piece towards enabling concepts like Industry 4.0, Smart Cities, Smart Agriculture, and so on. 5G NR falls within *transmission* (see Section 2.2). On the other hand, the term 5G is also used to encompass sofwarization techniques based on the use of *(i)* computing in *(ii)* 'smart' scenarios: both are not considered here.

[1] Big Data https://ec.europa.eu/digital-single-market/en/big-data

[2] The value of Big Data is in the information that can be derived from them through the so-called Big Data Analytics.

2.2. The cyber-physical system (CPS) model

In the DESIRA Conceptual and Analytical Framework (CAF), CPSs are defined as generation of systems with integrated computational and physical capabilities. Those systems have the ability to interact with, and expand the capabilities of, the physical world through computation, communication, and control [2].

The DESIRA project relies on the CPS conceptual model to describe the physical-digital-physical (PDP) loop (or perception-action loop). According to this paradigm and focusing on digitisation, two key functions must be considered: the first one is in the possibility to *sense* the physical world, i.e., converting physical states into digital data; and the second one is in the possibility to *act* on the physical world, i.e., converting digital data into actions performed on the physical world. Collected data can be stored and analysed by a CPS, which typically expose an application to users by means of a human-machine interface. A typical interaction among the CPS and users occurs through such an interface, at the application layer.

A simple yet effective framework to describe CPSs is depicted in Figure 3, considering four main layers:

1. **sensing and actuating** (or perception) layer: at this level, the conversion from analogic to digital (and vice versa) occurs by means of sensor devices and actuators;
2. **transport** (or network) layer: short- to long-range network communications to exchange data via wired and wireless interfaces, conveying sensed data to upper layers and commands to lower ones;
3. **computation** layer: at this level, the functionalities of data storage, data curation, and data analysis are performed; for the sake of clarity, big data, cloud and edge computing are located at this level;
4. **application** or **intelligence** layer: implementation of the *function*. this is the link to the application scenarios, where the so-called ‘business logic’ resides.

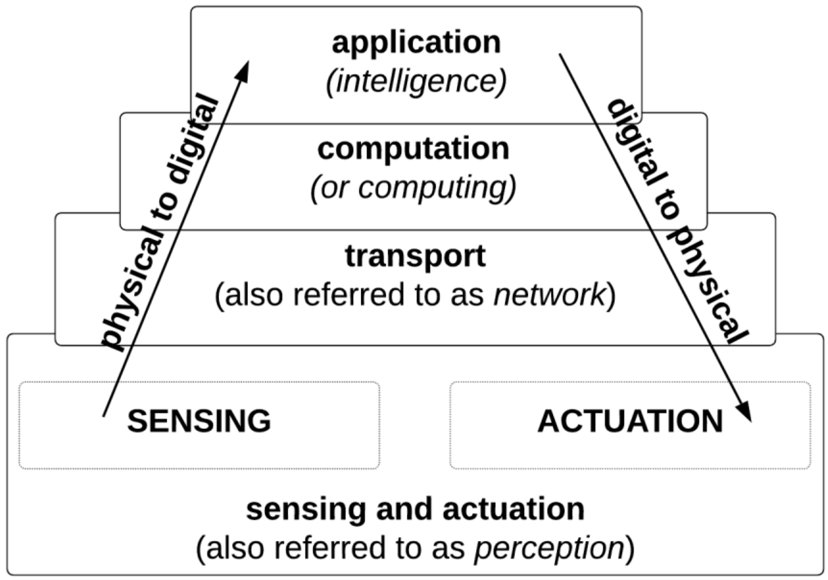


Figure 3: representation of a cyber-physical system with a four-layer logical framework.

2.2.1. Interactions among cyber-physical systems

Two (or more) systems can interact, automatically or upon request, among them, exchanging data, as depicted in Figure 4. The generated traffic is called *machine-to-machine traffic* and it is the largest portion of data flowing in our communication networks, well beyond the rate of *human-to-machine* traffic.

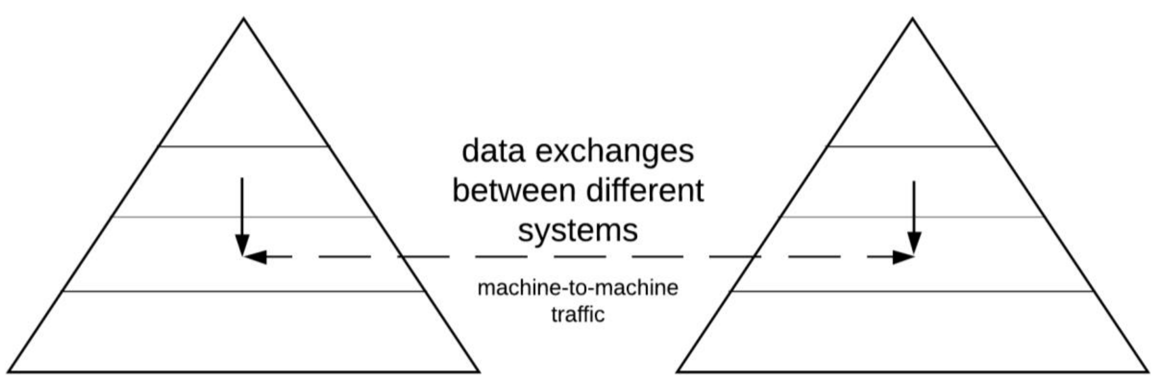


Figure 4: interactions between two CPSs.

2.2.2. Interacting with cyber-physical systems

A system can interact with humans (or other living beings) at different level. Considering the case of a person, several interactions are possible, as logically depicted in Figure 5. Consider that a HMI is necessary in any case, as shown in Figure 6.

Humans can input new data into the system (data source in Figure 5) by e.g. taking a pic with their phones, or can e.g. read data gathered by a standalone sensor and input them into the system (data mule in Figure 5). Conversely, humans can actuate actions suggested by a system by e.g. opening a valve (actuator in Figure 5). At this layer, analogic readings are transformed into digital data by means of e.g. the phone, the input interface; or, vice versa, received digital data in the form of a e.g. suggestion are transformed into a physical action (opening a valve). Similarly, humans can be in charge of data elaboration (as opposed to automatic data elaboration) or change the way the system works reconfiguring it through the application.

The interaction among humans and systems occur by means of the so-called human-machine interfaces, e.g. touchscreens in smartphones, keyboards, dashboards, wearables, XR techniques, as depicted in Figure 6.

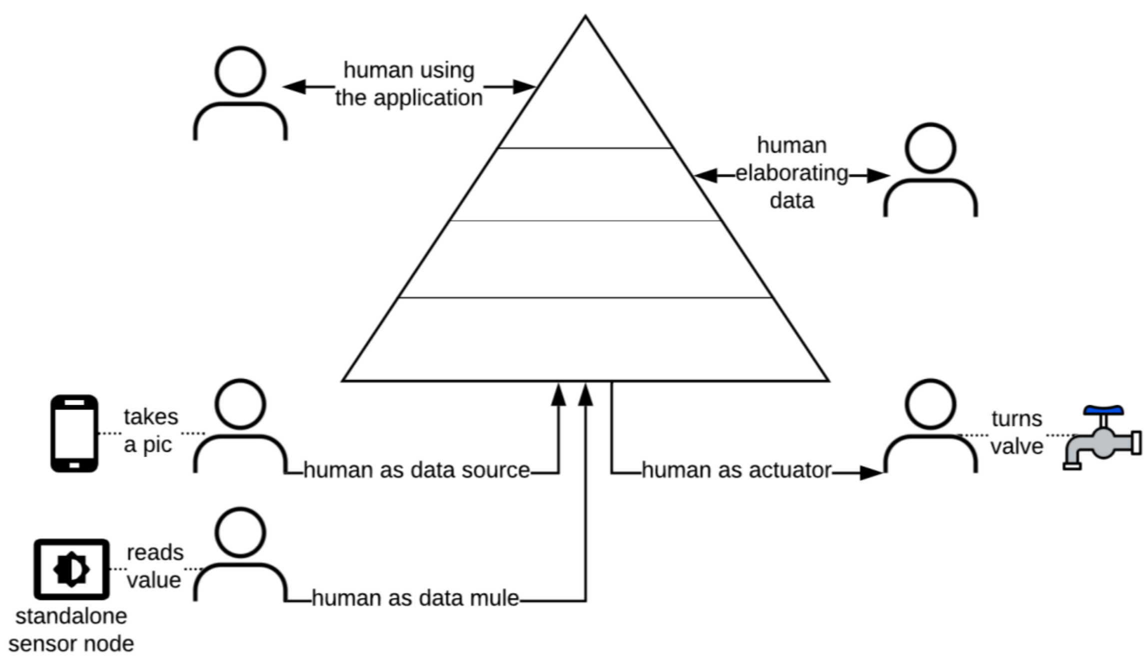


Figure 5: interactions between a CPS and a human actor.

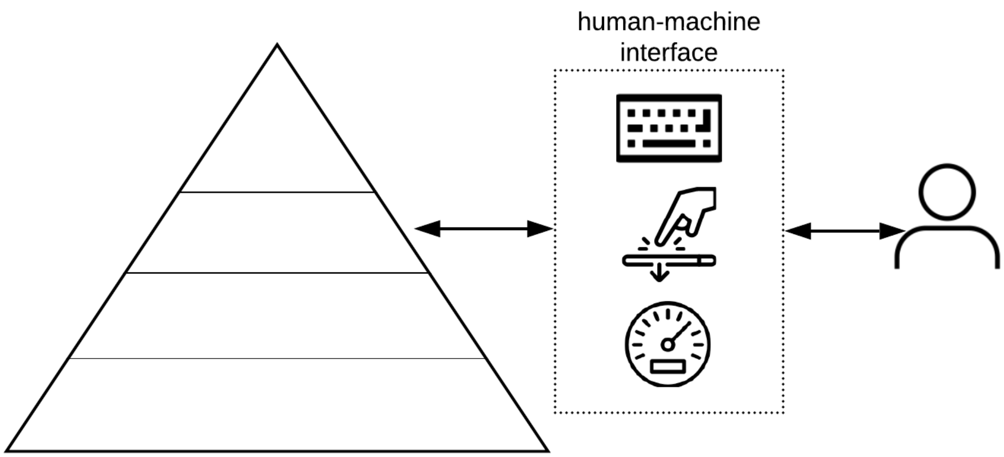


Figure 6: all interactions between a CPS and a human actor are performed by means of human-machine interfaces.

2.3. Classification of digital technologies per CPS layer

In order to emphasize the link among digital technologies and the system view provided by the CPS paradigm, a classification of digital technologies is presented in Table 1. Listed technologies are extracted from the online survey and other sources, and the list is not supposed to be exhaustive. The application scenarios – see Table 2 - are examples of possible classes of applications running at the top layer of the CPS pyramid.

Table 1: a basic classification of digital technologies under consideration in this document according to the four-layer CPS paradigm presented above.

Layer	Sub-layer	Examples
Sensing and Actuation	Sensing	Distance
		Contact
		Force / Torque
		Vision
		Temperature
		Humidity
		Light detection

		Vibration
		Voltage
		Compass
		Hyperspectral
		...
	Actuation	Robotic arm
		Switches
		Valves
		Sprayers
		...
Transport	Short range (few meters)	Bluetooth
		Infrared (IR)
		Near-field Communication (NFC)
		Radio-Frequency Identification (RFID)
		Ultra-wideband (UWB)
		...
	Medium range (tens to hundreds of meters)	Wi-Fi
		ZigBee
		Z-Wave
		DSRC (WAVE)
		...
	Long range (> kilometers)	LoRa / LoRaWAN
		Satellites
		WiMAX
		3G / 4G / 5G (cellular)
		LTE-M / NB-IoT
		...
Computation	Data storage	Edge (close)

		Cloud (remote)
		Local
		Distributed
		Centralised
		Decentralised
		Traditional databases
		Distributed ledgers
		...
	Data analysis	Statistical approaches
		Mining approaches
		Machine Learning (AI)
		...
	Computation	Edge (close)
		Cloud (remote)
		Local
		Distributed
		Centralised
		Decentralised
		...
Application	Function	*(see the map on the application scenarios in Section 3.2)*
	User interface	Graphical user interface
		Gesture interface
		Motion tracking
		Screen / multi-screen / touchscreen

		Natural language / voice
		Web interface
		Command line
		Mobile user interface
		Tangible user interface
		...

3. Inventory of digital tools and related application scenarios

According to the description of work, the inventory of digital tools is a preliminary task towards a better understanding of potential digital game changers in agriculture, forestry, and rural areas. More than 650 responses have been collected through the online survey and have been analysed. Those will feed the inventory of digital tools, to be developed in DESIRA Task 5.3.

Each response to the survey describes a digital tool with a specific **function**, i.e., it operates in a specific way to fulfil a given task, which can be useful in one or more application scenarios (see Section 3.2); for DESIRA purposes, each digital tool relies on the use of digital technologies (or technological paradigms, depending on the case).

EXAMPLE

The Ingageo digital tool (one response to DESIRA internal survey) is a geographic information system (GIS) viewer oriented to facilitate the elaboration of georeferenced information in a digital manner. It is based on the use of a web interface and of satellite imagery to collect data to be presented.

A full example of an answer collected through the internal survey can be found in Annex I.

3.1. Statistics on digital tools collected through the survey

Some statistics on the collected tools are presented below. The sample cannot be considered as representative of the EU situation (such a statistical validation falls outside the project scope); yet, it provides a valuable sample for DESIRA purposes, providing a qualitative survey covering multiple features. Like, for instance, the distribution on: 1. the three domains of interest for DESIRA, 2. the need of Internet connectivity and whether 3. data are collected from final users or not, 4. the maturity level of the digital tools, 5. the level of automation, and 6. the core digital technologies (DTs) they exploit.

Table 2: distribution of the tools over the three domains. Some tools have been indicated as of interest in multiple domains.

Domain	Number of collected digital tools
Agriculture	435 (65%)
Rural Areas	199 (30%)
Forestry	174 (26%)

85% of the tools require Internet connectivity to properly work; 58% of them collect data from users, and 34% of them deal with sensitive data, considering both personal and business ones.

Table 3: maturity level of the collected digital tools.

Maturity level	Number of collected digital tools
Proof of concepts	73 (11%)
Under testing / prototypal phases	101 (15%)
Already in the market	492 (74%)

40% of the tools have been designed to provide support to users, 47% of them can partially substitute or significantly reduce the need of human work, and 9% of them are fully autonomous solutions based on e.g. robotics. The remaining 4% cannot be easily categorized because of an unclear description.

Table 4: core DTs and DPs used by the digital tools. A single tool can be based on the use of multiple DTs / DPs.

Digital Technologies (DTs) and Digital Paradigms (DPs)	Number of digital tools using the DT/DP
web-based tools	65%
data analytics	57%
local data collection	42.5%
remote data collection	31%
cloud / edge computing	22.5%
robotics or other autonomous solutions	16%
AI-based techniques	15%
social networks	14.8%

blockchain	7.5%
AR/VR	3%
3D printing	0.4%

3.2. Application Scenarios

This section presents the map of application scenarios. As anticipated, it is derived from the responses to the online survey, thus covering only scenarios in which the surveyed digital tools can be used; this set of scenarios will be potentially enlarged through the use of the online browsing and editing tool to be developed in Task 5.3 of the DESIRA project.

An **application scenario** can be defined as the context in which a given goal can be accomplished by using digital tools. It takes into account the technical requirements around which a digital tool (or digital solution) should be designed, and defines the objective to be achieved.

In DESIRA, application scenarios have been built by grouping digital tools according to the function they serve. For instance, the scenario *livestock* in agriculture groups all digital tools that can be used to support animal husbandry activities, which differ from those that can be used for e.g. *machinery*, which consider digital tools to log e.g. machinery activities, or to improve its performance.

A graphical representation of the main application scenarios is in Figure 7. The analysis of the collected responses through the online survey highlighted the following classes of applications, which are presented grouped per topic. More detailed scenarios, per topic group, are in Table 5. By using those application scenarios, digital tools collected through the survey can be grouped together according to their main function, and each tool can be described as presented in Section 5.

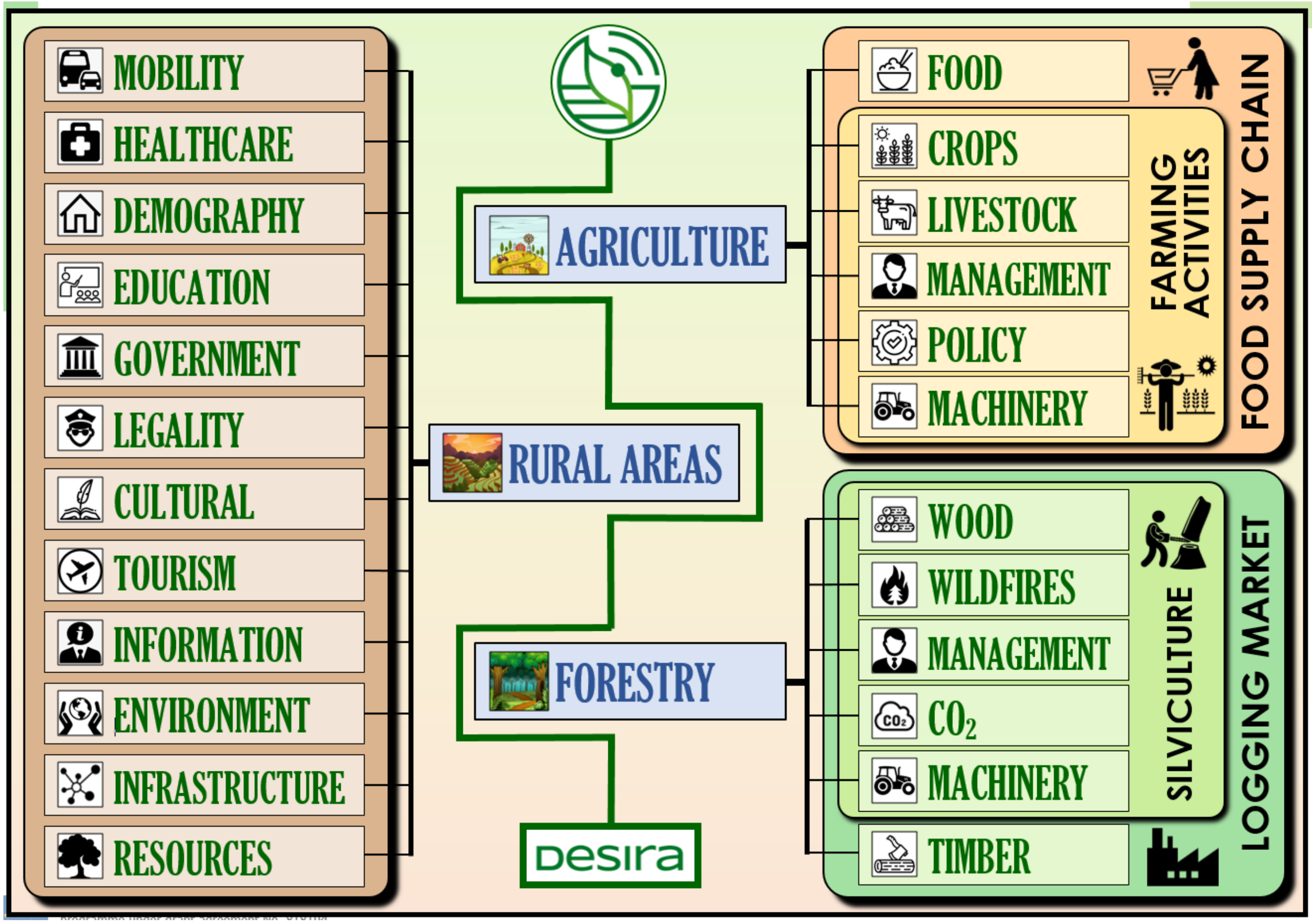


Figure 7: the application scenarios derived from the online survey.

Table 5: classification of the application scenarios derived from the online survey. The list is not exhaustive.

DIGITISATION

AGRICULTURE

CROPS	***Sowing***	Variable-rate sowing depending on the characteristics of the field (precision techniques)
	Spraying	Intelligent spraying systems applied to identified weeds (precision techniques)
	Fertilization/ fertigation	Software for irrigation management, needs mapping and automatic fertilization according to requirements (precision techniques)
	Harvesting	Robots that harvest fruit and vegetables in the field and the greenhouse. Yield mapping.
	Pest control	Drones spraying pesticides or using biodegradable spheres for biological control.
	Vertical farming	Innovative practice in which the use of software solutions to control the growth factors of plants in the greenhouse (cooling, humidity control, heat reuse, …) is common.
	Monitoring	Data collection and field mapping (plant health, microbiological screening, soil analysis, …), and weather stations (precision techniques)
	Modelling	Production of maps for plant phenotyping, prescription maps, and disease estimation.
LIVESTOCK	***Welfare and health***	Track animals and analyse their behaviour for their health and well-being.
	Herd monitoring	Monitoring of herd movements and location systems that prevent dispersion (virtual fences).
	Feeding	Automated management of the correct ration (quantity and nutritional quality).
	Milking	Semi-automatic and automatic systems to milk animals in dairy farming settings.
	Reproduction	Systems to increase pregnancies and optimize productivity (heat monitoring, genetic improvement).
	Manure	Automatic devices for the treatment and management of livestock manure (environmental protection and sustainability).

	Carcasses	Software for the logistic management of carcasses (removal, transport, and destruction). Tracking operations.
MACHINERY	***Renting***	Applications and services for renting agricultural machinery.
	Autonomous operations	Autonomous driving technology of the tractor and agricultural machinery.
	Performance	Improve the working performance of machines through the use of prescription maps.
	Interoperability	Integration of different communication standards, and service architecture (hardware and software) to allow data exchange and interoperability between machines.
	Maintenance	Applications for machine maintenance (digital registers).
POLICY	***EU CAP***	Everything related to the CAP (controls, reports, news, CAP aid calculator, and consultancy services).
	Incentives	Territorial information systems that collect information on agricultural land eligible for grants.
MANAGEMENT	***FMS/FMIS***	Decision support tools, business planning, efficiency, finance and market monitoring.
FOOD	***Quality***	Measurement of physical, chemical, and microbiological parameters that may affect the quality of semi-finished/finished products.
	Shelf life	Systems for the estimation of the shelf life of food products.
	Safety	Intelligent data collection systems to minimise risks along the supply chain (microbiological problems, pesticide residues).
	Supply chain	Systems to bring together all stakeholders, shorten the food supply chain, and simplify bureaucracy.
	Traceability	Systems to trace agricultural and animal/animal products from farm to consumer.
FORESTRY		
WOOD	***Traceability***	Traceability of timber supplies (quantity and quality) from forest/field to sawmill.

	Certification	Network for monitoring the physiological parameters of trees and timber quality for certification.
WILDFIRES	***Prevention***	Systems to support operations preventing wildfires.
	Early detection	Systems for the early identification / locating of wildfires.
	Modelling & real-time analysis	Software for real-time analysis of wildfires forming/diffusion (decision-support simulations).
	Protection	Support systems for fire-fighters (fire department), identification of escape paths.
MANAGEMENT	***FMS/FMIS***	Implementation of Information Systems to be used for forest management (geographic decision support and management of forest resources).
CO_2	***Credits***	Systems for trading emission credits.
	Compensation	CO_2 compensation through e.g. forestation activities.
	Sequestration	Estimation of the amount of carbon absorbed by the plant.
TIMBER	***Supply chain***	Promotion of value-added products in the wood supply chain, monitoring of raw materials, and semi-finished products.
	Market	Online markets for professionals and wood-working industries, accelerating sales of wood lots with attention to market transparency.
MACHINERY	***Renting***	Automation and optimization in timber harvesting (e.g. using calculation formulas on the machines). Integrated systems (machines and digital technology) to improve work efficiency in mountain areas (where work is more complex than in flat areas). Systems for precisely locating forestry machinery to enhance autonomous operations.
	Autonomous	
	Performance	
	Interoperability	
	Maintenance	
RURAL AREAS		
MOBILITY	***Public and private transportation***	Optimisation and integration of rural mobility (bus on demand, alternative mobility platforms).

	Car sharing and carpooling	Applications based on sharing economy (digital hitch-hiking, vehicle sharing, and rental).
HEALTHCARE	***E-health/ telemedicine***	Medical examinations from home, social integration of disabled people, medical assistance for accidents, and natural disasters.
DEMOGRAPHY	***Promotion***	Platforms for buying houses and starting businesses in depopulated rural areas.
EDUCATION	***Knowledge***	Tools to facilitate access and exchange of knowledge between farmers, science and society (e-learning).
	Training	Platforms that collects educational resources (online courses, and monitoring tools for educational purposes).
	Advisory	Software for agronomic and environmental consulting, providing advice on the whole agricultural process.
	Schools	Schools that offer distance lessons even for isolated areas.
GOVERNMENT	***E-government***	Tools to simplify official controls and communication between citizens and institutions. Databases of laws and regulations, administrative services, and digital cadastre.
LEGALITY	***Corruption***	Contrast illegal activities for public safety and the protection of company assets.
	Neighbourhood watch	Platforms where people living in the neighbourhood/village can provide a security service.
	Environmental crimes	Promote citizen participation (report deforestation, arson, illegal waste dumping).
	Frauds	Commercial fraud (e.g. authenticity of products), fraud against institutions (e.g. CAP parameters).
CULTURAL HERITAGE	***On-line discovery***	Websites with interactive maps of the territory and information on cultural and environmental heritage.
	Regional history	Digital tools to describe the history of geographical areas; for tourists mainly.
TOURISM	***Promotion***	Government and private initiatives for the promotion of local tourism (information and sharing of experiences).

	Offered activities	Information on nature trails, cycling routes, hiking planning, commercial activities (hotels and local shops).
	Market prices	Dynamic forecast of prices.
INFORMATION & PROMOTION	***Start-ups***	Promotion of local producers and shops and youth entrepreneurship (new activities in rural areas).
	Incentives	Systems to encourage (with simplification and promotion) the development of productive activities.
	Stakeholder involvement	Applications that support and develop cooperation between entrepreneurs and farmers (data and experience sharing).
ENVIRONMENT AND CLIMATE	***Monitoring***	Monitoring ecosystems and climate change. Forecasts and assessments of environmental impacts.
	Protection	Reporting problems to authorities, combatting alien/invasive species, and promoting the conservation of natural areas.
	Intervention	Intelligent systems for the sustainable management of production processes and to minimise the impact of activities.
	Communication and information	Tools to increase public awareness of the values of nature conservation.
INFRASTRUCTURE	***Connectivity***	Digital infrastructure to provide the rural population with connectivity for the development of e.g. Smart Village.
RESOURCES	***Soil***	Monitoring and analysis of physical and chemical parameters of agricultural soil, CO_2 sequestration, cover, and use.
	Water	Water management (rainwater reuse) and water supply planning (climate data and water infrastructure).
	Energy	Optimize energy supply from biomass, thermal energy control, and consumption monitoring.
	Waste	Applications for the management of waste and agricultural by-products (recycling, reduction, valorisation, no waste).
	Air	Monitoring and forecasting of air quality parameters.

			Digital data	Internet sites and platforms offering open databases, weather data, and spatial data (agriculture and forestry).

3.3. Experts' interviews

This section analyses the experts' interviews that have been conducted to support and enrich this document, especially the selection of potential DGCs in Section 4. The interviews mostly consist of written responses to questions enquiring about what the experts perceive as current and future technologies with the potential of changing the game, especially for agriculture, forestry, and rural areas, and their socio-economic impacts. The interviews have been conducted by DESIRA project partners, according to two internal templates: one targeting ICT experts, thus focusing more on technology and the potential of current and future tech developments; the other one targeting social and economic expertise, thus focusing more on the impacts of technology, looking both at the current situation and plausible ones in the future.

Both templates contain six main questions, slightly different according to the target:

1. Digital technologies (DTs) you deal with or encounter most commonly in the three domains (agriculture, forestry, and rural areas), and their main uses;
2. (ICT expert) Plausible tomorrow's use of DTs in Q1;
   (Socio-economic expert) Impact of DTs in Q1 in the three domains;
3. (ICT expert) Examples of uses of DTs in the three domains, and new developments you are participating to / you are aware of. Potential of those development to be game changers;
   (Socio-economic expert) Drivers for the adoptions of DTs in the three domains in your experience;
4. (ICT expert) Positive and negative impact of technological advancement on SMEs, workers, and other actors when DTs are introduced and used, especially considering cases you have been involved to, if any;
   (Socio-economic expert) Barriers for the adoptions of DTs in the three domains in your experience;
5. (ICT expert) Drivers and barriers for the adoptions of DTs in the three domains in your experience;
   (Socio-economic expert) How new and deeper reflections / methodologies to assess the impacts of technology could help you in your work, if applicable;
6. Previous involvement in any activities to assess the socio-economic impacts of DTs.

27 experts' interviews were collected. Excerpts from those interviews are presented below, focusing on the main topics raised by the experts, highlighting what they perceived as disruptive from both technological and socio-economic perspectives. Each excerpt from the interviews says whether the '*ICT expert*' or the '*socio-economic expert*' template has been answered by the expert, thus providing

information about the specialization field of the interviewee. Section 3.3.1 focuses on digital technologies and their potential for disruption, while Section 3.3.2 focuses on the socio-economic considerations linked to the technological development.

3.3.1. Digital technologies and the PDP loop

This section reports the experts' opinions about digital technologies and their uses in agriculture, forestry, and rural areas, also considering their potential to be disruptive. Four main topics are analysed below, namely data and data collection, connectivity, data analysis, and automation; those four are conceptually linked to the four layers of the CPS model presented in Section 2.2.

3.3.1.1 Data and data collection (sensing layer)

Data and sensing systems are what the experts see as both central and critical today and in the near future. Monitoring (or sensing) systems are those deployed to collect data about a phenomenon, like soil conditions, weather, animal health, fire prevention, and so on. Both local and remote sensing technologies are cited, with a great prevalence of the former, and large attention is devoted to the **Internet of Things** (IoT) paradigm. One of the cornerstones of IoT is **interoperability**, which means that collected data can be shared and reused; to enable it, **standard** data representations and exchange protocols are needed, but a clear solution has not been identified yet. However, the experts mentioned that both industrial and research fields are actively working on this. **Sharing data** means having the agreement to do so from the data's owner(s), and the agreement must specify who can share the data, with whom, under which conditions, in a secure manner, and with the possibility for the data's owner to know who is accessing and using his/her data, and to revoke such a possibility[3].

IoT, monitoring, and **sensing** have been largely used as keywords by the experts to refer to the technologies underlying data collection, and two key points are raised in this respect: the first is related to the use of data and their sharing, and the second one to the benefits that **precision techniques** can bring once fed with collected data.

Use of data and data sharing

Some experts are skeptical about the usefulness of **data sharing**:

"I am skeptical about agricultural networking and data sharing because other standard tools, with similar functions, already exist. It is not certain that those initiative can provide added value. Nonetheless,

[3] In the agricultural field, COPA-COGECA and CEMA have developed a code of conduct on data sharing (https://ec.europa.eu/eip/agriculture/en/find-connect/online-resources/code-conduct-developed-copa-cogeca-cema).

networking will persist focused on existing tools around very strong stakeholders (e.g. Google) [socio-economic expert]."

Instead, others see the potential in sharing **interoperable data** subject to clear **use agreements**:

"*Big data technologies can be efficient to manage data complexity, especially for short food channels because there are faced with the diversity of norms and standards. In this point of view, "Data food consortium" (developing open data standards for the food system) works on the issue of interoperability. It is about developing a digital standard in order to integrate all data from one digital catalogue of products to another one, decreasing organizational costs and reinforcing control over data ownership. Farmers should give their agreement on data sharing only for a precise and known use. The data sovereignty is a real issue and it is extremely important that a single stakeholder does not control all the information. The limitation of uses and centralization is now possible thanks to metadata systems, and that is the stake of semantic and distributed web. However, this technically possible solution is still only in its emerging phase* [ICT expert]"

Thus, the importance of metadata and semantic analyses is highlighted as well in the previous excerpt.

But, being able to collect local data may require installing some equipment, and this can be challenging. For instance, in the case of livestock, it means that:

"*A barrier is related to the properties of infrastructure. Installation of hardware needed to gather data for management systems or to install milking robots requires that farms correspond to certain characteristics. This might mean that farm building is too small, the ceiling is too low, the farm doors are too narrow, or some other solutions should be introduced before a farmer can incorporate what he/she is aiming for. In these cases, the modernization is just too expensive and might include complete reconstruction of the farm* [socio-economic expert]".

Precision techniques

Precision techniques are another topic often mentioned by the experts when discussing data collection. Those refer to techniques, for both agriculture and forestry, based on data collection with the aim to observe, analyse, and act in a precise manner, according to both temporal and spatial variances.

The potential of precision techniques to reduce the **environmental impact** while maintaining or raising the productivity level is mentioned as a **driver** for the adoption of technological development:

"A driving force is the whole concern on the impact of food production on the environment. The question is whether we can remain productive with a lower impact, and precision agriculture can play a role in this. Before the idea of precision techniques, we gave more fertilizer than required, but now we see that this is no longer possible. And now the margin of fertilizer is reduced, and to prevent yield losses we need to efficiently apply fertilizer and drive the need for innovation. And similarly, we see a need to reduce the use of pesticides. The consumer wants less inputs while we do need to be able to protect the crops, and we see a driving force for innovation there, driven by society. But I do not think the farmer is the party asking for

these development, society requires this from farmers, and farmers will have to comply with these regulations. And if technology can aid in this, there is of course an interest for this” [ICT expert]

According to this opinion, the request for a lower environmental impact may come from society rather than farmers themselves, thus gradually forcing them to meet such a request to stay in the market.

A similar consideration, this time on **regulations** acting as drivers to introduce technology towards **precision fertilization**, is highlighted by another expert, referring to the EU Common agricultural policy (CAP):

“*Required reduction of the N balance in the new agricultural policy (CAP 2020) will certainly increase the interest in carrying out N fertilization more precisely and using the available N as optimally as possible.”* [ICT expert]

Another example of the use of precision techniques comes from **automatic irrigation**, but stressing the fact that trust is a key factor toward larger adoption, because farmers must be in control at any time:

“*I would give the example of precision irrigation. It is a solution that already has a big uptake from the farmers. You set up a system in a field that automatically estimates the water needs of the plants and gives a signal to the controller and through the use of electro valves it automatically opens or closes the irrigation system. So, the only thing that the farmer has to decide is the moisture threshold in the soil everything else is done automatically. So, to summarize, a disruptive technological paradigm is the one that combines smart solutions for hardware with AI and even sometimes simple algorithms. Solutions where everything is done automatically without the farmers’ interaction, it must be noted anyway that the farmers have to know how the systems works in order to trust it, since the system will have control of the farmers’ field”* [ICT expert]

Here, another point of attention is the **simplicity** of the system or solution in use as a driver for adoption, in addition to the aforementioned need for trust.

Spectral and **hyper-spectral** techniques, in the field of **machine vision**, have the potential to boost what precision techniques can provide, also reducing the need of **fixed sensors** e.g. in the soil because the camera can be installed on the machine moving in the field and collecting data as it goes:

“*Spectral cameras have a lot of potential. But they still have a lot to prove as well. While a lot of other digital and sensing technologies have shown their use and are available on the market already. In digital technologies, especially sensors for automation, we see more and more technologies to automate parts of agricultural machinery”* [ICT expert]

Still, the technology is here deemed as not yet mature for actual use.

3.3.1.2 Local and Internet Connectivity (connectivity layer)

Connectivity is perceived as one of the main enabler and barrier, at the same time, to the introduction and use of DTs, which often rely on the possibility to exchange data through **Internet**, and on the use of **online services and applications**. Two main factors are central in this regard according to the experts: the availability of connectivity, certainly improving over time but still lacking in certain areas; and the costs associated with it.

The lack of connectivity has had a sensible impact on rural communities, still coping with it:

"*Rural communities have been, and still are, on the wrong side of a **digital divide**. Over the past two decades this was mainly a material matter, with a lack of connectivity as the prime issue. Over the past few years, I have seen that, where the lack of connectivity was solved, community members and businesses struggled with making effective use of digital technologies. This does not merely affect the 'traditional' vulnerable groups such as elderly and poorly educated person – it also strongly impacts community members and businesses who have worked with 'digital by-pass and coping strategies' for a long time. Because of the poor material connectivity, people managed to cope without digital connectivity, and now they lack the 'digital capital' to join the bigger leap in digitalisation (using big data for business, using apps in their daily life, maintaining digital (business) relations and so on)"* [socio-economic expert]

In this context, one of the key objectives would be reducing *losers*, i.e., rural areas left behind because of poor connectivity, among other factors:

"*You do need the technology. So the connectivity has to be there. And that's essential. It doesn't have to be the kind of technology we talked about in the Ludgate hub*[4]*. It doesn't have to be done very, very high technology, but it has to be, you know, comparable"* [socio-economic expert]

Connectivity (or the lack of it), among other factors, is a driver (barrier) towards the adoption of DTs: "*Adoption seems to depend on (1) price of the product; (2) estimated cost-effectiveness of investment (does it really offer added value if you decide to make the investment?); (3) connectivity (if you live in a rural area without connectivity, it is no use to have the technologies); (4) age of the farmer and his/her dependence on traditional farming skills; (5) lack of trust in partners who use the data, which can be ICT companies (who may use the data for profiling, or on the stock market or who may sell the data) or other partners in the value chain (for example, if the farmers and the slaughterhouse start to share data, who will then harvest the benefits: the farmer or the slaughterhouse?), (6) lacking digital skills among some farmers"* [socio-economic expert]

[4] https://www.ludgate.ie

In the end, connectivity is still one of the greatest challenges in rural areas: "*There is a digital divide between companies in rural areas and those located in urban areas, so the great challenge facing the digital transition is connectivity. Connectivity is necessary for the interoperability of the data through adequate infrastructures that allow open and secure data flows and facilitate the exchange of data between the different actors within the value chain"* [socio-economic expert]

Internet of Things

In this scenario, Internet of Things (IoT) plays an important role because it has been designed to facilitate **data exchanges** through the use of **standard solutions**, thanks to the interoperability feature, as already anticipated. In other words, it can be an outstanding digital enabler for new services and applications: "*The existence of digital enablers will allow progress in the digital transformation of the sector and the rural environment. Digital enablers are the set of technologies that make possible for new processes to take advantage of the full potential of digitisation. In particular, technologies such as the Internet of Things (IoT), data analysis and Big Data, blockchain or artificial intelligence allow the agrifood sector and rural areas to be connected, smart and with an overall vision of the food chain. All these technologies allow for better **decision-making**, to develop more **predictive and precise systems**, to promote positive effects and to mitigate the negative ones for the economic, social and environmental sustainability of the sector and the territory"* [ICT expert]

IoT is already playing a role in **digital transformation**, contrarily to other digital technologies: "*Cloud technologies, Internet of Things (IoT technologies), mobile/web apps (still), those are technologies already widely used within different application areas. More advanced technologies such as Artificial Intelligence, blockchain, VR/AR are of relevance but can be seldomly found in practical and sustainable application scenarios"* [ICT expert]

3.3.1.3 Data Analysis (computing layer)

Data analysis is a key functionality to provide **actionable information** to end-users. Exploiting the raw data collected at the sensing layer, both automatically or manually inserted, analysis routines can feed e.g. support systems. **Decision support systems** (DSSs), recommendation tools, automatic systems, and so on, depends on the availability of data to extract information to be presented to end-users. In recent and common setups, data analysis and DSS software routines run in remote machines thanks to the **cloud** paradigm, avoiding the need of **local computing power**.

"Today our computer models are based on cloud, which means that farmers are locally collecting information thanks to sensors, smartphones or computers. Then raw data are sent to a distant server which will treat them, make calculations, cartographies and recommendations. After that, those results are sent back to farmers' terminals. But cloud needs that raw data are delivered, so it needs a big

communication effort between server and data collection area. Now we are asking some question about that concerning the environmental impact and, moreover, this not really fit with agricultural IoT, especially in cases of isolated farms, outside networks, or not being able to access the necessary energy. So today the edge paradigm is supplementing the cloud model, allowing for treatment to be performed where data is collected" [ICT expert]

Here, there is an additional reference to the **edge computing** paradigm, and its potential to decentralize a fraction of the **cloud** (centralized) infrastructure, opening to better distributed loads on the network and thus reduced delays, and to the possibility to enforce privacy policies also on a geographical scale.

Decision Support Systems (DSSs)

Specific scenarios are mentioned by experts, like for instance **agrivoltaics**, in which **DSSs** are supposed to play a large role: "*In agrivoltaics, digital will also find its place because some systems are emerging. Cultivations below solar panels protecting the plant while allowing it to have the needed light to grow. Decision supports systems and digital allow to manage this type of systems (e.g.: regulate the light as better for the plant while optimising the electricity production with the panel inclination)"* [ICT expert]"

The availability of digital data to support **management procedures** can provide gains e.g. from a productivity point of view, but also creates diverse ways of dealing with procedures: "*Digital tools risk to reinforce the diversity of practicing farming. As an example, farmers who are not attracted in those digital tools will have a more sensitive practice, but the ones who are interested in that will have a more managerial and material approach of the profession. Talking about performance, a study was made few years ago on the use of* ***milking robots****. This work shows how diverse was the use of the same tool among farmers, ranging from simple milking to enhance generated data during milking for operations management. It also shows that a great productivity gain was achieved through the intensive use of* ***digital data****, while the gain was pretty modest for those who used it as a simple milking tool. To have a positive effect of the economic performances digital equipment must be combined with some data treatment skills and management abilities. Thereby, it exists a risk of increasing performances inequality"* [socio-economic expert]

Furthermore, challenges like irregularity in production can be better dealt with thanks to DSSs: *"Digital can help to manage irregularity in production. If the farmer has an alert all along the production process, he/she can adjust his/her position on the sector with more adapted specifications and better valorise the product on the final market. And the little producer has a bigger interest because, in a context of competition, digital will allow him to create a direct* ***marketplace*** *to the consumer"* [ICT expert]

3.3.1.4 The case of automation (intelligence layer)

Automation in business practices is perceived as a likely future by the experts, which consider it as mainly enabled by AI. Being concerned or not by its advent, all experts see **AI** as something that will occur sooner or later changing practices and provoking disruptions. For some experts, automation that can be brought by such tools will have a positive impact on business: *"Artificial intelligence will help to* ***develop advice and automatize it****. Today, advice rests on advisors, which are linked to suppliers or decision making tools, which calculate and sometimes make recommendations, but this not really an advice. AI could change the deal and this goes together with the legal evolution: sell and advice separation. Digital allows to relocate advice where services and cost are more beneficial for farmers and AI could totally automatize advice"* [ICT expert]

But, to fully enable AI (and its training phases), lots of data are required, and this is still an unsolved question: "*AI, deep-learning, etc.* ***data are like petrol****. The real issue, since few years, is big scale data collection and sharing by farmers. Without any data we can have the better algorithms, but they can't provide anything. Deep-learning's software need lot of data to improve because they learn by themselves"* [ICT expert]

The first use of automation is in replacing **repetitive labour**, while higher-level management tasks will still be performed by humans: "*I think you will see the replacement of repetitive labour. Because you can automate more with this technology [****imagery****]. Also the monitoring is automated with this technology. And that will mean, that when farms get bigger they can still keep an overview of the farm. Even though the size of the farm is increasing. And especially you will see a shift between low-skilled, repetitive labour to more technology-based labour where the dirty work is done by the machine. And the oversight and interpretation is still a task for people"* [ICT expert]

In the case of agriculture, the introduction and adoption of automated systems is supposed to increase in the next years: "*I see* ***agriculture automating further****. I think a lot of work that is currently done manually will be automated in the future. Especially work that requires a lot of manual labour will be automated. The moment that you need to consider the employment of external labour or further automation, at that point there will be a tendency to go for automation. And I think especially seasonal labour, in fruit and vegetable production, and the fact that some farms employ someone for milking. Some farmers will sooner look towards* ***robots****, also* ***harvesting robots****. And also our current situation, with corona [SARS-CoV-2], will stimulate this more. Because the farms using robots are still doing fine, but the ones that hire in workers have more difficulties. Especially when those workers need to come from foreign countries"* [ICT expert]

And the focus on labour also highlights the costs associated with it, but the negative social effects as well: "*I think those sectors, the ones where we do want to keep the production within our borders, but the production is not profitable. I think in those sectors we will see a move towards **automation**. We have a lot of work where an employee is too expensive, and those are automated. The less cheap labour can be used, also with negative social effects, the more innovation is needed. So I also think you will see that with long-distance freight shipping, which is currently done by foreigners, that might be automated. Whereas in the cities you might need someone still for unloading and other tasks"* [ICT expert]

Automation can leave space for other tasks, and also increase the profitability of agriculture: "*You also see that a lot of developments in agriculture have led to a decrease of labour needed in agriculture. This allows time to pursue other goals. But also on the other hand, because the economy is doing well, labour is too expensive for agriculture. And because of that you do need to innovate to remain profitable"* [ICT expert]

And profit and efficiency are the main stimulus towards automation: "*I think what is a stimulus is the need to produce efficiently with a limited availability of labour. And especially in (...), even with an expensive machine, the most expensive is the person inside the machine. I think that is the driving force behind technology development* [ICT expert]*".*

3.3.2. Digital changes in rural domain: actors and socio-economic impacts

According to the purposes of the DESIRA project, it is also relevant to outline which subjects can be considered as *winners* (who benefit from the change), as *losers* (who are marginalised by the changes), or as *opponents* (who resist and elaborate alternative rules of the game) of the digitalisation process. New digital solutions can produce both negative and positive economic effects. They can also impact on the **environment** (e.g., reducing pollution sources) and **social world** (new services for rural areas, increasing quality of life, etc.). However, the adoption of any innovation is not easy, and **not everyone can benefit in the same way from the innovation process**.

The interviews with the experts sought to gather the opinion of competent people about actors and problems involved in the digital innovation process. Two crucial elements emerge from the interviews: *i)* actors (farmers, local communities, women, young people, etc.) may be at the same time winners, losers, and opponents of the digitisation process depending on their social position (e.g. in the value chain) or on their features; *ii)* despite the variety of digital technologies reported for different domains (agriculture, forestry, rural communities), barriers and limits for the digitalisation process seem to remain unchanged. Farmers, for example, can be winners because, in production activities, digital technologies can reduce costs. DTs can offer higher guarantees of product quality to consumers, and digital solutions can improve their quality of life (e.g. by gaining spare time). At the same time, farmers may lack the financial resources to implement these solutions, which are often expensive. They can have a low level of digital literacy or their 'culture of work' does not take into consideration digital solutions. Structural limitations of the rural areas (low connectivity, low attractiveness of sparsely populated areas by technology operators, etc.) slow down the digitalisation process. Other factors have an impact as well, like the design of digital solutions, because some of them are designed for urban zones, thus matching inefficiently the needs in rural areas. At the same time, the interviewees almost agree that large agricultural operators (large farms or agri-food groups) are highly interested in digital solutions, in investing in them and obtaining massive benefits. Such large interest represents a core concern for experts because it can generate relevant socio-economic asymmetries in the sector. Digitalisation can reinforce the oligarchic position of few operators. Moreover, the inability to cope with the digital revolution by smaller farmers can ingenerate issues with data (mining, managing, and ownership.

The following topics are discussed below: barriers on digitalisation and solutions proposed by the respondents and the possible winners, losers and opponents of digital solutions.

3.3.3. Digitalisation: facing barriers

Both technology and non-technology experts report similar barriers to the spread and the adoption of digital solutions in agriculture and rural territories. Respondents especially stress the issues related to the **structural features of rural areas**. The lack of **infrastructures** (e.g., low high-speed connectivity), **demographic** aspects (few residents and elderly), unfavourable **economic conditions** (low incomes, low investment attractiveness) **cognitive aspects** (knowledge, skills) are the main barriers to digitalisation.
A digitalised agriculture and smart villages can contribute to attract or retain population or can increase the average income in rural areas, for example, but the **market** - as key driver quoted by some respondents – should not be considered as the only driving factor. Moreover, respondents report that leaving digitalisation to the market can produce inefficient or unfair outcomes in rural areas. More in particular, the phenomenon where the market (on the supply and demand side) pushes the economic players to adopt innovation to reduce direct and indirect costs and to increase profits and incomes is considered as not enough by some experts. Economic drivers are not able, for example, to adequately reduce **digital illiteracy** or to increase **digital skills** and attitude to innovation for rural actors, particularly for small farmers or small agri-food companies. For this reason, policies are considered by experts as relevant and to the overcoming of rural barriers.

As some respondents' report:

> *«An overall approach to digitisation in all sectoral policies might boost economic growth and employment, improve agricultural and rural infrastructures, educational plans, and social services, and overall increase the attractiveness of rural areas, especially for youth and women. The (…) Ministry of Agriculture created a Focus Group on Digitisation and Big Data in (…) rural sectors to (…)*

1) reduce the physical digital breach of infrastructure and training in the adoption of new technologies; 2) promote the use of open and interoperable data; 3) promote business development and new business models» [ICT expert]

« (…) policies that will incentivize people to adopt new technologies. (…) public awareness, taxes and subsidies, training and education, cohesion funds and in general policies that aim to shift the risk away from the technology user can become a driving force in ICT adoption» [ICT expert].

However, on the one hand, **policies** need to be coordinated and explicitly designed on rural features to meet the rural actors' needs. The governance of digital transformation emerges as a crucial issue. In particular, for some experts, the participation of stakeholder is essential to achieve digitalisation. The process of intermediation among policy-makers, the technology solutions, and the local needs is reported as an appropriate strategy to overcoming barriers.

«we have (…) a vast number of policies (…) these are often not interconnected, and they are often not in tune with the local people. (…) So even if you have the skills and you have the good connectivity, if people don't see how the technology can be used and don't understand its value in their day to day lives, there is not going to be the demand or the take up. (…) It is the critical role of involving stakeholders. Creating mechanisms for involving and engaging stakeholders in digital rollout. So not just working on the skills but working with them on what their needs are, working with them on how the technology could be used in the different areas of their lives. (…) Again, this is on drivers, I think there are critical intermediaries that play a vital role. (…) These intermediaries play a vital interface role between the people who are using the technology and the providers of it» [socio-economic expert].

The experts suggest how digitalisation can attract young people and women to farming to reduce the burden of farming activities, making them more environmentally sustainable, and thus helping in reducing the management risks. Digital technologies can transform agriculture in a modern and interactive sector closer to (new) consumers' social values and needs. For example, consumers appreciate organic products and they are interested in getting more information about food, from the adopted cultivation or breeding methods to nutrients features and to historical-cultural tradition linked to food (e.g., the preservation of old cultivars or native breeds of livestock, etc.).

Data collected by sensors, drones, satellites, then elaborated by algorithms and sent back to farmers (or managed by AI) can facilitate the match between the demand and supply side of agricultural and forestry goods and services. Nevertheless, in particular for small and family farms – for instance lacking Internet connectivity, among others -, finance and skills reduce the rate of innovation adoption, but a role is played also by the traditional cultural attitude and the suspicious behaviour about the processing of personal data, at least according to the following opinion.

«Another negative point is the farmers' digital culture (…) if we present to French farmers 80% reliable digital technologies, they will not want to test it, while American farmers will. (…) Cultural factors, connection's problems and needs for farmers to open mind on the outside» [ICT expert].

«So far, many of them are reluctant to use a lot of technology as it does not fit to their image of being a farmer, e.g. working with the soil» [ICT expert]

«The attachment to the current pattern of farming, the traditional approach to life and the low openness to change for traditional family farms. Relatively greater technological backwardness in farming families, often resulting from the unfavourable demographic structure of farm managers» [socio-economic expert].

Thus, some experts suggest that the spread of digital solutions is **not a linear process** that can be promoted only through **funding**. If requests coming from the market can be a push factor, the lack of finance for many farms or small communities can limit the adoption of any digital solution. At the same time, the European rural development policy can bring a cost reduction in innovation actions, but it is not adequate to promote a socio-territorial fair distribution of digital benefits. Many other dimensions are involved in the adoption decision process, like skills, social needs, cultural aspects, etc., that need a specific approach. Moreover, digital solutions have to be designed to be suited to final users, before being considered as accessible (for skills and costs) and as reliable (simplicity of use and robustness) technologies by final users. In general, experts consider that both cooperation and mutual listening among peers (rural villages or farmers), digital service providers and users, as well as between rural communities and policy-makers seem the best option to reduce the obstacles for a digitalisation process not leaving anyone behind.

In Table 6, a sum of the experts' opinions on initiatives to face problems for a fair spread of digital solutions in rural domains is presented. In particular, *'policy'* refers to actions and investments over a long-term time horizon. *'Cooperation'* means those activities of an equal exchange of resources (knowledge, data, information, funds, etc.) among actors to reach goals that produce differentiated benefits for all participants. Finally, *'intermediation'* means those actors/initiatives that facilitate the embedding of predefined solutions in specific contexts by adapting them.

Table 6 – *Supporting a fair digital transformation in rural domains in the experts' views*

Initiatives	Problems and Solutions
Policy	Improving access to online services and applications through high-speed connectivity
	Public incentives to reduce investment costs for innovation actions
	Promoting training initiatives to increase digital skills
	Funding the research to increase knowledge on digital issues in rural domains
	Data as 'commons' to reduce monopoly risks
Cooperation	Co-design of digital solutions to match efficiently rural needs
	Knowledge exchange about digital benefits/limits to promote adoption
	Shared investment costs to implement infrastructure or digital tools
	Shared data, information and advices to promote autonomy
Intermediation	Increasing trust and reliability of digital tools
	Promoting a positive attitude towards changes
	Training initiatives for the proper use of digital solutions

Source: interviews analysis.

3.4.4 Who wins and who loses in digitalisation

As aforementioned, the experts observe that digital transformation in agro-rural domains offers chances to improve the **quality of life** of the rural population (e.g. through new services) and increase the **profit opportunities** of agriculture and forestry businesses (e.g. reduction of costs and consumers' demands matching). Furthermore, digital technologies can reduce the **environmental footprint** thanks to a more efficient use of natural resources (water, soil) and chemical agents (fertilizers, pesticides). Also the impact of risks due to natural events can be lowered (e.g. fires, floods).

At the same time, the diffusion of digital solutions in rural areas faces **physical-technological barriers** (e.g. lack of high-speed connectivity), **economic and finance difficulties** (e.g. costs and long term return for some technologies like robots), and **socio-cultural limits** (attitude to technology, skills). These problems do not affect all the agricultural and forestry actors in the same way. Respondents do not classify specific actors as winners, losers or opponents because this depends on their features and position in the sector value-chain. Below is reported an example from the forestry domain, where some low-skilled workers at the first steps of the production chain seem to be less affected by digital solutions:

> *«What regards forestry, digitisation and digitalisation will not have a displacement effect (…). The domain profiting from digitalisation will be the wood industry, raising efficiency and optimization»* [ICT expert]

« (…) two levels. The first concerns the forest operator that has to use already organized and simplified tools (…) The other level is related to the subsequent processing phases, where companies must be able to lead and innovate. (…) important aspect is related to the investment in human capital (…) a worker knowing how to handle tools such as chainsaw and harvester (…) is a key resource» [ICT expert]

Advantages or disadvantages emerge in conjunction with several contextual aspects, such as a mix of policies (e.g., to promote digital solutions, to support the acquisition of digital tools, digital literacy), different forms of cooperation in the territory among experts, users, policy-makers and providers of digital technologies, and intermediation initiatives. For this reason, in Table 7, the main subjects quoted by the respondents are reported, as well as features that can plausibly define them as winners (benefitting from changes), as losers (marginalised by changes), or as opponents (resisting to changes).

Tab. 7 – Actors and features, according to the experts, making them winners, losers, or opponents of the digitisation process

Actors	*Winners*	*Losers*	*Opponents*
Small / family farms	Digital skills and attitude to innovation	Poor financial and knowledge resources	Traditional culture about work
Rural communities	Strong link among community stakeholders	Poor connectivity and weak local governance	Mistrust in authorities and local investors
Agri-food companies	Ownership of digital tools and promotion	Market position and dependence from digital providers	Loss/lack of privileges in elaborating and collecting data
Young people and women	Good education, digital skills, open to innovation	Low financial resources and attachment to traditional culture	Reduction of autonomy, loss of control over data
Workers	Good education and adaptability	Specialized workers: expensive, too difficult to find	Unskilled and seasonal job positions
Consumers	Digital skills and open to innovation	Low income and low education level	Poor trust in ICT companies, privacy issues
Advisors	Open to innovation, collaboration with digital providers	Poor digital skills, traditional professional culture	Knowledge and competencies transfer to digital providers

Source: interviews analysis.

Although the experts point out that the winners of digital transformation are those adopting certain attitudes, skills or resources, digitisation poses relevant risks on **economic concentration** (*de facto* monopoly positions), **loss of autonomy** (dependency to digital providers) and **unclear exploitation of data** (data ownership). Directly or indirectly, all these elements are related to ethics because, as an expert suggests, the spread of digital tools are changing several aspects of our socio-economic interactions.

> *«Digital technologies are not just 'tools' added to a farm; they thoroughly change farm management and practice. They demand therefore a revision of the actions of farmers and the interaction with stakeholders around it. (…) it also changes the types of stakeholders who are part of the social network around farms»* [socio-economic expert]

In short, **data** are the most specific product and condition of the digital society at the same time; their mining, exploitation, and use seem to define the effects on social actors. For this reason, respondents consider *'data sovereignty'* the most important issue of the ongoing digital changes for both rural communities and the agricultural and forestry sector. If we do not pose limits and rules on it, few actors can be the only winners in a digital society, like the leading global digital providers. On that issue, the experts seem to consider two possible solutions, which are not necessarily self-excluding. On the one hand, some respondents suggest that data should be considered like *commons* and, as such, they should be governed by 'digital communities'. In short, **data should be open, accessible and available by the users**, thanks to solutions offered by digital technologies.

> *«The data sovereignty is a real issue and it is extremely important that a single stakeholder doesn't control all the information. The limitation of uses and centralisation is now possible thanks to (...) semantic and distributed web. However, this technically possible solution is still only in its emerging phase. (…) we need to create digital commons and share the use of those commons»* [socio-economic expert].

> *«(Digitalisation) processes could be dominated by large companies with the risk to 'monopolize' many of these technological advances. Creating 'knowledge and technological' networks at different scales, from micro to large enterprises will avoid these restrictions»* [ICT expert]

On the other hand, some other experts highlight that information generated by digital tools can represent a barrier for the adoption of that technology. Users are concerned about **privacy issues**, the unclear process of data mining, and the **use of** their **information**. **Data protection**, through norms and laws, represents a solution, effectively enacted by a supra-national legislator. In this case, the focus is not on the governance of data.

> *«An interesting and even controversial aspect of new technologies (…) is data sovereignty. A barrier for the adoption of new technologies might be the information the technology generates, rather*

than the technology itself; potential evolving issues are related to data protection, GDPR» [ICT expert]

Besides, a respondent observes that an advanced digital society can produce a massive 'failure' involving the entire society. Robots, drones, and other digital technologies may not bring a wealthier and more sustainable world, but instead a 'dystopia' because they can disrupt the countryside social fabric. According to this viewpoint, rural areas are the reservoir of relevant resources developed over time and social interactions: resilience and caring. The digital intermediation of social relations and the increasing distance between agricultural and forestry activities and the direct human experiences of them, could not enhance those resources, but dissolve them.

« (…) the dystopia is definitely a countryside where there are no people and farmers are people who are sitting in an office in the city and where huge tractors and robots and drones are going around picking and sending and packing everything for all the city dwellers. So that to me is a risk. (...) The strength of rural areas is not just the fact that they have cleaner air and nice environments and green trees, but there is also a history of resilience and caring which in the current crisis has been shown to be more and more important and something that we have ignored. So hopefully the technology will not be a substitute for this but it will actually enhance it» [socio-economic expert]

In short, experts seem to suggest that, in order to contain the possible adverse social effects and ethical problems of digitisation, it is necessary to find a middle ground between full automation, the public data management, and off-line social interactions.

4. Digital Technologies with the potential of being Digital Game Changers

This section presents the digital technologies (DTs) herein considered as potential digital game changers (DGCs). As stated in Section 3.3 of the DESIRA CAF, DTs can be seen as potential internal digital game changers, able to deeply reconfigure routings, rules, actors, and artefacts of social and economic life. Some of those are already changing the game in several contexts, others must be considered as potential ones. DTs have been selected through a literature survey and by analysing the experts' interviews. In both cases, the so-called Industry 4.0 paradigm comes as reference, through explicit mentions or because the technologies most referred to are those comprised in it. It is likely, and partially already occurring, that Industry 4.0 represents the next wave of technology in the market, thus with impacts to be better understood.

In Sections 4.1, a brief literature review is presented on the topic of DGCs, then the set of potential DGCs is presented in Section 4.2. In both sections, the focus is mainly on technological aspects. Complementarily, Section 4.3 focuses on the potential social, economic, and environmental impacts of the selected DGCs.

4.1. Understanding potential digital game changers

We are in the middle of the fourth industrial revolution, with digital technologies transforming whole sectors, and this process will continue to drive disruptive changes in its way. Digitisation, in order to occur, needs *basic conditions*, such as IT infrastructures, networks, and data protection, and *enablers*, such as digital skills and investments [3]. Digital technologies have the potential to thrive and provide benefits once those are met. According to [4], the most successful digital technologies are those stemming from a clear problem, rather than beginning with a technology and finding a problem to address down the line.

In the agricultural field, for instance, several digital technologies have been already marked as game changers: 3D printing, remote sensing, Internet of Things (IoT), Unmanned Aerial Vehicles (UAVs), hyperspectral imagery [4]; Global Navigation Satellite System (GNSS) and Real-Time Kinematic (RTK), big data, cloud computing, data analytics, cybersecurity, blockchain, narrow Artificial Intelligence (AI), robotics and autonomous systems [3]; such a list can still potentially grow. What is important to recognise and understand is that digital technologies amplify their potential when jointly used (*integration*), and when the context is ready for adoption. For instance, in [3], the authors describe how developing countries are trying to leapfrog the process of digitalisation by early adopting advanced technologies, but the gap to be filled (digital divide) is such that only developed countries are instead succeeding in this. Looking to rural areas, people seem to find ways to use new technologies even when digital skills are not adequate [5], for instance using videos for learning purposes. Anyway, viewing technology as a solution can be misleading because more complex dynamics need to be jointly addressed [6]. For instance, considering the case of small-scale farmers, the digital transformation has the potential to empower them, but the absence of public policy may exclude them from the supply chain, or leave them in a new situation of economic dependency, in which they own their land, but rent their data and digital equipment from larger agrifood companies, or even tech giants [7]. This is clear also to technological innovators, which underline how digital infrastructure, e-services and high-performance connectivity are crucial to the competitiveness of rural areas [8], so guaranteeing that all actors can benefit from the investments being made in Europe in e.g. Galileo and Copernicus programmes. A key barrier is still the lack of proper Internet connectivity; according to some authors, 5G networks should be regarded as a real opportunity for improved connectivity in rural areas [8] [9], and the rapid evolution of aerospace networks is supposed to provide alternatives to infrastructure on the ground through e.g. mega-constellations of thousands of Low-Earth Orbit (LEO) / Very Low-Earth Orbit (VLEO) satellites for Internet connectivity (see the case of OneWeb, SpaceX, etc.), or for IoT connectivity (see the case of Eutelsat, ORBCOMM, etc.).

Looking at digital technologies in a systemic manner, it is important to highlight their increasing ability to support the digitisation process through the so-called *physical-digital-physical loop*, which is the possibility to sense the physical world to collect digital data. Those are analysed to extract meaningful information, which are used to act on the physical world, actually closing the loop. The fourth industrial revolution is based on the concept of *integration* [10], which can be horizontal (along a value chain), vertical (extensive automation in a specific activity of the value chain), and end-to-end (connecting the value chains). A key enabler of integration is the CPS conceptual model, i.e., systems embedding the aforementioned physical-digital-physical loop, and system of systems (SoSs), i.e., the integration of several CPSs. Smart connected things, as in the Internet of Things (IoT) paradigm[5], are designed to sense the physical world and/or to actuate actions in it, thus being at the physical-cyber border, a blurred line where the cyber and physical dimensions converge. In Figure 8, the relation between the physical and cyber dimensions is graphically shown, highlighting how CPSs can be used to describe this interaction; also, the role of Internet in connecting CPSs is shown, generating the so-called SoSs.

[5] It is argued whether CPSs and IoT are different paradigms or not [34].

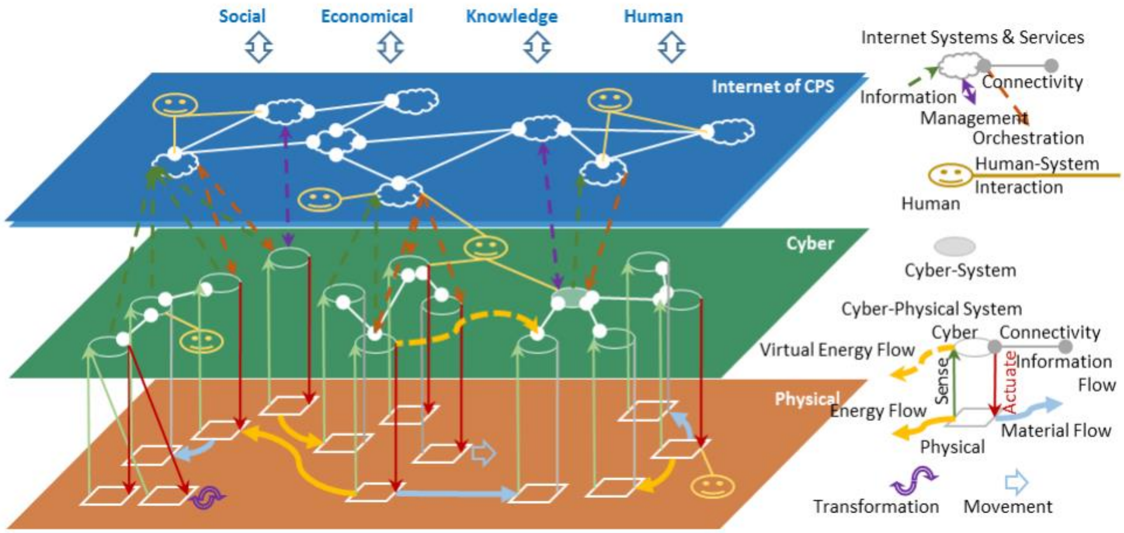
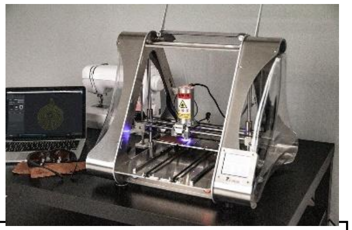


Figure 8: the physical world can be sensed, thus opening to the possibility to represent it in the cyber dimensions. The CPS paradigm has been introduced to model such a dynamic, which can be further expanded from a logical viewpoint to connect (integrate) different CPSs. Their use has social and economic effects (credits: CPS WG[6])

4.2. Potential digital game changers

Which digital technologies can be considered crucial to support such a process? At today, the so-called fourth industrial revolution -and related technologies- is driven by the use of technology to digitally transform existing practices in the industrial sector. The key disruptive concept is the CPS paradigm, which challenges both technology and business, but also law and ethics [11].

Within the Industry 4.0 paradigm, the first technology worth of mentioning is additive manufacturing, or **3D printing**, which refers to a production process involving the use of 3D printers, able to generate a 3D structure by deposition of thin layers. 3D digital models can be created via software, or can be generated using **3D scanning** techniques [12]: both techniques have large potential in several scenarios. Healthcare, manufacturing, and food production are considered to be the ones where 3D techniques can have large impacts [13], opening to local production of



3D PRINTING
3D printing can be used to print custom tools and spare / replacement parts. Open source and copyright-free solutions can reduce costs for e.g. small farms [36].

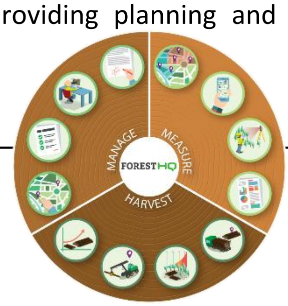
[6] Framework for Cyber-Physical Systems, Release 1.0, May 2016 - Cyber Physical Systems Public Working Group: https://s3.amazonaws.com/nist-sgcps/cpspwg/files/pwgglobal/CPS_PWG_Framework_for_Cyber_Physical_Systems_Release_1_0Final.pdf

potentially anything. 4D printing is considered the next frontier in this field [14], i.e., the possibility of printing objects able to respond to external stimuli, such as temperature, humidity, and so on, in order to mimic natural behaviours (leafs, for instance, or organs).

In [10], ten key technological paradigms are identified by the authors as crucial for Industry 4.0, encompassing broadband connectivity, Internet, IoT, cloud and fog (edge) computing, big data, AI, robotics, human-computer interaction, blockchain, as well as open source software. Those will change the current shape of the industrial sector and consequently of the cities we live in, generating a wave of changes through a cascade effect also outside urban areas. **Internet** is the universal communication service, able to connect any couple of devices equipped with a networking interface, thus representing the bus for all data exchanges; this is more evident when considering IoT, the paradigm under which all things transform into connected ones, reachable through Internet in an interoperable manner. **Broadband connectivity** represents the infrastructure providing Internet access, and advanced technologies, such as robotics, may partially or completely depend on it according to the considered scenario; low-delay and high-throughput networks, such as 4G/5G cellular networks or fibre lines in the case of fixed connectivity, are typically needed in the presence of complex technological systems and/or real-time scenarios, such as autonomous vehicles. We refer to traffic exchanged through machines as machine-to-machine (M2M) traffic. Complex technological systems require computing power, and **cloud computing** can be thought as the leasing of computing resources, simplifying operations and opening to the paradigm of *everything-as-a-service*; anyway, such a vision has had a significant role in the "data war", because sensible (personal, business) data may be stored on remote hosts and accessed by third parties with partial or full lack of control from the data originator. Cloud resources can be placed close to users instead of being in a remote location, and this is referred to as **edge computing**; communication delays are reduced in this case. Furthermore, edge computing has the potential to provide a stronger control on sensible data by data owners through the idea (yet to be fulfilled) of the so-called *Personal Spaces* [15].

CLOUD COMPUTING

Cloud computing has already shown great potential in several fields. For instance, Treemetrics (http://www.treemetrics.com) proposes a solution for forest management based on a cloud platform aggregating data from satellites and mobile devices, and providing planning and analytical tools to forest owners.



The concept of **Big Data** refers to the techniques to extract information from large datasets (collected, for instance, by sensing the physical world), which require specific solutions for data storing and analysis procedures because of their volume, variety, and velocity (3V); in time, veracity and value (5V) dimensions have been considered as equally necessary and important. Data storing typically occur in centralized databases, but such an idea is being confronted with the use of distributed solutions, such as **distributed ledgers**, in which every participant has a copy of the whole database in a peer-to-peer fashion. Blockchain [16] is a special case of distributed ledger, in which data are stored in encrypted blocks, and new blocks are added through a consensus mechanism (voting). Blockchain, useful in trust-dependent scenarios, can also provide 'smart contracts' [16], which can be described as self-executing functionalities residing within the blockchain to facilitate, verify, or enforce the negotiation or performance of a contract.

DIGITAL LEDGERS (BLOCKCHAIN)

Blockchain-based applications and services are currently entering the market, and are expected to boost transparency and trust all along e.g. the food chain, from production to consumption. For instance, bext360.com provides a blockchain-based platform for traceability and sustainability for products like coffee, cotton, palm oil, and other ones.

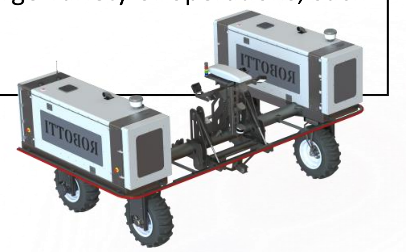
Online social networks should be considered as one of the first sources of big data, networks in which human relationships are conveyed through digital systems (see the case of Facebook or Twitter). Big Data make large use of **narrow AI** techniques to extract information from large datasets; a crucial aspect, in this regard, is the quality of analysed data (data quality over data quantity) in order to avoid biased outputs. The AI umbrella covers topics such as Machine Vision, Natural Language Processing, and **advanced robotics**. The latter are able to carry out actions in an automatic manner, exploiting the ability of sensing the environment, taking decisions, and actuate them. Robots can be very complex systems, and autonomous vehicles are an example of advanced robotics that can be often found in our newspapers; during the COVID19 pandemic, the use of medical robots to substitute or to complement human operators in hospitals has been considered, and actually tested in some contexts[7]. In order to properly move and operate in a given environment, a robot needs contextual information, which can be obtained through **sensing**, occurring on-board the robot or in the form of data provided by other sources. Those sources can be local, i.e., in the immediate proximity of the phenomenon under consideration (e.g., sensor nodes in the ground for agricultural uses) or remote ones, such as those on-board satellites or UAVs. When

[7] https://www.eu-robotics.net/eurobotics/newsroom/press/robots-against-covid-19.html

those sensor nodes are accessible through Internet, possibly in an interoperable way, IoT systems appears, or Internet of Remote Things (IoRT) when considering satellites or other aerospace solutions.

ROBOTICS

The AgroIntelli Robotti is a completely autonomous agricultural robot that can be used in farming operations. It can equip different implements and perform and large variety of operations, such as harrowing, sowing, mechanical weeding, and spraying.



Collecting data to be fed to data analysis procedures is a process that can support a plethora of different applications used by human operators. This leads us to the paradigm of **human-computer interaction** (HCI), a process seeing the transfer of information from humans to computers (and vice versa): the transferred information can be used in different ways according to the level of autonomy of the system, for instance in the case of autonomous systems and robotics. Nowadays, HCI can benefit from the introduction of extended reality (XR) techniques, such as **Virtual Reality** (VR) or **Augmented Reality** (AR), more sophisticated ways to interact with a machine than just using a keyboard, a mouse, or even a touchscreen; smartphone-enabled AR is already entering into the market[8]. Speech recognition, empowered by NLP techniques, as well as wearables, are revolutionizing the way in which we interact with machines. In Table 8, the digital technologies described above and listed in the online survey are presented in a concise manner. They are grouped into: (i) technologies that can be considered at the cyber-physical border, which convert physical states into digital data and vice versa; and (ii) enabling technologies, in the sense of fully digital technologies purely exchanging digital data (thus there is not a physical-digital or digital-physical conversion, strictly speaking), providing from basic to advanced functionalities for: data transmission, data storing, data analysis, and data visualisation.

[8] For example, the so-called Live View in the Google Maps mobile application is already available: https://www.blog.google/products/maps/take-your-next-destination-google-maps/

Table 8: selected digital technologies[9] with the potential to change the game.

DIGITAL TECHNOLO-GIES	SHORT DESCRIPTION	physical-digital-physical (D) and enabling (E) technologies		EXAMPLES		
		D	*E*	*agriculture*	*forestry*	*rural areas*
social media and social network **web-based technology**	web-based tools and social tools for interaction or access to services	physical interactions into digital ones		access to online services and connection with the market	access to online services and connection with the market	access to information, knowledge exchange
cloud / edge computing	storage and computing resources available remotely (cloud) or in close proximity (edge)		enabling technologies to deploy and use digital services	provision of remotely deployed services; better support to real-time sensitive scenarios	provision of remotely deployed services	provision of remotely deployed services to be accessed through web or mobile apps
local and remote sensing	sensing capabilities available remotely (aerospace solutions) or in close proximity (in the field)	joint use of hardware and software to gather digital data from the physical world		advanced monitoring capabilities applied to crops and livestock to increase the production, assess health status, and other	advanced monitoring capabilities applied to trees to monitor physiological parameters, growth, and other	wearables have a large potential in e-health scenarios; sensing can prevent and reduce the impact of natural hazards
distributed ledger (DL)	distributed and replicated database without central authority. If data are stored in		enabling technology to store, share, and synchronize transactions	traceability and smart contracts; insurances	traceability and smart contracts; insurances	trust-dependant services and applications

[9] For the sake of simplicity, only the label 'digital technologies' is used here; but, as anticipated, the label 'digital paradigms' should be used as well.

	immutable blocks cryptographically linked, the DL is known as *blockchain*	among participants			(digital identity, education, health, insurance, energy) [17]
data analytics	techniques to extract information from data. If the 3Vs are met, Big Data techniques should be used	enabling technology to extract information from data sources	information from sensed data to support decision-making	information from sensed data to support decision-making	supporting decision-making at different levels in communities
augmented reality / virtual reality	extended reality (XR) techniques for human-machine interaction (often through wearables)	enabling technologies to visualise digital information	educational purposes; easily accessible visual information	educational purposes; easily accessible visual information	educational purposes; easily accessible visual information
3D printing	production of 3D objects through a printing-like process	digital information into physical objects	design and printing of custom parts and small equipment	design and printing of custom parts and small equipment	empowered local production
artificial intelligence (narrow AI)	umbrella term for machine learning and machine vision techniques, NLP, robotic automation	enabling technology assisting in process automatization	decision support and management system; planning and simulation	decision support and management system; planning and simulation	decision support and management system; planning and simulation
autonomous systems and robotics	integrated systems using several technologies altogether to achieve simple to complex (semi-) autonomous behaviours	transformation of digital information into context- and location-aware actions towards a given purpose	semi and full autonomous systems for agricultural practices [18] [19]	semi and full autonomous systems for forestry (cutting, loading, harvesting, yarding)	health (quality of life and independent living), mobility

connectivity	infrastructure providing Internet connectivity	enabling technology to access and exchange digital data	connectivity for M2M and H2M traffic in both local and non-local settings	connectivity for M2M and H2M traffic in both local and non-local settings	connectivity for M2M and H2M traffic in both local and non-local settings

4.3. A map of plausible social, economic, and environmental impacts

This section presents a guide map of socio-economic impacts of the digitalisation process, as well as environmental ones. It identifies some relevant domains and areas involved in the wider changes produced by digital technologies that represent (potential) digital game changers.

Based on an extensive analysis of the field literature (both white and grey) regarding digital transformation in agriculture, forestry and rural areas, socio-economic impacts linked with the use of digital technologies have been identified. In DESIRA CAF, socio-economic impact has been defined as: the opportunities and threats of digitisation which has "deep repercussions on people's lives, and generates losers (who are marginalized by the changes), and opponents (who resists and elaborate alternative rules of the game), as well as winners (who benefit from the change)".

From the literature review, it emerges that SDGs are the primary references for both institutional reports and academic literature when dealing with impacts generated by digitalisation. In the literature, most works refer in a very different way to domains and impacts of digitalisation. In facts, there are documents, mostly grey literature ones, issued by international institutions such as FAO, OECD or the European Union that after the analysis of the digitalisation mainly focus on the identification of possible best policies needed in order to implement digital technologies to maximise positive impacts while containing or eliminating negative ones.

Concerning the literature published by or supported by political institutions, like the EU, it emerged that there is a specific attention on social impacts and ethical implications of digital innovation in agriculture [20]. Despite these documents report areas of impacts (like farming activities, the ecosystem, etc.) and implications, they particularly focus on governance and protection of 'sensitive data' (or data ownership), the necessity to establish protocols and norms for a safe and unharmful use of data collected by private companies or public agencies. On the contrary, institutions like the OECD and FAO report effects of digitalisation in relation to natural environment (decline in greenhouse gas emissions, water and fertilizer reduction, etc.), economy (productive process, labour skills, commerce issues, etc.), food security and gender equity [21]. In these cases, those documents describe the potential effects of specific digital tools and more precisely, how these technologies can prevent (or help to face) a combination of risks caused by macro-trends like population growth and climate change. At the same time, it is stressed how digitalisation could also produce negative outcome due to the unequal access to digital technologies (e.g., gender or age gap) or worsening of working conditions (work intensification, technological unemployment, etc.) and governance related issues (data management and control, process decision, etc.) [22]. The literature results to be fragmented in this regard. It inquires both theoretical and methodological aspects related to the digital innovation in agriculture and rural life (what are the challenges of digitisation in agriculture? How to measure this phenomenon, etc.) [23] [24] [25] [26] [27] [28].

In particular, the above mentioned studies reflect on the social (or socioeconomic) transformations generated by the digital revolution and on the raised implications (ethical aspects, transformations of rural societies, cognitive change). In these works, the indications of impacts are often less precise, since they are interested in describing general situation, however, these studies are more attentive to the unexpected and more problematic consequences of digitisation. This work investigates impacts on a wide range of domains, which for this reason are reduced to macro-domains (environment, social and economic) and macro-trends.

A second set of investigation referring to academic works refers to papers related to research results on case-studies or to effects of policies associated to specific examples (rural regions, specific merchandise sector, etc.) [29] [30] [31] [32] [33]. About the second aspect, it offers indications for policies and practical suggestion to adopt digital solutions. The main area of impact refers to production, commercialisation, efficiency of economic process in rural areas, etc.

As it emerges from this literature review, several areas of impact and many possible effects or outcomes can be indicated in relation to digital transformation of agriculture and rural areas. To reduce the complexity of these reflections, in what follows, several typology of impacts are provided as emerging from the literature, in order to support the first steps of analysis in Living Labs. The aim is to highlight plausible effects of digitalisation, whose positive or negative outcomes must be evaluated according to the considered context, as for instance a Living Lab. Data have been classified and clustered based on the principle of **prevalence**: technology has a greater effect in a certain socio-economic *domain*, it affects a specific dimension or *area of impact*, and it produces a certain *outcome*. Responses collected through the online survey have been used to test and refine the proposed classification. The result of this process is can be visualized in Figure 9 and then, in a tabular form, in Table 9.

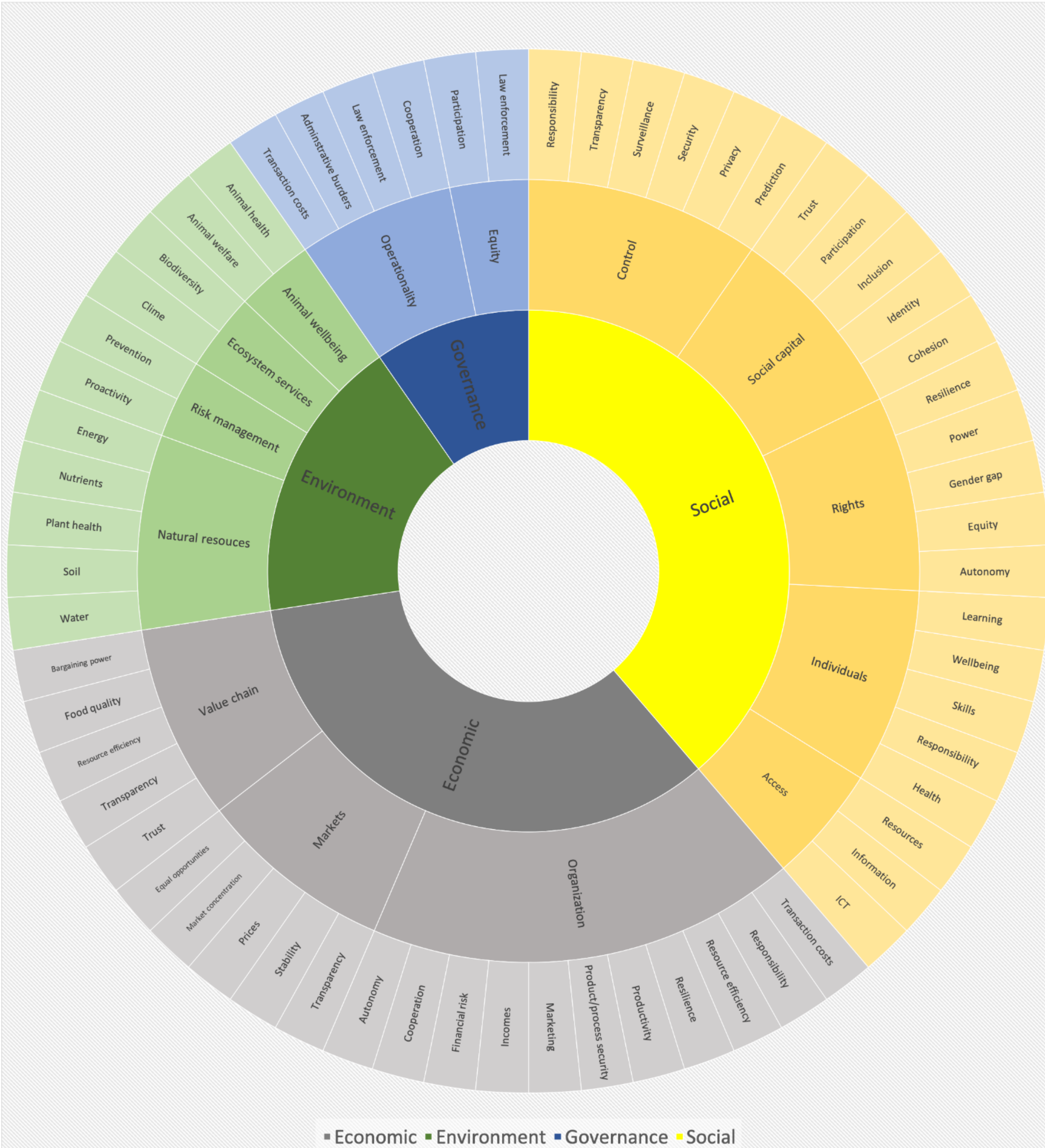


Figure 9: Domains and areas of socio-economic impacts.

The qualitative analysis should be considered as an effort to support Living Labs during their activities; the aim is in providing a guiding approach to be adopted for the identification of possible outcomes when using a specific digital tool or a combination of digital technologies.

The map in Table 9 is composed of three layers:

1. **Domain:** it refers to the macro-dimensions involved in the digitalisation process as emerging from the literature review. In the literature, the *governance* domain is considered part of the *social* domain; instead, in the proposed map, it represents a domain per se to emphasize its policy and administrative macro-dimensions;
2. **Area of impact**: sub-dimensions or specific areas within each domain, as emerging from the literature review. It should not be considered as exhaustive, yet it identifies several areas of interest to provide a detailed impact map;
3. **Outcome**: for each area of impact, the main outcomes of digital technologies have been identified and selected. For example, in the economic domain, the digitalisation has an impact on companies (organizations) determining a higher decision-making autonomy in the production process as an outcome; in the environmental domain, the area of impact *ecosystem services* has as outcome the capability of reducing pollution emissions, thus having an impact on climate, etc.

Table 9: socio-economic impacts: domains, areas of impacts, and outcomes.

DOMAIN	AREA OF IMPACT	OUTCOME IN		
Economic	*Organizations*	Autonomy	Cooperation	Financial risk
		Incomes	Marketing	Product/process security
		Productivity	Resilience	Resource efficiency
		Responsibility	Transaction costs	
	Value chain	Bargaining power	Food quality	Resource efficiency
		Transparency	Trust	
	Markets	Equal opportunities	Market concentration	Prices
		Stability	Transparency	
Environment	*Animal wellbeing*	Animal health	Animal welfare	
	Ecosystem services	Biodiversity	Clime	
	Natural resources	Energy	Nutrients	Plant health
		Soil	Water	
	Risk management	Prevention	Proactivity	
Governance	*Operationality*	Cooperation	Law enforcement	Administrative burdens
		Transaction costs		
	Equity	Law enforcement	Participation	
Social	*Individuals*	Health	Responsibility	Skills
		Wellbeing	Learning	
	Access	ICT	Information	Resources
	Rights	Autonomy	Equity	Gender gap
		Power	Resilience	
	Social capital	Cohesion	Identity	Inclusion
		Participation	Trust	
	Control	Prediction	Privacy	Security
		Surveillance	Transparency	Responsibility

The next step is to link together the impacts in Table 9 with the potential digital game changers in Table 8. The result is presented in Table 10, linking specific outcomes to the selected DGCs. As already said, a literature review has been performed to provide the results presented in Table 10, and then the data collected through the online survey have been used to test and refine those qualitative results.

Table 10: socio-economic impacts of the selected digital technologies and digital paradigms.

			POTENTIAL DIGITAL GAME CHANGERS									
DOMAIN	**AREA OF IMPACT**	**OUTCOME IN**	*Social Media*	*Cloud*	*Local and remote sensing*	*Distributed ledger*	*Data and analytics*	*Augmented reality*	*3D printing*	*Artificial intelligence*	*Autono-mous systems*	*Connecti-vity*
Economic	Organization	Autonomy	X	x	x	x	x	x	x	x	x	X
		Cooperation	X	x		x					x	x
		Financial risk	X		x	x	x			x	x	
		Incomes			x	x	x	x	x	x	x	x
		Marketing	X		x		x	x		x		x
		Product/process security	X		x		x			x	x	x
		Productivity		x	x		x	x		x	x	x
		Resilience	X	x	x		x		x		x	x
		Resource efficiency			x		x			x	x	x
		Responsibility	X			x	x					
		Transaction costs	X		x	x	x			x		x
	Value chain	Bargaining power		x	x		x			x	x	x
		Food quality	X		x	x	x			x	x	x
		Resource efficiency					x			x		x
		Transparency			x		x			x		x
		Trust	X		x	x						x
	Markets	Equal opportunities			x	x	x			x	x	
		Market concentration			x		x			x		
		Prices			x		x			x	x	x
		Stability	X	x	x	x						x
		Transparency	X		x	x						x

			POTENTIAL DIGITAL GAME CHANGERS									
DOMAIN	**AREA OF IMPACT**	**OUTCOME IN**	*Social Media*	*Cloud*	*Local and remote sensing*	*Distributed ledger*	*Data and analytics*	*Augmented reality*	*3D printing*	*Artificial intelligence*	*Autonomous systems*	*Connectivity*
Environment	Animal wellbeing	Animal health			x	x	x			x	x	x
		Animal welfare			x	x	x			x	x	x
	Ecosystem services	Biodiversity	x		x		x	x		x		x
		Clime	x		x	x	x			x	x	x
	Natural resources	Energy			x		x			x	x	x
		Nutrients			x		x			x	x	x
		Plant health			x		x	x		x	x	
		Soil			x		x			x	x	
		Water		x	x		x			x	x	
	Risk management	Prevention	x		x	x	x			x		x
		Proactivity										
Governance	Operationality	Cooperation	x	x		x					x	x
		Law enforcement	x			x						x
		Administrative burdens	x		x	x	x			x		x
		Transaction costs	x		x	x	x			x		x
	Equity	Law enforcement	x			x						x
		Participation	x			x					x	x

DOMAIN	AREA OF IMPACT	OUTCOME IN	POTENTIAL DIGITAL GAME CHANGERS									
			Social Media	*Cloud*	*Local and remote sensing*	*Distributed ledger*	*Data and analytics*	*Augmented reality*	*3D printing*	*Artificial intelligence*	*Autonomous systems*	*Connectivity*
Social	Individuals	Health	x		x		x			x		
		Responsibility			x	x	x			x	x	x
		Skills	x	x		x	x	x	x			x
		Wellbeing	x				x			x	x	x
		Learning	x	x	x	x		x	x		x	x
	Access	ICT	x	x	x	x		x	x			x
		Information	x		x	x						x
		Resources		x	x						x	x
	Rights	Autonomy	x	x	x	x		x	x	x	x	x
		Equity	x		x	x	x			x	x	x
		Gender gap	x		x		x			x	x	x
		Power	x		x	x	x			x	x	x
		Resilience	x	x	x		x		x		x	x
	Social capital	Cohesion	x			x				x		x
		Identity	x				x	x				x
		Inclusion	x	x		x		x				x
		Participation	x	x		x	x	x	x			x
		Trust	x		x	x						x
	Control	Prediction			x		x	x		x		
		Privacy	x		x	x	x			x		x

Security	x		x		x			x	x	x
Surveillance	x		x		x	x		x		x
Transparency	x		x	x				x	x	x
Responsibility	x	x	x	x		x	x	x	x	x

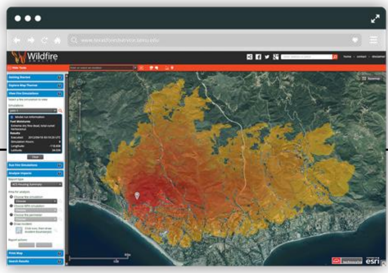
5. How to use the toolkit

As stated in the summary, the toolkit can provide support to the workshops performed in the 20 DESIRA Living Labs. Each Living Labs is characterized by a focal question, a 'digitisation-related question on which Living Labs are constituted', according to the project proposal; for instance, 'how to reduce the risk of forest fires?' (page 11 of DESIRA proposal).

The focal question conceptually embodies one or more application scenarios, as the ones derived in this document from the collected digital tools. For instance, and referring to the example focal question above, the application scenarios closely related to it are those labelled as 'wildfires' in Table 5. By using the already available dataset collected through the internal survey - which feeds the Knowledge Base Tool (Task 5.3) that will provide an interface to browse, add, and edit items to the dataset - Living Labs can e.g. look for digital tools whose function is centered around their focal question.

Example of a digital tool collected through the survey for wildfires prevention
WILDFIRE ANALYST (https://tecnosylva.es)

It provides real-time analysis and a simulation engine to track the evolution of wildfires to support decision-making and firefighting strategies. It is based on the use of a web platform collecting data from remote sensing sources (e.g. satellites) and offering advanced data analytics tools.



In this way, participants to the workshop may discuss existing or under development digital tools that can support the digitisation process around their focal question. Each digital tool in the Inventory is described in terms of used digital technologies, especially those selected as digital game changers in this report. This provides the opportunity to also discuss the role of specific digital technologies, and to consider plausible impacts due to their use, according to the map provided in Section 4.3. For instance, according to Table 10, remote sensing and data analytics (cited in the example box above) have impacts in the environmental domain. In more details, risk management is probably of interest in the case of wildfires, thus further specializing the plausible areas of impact.

Finally, the toolkit provides the conceptual model of CPS, which in DESIRA CAF (see Sections 2.4 and 2.5 of the CAF) has been extended to also consider the social component (SCP system): through it, the Living Labs can discuss how to move from the as-is system to the desired to-be system (see Figure 10) thanks to the use of digital technologies in a systemic manner (i.e., according to the CPS model).

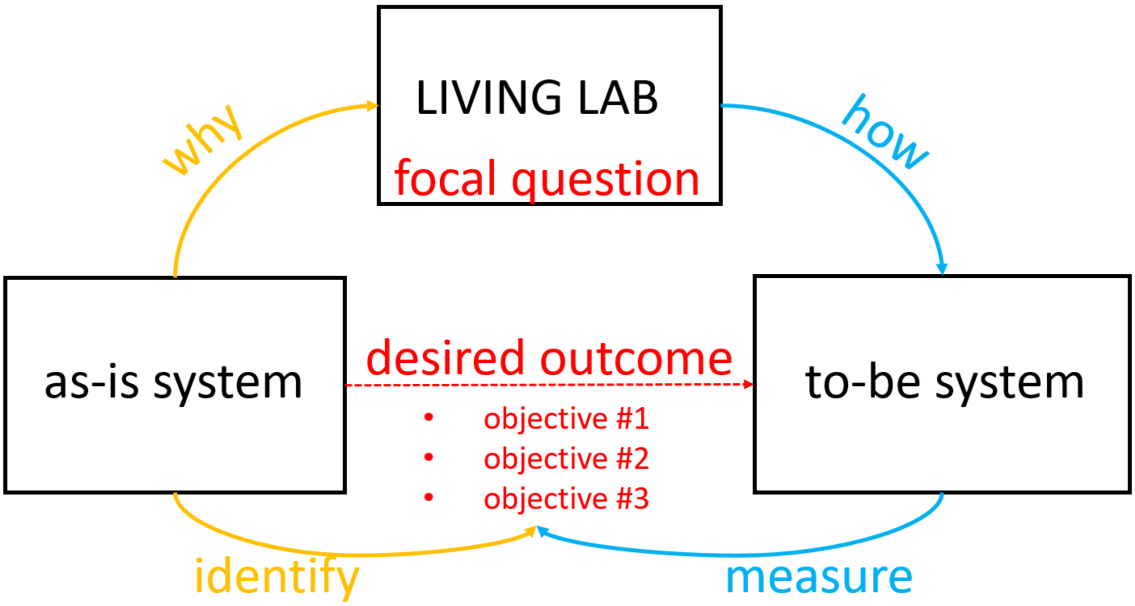


Figure 10: process of discussion within the Living Labs to understand the role that digital game changers can play in their transformation.

5.1. Example of analysis of digital tools

In the following, three examples are presented: the first one, namely GAIA, falls within the agricultural domain; the second one, namely La Era Rural, within rural areas; and the third one, namely TRACE, within forestry. Those three digital tools have been collected through the internal survey, and the analysis presented in what follows in tabular form has the objective of providing a compact way to describe digital tools, exploiting the selected DGCs, by highlighting the function of the tool and plausible areas of impacts. The same methodology has been used to compile the practice abstracts in the report D1.4 of the DESIRA project.

Each table is composed as follows: name of the tool, URL, and short description of the function. Furthermore, the used core digital technologies are listed, and then the tool is linked with the three proposed classifications: application scenario, cyber-physical system, and qualitative socio-economic impact. The penultimate row shows what is 'connected / digitalised' through the use of the digital tool, which qualitatively defines the physical-digital connection, according to the following options:

- connection among people (e.g. social media, actions to increase participation)
- connection among people and private services (e.g. marketplace, tourism)
- connection among people and public services (e.g. e-government, e-health)
- connection among animals and ICT systems (e.g. tracking collar)

- connection among plants and ICT systems (e.g. in-field sensors, satellite imagery)
- connection among physical things and data (e.g. traceability, tracking systems)
- connection among services (e.g. smart grids for electricity)

Finally, the last row reports the keywords, as chosen by the respondent while compiling the online survey, to describe the tool.

GAIA				AGRICULTURE
URL: projectgaia.ai		Better disease prevention and management, assessment of crop-health, better market analysis		
digital technologies		application scenario	crops, management, data	
social media	Web	cyber-physical system	sensing, networking, computation, application	
local sensing	remote sensing	socio-economic impact	*economic* (organization autonomy, financial risk, incomes, productivity; value chain food quality and transparency) *environmental* (natural resources plant health and soil) *social* (individual health and skills; control prediction)	
Digitalizing		plants, private services		
Keywords		*crop, management, monitoring*		

La Era Rural			RURAL AREAS
URL: laerarural.es	Help young people to develop their own businesses in small villages of rural areas		
digital technologies	application scenario	knowledge exchange, local economy, smart villages	
	cyber-physical system	computation and application	
social media; Web	socio-economic impact	*economic* (risk management prevention) *social* (individual skills, access ITC, rights autonomy and power) *governance* (operationally administrative burdens)	
Digitalizing	people's interactions, private services		
Keywords	*rural development, youth, rural business*		

<table>
<tr><th colspan="3">TRACE</th><td rowspan="7">FORESTRY</td></tr>
<tr><td>URL: https://www.pefc.org/what-we-do/our-collective-impact/our-projects/fostering-tree-monitoring-technologies-to-support-climate-adaptation-and-mitigation</td><td colspan="2">all around monitory of physiological parameters of trees</td></tr>
<tr><td rowspan="3">digital technologies

web cloud

local sensing</td><td>application scenario</td><td>wood parameters, management</td></tr>
<tr><td>cyber-physical system</td><td>sensing, networking, computation, application</td></tr>
<tr><td>socio-economic impact</td><td>economic (organization autonomy, financial risk, resilience; value chain transparency)

environmental (ecosystem services biodiversity and plant health)

social (access information)</td></tr>
<tr><td>Digitalizing</td><td colspan="2">plants, things</td></tr>
<tr><td>Keywords</td><td colspan="2">sensors, eco-physiological parameters, trees, health</td></tr>
</table>

Annex I - Structure of responses collected through the survey: a full example (GAIA)

Survey response	
Name / identifier of the tool you are describing	GAIA
Can you provide a link to the main website or to a site containing useful information?	Yes
Link to the main web page	https://projectgaia.ai
To which domains of the project the application scenario is related? [rural areas]	No
To which domains of the project the application scenario is related? [forestry]	No
To which domains of the project the application scenario is related? [agriculture]	Yes
What is the intended outcome of the tool in this application scenario?	Better disease prevention and management, assessment of crop-health, better market analysis
How is this outcome achieved? By means of which core digital technology?	Inclusion of advanced analytics and machine learning in technologies that enable Cloud-based data sharing, automated crop-mapping, crop-health monitoring
Which digital technologies are used?	Ground Penetrating Radars (GPR), Multispectral Remote Sensing
Countries where the tool is used. [Austria]	No
Countries where the tool is used. [Belgium]	No
Countries where the tool is used. [Bulgaria]	No
Countries where the tool is used. [Croatia]	No
Countries where the tool is used. [Republic of Cyprus]	No
Countries where the tool is used. [Czech Republic]	No
Countries where the tool is used. [Denmark]	No
Countries where the tool is used. [Estonia]	No

Countries where the tool is used. [Finland]	No
Countries where the tool is used. [France]	No
Countries where the tool is used. [Germany]	No
Countries where the tool is used. [Greece]	No
Countries where the tool is used. [Hungary]	No
Countries where the tool is used. [Ireland]	No
Countries where the tool is used. [Italy]	No
Countries where the tool is used. [Latvia]	No
Countries where the tool is used. [Lithuania]	No
Countries where the tool is used. [Luxembourg]	No
Countries where the tool is used. [Malta]	No
Countries where the tool is used. [Netherlands]	No
Countries where the tool is used. [Poland]	No
Countries where the tool is used. [Portugal]	No
Countries where the tool is used. [Romania]	No
Countries where the tool is used. [Slovakia]	No
Countries where the tool is used. [Slovenia]	No
Countries where the tool is used. [Spain]	No
Countries where the tool is used. [Sweden]	No
Countries where the tool is used. [UK]	Yes
Countries where the tool is used. [all Europe]	No
Countries where the tool is used. [global]	No
Countries where the tool is used. [Other]	New Zealand
Who uses the tool?	Brown Family Wines, De Bartolli Wines
Maturity level of the tool [maturity level]	actual system in use in real environment
Insert 3 to 5 keywords strictly related to the application scenario. [1st keyword]	crop

Insert 3 to 5 keywords strictly related to the application scenario. [2nd keyword]	management
Insert 3 to 5 keywords strictly related to the application scenario. [3rd keyword]	monitoring
Insert 3 to 5 keywords strictly related to the application scenario. [4th keyword]	
Insert 3 to 5 keywords strictly related to the application scenario. [5th keyword]	
To what extent does the tool replace or reduce human work?	no reduction or replacement of human work
To what extent does the tool replace or reduce human work? [Other]	
Does the tool require Internet connection to work?	Yes
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among people (e.g. social media, actions to increase participation)]	No
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among people and private services (e.g. marketplace, tourism)]	No
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity?	No

[connection among people and public services (e.g. e-government, e-health)]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among animals and ICT systems (e.g. tracking collar)]	No
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among plants and ICT systems (e.g. in-field sensors, satellite imagery)]	Yes
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	crop fields connected to satellite
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among physical things and data (e.g. traceability, tracking systems)]	No
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [connection among services (e.g. smart grids for electricity)]	No

What is "connected" (digitalised) in the application scenario? In other words, which real (physical) entity is connected to which digital (cyber) entity? [Comment]	
Select the digital technologies used in this application scenario. [social media and social networks]	No
Select the digital technologies used in this application scenario. [web-based technology]	No
Select the digital technologies used in this application scenario. [cloud/edge computing]	No
Select the digital technologies used in this application scenario. [local (close) sensing [sensor networks, ...]]	No
Select the digital technologies used in this application scenario. [remote (from distance) sensing [satellite imagery, drone imagery, ...]]	Yes
Select the digital technologies used in this application scenario. [digital ledgers [blockchain, ...]]	No
Select the digital technologies used in this application scenario. [data analytics]	No
Select the digital technologies used in this application scenario. [artificial intelligence [learning / cognitive techniques]]	Yes
Select the digital technologies used in this application scenario. [augmented reality / virtual reality]	No
Select the digital technologies used in this application scenario. [3D printing]	No
Select the digital technologies used in this application scenario. [autonomous systems and robotics]	No
Select the digital technologies used in this application scenario. [Other]	

Does the tool collect any data from final users?	No
Collected data are sensitive user / business data?	N/A
Provide information, as detailed as possible, on collected sensitive data: type, manner of collection, frequency of collection, and other you may find relevant.	
Describe what kind of interactions are designed among people and the tool in this application scenario. [almost no interactions are designed (i.e., users can only receive information or suggestions)]	Yes
Describe what kind of interactions are designed among people and the tool in this application scenario. [Comment]	reduce variability to crop, optimal resource deployment, receive information for strategic management decisions
Describe what kind of interactions are designed among people and the tool in this application scenario. [the tool allows knowledge exchange (i.e., experts can collaborate with farmers to develop new solutions)]	No
Describe what kind of interactions are designed among people and the tool in this application scenario. [Comment]	
Describe what kind of interactions are designed among people and the tool in this application scenario. [the tool allows users to participate by creating public data or information (i.e., they can inform about the condition of forestry paths)]	No
Describe what kind of interactions are designed among people and the tool in this application scenario. [Comment]	
Describe what kind of interactions are designed among people and the tool in this application scenario. [the tool allows learning activities (i.e., through the tool, farmers can increase their professional knowledge)]	No

Describe what kind of interactions are designed among people and the tool in this application scenario. [Comment]	
Describe what kind of interactions are designed among people and the tool in this application scenario. [Other]	
Describe what kind of interactions are designed among people and the tool in this application scenario. [Other comment]	
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Economic conditions (i.e., income, production costs, etc.)]	+4
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Food and nutrition security (i.e, quality and quantity of food production, food storage)]	+4
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Public health (i.e., new services or management of health services, etc.)]	+5
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users.	0

[Gender gap (i.e., women participate in the labour market, woman use of ICT, etc.)]	
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Education (i.e., e-learning, professional skills, vocational training, etc.)]	0
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Water and soil (i.e., resources use, contamination of them, etc.)]	+4
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Sea and land resources (i.e., resources use, contamination of them, etc)]	+3
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Energy (i.e., energy savings / efficiency, renewables, etc.)]	+2
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users.	0

[Work (i.e, working conditions, work efficiency, safety at the workplace, etc.)]	
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Infrastructures (i.e., digital networks and infrastructures, connectivity, etc.)]	+5
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Services (i.e, widens/improves commercial services, service for the supply and demand chain, etc.]	+2
According to a negative-positive scale (from -5 to +5, i.e., from 'very negative' to 'very positive' with 0 translating into 'no effect'), please provide a qualitative assessment on the tool impacts in the following aspects (at least 5). More specifically, score direct and indirect effects on final users. [Consumption (i.e., waste production, waste recycling, conscious consumption, etc.)]	+3
Briefly explain your assessments in the previous question.	
Based on your previous assessment, to what extent do the following aspects represent ethical concerns related to the application scenario? Focus on final users. scale: 0 (no concerns) - 5 (very strong concerns). [privacy / safety]	1
Based on your previous assessment, to what extent do the following aspects represent ethical concerns related to the application scenario? Focus on final users. scale: 0 (no concerns) - 5 (very strong concerns). [autonomy]	0

Based on your previous assessment, to what extent do the following aspects represent ethical concerns related to the application scenario? Focus on final users. scale: 0 (no concerns) - 5 (very strong concerns). [human relations]	0
Briefly explain your evaluations in the previous question.	
If there are other important aspects not being covered by previous questions, describe them here.	

Bibliography

[1] A. Przegalinska, «State of the art and future of artificial intelligence,» EU Policy Department for Economic, Scientific and Quality of Life Policies Directorate, 2019.

[2] R. Baheti e H. Gill, «The impact of control technology,» *Cyber-physical systems,* vol. 12, n. 1, pp. 161-166, 2011.

[3] N. M. Trendov, S. Varas e M. Zenf, «Digital Technologies in Agriculture and Rural Areas: Status Report,» *Food and Agricultural Organization of the United Nations,* 2019.

[4] Global Food Security, «Game-changing technologies in agriculture».

[5] FAO, «REGIONAL CONFERENCE FOR ASIA AND THE PACIFIC,» 2020.

[6] L. Klerkx e D. Rose, «Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways?,» *Global Food Security,* 2020.

[7] A. Renda, N. Reynolds, M. Laurer e G. Cohen, «Digitising Agrifood: Pathways and Challenges,» Centre for European Policy Studies, 2019.

[8] AIOTI, «AIOTI WG06 Report on IoT and digital technologies for monitoring of the new CAP,» 2019.

[9] L. Chiaraviglio, N. Blefari-Melazzi, W. Liu, J. Gutiérrez, J. Van De Beek, R. Birke, L. Chen, F. Idzikowski, D. Kilper, P. Monti e A. Bagula, «Bringing 5G into rural and low-income areas: Is it feasible?,» *IEEE Communications Standards Magazine,* 2017.

[10] G. Aceto, V. Persico e A. Pescapé, «A Survey on Information and Communication Technologies for Industry 4.0: State-of-the-Art, Taxonomies, Perspectives, and Challenges,» *IEEE Communications Surveys & Tutorials,* 2019.

[11] D. Serpanos, «The cyber-physical systems revolution,» *IEEE Computer,* vol. 51, n. 3, pp. 70-73, 2018.

[12] L. Zhang, H. Dong e A. E. Saddik, «From 3D sensing to printing: A survey,» *ACM Transactions on Multimedia Computing, Communications, and Applications,* pp. 1-23, 2015.

[13] L. Bechthold, V. Fischer, A. Hainzlmaier, D. Hugenroth, L. Ivanova, K. Kroth, B. Römer, E. Sikorska e V. Sitzmann, «3D printing: A qualitative assessment of applications, recent trends and the technology's future potential,» 2015.

[14] F. Momeni, L. Xun e J. N., «A review of 4D printing,» *Materials & design,* vol. 122, pp. 42-79, 2017.

[15] P. Garcia Lopez, A. Montresor, D. Epema, A. Datta, T. Higashino, A. Iamnitchi, M. Barcellos, P. Felber e E. Riviere, «Edge-centric computing: Vision and challenges,» *ACM SIGCOMM Computer Communication Review,* 2015.

[16] K. Christidis e M. Devetsikiotis, «Blockchains and Smart Contracts for the Internet of Things,» *IEEE Access,* pp. 2292-2303, 2016.

[17] UN FAO; ITU, «E-agriculture in action: Blockchain for agriculture - opportunities and challenges,» 2018.

[18] F. S., M. N., M. I., R. E., S. C.H. e E. Pekkeriet, «Agricultural Robotics for Field Operations,» *MDPI Sensors,* vol. 20, n. 9, 2020.

[19] T. Duckett, S. Pearson, S. Blackmore, B. Grieve, P. Wilson, H. Gill, A. Hunter e I. Georgilas, «Agricultural Robotics: The Future of Robotic Agriculture,» UK-RAS Network, 2018.

[20] I. Ferreira, M. Kirova, F. Montanari, C. Montfort, J. Moroni, R. Neirynck, A. Pesce Arcos Pujades, E. Lopez Montesinos, E. Pelayo, J. Diogo Albuquerque, J. Eldridge e D. Traon, «Declaration. A smart and sustainable digital future for European agriculture and rural areas,» EPRS, European Parliamentary Research Service; The High-Level Expert Group. 2019. The impact of digital transformation one EU labour market. Luxembourg. Publications Office of the European Union., 2019.

[21] S. Dury, P. Bendjebbar, E. Hainzelin, T. Giordano e N. Bricas, «Food Systems at risk: new trends and challenges,» CIRAD, 2019.

[22] A. Zara, F. Simonelli, K. Lenaerts, S. Baiocco, S. Ben, W. Li, W. Echikson e Z. Kilhoffer, «Sustainability in the Age of Platforms,» CEPS, 2019.

[23] K. Bronson, «Digitization and Big Data in Food Security and Sustainability,» *Encyclopedia of Food Security and Sustainability,* vol. 2, pp. 582-587, 2019.

[24] L. Floridi, J. Cowls, B. M., R. Chatila, P. Chazerand, V. Dignum, C. Luetge, R. Madelin, U. Pagallo, F. Rossi, B. Schafer, P. Valcke e E. Vayena, «AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations,» *Minds and Machines,* vol. 28, pp. 689-707, 2018.

[25] L. Klerkx, E. Jakku e P. Labarthe, «A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda,» *NJAS - Wageningen Journal of Life Sciences,* Vol. %1 di %290-91, 2019.

[26] J. Raisanen e T. Tuovinen, «Digital innovations in rural micro-enterprises,» *Journal of Rural Studies,* vol. 73, pp. 56-67, 2020.

[27] S. van der Burg, M. Bogaardt e S. Wolfert, «Ethics of smart farming: Current questions and directions for responsible innovation towards the future,» *NJAS - Wageningen Journal of Life Sciences,* Vol. %1 di %290-91, 2019.

[28] S. Wolfert, L. Ge, C. Verdouw e M. Bogaardt, «Big Data in Smart Farming – A review,» *Agricultural Systems,* vol. 153, pp. 69-80, 2017.

[29] A. Barnes, I. Soto, V. Eory, B. Beck, A. Balafoutis, B. Sánchez, J. Vangeyte, S. Fountas, T. van der Wal e G.-B. M., «Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmersBarnes, A.P.; Soto, I.; Eory, V.; Beck, B.; Balafoutis, A.; Sánchez, B.; Vangeyte, J.; Fountas, S.; van der Wal, T.; Gómez-Barbero M.,» *Land Use Policy,* vol. 80, pp. 163-174, 2019.

[30] J.-P. Belaud, N. Prioux, C. Vialle e C. Sablayrolles, «Big data for agri-food 4.0: Application to sustainability management for by-products supply chain,» *Computers in Industry,* vol. 111, pp. 41-50, 2019.

[31] A. Kamilaris, A. Kartakoullis e F. Boldù, «A Review on the Practice of Big Data Analysis in Agriculture,» *Computers and Electronics in Agriculture,* vol. 143, pp. 23-37, 2017.

[32] S. Rotz, E. Gravely, E. D. E. Mosby, E. Finnis, M. Horgan, J. LeBlanc, R. Martin, H. Neufeld, A. Nixon, L. Pant, V. Shalla e E. Fraser, «Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities,» *Journal of Rural Studies,* vol. 68, pp. 112-122, 2019.

[33] G. Zhaoa, S. Liua, C. Lopezb, H. Lua, S. Elguetac, H. Chena e B. Boshkoska, «Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions,» *Computers in Industry,* vol. 109, pp. 83-99, 2019.

[34] E. R. Griffor, C. Greer, D. A. Wollman e M. J. Burns, «Framework for cyber-physical systems: Volume 1, overview,» NIST Special Publication, 2017.

[35] Y. Shiroishi, K. Uchiyama e N. Suzuki, «Society 5.0: For human security and well-being,» *IEEE Computer,* vol. 51, n. 7, pp. 91-95, 2018.

[36] P. J. M., «Applications of Open Source 3-D Printing on Small Farms,» *Organic Farming,* vol. 1, n. 1, pp. 19-39, 2015.

Disclaimer: This document was produced under the terms and conditions of Grant Agreement No. 818194 for the European Commission. It does not necessarily reflect the view of the European Union and in no way anticipates the Commission's future policy in this area.