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DIGITISATION: ECONOMIC AND SOCIAL IMPACTS IN RURAL AREAS

D1.2 CONCEPTUAL AND ANALYTICAL FRAMEWORK (CAF) REPORT II VERSION

DIGITAL TRANSFORMATION OF AGRICULTURE, FORESTRY AND RURAL AREAS FOR A FUTUREPROOF SOCIO-CYBER-PHYSICAL SYSTEM

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D1.2 CONCEPTUAL AND ANALYTICAL FRAMEWORK (CAF)

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History of Change

Compared to the previous version (Draft 1) of the DESIRA Conceptual and Analytical (CAF) Framework, a number of improvements have been made:

- In Figure 1 the Responsible Research and Innovation concept has been included
- A better explanation was given on the literature review and the background to this document in section 1
- The Living Lab methodology is explained in section 1.1.1
- The link between the conceptual and analytical parts of this framework is made in section 1.1.2
- All analytical questions have been moved to section 1.1.3
- The results of the participatory theory building and how these are integrated in the initial CAF has been described in section 1.1.4
- Sections 2.1, 3.1, 4.3, 5.4, 6.2, 7.1, and 7.2 address the empirically grounded CAF that emerged from the participatory theory building and other empirical research in DESIRA

Executive Summary

The DESIRA project aims "to improve the capacity of society and of political bodies to respond to the challenges that digitisation generates in rural areas, agriculture and forestry in the next ten years." (DESIRA, 2018, p. 5). The empirically grounded conceptual and analytical framework (CAF) presented here shows the initial CAF that forms the theoretical underpinning for other activities within the DESIRA project that support meeting the projects aim, and includes changes and additions that were made based on empirical research of the DESIRA project, mainly based on the experiences made in the LLs.

In the form of a Participatory Theory Building process a wide range of project partners and broader project participants commented on, improved, applied and operationalised, for instance during the Living Lab activities, the concepts described in this empirically grounded CAF. This allowed us to further improve the concepts and their operationalization.

The initial CAF defined and elaborated on the key concepts of this project i.e. the Responsible Research and Innovation approach, Digital Transformation, the Socio-Cyber-Physical system, Digital Game Changers; the Socio-economic Impact and the SDGs. This is all set in relation to digital technology use in agriculture, forestry and rural areas. After four years of applied research and lived experience, this document presents a summary of our lessons and an empirically grounded revision of the initial CAF. Among the main changes, this deliverable sheds lights on the following:

- A stronger (upfront) awareness of the existing and potential future impact of digital transformation will help all participants in the system to improve the innovation process and the desired impacts. The Responsible Research and Innovation approach supports this and provides an analytical lens.
- The relationship between the Responsible Research and Innovation approach and its four main concepts has been explained since the LL methodology is based on the RRI approach.

- The concept of SCP system has been further defined in its components (entities, relationships, activities, needs and impacts).
- To grasp the impacts of digitalisation more accurately, we have recommended to accompany this descriptive and exploratory concept based on SCP thinking with additional theories and critical questions.
- Besides fine tuning the concept of digital game changer, we introduced also the concept of digital game locker to acknowledge the instances in which digital transformations are a continuity with business-as-usual situations and locks-in actors and process in existing path dependencies
- The concepts of winners and losers, have been introduced. However, since the categorization in either of the two is difficult, because actors can play many roles and face many shades of digitalisation, we welcome additional critical studies in these directions but warn about the complexity of such endeavour.
- s*ocio-economic impact* is based on the three different mechanisms of design, access, and system complexity that facilitate an in-depth analysis of impact and can be measured via a multidimensional approach, e.g. a social, economic, and ecological impact.
- The Sustainable Development Goals (SDGs) are a consensus framework for the assessment of the socio-economic impact, and integrative approaches help turning from general goals to more specific targets. Finally, the relevant SDGs for the DESIRA project are described.

1 Introduction

The EU Horizon 2020 Framework, and more particularly the work programme of food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bio-economy, developed a call for proposals under the name of Rural Renaissance. Within this call there was a theme on socio-economic impacts of digitisation on agriculture and rural areas (RUR-02), which ultimately led to the DESIRA (Digitisation: Economic and Social Impacts in Rural Areas) project. **The aim of DESIRA is "to improve the capacity of society and of political bodies to respond to the challenges that digitisation generates in rural areas, agriculture and forestry in the next ten years."** (DESIRA, 2018, p. 5). To achieve this goal, the project developed "a knowledge and methodological base that increases the capacity of a wide range of actors to assess past, current and future socio-economic impact – including gender differences – of ICT related innovation, to embody Responsible Research and Innovation into researchers', developers', users', practices and policies, and finally offer mechanisms and tools that will support decision-making to challenges and opportunities related to digitisation." (DESIRA, 2018, p. 5). With this aim the project addresses two priorities of the RUR-02 call, namely 'boosting major innovation on land and sea', and 'developing smart, connected territories and value chains in rural and coastal areas'.

The conceptual and analytical framework (CAF) presented here formed the theoretical underpinning for activities within the DESIRA project that aimed to meet the project goals for past, present and future digital technology use and support the above mentioned social and political bodies. The initial CAF was targeted to review current literature. Instead of giving a review of the full literature base, it aimed to yield actionable knowledge from a selective review on the core concepts of DESIRA, to inform subsequent work packages[1]. At the end of the project, the experiences made in Living Labs of the DESIRA project, that gave insight into the significance of the concepts and theories in practice, fed into the initial CAF. The empirically grounded CAF is aligned with this experience and is adapted accordingly.

The initial CAF builds on the conceptual choices made in the DESIRA proposal, which were later discussed and validated in the DESIRA general assembly, several steering committee meetings and by the DESIRA international advisory board, and further elaborated with relevant scientific literature. Moreover, at EU level there are a number of other relevant (digitisation related) projects, which we used to inform the initial CAF. These projects include (non-exhaustive): IOF2020; SmartAgriHubs; Smart-AKIS; 4D4F; RRI Tools; and RRI-Practice.

The present document provides an empirically grounded CAF for the analysis of digital technology use in agriculture, forestry and rural areas. The empirically grounded CAF is based on the outcomes of the DESIRA project related to how the original CAF was consolidated in the Living Labs. These outcomes have been used to integrate, refine, and in some cases, revise the early assumptions about the concepts and framework included in the initial version of the CAF.

1 For elaborate reviews of the state of the art on digitalisation in different social, technical and institutional aspects (also drawn on when appropriate for the CAF), see for example: Aker, 2011; Baumüller, 2017; Birner et al., 2021; Bronson and Knezevic, 2016; Cowie et al., 2020; Eichler Inwood and Dale, 2019; Galloway and Mochrie, 2005; Kamilaris et al., 2017; Klerkx et al., 2019; Mogili and Deepak, 2018; Patrício and Rieder, 2018; Rose and Chilvers, 2018; Rotz et al., 2019; Sparrow and Howard, 2020; Tey and Brindal, 2012; Verdouw et al., 2013; Wolfert et al., 2017; Zhao et al., 2005

The key concepts of this project i.e. digital transformation; the Socio-Cyber-Physical system; digital game changers; the socio-economic impact; and the Responsible Research and Innovation approach are first defined and elaborated and thereafter implications for empirical analysis are identified per concept. Per concept, some analytical questions are also presented which support making linkages between the various concepts and provide ground for the operationalization of the concepts. Together these were used as a basis to guide methodological decisions, data analysis, and implementation of the DESIRA activities, such as the Living Labs.

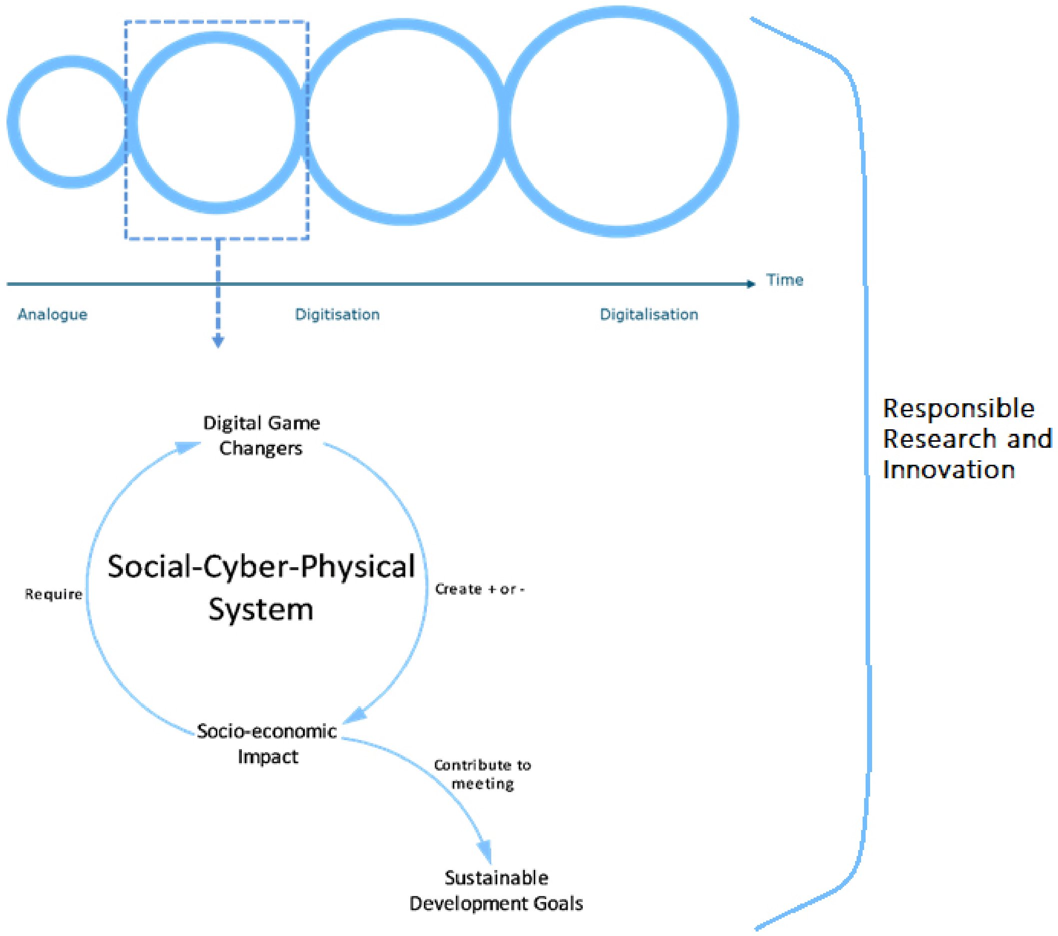
The line of thinking in this document is as follows (see also Figure 1):

- stronger (upfront) awareness of the existing and potential future impact of digital transformation will help all participants in the system to improve the innovation process and the desired impacts. The Responsible Research and Innovation approach will support this and provide an analytical lens.
- We want to unravel digital transformation, which proceeds from digitisation to digitalisation, in agriculture, forestry, and rural areas by trying to understand what, why, how, when and where transformation occurs.
- The object of transformation is a Social-Cyber-Physical System (SCPS). This system is transformed because (parts of) it goes through a process of digitisation and/or digitalisation. In order to understand what a Socio-Cyber-Physical System is we first describe a number of steps:
  - What are systems?
  - What are Cyber-Physical Systems?
  - What are socio-technical systems?
- Digital technologies are a key element in digital transformation, and some of the technologies that are embodied into a SCPS are (digital) game-changers (DGCs). They disrupt existing patterns of interaction and generate a radical redistribution of costs and benefits within the SCPS.
- The digital transformation of a SCPS, including the role of digital game changers, has a socio-ecnomic impact. The impact is based on three different mechanisms (design, access, system complexity) and can be measured via a multidimensional approach, e.g. a social, economic, and ecological impact.
- Sustainable Development Goals are a consensus framework for the assessment of the socio-economic impact, and integrative approaches help turning from general goals to more specific targets. Trade-offs imply a different distribution of (costs and benefits/ opportunities and challenges) among the entities in the system. Because of these trade-offs between goals, inequalities can arise between social actors. Gender inequality has our particular attention.

Figure 1 provides an overview of the connections between the key concepts. The concepts and connections will be further elaborated on in the different sections.

The CAF was considered a living document. In the form of a Participatory Theory Building process, a wide range of project partners and broader project participants used the ability to comment on, improve, apply, and operationalise, for instance during the Living Lab activities, the concepts described in the initial CAF. This allowed us to further improve the concepts and their operationalization. The CAF was finalized at the end of the DESIRA project.

Fig. 1: Overview of connections between key concepts



1.1 Implications for Analysis

In this section we further elaborate on the various connections between the concepts (see Figure 1), and what implications there are for the analysis. To do so we first define the Living Lab concept which was the principle space in which the CAF was implemented. This is followed by the link to two key concepts that are both analytical (as explained in previous sections) but also had a more methodological role in this project, as they not only helped to unravel and understand the socio-economic impacts of DGCs in SCPS, but they also helped to formulate actions within these LLs. Subsequently, we raise a number of analytical questions related to the key concepts that could be used by the Living Labs to guide their analysis and activities. Finally, an overview of the relation of the CAF to the flow of tasks of the project are presented to show how the CAF was applied and how the empirical experiences have been included in the empirically grounded CAF by means of the Participatory Theory Building. This section ultimately shows how the goal, to improve the capacity of society and of political bodies to respond to challenges of digitisation, was aimed at and was studied in the DESIRA project.

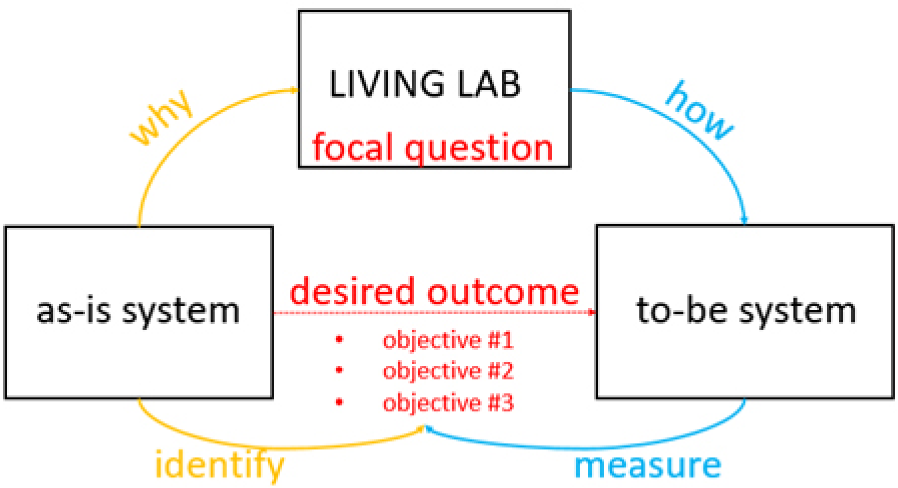
1.1.1 Living Labs

In the DESIRA proposal, the concept of Living Labs (LLs) has been defined as following: "user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings" (p.3). This methodological concept of LLs is increasingly applied in Europe for the involvement of users in technology development (Gamache et al., 2020; Leminen & Westerlund, 2019; Veeckman, Schuurman, Leminen, & Westerlund, 2013).The aim of these LLs is to mobilize a network of rural businesses and services, public authorities, citizen groups, digital technology operators, farmers, media and academics (see also Leminen, 2015).

The 20 LLs (i.e. at least one per consortium partner country) have been chosen to represent different rural typologies, including coastal areas. They represent eight agriculture, three forestry and nine rural development domains. The key activities within these LLs was to assess past, current, and future socio-economic impact of digital transformation in relation to a focal question agreed upon with their participants. This question, co-developed with the LL participants, embodies local needs and expectations. Moreover, the focal question provided guidance to build the representation of the local SCPS and to set its boundaries.

Ultimately, the focal question was intended to guide the LLs to analyse the current state of the SCPS in terms of the outcomes it generated and to explain why and how the process of digital transformation has affected this state. The analysis of the state of the SCPS (**as-is system**) allowed LLs to identify the desired **outcomes** of the system, to set the targets to be achieved and to measure the distance to these targets. The LLs then continued to analyse how the desired outcomes could be achieved through incorporation of digital game changers into the current SCPS (**to-be system**) (See Figure 2).

Fig. 2: Process of analysis of SCPS within a Living Lab



The specific activities for the impact assessments were further elaborated in WP2 and WP3, but overall the LL participants co-developed ideas, scenarios, and socio-technical solutions related to digital transformation in their specific study contexts such as rural areas, supply chains, and sectors of activity. Especially during the scenario workshops in WP3, the concepts described in this empirically grounded CAF were used to guide the discussions and define questions that address the future development of digital societies in LLs. National teams of the consortium organized the preliminary data collection and analysis, tailored the methodology to the specific characteristics of their LL, facilitated the (online) workshops, recorded the discussion, and analysed the information.

1.1.2 Connections to key concepts

For the LLs to be able to undertake their activities around the jointly identified focal questions it is important to take an analytical lens to investigate and understand the situation (past, present and future) in the LLs. In this case the RRI approach provided this lens (see Figure 3) and supported the LLs to increase social acceptability and reduce the possibility of unintended consequences. But it also implied a 'way of working' within the LLs, as they already started with being inclusive in terms of inviting participants before the start of the project activities. These participants needed to reflect on their actions and consider the consequences of them, etc.

Additionally, RRI as an analytical concept and the other key-concepts, provided the basis for understanding the LL situation and how activities in the LL (practically) contributed to meeting the SDGs that are specifically related to the LL focal question. I.e., the SDGs equally put a stamp on how the LL is organised and what it should focus on. This is key as one of the purposes of DESIRA was to analyse the potential of digital technologies to improve conditions in 20 European regions.

1.1.3 Analytical questions

Now that we have an overview of how the conceptual and analytical part of this framework are connected (e.g., by means of the LL methodology and the RRI and SDG concepts), it is important to look at the type of questions the different LL teams may have asked to their LL participants and/or may have used for assessing the past, present, and future impact of digital transformation in their LL context, drawing on the initial CAF.

The following analytical questions guided the analysis of the **SCPS**:

- What are the specific social, cyber and physical entities that contribute to answering the focal question?
- What activities do these individual entities undertake?
- What are the inputs and outputs of the activities?
- How are the entities (of different domains) related to each other?
- Who uses the outputs of the system? In what way?
- What interactions occur between the entities (of different domains)?

- What are the (positive/negative, expected/unexpected) outcomes of the activities, relations and interactions?
- How do you define the system and its relation with the environment?
- Which entities (social, cyber, physical), activities, relations, interactions and potential outcomes, will be potentially affected by the digital transformation of the SCPS? In what way?
- How do outputs turn into outcomes, and for whom, in what way?
- What is the current distance-to-target?
- How do stakeholders' needs and expectations change over time, for whom and in what way?

With regards to **DGCs**, analytical questions are:

- How have digital technologies contributed to the present state of the system? E.g. how have entities, relations and activities, outputs and outcomes, relations with the environment changed?
- How can or digital technologies (potentially) change the way activities are carried out in the area?
- Will digital technologies help to bypass regulatory barriers?
- Will digital technologies reduce the costs of activities?
- Will digital technologies change the relations between people?
- Will digital technologies make it possible to offer new products and services in the area?
- Will digital technologies give access to information previously not available?
- What might be potential new games that will be changed by digital technology use?
- Are there any specific potential agriculture, forestry or rural areas games that might be changed?

The following questions helped to assess the **socio-economic impact** of digital transformation within the LLs:

- Which digital divide related to digital technologies do you identify?
- Which design related risks related to digital technologies do you identify?
- Which digital traps related to digital technologies do you identify?
- Which opportunities do you identify related to access, design and system complexity?
- What are the most relevant SDGs for your LL and how does digital transformation impact these goals? E.g., positive, negative, for whom in what way?
- What is the impact of digital transformation of your LL on gender equality?

1.1.4 Participatory theory building

Participatory Theory Building (PTB), as part of WP1, improved the CAF based on the input of a diverse range of participants and experts, through further refinement of the concepts used, and by grounding these concepts in practice. The CAF builds on the information presented in the DESIRA proposal and was further elaborated with relevant scientific insights and was considered a living document during the course of the project.

In the form of a Participatory Theory Building process a wide range of project partners and broader project participants had the ability to comment on, improve, apply and operationalise the concepts described in this CAF, for instance during the Living Lab activities. By providing a framework that was applied in practice, the empirically grounded CAF provides a knowledge base with the aim to reconcile and integrate evaluation objectives and concepts in various participatory situations (Metta et al., 2022). Combined, this ensures that the CAF is grounded in the empirical findings of the project, which lead to this refined framework at hand.

PTB is a process that started after the first version of the CAF was written. The process was focused on collecting empirical insights into the use of theory from the CAF and to use these empirical insights to further strengthen the CAF. Seven of the 20 LLs (Italy, Netherlands, Belgium, Scotland, Latvia, France, Spain) were included in the process of improving our understanding of the concepts. These seven LLs volunteered to participate in the PTB process.

We opted to use a combination of workshops and semi-structured interviews to collect data on how theory was used in the LLs. As a preliminary exercise, two workshops have been organised, one with all the LL partners, where a selection of LLs has continued with the PTB work. This resulted in a selection of six LLs, with a good geographical and topical distribution. A second workshop with these six LL partners was held to further define the needs and expectations for the PTB process, and based on this, we developed an approach for further monitoring and reflection of the PTB process in the LLs throughout the DESIRA project. As available time for activities was limited, we opted for semi-structured interviews with living lab coordinators as our primary form of data collection. Interviews with living lab coordinators were held after the WP2 (NEI workshop) and WP3 (scenario planning) workshops, for a total of 10 interviews. Interviews lasted between 30-90 minutes. A workshop between the WP2 and WP3 activities provided us with additional information for the PTB process.

Interview questions focused mainly on the use of concepts that were developed in the CAF (SCP system, digitalisation/digitisation, digital game changers, access-design-complexity). LL coordinators were asked how they used these concepts and how participants related to them. Interviews were transcribed and analysed using Nvivo12. For the data analysis our coding was based on the list of concepts from the CAF. Both the interview questions and the list of codes can be found in annex 2.

Two reports, one following the WP2 activities and one following the WP3 activities were written based on the analysis of these interviews. These reports, together with input the project partners gave at the annual meeting in Gent in 2023, were used in developing the empirically grounded version of the CAF.

1.1.4.1 Limitations

A limitation in the PTB process, and an issue that will be explored in future work, is the fact that there was limited reflection on the CAF from stakeholders in the LLs. This occurred despite the fact that the LLs involved in this process had volunteered to join the PTB process and could thus be expected to be more involved in connecting the CAF to their activities. In the interviews we did reflect on this, and research participants provided three main reasons for not introducing the CAF to their LLs. First, concepts and theories provided in the CAF were seen as not matching the needs of stakeholders in the LLs. Secondly, theory was sometimes seen as too complex for stakeholders and was seen as alienating stakeholders when introduced in the LLs. Third, the CAF is seen as a tool that can be used in the analysis of LL data by researchers. This means that the CAF does not function as a shared document to be used in collaboration with stakeholders. These three reasons also mean that the participatory element of the theory building was relatively limited and that the reflections were based on discussions between researchers.

Whether stakeholders should be involved in the theory building processes is up for debate and can be an element for future research. Participatory theory building implies that there is a broader participation in theory building, but it remains fairly open who needs to be included in this process and how participants should be able to contribute to theory. In this project, PTB has remained limited to discussions between researchers and to reflections based on empirical data.

1.1.4.2 Other empirical limitations when applying SCP systems concepts into practice

Adding to the limitations mentioned above, applying the SCP system concept in practice means dealing also with the following methodological challenges:

- Research biases: Digital impacts assessments were restricted to the Living Labs' focal questions and, in some cases, determined by the LL's own research agendas. Common guidelines and trainings were provided by the Work Package leading partners to harmonise the multiple analyses, but future research can start from acknowledging the consequences of these research assumptions.
- Selection bias: e.g. in the stakeholder engagement and composition of Living Labs (e.g. gender, age, education, professional status, location).
- Digital bias in data collection tools: some stakeholders were excluded by the digital means of data collection (online focus groups, online survey) and this issue was further exacerbated by the COVID-19 restrictions.
- Low level of digitalisation: for some Living Labs, focal questions were selected where none or few general examples of digitalisation were available (e.g. social media).
- Conceptual challenges: difficulties in distinguishing past, present, and future impacts of technologies and skills widely used or still under developing and piloting phase.

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

2 Responsible Research and Innovation

Responsible Research and Innovation (RRI) is the overarching theory applied in the DESIRA project. The framework was used as a guiding principle in all LLs and is also the basis for de SCPS framework. In the DESIRA proposal RRI has been described as "an approach to research and innovation that aims at anticipating and assessing potential implications and societal expectations with regard to research and innovation" (DESIRA, 2018, p. 4). Using this approach is relevant as "there is a tendency to highlight only the opportunities of digitisation, and underestimate the threats" (DESIRA, 2018, p. 5) and digital transformation includes winners and losers, as well as proponents and opponents. RRI aims to "bring issues related to research and innovation into the open, to anticipate their consequences, and to involve society in discussing how science and technology can help create the kind of world and society we want for generations to come" (RRI Tools, 2020).

Moreover, RRI allows us to not only reflect on the things we know or can predict/expect, but also helps to consider the unseen and unknown aspects or digital transformation, whereby unseens are unintended side-effects or impacts (both positive and negative) on the same or a different system in which an action took place (Scholz et al., 2018). This is different than unanticipated barriers (or opportunities for that matter) that can prevent or support an action unintentionally, usually within the same system (Scholz et al., 2018). Unknowns can be divided into 'known unknowns' and 'unknown unknowns'. This division originates from a quote by former US Secretary of Defence, Donald Rumsfeld, who stated: "(...) there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know" (Rumsfeld, 2002). Known unknowns and unknown unknowns have also been explored in scientific studies (Little, Cleven, & Brown, 2011; Logan, 2009; Pawson, Wong, & Owen, 2011) where it is stressed that we can study and hypothesise about known unknowns, but that it is unclear how we deal with unknown unknowns. Unknown unknowns represent uncertainties and unforeseen phenomena. If unknown unknowns go undetected, they could lead to missed opportunities, but in extreme cases could also result in catastrophes (Pawson et al., 2011; Wintle, Runge, & Bekessy, 2010).

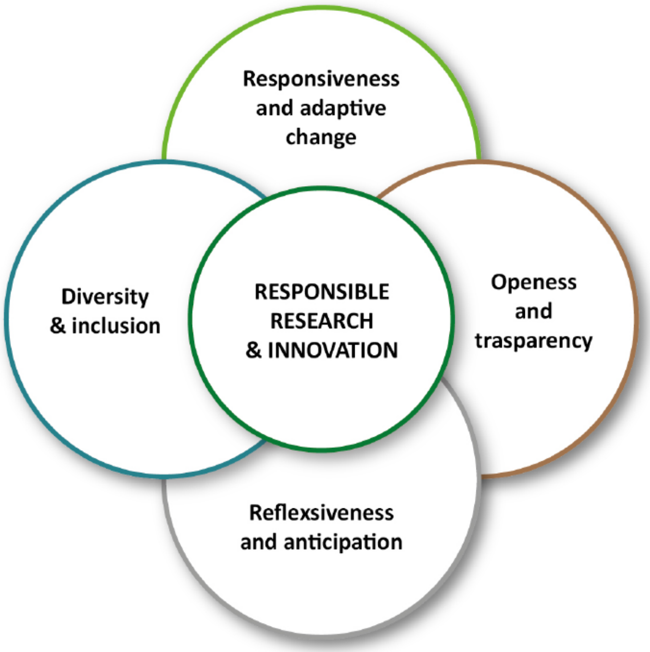
Using an RRI approach involves a framework with four main principles. This framework is based on the AIRR (anticipation, inclusion, responsiveness and reflexivity) framework developed by Stilgoe and colleagues (2013), which has been further adapted in EU project on RRI Tools (www.rri-tools.eu) (see also Figure 3):

- Diversity and Inclusion: Be sensitive to research biases, include diverse voices and make results beneficial to a wider community
- Anticipation and Reflection: Think on the purposes and possible implications of your research and its outcomes and envisage all possible strategies and methods
- Openness and Transparency: Share objectives, methods and, whenever possible and appropriate, results, and inform about potential conflicts of interests

- Responsiveness and Adaptive Change: Be responsive to changes and external inputs, adapting your research plans to changing social values and expectations

Furthermore, agricultural innovation is not an inherently good and value free process, but normatively laden and driven by different worldviews and visions. Correspondingly, different development directions exist, each with its own winners and losers (Brooks & Loevinsohn, 2011; Thompson & Scoones, 2009; Vanloqueren & Baret, 2009).

Fig. 3: Overview of main principles of RRI



Additionally there are six key issues that should be part of the considerations when undertaking an RRI approach: ethics, gender equality, governance, open access, public engagement and science education (RRI Tools, 2020).

The RRI framework has been applied to a variety of topics and is studied in various EU projects. The EU project RRI-practice reviews 22 organisations and aims to further outline RRI objectives, targets and indicators. This project looks at barriers and drivers of successful implementation of RRI, reflection on organisational structures and cultures and identification and support of best practices. A number of scientific publications focus on RRI in a variety of fields, from synthetic biology (Macnaghten, Owen, & Jackson, 2016) and information and communication technologies (ICT) (Stahl, Eden, & Jirotka, 2013) to nanotechnology (de Bakker, de Lauwere, Hoes, & Beekman, 2014). This has resulted in further development of RRI in new directions, although more empirical research is still needed in order to provide a broader empirical basis for further development of the concept (Burget, Bardone, & Pedaste, 2017).

Even though RRI is now increasingly studied and adopted by national research councils, e.g. in the UK, the Netherlands and Norway (Von Schomberg, 2013), there are also authors who voice their concern or critique about its definition and/or application. Lubberink, Blok, Van Ophem, and Omta (2017) describe several problems with current RRI application as being developed by researchers and policy makers without differentiating between research, development and commercialisation, thereby neglecting the implementation of RRI in a business context. Blok and Lemmens (2015) first conclude that practical applicability of RRI as a concept is problematic and requires a more thorough examination of RRI, because of a mismatch between the ideal of responsibility and the realities of existing innovation processes. Second, they challenge RRI as a concept and judge the concept of *innovation* within RRI to be narrow and uncritical, as responsible innovation is seen as: 1) *technological* innovation, 2) primarily recognised from an economic perspective, 3) innovation is inherently good and 4) an assumed symmetry between moral agents and 'the other'. Forsberg, Shelley-Egan, Ladikas, and Owen (2018) point out that there is a lack of research assessing the possible challenges, efficacies and impact of programmes focused on RRI. This can be explained by the lack of standardised methodologies and because the concept of RRI itself is still new (Forsberg et al., 2018). Therefore, further research should also focus on addressing the challenges that are now being discovered (Blok & Lemmens, 2015; Forsberg et al., 2018; Lubberink et al., 2017).

The RRI framework has also been applied to (smart) agriculture. Several authors have indicated, however, that socio-ethical implications of smart agriculture have been neglected (Bronson, 2015, 2019; Eastwood, Klerkx, Ayre, & Dela Rue, 2017; Rose & Chilvers, 2018). Innovations around smart farming have focused on technological development and on-farm use without taking into account socio-ethical implications (Eastwood, Klerkx, Ayre, et al., 2017). Failing to engage certain food system actors (e.g. citizens, consumers, rights holders) in the innovation process is mentioned by several authors as well (Bronson, 2015, 2018, 2019; Eastwood, Klerkx, & Nettle, 2017). Rose and Chilvers (2018) argue that we need a more comprehensive framework for RRI in sustainable agriculture in order to make ideas around RRI more relevant and robust for upcoming agri-technology. To achieve this, they call for: 1) a more systemic approach to map innovations associated with digitalisation of agriculture; 2) broadening of notions of inclusion in RRI in order to include a diversity of participants; and 3) testing responsible innovation frameworks *in practice* to estimate if innovation processes can be made more socially responsible.

2.1 Living Labs and RRI

The DESIRA methodology applied in the LLs is strongly adherent to RRI. In the following you find a brief explanation of the four main concepts of the Responsible Research and Innovation framework in de LL.

Diversity and inclusion are inherent in the concept of Living Labs. Living Lab activities have involved more than 200 farmers, consumers, advisors, policymakers, rural inhabitants. The choice of different rural contexts has allowed us to grasp a high level of diversity across Europe.

Reflexiveness and anticipation have been carried out through foresight exercises, which have mobilised LL members in scenario building activities.

Openness and transparency of the work of LLs is reflected in the fact that all DESIRA reports and tools are available online.

Responsiveness and adaptive change has been put into practices through a constant dialogue with policymakers and stakeholders. At EU level, for example, DESIRA has contributed to the Long Term Vision for Rural areas, and has hosted during its General Assembly a foresight exercise in collaboration with the JRC.

An addition to the RRI framework has been made through the ethical code of the DESIRA project. By connecting the 4 principles of RRI listed above to value sensitive design and virtue ethics it is possible to work towards the ethical and just development of novel digital technologies. The normative elements of RRI and the concrete steps that value-sensitive design and other ethical design methods propose have been integrated to enable ethical reflection in technology design. The main take-away is the importance of shared values, which are defined as everything that is found to be important by people and communities. Everything that matters to humans is a value and of value. Values are the things that are important to people in their lives with a focus on ethics and morality.

This is reflected in twelve main values that are important to the ethical development of digital technologies for agriculture, rural areas and forestry. Existing ethical codes and empirical work in the DESIRA project provide the basis for this list of values (see below). This list provides a basis for discussion with stakeholders and provides a background for technology developers who want to reflect on the impact of their technology on broader society. The values are provided in the list below, descriptions of how the values have been selected and an explanation for each of the values can be found in the DESIRA ethical code deliverable.

privacy	human welfare	community	self-development & self-actualisation
diversity, inclusion & identity	agency	trust	environmental sustainability
animal wellbeing	freedom from bias	resilience	universal access to technology

3 Digital Transformation

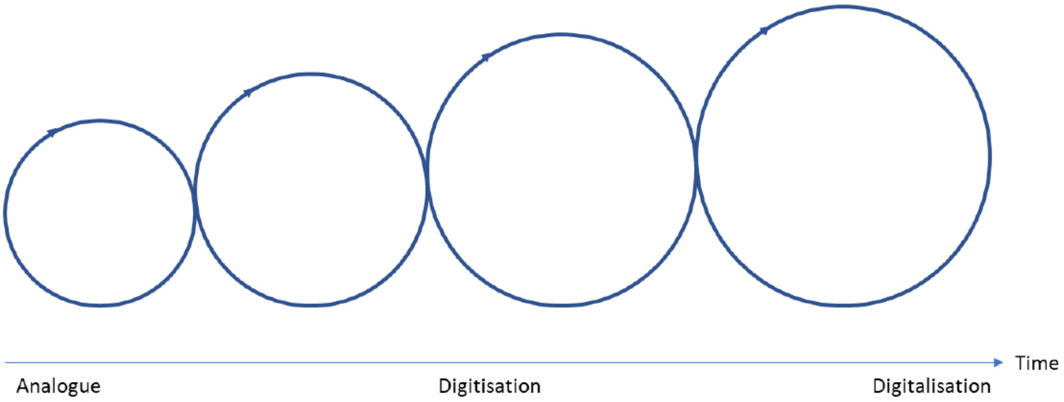
Digitisation can be described as transforming physical entities into digital objects (DESIRA, 2018) or described by (Autio, 2017), the “technical conversion of analogue information into digital form”. In the DESIRA proposal (2018) digitisation has been referred to as follows: “digitisation will allow remote (or even self-) control of production, processing and logistic operations” (DESIRA, 2018, p. 5), summarising what digitisation can achieve. Digitisation is also referred to as the third industrial revolution (Greenwood, 1997; Schwab, 2017), whereby the use of computers became commonplace during the 1960s and 1970s and automation replaced a lot of manual activities. Digitisation is thus often linked to a single or a low number of digital technologies implemented at business level. In agriculture, rural areas and forestry digitisation is often seen in the form of digital technology at the level of a single business or entity, thus focussing on on-farm level often using (mainly spatial) data to feed decision support tools for farmers, such as milking and harvesting robots and other precision agriculture technologies (Klerkx, Jakku, & Labarthe, 2019).

Following the rise of the internet during the 1980s and 1990s, and the increased connectivity this brought, more coordination and integration between activities could take place (Porter & Heppelmann, 2014). While this process of automation and increasing connectivity is still ongoing, the next wave of digital technology has introduced itself (Porter & Heppelmann, 2014) and is often referred to as the fourth industrial revolution (Schwab, 2017), Industry 4.0 (Meyer, 2019; Sommer, 2015), or Smart Industry (Team Smart Industry, 2014). This also impacts agriculture, forestry and rural areas (Poppe, Wolfert, Verdouw, & Verwaart, 2013).

Through ubiquitous connectivity, the use of sensors for (big) data collection, many technologies have become ‘smart’ and are able to communicate autonomously leading to the Internet of Things and Artificial Intelligence (see for example Alm et al., 2016). These types of technologies and the process of using and implementing digital technologies in everyday life require, however, more than only a technical conversion. *Digitalisation* is the term often used to describe the socio-technical processes surrounding the use of (a large variety of) digital technologies that have an impact on social and institutional contexts that require and increasingly rely on digital technologies (Tilson et al., 2010). In agriculture, rural areas and forestry digitalisation it thus goes beyond the level of a single business or entity, for example using digital platforms to coordinate demand and supply in value chains, linking on- and off farm data and managements tasks, which are enhanced by context- and situation awareness and triggered by real-time events (Rose & Chilvers, 2018; Wolfert, Goense, & Sørensen, 2014). It is therefore often referred to as ‘Smart farming’, “Smart Forestry’, ‘Smart Rural Development’ and ‘Smart rural areas’, as well as concepts such as digital agriculture and Agriculture 4.0 (Klerkx et al., 2019; Klerkx & Rose, 2020; Müller, Jaeger, & Hanewinkel, 2019; Naldi, Nilsson, Westlund, & Wixe, 2015; Watanabe, Naveed, & Neittaanmäki, 2018). Thus, precision agriculture can be seen as an on-farm digitisation process whereas digital agriculture is linked to digitalisation, encompassing the entire value chain with the intent to cause broad change in the agricultural sector.

Both digitisation and digitalisation are considered here part of *digital transformation*, allowing for a spectrum of digital transformation activities, whereby over time the options of digital technology use, the associated complexity (i.e. interactions between the various aspects, such as (digital) technology, institutions, people & organisations, environment, etc.) and their related, either positive or negative, impacts on society continuously increase (see Figure 4). Digitisation in this figure can be seen as a crucial part, or step in the direction of digitalisation, as the use of digital technologies often induces social, economic and institutional changes. And vice versa, social, economic, and institutional changes in society result in a demand for the development of digital technologies. This results in an ongoing and iterative process (Nochta et al., 2019).

Fig. 4: The digital transformation process



3.1 Empirically grounded Digital Transformation Concept

In the initial CAF, the concept of digital transformation is described as the process of digital transformation activities that differ in progress and that can be understood as a spectrum from analogue through digitisation to digitalisation. Over time, options of digital use, associated complexities, and societal impacts continuously increase. In the initial conceptualisation, *digitisation* refers to the transformation of physical entities into digital objects and *digitalisation* describes socio-technical processes related to the use of digital technologies that impact social and institutional contexts that require and increasingly rely on digital technologies.

From the PTB interviews it was found that LL facilitators had difficulties to operationalize the concept of digital transformation including the concepts of digitisation and digitalisation. In many LLs this was partly because the terms digitisation and digitalisation do not translate to the local language (e.g., in Dutch both terms translate to 'digitalisering'). Since LLs used the concept of digital transformation only indirectly to explain how "digital tools becoming more complex" (participatory theory building report, 2021), and how different actors and things are connected to each other and how digital tools and data are integrated and used in the LL, the concept of complexity is added to the initial conceptualisation as explained in the following.

Some of the LLs recognised that the further the digital transformation proceeds, the more complex the system becomes. Analogue processes are translated to digital tools that become more embedded into society leading to digital transformation processes, thereby increasing societal impact and influencing the social reality of the LL to a greater extend. As it was said by a participant of the workshop during the general assembly in January 2023: "You cannot just change one thing, systematic change is happening and unsure where it is going." The previous comment sheds light on the interconnection between different elements or entities within the system, that make the understanding of the impact of digital tools more complex.

This connection between digital transformation and complexity also illustrates the interconnectedness between concepts in this Conceptual and Analytical Framework, as system complexity is also described as part of the concept of socio-economic impact (see Chapter 4.1).

3.1.1 Theoretical Reflection on the initial Digital Transformation Concept

Apart from the fact that LL participants did not use the term digitalisation or digital transformation and rather expressed the concept as digital tools that make society more complex, generally speaking it can be stated that the concept of digital transformation is in its core meaning useful as an analytical tool to discuss the broad movement and phase of digitalisation in a real-world context. The concept is perceived as broad and open, which leaves room to look at winners, losers, positive as well as negative effects. Moreover, the translation of analogue processes into digital tools was also reflected upon as creating opportunity for increased social impact.

Digital transformation and increased social impact

The Netherlands digital platform providing a peri-urban community with new ways to collaborate

A 'low tech' digital solution in the form of a digital platform for exchange around a short food supply chain provides a local peri-urban community with a way to communicate, exchange and increase community building. This results in the process of digitalization (translating analogue processes into digital tools) contributing to increased social impact for the local community of peri-urban gardeners and food producers in Oosterwold.

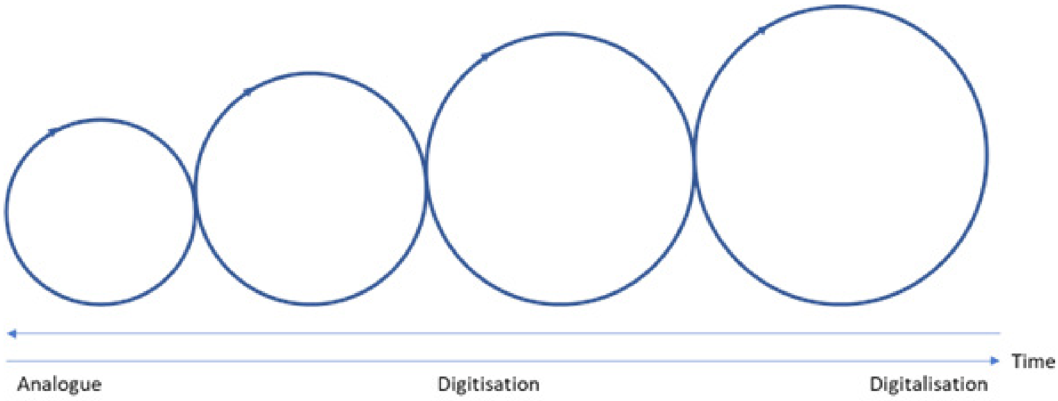
Italy WhatsApp as a game changer

WhatsApp is a widely used communication app that is installed on most European people's phones but it can have game changing effects depending on the context in which it is used. In the Living Lab in Tuscany, Italy it has a game changing effect because it enables people to better organise communicate in a context where in the past there was no means to communicate and re-organise their work. WhatsApp then becomes a game changer with increased social impact.

However, from the discussions with the project participants it became apparent that the deterministic notion of the concept can be misleading. Digitalisation is stated to progress over time, while this leaves no potential for non-digital future pathways. There is a logic flaw in the one-way linearity of the concept. The same person (or group) may show contrasting behaviours, in that she might e.g. digitalise her vegetable garden, whereas she uses less digital tools for e.g. communication. People may purposefully disconnect from digital tools or systems. It has been criticised that the concept of digital transformation seems to focus on the end-goal of becoming more digital. To indicate that de-digitalisation processes may also occur, it is proposed to add a second timeline (into the other direction) to the initial figure of the digital transformation process (Figure 4; Figure 5).

Moreover, the responsible use of digital technology is gaining more and more interest (see e.g., Klerkx and Rose, 2020) since digital technology is believed to be able to support bottom-up innovation and supports small-holder farmers who can use the digital support to save time and other resources (see e.g. Rotz et al. 2019). This agriculture 4.0 concentrates more on ethical aspects of digitalisation and reacts on the kind of digital transformation that is biased in favour of powerful players in the agri-food chain (see Rose and Chilvers, 2018), therefore the concept of readiness is included in the empirically grounded CAF, as will be explained in the following.

Fig. 5: updated figure 4; The digital transformation process



3.1.2 Transformative policies and digital transformation

Digital transformation requires the promotion and adoption of digital technology. It has been criticized that policy makers often support digital transformation without taking into account the possible negative implications of these processes. In this, the concept of **readiness** can be of added value. The concept is also applied by the EC, concentrating on the Technological Readiness Index to explain the progress of digitalisation and European public services in the EU (Bruno et al., 2020) . The concept of readiness gives insights into the maturity of a certain technological tool. Digital policies may have unintended consequences which lead to digital divide or digital gap (see also the section on socio-economic impacts). Taking into account the maturity of digital technology also in terms of social maturity, which means that the technology needs to be adaptive to the social context the technology is or will be embedded in, adds a normative notion to the initial concept of digital transformation and the understanding of policies that promote this transformation.

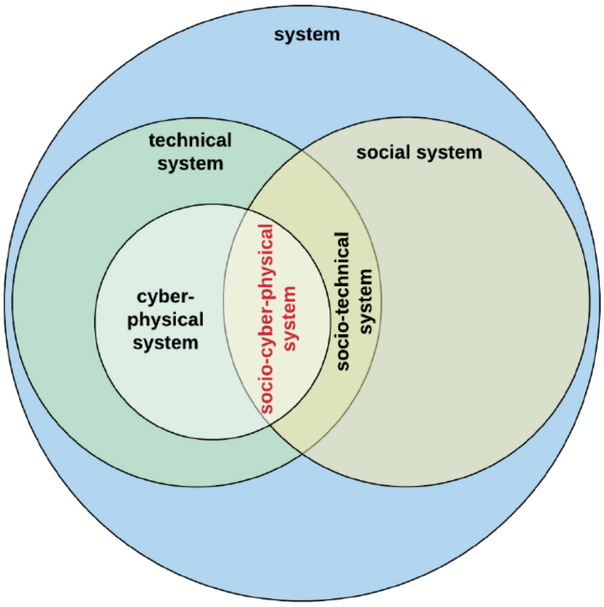
To evaluate whether or not digital technology can transform society for the better, policy makers and scientists need to understand which indicators and criteria show differentiation of access and adoption rates across actor groups. Our empirical data shows that readiness also relates to most LL not having the appropriate skills needed for a digital transition. Readiness is therefore not only about technical maturity but can also be related to concepts such as **digital literacy**. From the LL experiences it can be concluded that readiness may help to explain and overcome the digital divide. Moreover, including readiness as a concept enables better integration of knowledge on digital and social factors.

4 Socio-Cyber-Physical System

The concept of Socio-Cyber-Physical Systems (SCPSs) is introduced and used in DESIRA to approach the specific challenges associated with the fourth industrial revolution. This revolution is characterized by the entangling of digital, physical and social worlds through a multiplicity of technologies. This entangling is what we call the digital transformation process (see Section 1).

As illustrated in Figure 6, there is a range of concepts building on the idea of a system, such as a social system, a technical system and the intersection between them, captured in a broader socio-technical system. SCPSs are a particular subcategory of the latter, while a more known concept, namely cyber-physical system (CPS), is a subcategory of the technical system. We will elaborate on this diverse range of systems before deepening the concept of SCPS.

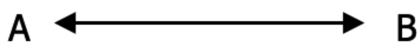
Fig. 6: Hierarchy of system concepts



4.1 What is a system?

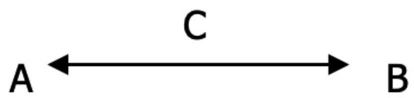
A system can be defined as a mental representation of given aspects of reality for analysis and control purposes. Through the system concept, reality is represented as a set of **entities** that interact together through (jointly) performing **activities**. In Figure 7, A and B are entities (people, things, animals, or even immaterial entities such as texts or images). A and B can potentially be connected through a **relation** (represented by an arrow).

Fig. 7: The potential relation between entities A and B



In the case of humans, a **relation** can be based on kinship, neighbourhood, work, casual encounters, business, and many other types. In the case of other living organisms, relations can, for example, be based on parasitism, symbiosis, competition. Relations between humans and the physical world can be identified as services or disservices: tools are things that help humans to do a job or task, food is necessary for nutrition. **Interaction** is possible when a relation between A and B is established, although relations can exist without interaction, e.g. A may be the son of B but living on the other side of the world, and therefore may not have interactions with B. Furthermore, relations can be qualified based on the type of interactions that potentially occur between entities. Relations could for example be peaceful / hostile, autonomous / dependent, cooperative / competitive. In case of interaction it links together A's and B's activities, or is part of a joint activity. These activities require **input** of A and/ or B and create **output** for A and/or B. These activities thus generate flows of material and immaterial entities between A and B, indicated by C. These new entities are then also part of the system (see Figure 9).

Fig. 8: The flow of material and immaterial entities in a system



Depending on the mental representation of the observer and its purposes a system therefore has boundaries (see Figure 9). Within these boundaries, the entities, and all possible relations and interactions between them operate within a given **context**, which generates additional entities in the system. Also the context may have a particular set of (formal and informal) rules (D in Figure 9). This in turn creates challenges and opportunities for interaction between the various entities. However, the system is not all encompassing and beyond the boundaries there is a wider **environment**. This environment is then a potential external influence (E in Figure 9), which often cannot be controlled by the entities in the system (Gharajedaghi, 2011). The interactions and related activities, based on input and output by and for entities, as well as external influences, may result in (positive or negative) **outcomes** that could change the system and its boundaries.

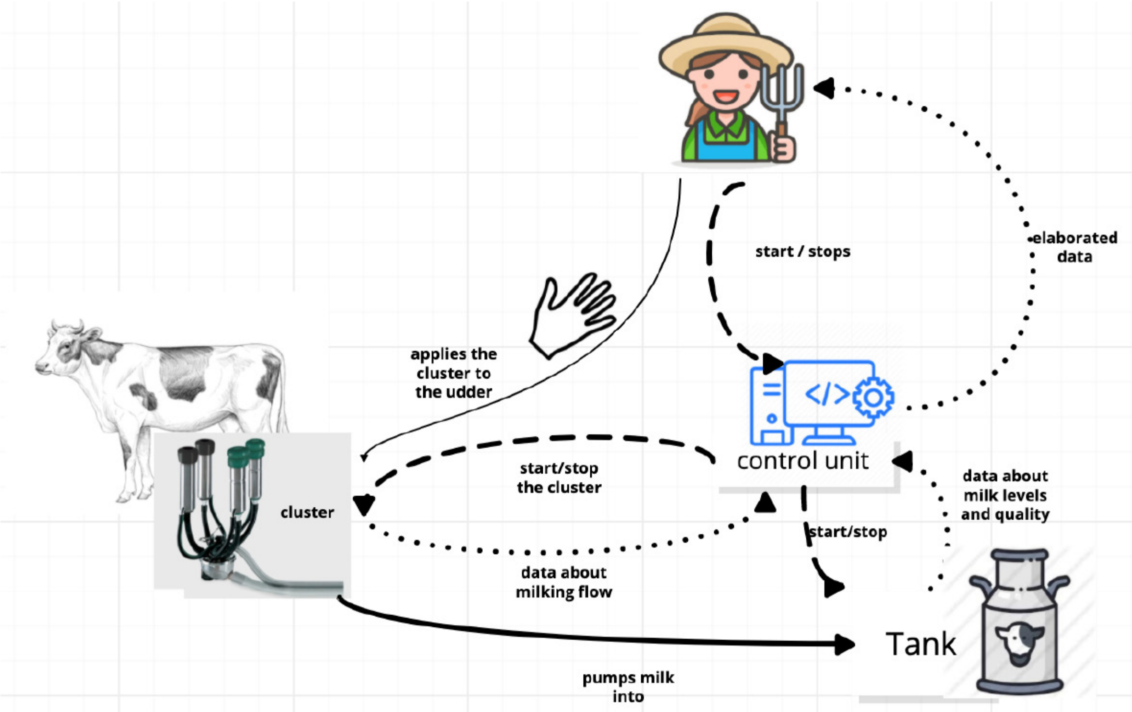
Fig. 9: The system boundary and the environment

In summary: A system is a set of entities with relations and interactions between them. These interactions can create new entities. The entities and the boundaries of a system are defined by the observer in relation to his/her purposes. Hence a description of a system is a representation of reality according to a specific observer. The context within the system boundary may also provide entities to take into account. Outside the system boundary there is the environment, which may provide external influences. A system is complex and adaptive, due to the interactions between the entities, their relations, the activities, and external influences.

Box 1: Example of a system

In the figure below a milking system is shown. The observer of this system may want to understand how a milking machine works in order to answer a particular question or solve a problem. For example, what is the quality of the milk, what the health status of the cows, or what are the energy cost of the process?

Entities: Involved entities are the cow, the milking cluster, the farmer, the control unit; the milk collection tank.
Relation: Some of these entities are tools, in which the relation to the other entities is to support the farmer and the cow in the milking process.
Interaction: The interaction happens through a number of activities, e.g. application of the cluster to the udder, milking, transfer of milk to the tank.
Input & output: The farmer can start and stop the system through a switch. Milk from the cow goes through the cluster. The control unit receives data about the regularity and intensity of the milk flow from the sensors applied to the cluster, and processes them into information that tells to the control unit when to stop milking. The processed information also gets back to the farmer to help in decision making.
Context: Milk hygiene regulation applied by the farmer; animal welfare of the cow; internet connectivity between the cluster and the control unit.
Environment: Farmer household; milk collection routines; energy prices; etc.
Outcomes: Good quality milk; excellent health status of the cows; or low energy costs of the process.



4.2 Cyber-physical system

Cyber-physical systems (CPSs) stem from an engineering and technical perspective, and refers to a 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 (Baheti & Gill, 2011). Monostori et al. (2016, p. 621) define them as "systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the Internet." Or in other words, physical systems are monitored, coordinated, controlled and integrated with and by digital technology, and work together to achieve common goals (Rajkumar, Lee, Sha, & Stankovic, 2010; Sousa & Rocha, 2019).

A framework for CPSs shows that devices are used to sense and interact with the physical world through data collecting and actuation; multiple devices interacting with the physical world and among themselves via data exchanges create a system, which is composed of both physical and cyber components in an intertwined manner. Eventually, a system can interact with other systems, thus creating a system of systems (SoSs) (Griffor, Greer, Wollman, & Burns, 2017). The interaction between the physical and cyber entities is therefore of critical importance (Monostori et al., 2016) and can occur in a myriad of ways that depend on the environment in which the system operates. CPSs can be simple or rather complex solutions, according to the purpose they serve in different scenarios (Khaitan & McCalley, 2014), for instance: vehicular systems and transportation; medical and health care systems; smart homes and buildings; social networking and gaming; power and thermal management; electric power grid and energy systems; surveillance, and so on. Three key characteristics of CPSs can be identified: intelligence or smartness, i.e. the elements are able to acquire information from their surroundings and act autonomously; connectedness, i.e. the ability to set up and use connections with other entities in the system – including human beings – for cooperation and collaboration, and to the knowledge and services available on the Internet; responsiveness towards the context and the environment (Monostori et al., 2016).

Sousa and Rocha (2019, p. 5) emphasise and clearly acknowledge the human role in CPSs, stating that "it is not sufficient for interconnected and intelligent tools to communicate with each other without any human involvement. Human technology is made by humans, for humans. In addition to providing basic functionality, openness, heterogeneity, and integration capabilities, it is equally important to discern how systems or tools can be used within a certain [human] context." Thus also considering issues like e.g. communication, data security and privacy. This has led to the emergence of Human CPSs and Human-centred CPSs (Hadorn, Courant, & Hirsbrunner, 2016), or Human-in-the-Loop CPS (HiTLCPSs) (Sousa & Rocha, 2019) in which technology is designed to put human beings into the focus often resulting human-machine interaction. Human involvement in CPSs can be determined in a number of different ways, often being an input provider or data source; an information processor and communicator as part of the system; or an user of the service provided by the CPS. This however does not mean the human is always accountable for what happens in the CPS, nor does the human have to be an expert or a deliberate collaborator of the system. In other words an human can unknowingly be part of a CPS by providing data unknown to that human (Calinescu, Cámara, & Paterson, 2019; Sousa & Rocha, 2019).

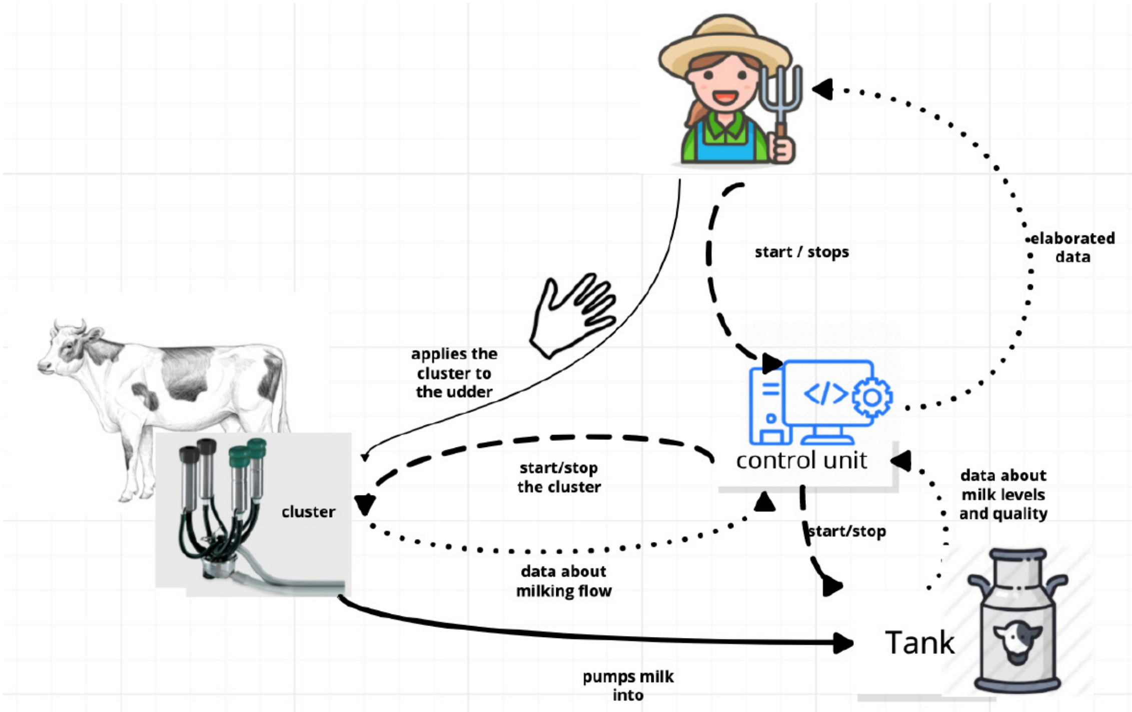
In summary: Cyber-Physical Systems (CPSs) are next-generation engineered systems that integrate embedded computing technology (cyber part) into the physical phenomena by using transformative research approaches that account for the complexity and multi-disciplinarity of such systems (Gunes et al., 2014). This integration mainly includes observation, communication, and control aspects of the physical systems, which can involve humans in various ways.

Box 2: A Milking system as a CPS

Physical entities: Cow, cluster, farmer, milk tank

Cyber entities: Control unit, sensors on cluster, sensors in milk tank

Role of human: Collaborative and accountable information processor through starting and stopping the control unit.

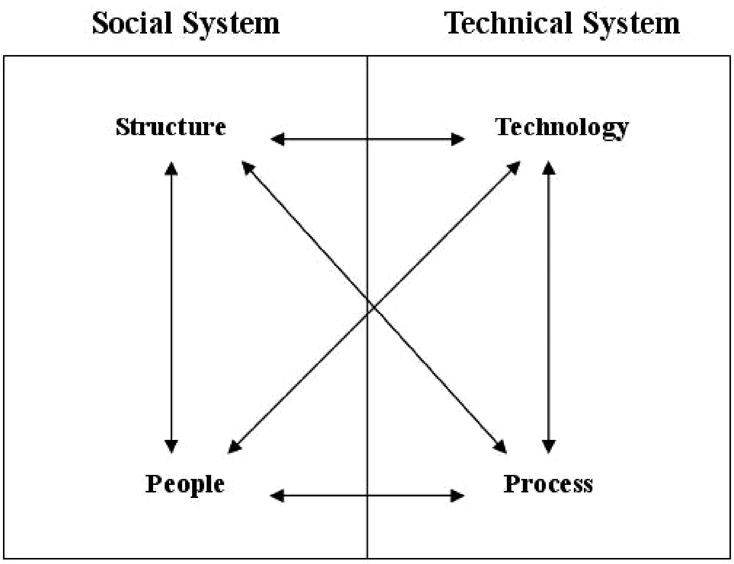


4.2.1 Socio-technical systems

The notion of a *socio-technical system* emerged in organisational and labour studies as a response to the predominance of the mechanistic/scientific view of industrial management and the overemphasis on psychological factors in industrial relations (Ropohl, 1999). Researchers interested in organisational performance and change used the concept of the socio-technical system as an approach to design workplaces recognising the interaction between people and technology (Clegg, 2000). A socio-technical system refers both to the interrelatedness of social and technical aspects of an organisation or the society as a whole (Ropohl, 1999), whereby technology, besides material things, also includes organisational structures and processes (Botla & Kondur, 2018). For more theoretical underpinning in social theories such as the Actor-Network Theory and Social Practice Theory see Annex 1.

In more analytical terms: socio-technical systems are composed of a technical system and a social system (Bostrom & Heinen, 1977; Lui, Piccoli, & Desouza, 2007). Imran and Kantola (2019, p. 119) state that "Sociotechnical system theory accounts for social factors while implementing new technologies [...]. It discusses changes in working practices and social issues during the design and implementation of new technologies. It considers both technical and social issues in quest of promoting change in the organizations". The technical system encompasses both technology and process and the social system encompasses the people involved in the system and the structure in which they are embedded (Lui et al., 2007) (see Figure 10).

Fig. 10: Information System as a socio-technical system (Lui et al., 2007)



In order for a system to function, these four components should not only be present, but they should also interact with each other. Thus, while technology, process, structure and people are distinct components of an information system, they are interdependent and interact with each other (Lui et al., 2007).

The complexity of the interactions among the system entities has been highlighted by various authors (Lamb & Kling, 2002; Saurin & Patriarca, 2020). To bring structure to this complexity Saurin and Patriarca (2020) propose a holistic taxonomy of socio-technical interactions, considering multiple criteria, e.g. the nature of actors and for each criterion two descriptors are proposed; i.e. interaction between entities and what the interaction looks like. By using this taxonomy in the analysis of a specific socio-technological system, and therefore better understanding the different interactions that exist, it can help to clarify both the system outcomes as a result of the internal interaction among entities, and the leverage points in the system regarding its resistance to innovation processes, which can be considered as a negative point for stable systems, and its resilience, which the ability of the system to adapt and is considered a positive. This in turn is then useful in systems (re-)design.

It is important to stress that resistance and resilience are not only related to technological and organisational limits/flexibility, but also to social actors (Geels, 2014; Taysom & Crilly, 2018). Social actors that are part of the socio-technical system have different aims and interests among them, and are also endowed with different resources (knowledge, social capital, etc.). They hold different positions in society or in a specific organization), and act by following different routines, norms and social values.

Furthermore some actors can hold a power position over others. For example, they can control the system performance, influence other actors' activities, and restrict access to technology. At the same time, the use of new technologies or new regulations can also reset existing social asymmetries, depending on how socio-technical relations change the connections among technologies and social actors.

In summary: A socio-technical system consists of social entities and technical entities. Social actors, e.g. humans with agency, all have various needs, wants, skills, knowledge, etc. They also have different positions in the social structure. Hence there are different power relations. Technical entities are non-human entities, including technologies as well as processes surrounding those technologies. Social and technical entities interact with each other and have equal importance in the understanding of socio-technical systems. These interactions need to be consistently undertaken in order to maintain or adapt the system. In doing so the system may be resilient and positive towards adaptation, while there may also be resistance among the entities towards adaptation.

4.2.2 Socio-Cyber-Physical System

Building on the socio-technical system, as described in the previous section, a Socio-Cyber-Physical System (SCPS) is a particular form of such a socio-technical system, distinguishing between physical and digital entities within the technical part of the system. In the DESIRA proposal, a SCPS has been defined as "a system constituted by the social world (people), the digital world (data), and the physical world (things)" (DESIRA, 2018, p. 4). The SCPS can also be seen as an extension of the Cyber-Physical System (section 2.2.), hereby putting greater emphasis on the social aspect and the interlinkages between the three aspects. In other words, moving beyond the 'human' aspect as it is described in CPS, towards the social actors as described in the socio-technical systems.

SCPSs have been described and defined in the literature in a number of ways. Zayalova et al (2017, p. 396) mention that a "social network integrates social system and its cyber system, and further then the physical and social system can be mapped equivalently to their cyber systems. On that basis, the physical and social system and their cyber systems can communicate." In their view, however, SCPSs aim at modelling human behaviour to better understand complex situations. Ahmed et al. (2019) think along similar lines, aiming to understand human behaviour based on collected data and then influencing that behaviour through feedback loops. Sokolov, Yusupov, Verzilin, Sokolova, and Ignatjev (2016) acknowledge the complexity of SCPSs and indicate the dynamics of the parameters and the structures, i.e. boundaries, of such a system. Frazzon, Hartmann, Makuschewitz, and Scholz-Reiter (2013) furthermore also take the agency of humans into account, referring to them as 'human stakeholders' who are creative, flexible and have problem solving capacities. They place human stakeholders at the centre of the SCPS, meaning that both the cyber and physical aspects are there to support the social aspects. They also expand the thinking about the social aspect from human stakeholders as individuals towards the level of the organisation or other contextual backgrounds. Lioutas, Charatsari, La Rocca, and De Rosa (2019, p. 3) place the SCPS in a smart farming context and state that "human action is a necessary condition for transforming big data and the farm, while, at the other end of the spectrum, humans continue to be in charge for the decision making processes [...] which, in their turn, further alter the physical and the cyber dimensions of the system."

This aligns with the DESIRA perspective where the SCPS was used to understand the digital transformation in agriculture, forestry and rural areas. Novel or existing digital tools and platforms can be used to enhance knowledge exchange, interaction and documentation of information and in this way stimulate multi-actor innovation (Hansen et al., 2014). At the same time, Lindblom, Lundström, Ljung, and Jonsson (2017) argue that implementation of new technologies for (sustainable) smart farming should not only offer "technological fixes", but should also lead to the involvement of different stakeholders in the development of new knowledge and practices.

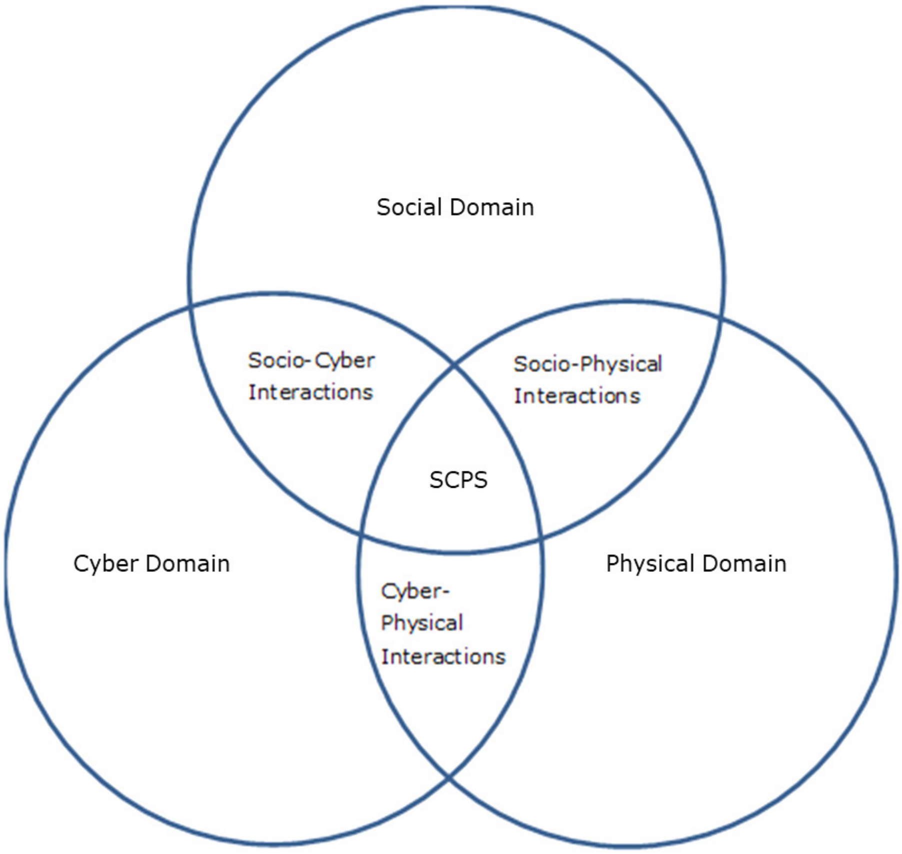
From an analytical perspective a SCPS consists of three domains, e.g. social, cyber and physical, which in turn each consist of a variety of entities (see Table 1 for definitions). Intradomain relations and interactions are often governed by a particular type of entity within that domain, which is a set of rules. The domains also interact with each other leading to certain (wanted and unwanted, known and unknown) outcomes and adaptations to the system which they form together. There is an existing SCPS in which actors operate at different scales (e.g. individual, organisational, markets and value chains, regional, national, global), which can be adapted according to the needs and desires of actors at these different scales and due to the interactions (e.g. feedback loops) between social, cyber and physical domains.

Tab. 1: Entities and domains of the SCPS

	Entities	Domain
Social	Markets, institutional elements (formal rules and regulations and informal – cultural non-written rules, norms and values), actors (more than the human aspect of CPS, because actors are also considered to have agency in order to make free choices) and the resulting groups, communities or organisations and their particular behaviour.	Relations between entities in the social domain are regulated by **social rules**, such as laws, conventions, routines, ethical norms, informal behaviour.
Cyber	Cyber entities are composed of a) digital reproductions of the physical sphere, as well as b) original digital constructs. In the first case, digital entities are created by digitisation processes, that is transformation of analogue entities into digital entities. In the second case, for example through the creation of software, data mining and analysis, image creation, digital entities are created through the interaction of other digital entities. Digital technologies can for example include big data; digital infrastructures; connectivity, e.g. 5G; sensors; front facing technologies, e.g. applications.	The relations between entities in the cyber domain are regulated by **cyber-rules**. For example, communication between devices is regulated by specific protocols (such as WiFi, Bluetooth, 5G); another example is the data format (PDF, DOC, …), a specific arrangement of data so that they can be stored, exchanged, and correctly interpreted, for instance. Digital technologies can communicate with other technologies, digital entities interact with other digital entities, performing operations and making choices potentially independently of humans, while initially being designed by humans.
Physical	These entities can be natural or artificial, according to the degree of manipulation they have undergone as a result of human activities. This includes living organisms and natural resources (plants, animals, etc.) and physical things to support living and working in the (natural) environment (e.g. analogue technology, infrastructure, finances)	Relations between entities in the physical domain are regulated by **natural rules** and by **technical rules**. For example, wild animals select in the environment the entities – plants or animals – that suit their nutrition, avoiding harmful entities. Water cycles are regulated by natural processes, such as evaporation and precipitation, but also by technical processes, such as water extraction from wells or circulation into pipes.

As can be read in Table 1, in the context of agriculture, forestry and rural areas, the physical world can also be understood to comprise the ecological world, so a socio-cyber-physical system may even be seen as a socio-cyber-physical-ecological system as has been tentatively argued (Klerkx et al., 2019). This already shows that it is difficult, in the real world, to isolate interactions between entities belonging to a single domain. Our social interaction is profoundly influenced by our physical world, and even when machines interact only amongst themselves, they have been designed by actors that can switch them off at any time. However, for analytical purposes, it is useful to make distinctions. Firstly, the interactions between cyber and physical domains occur through automation, data collection, management, monitoring and controlling, e.g. Internet of Things. This also includes feedback loops from cyber to physical. E.g. milking robots causing the cows to adjust their milking patterns. Secondly, the interaction between the social and physical domains, which could include the governance of natural resources, e.g. irrigation systems or the legal requirements for buildings in a natural environment. Other examples are ecotourism, or the connection between farmers and their livestock, the links between the quality of road infrastructure and rural entrepreneurship. And finally, the interactions between the cyber and social domains that for example influences jobs, enhances sensing capabilities of people, creates social media networks – i.e. the cyber entities function as a multiplier of the social entities. The social entities, such as values, in turn create the basis for, for example, programming and algorithm development.

Fig. 11: The socio-cyber-physical system with related interactions based on the three domains (social, cyber, and physical)



Hence, entities belonging to different domains interact through **hybrid rules**: that is, combinations of rules governing the respective domains or utterly new rules. In the interaction, the three domains constantly provide new inputs to each other and at the same time also receive outputs. In the process of digital transformation, special emphasis is put on the cyber domain, as the physical and social entities become encoded into digital entities. The interaction between the physical and social domains with the cyber domains opens unprecedented possibilities. In fact, the cyber sphere can augment the experience of social actors by amplifying human perception with additional information to sensorial experience, by reducing the friction of space (by interacting remotely) and drastically reducing execution time of operations. Moreover, the cyber sphere can create virtual realities, multiplying the experiences of actors. The interaction between the social domains and the other domains is operated by **interfaces**. A keyboard is a physical interface between the social and the cyber world. When we type on a keyboard, we transfer meaning from the social domain to the cyber domain. Likewise, a camera is a physical interface between the social and the cyber domain.

Box 3: Example of AirBnb as a SCPS

Airbnb is a digital technology that influences a socio-cyber-physical system which exists of people looking for tourism experiences (social) through means of housing (physical), making use of the Airbnb platform (cyber). However the interactions between those elements have multiple (positive or negative) consequences. They affect the tourism market for accommodation, the experiences as a tourist (accessibility, privacy, etc.), the city infrastructures, rules and regulations about sub-renting and ownership of housing, liveability in cities (busier city centres, increase tourism oriented shops), housing markets (price increase). Airbnb consequently needs to provide insight into their algorithms, adapt them accordingly to meet local legal requirements, moreover data privacy of both owners and renters has become an issue, as well as the physical safety of owners, renters, as well as the surrounding neighbourhood.

Example of a Milking system as a SCPS

If a robotic arm is introduced in a milking system (e.g., milk, farmer, control unit, etc.). The arm can replace the activity of the human in applying the cluster to the udder of the cow. However, access to the control unit; the ability to use it; the choice for a particular type of robotic arm; the regulation of the milking process; etc.; are set by social aspects. These social aspects can include organisational rules around the farming household or the developer of the robotic arm, skills of the farmer, regulations for using a robotic arm, social values of the farmer and the farming community.

In summary: A SCPS consist of three domains (socio, cyber and physical), all of equal importance and with the ability to influence other domains. Each domain has a broad range of different entities that not only within the domain are governed by a set of rules, but also between domains hybrid rules determine the relations and interactions of the entities within the domains.

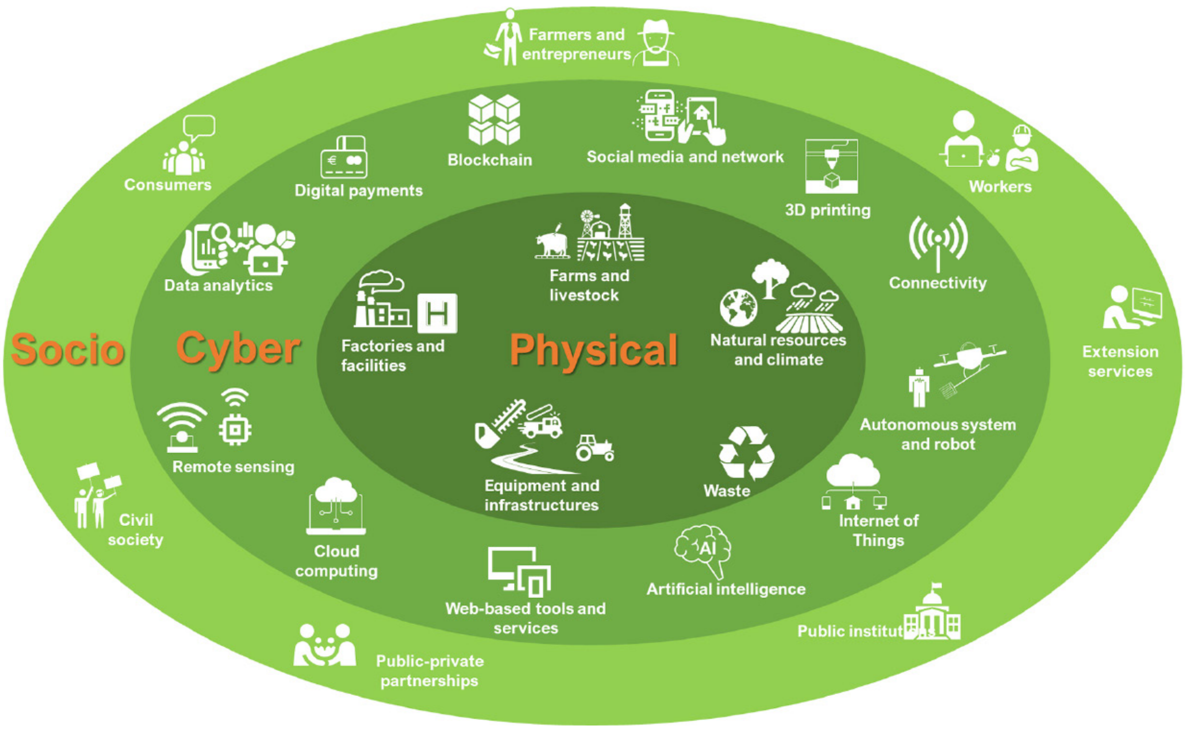
4.3 Empirically grounded Socio-Cyber-Physical Systems Framework

In the initial CAF the SCPS framework was described as a tool to think and learn about the nature of relations and interactions between social, cyber, and physical entities in a certain environment. The two distinct theories of cyber-physical system and the socio-technical system were both described first. The cyber-physical system theory is a frequently used theory to understand the expansion of the physical world through digital technologies. Since the social factor is missing in this theory, for a more human-centred approach the SCPS was introduced. The socio-technical system theory was also presented because it serves as the basis for the SCPS theory. The three domains of social, cyber, and physical entities within the system have been described, also by means of examples to provide a detailed overview of the SCPS framework.

Amongst all the concepts and theories of the initial CAF, the SCPS framework has been applied or used the most in the local LLs. The framework was used to discuss the different entities (social, physical and cyber entities) that interact in a given application scenario. The concept of application scenario has been introduced to identify the context where digitalisation intervenes. At broad level, we have identified three **application scenarios** - agriculture, forestry, rural areas -, and within each of them we have identified more specific application scenarios, such as, for example, irrigation, pest management, wildfire management, marketing of farm products.

Some LLs used a simplified version of the SCPS framework to study the structure of the LL, others mentioned that the framework is too narrow and that they rather use more holistic system theories that can be applied in practice.

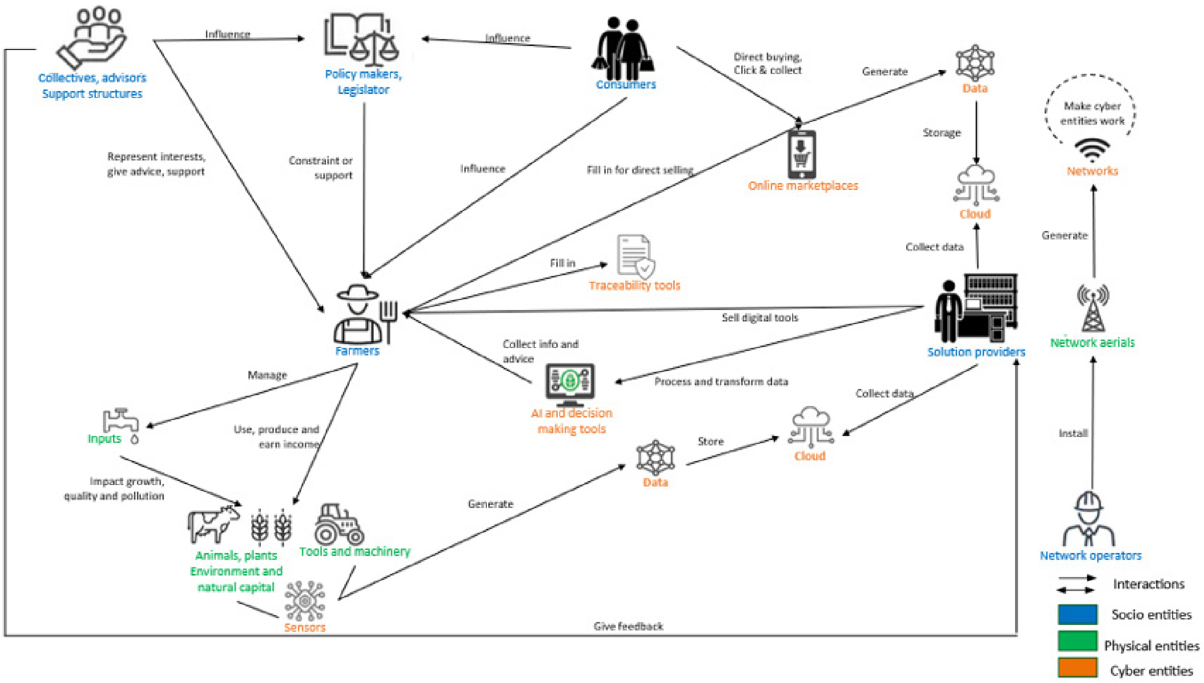
Fig. 12: Visualisation of an agri-rural and forestry SCPS and its entities (Source: D2.2)



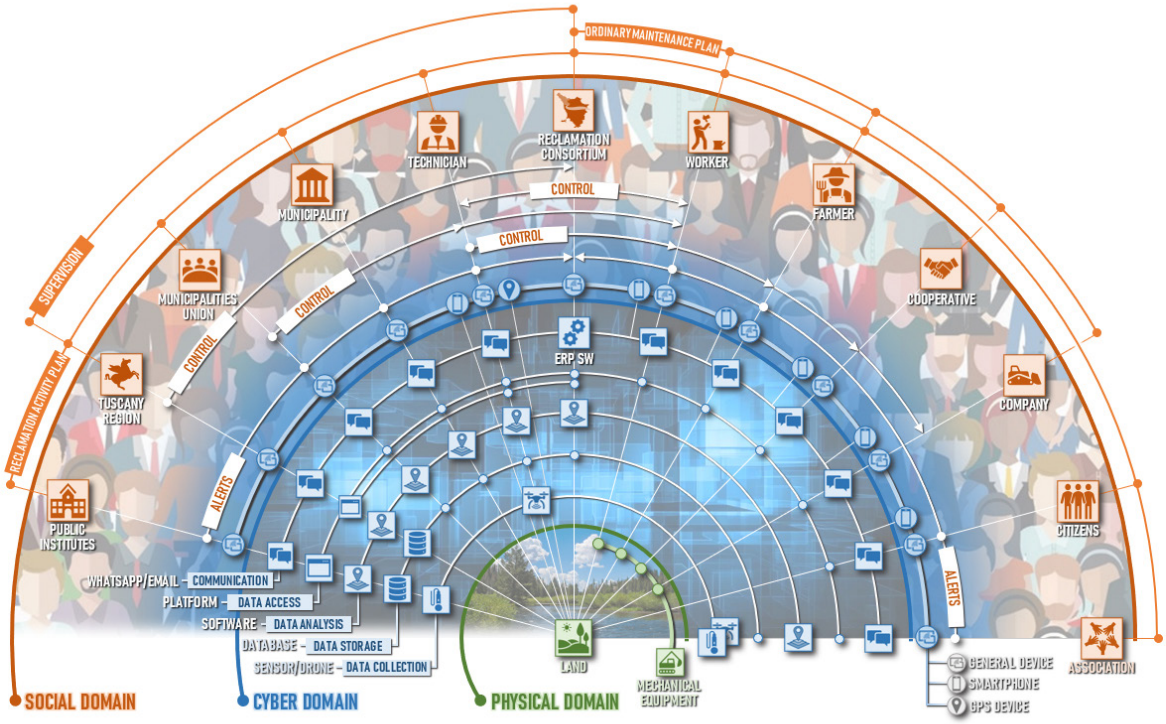
The LLs that applied the SCPS framework also highlighted they found it difficult to define the boundaries of the three entities. It was difficult for actors within the LL to determine which entity is defined as either physical or cyber. For example, is a robot a cyber or a physical entity? This brings us to consider the notion of **hybridity**.

SCPS are sometimes governed by **hybrid rules**, but the original CAF did not address if there are also hybrid entities (as for example bionic body parts that are arguably socio-physical). While the concept of hybridity is not explicitly mentioned, hybridity is seen as an inherent part of the SCPS by LL participants, and should thus be further explicated. The concept of hybridity helps to explain why certain entities within the SCPS evolve and merge from either socio, cyber, or physical (which could be referred to as mono-entities) entities to socio-cyber, or cyber-physical, or socio-physical entities (which could be referred to as e.g., poly-entities). Taking the concept of hybridity into account also clarifies the difference between interactions of the entities and shift or development of the entities into a specific area of the SCPS.

In general, the SCPS framework has been used to map the components of the focal question that the participants have addressed. So for example in Central val de Loire in France the focal question was "*How has digitalisation allowed companies in the French horticultural sector to remain competitive on the international market*", and the resulting SCPS is the following:



Similarly, the Toscana Nord case in Italy has mapped all the elements of the Land Reclamation Agency:



In hindsight, we could say that in these cases the SCPS have been used to describe the digital ecosystems in which LL operate.

A digital ecosystem can be defined as the set of cyber, physical, social components that contribute to a given goal. So, for example, when considering selling online we have to consider farmers, consumers, social media, the products, the e-commerce platform and its providers, etc... Each of them performs a given function in the system and activate specific forms of (digital) interaction with other components.

Fig. 13: Digital(ised) milieux in an agri-rural and forestry SCPS (source: D2.2)

The concept of digital ecosystem also helps to consider the differences between application scenarios.

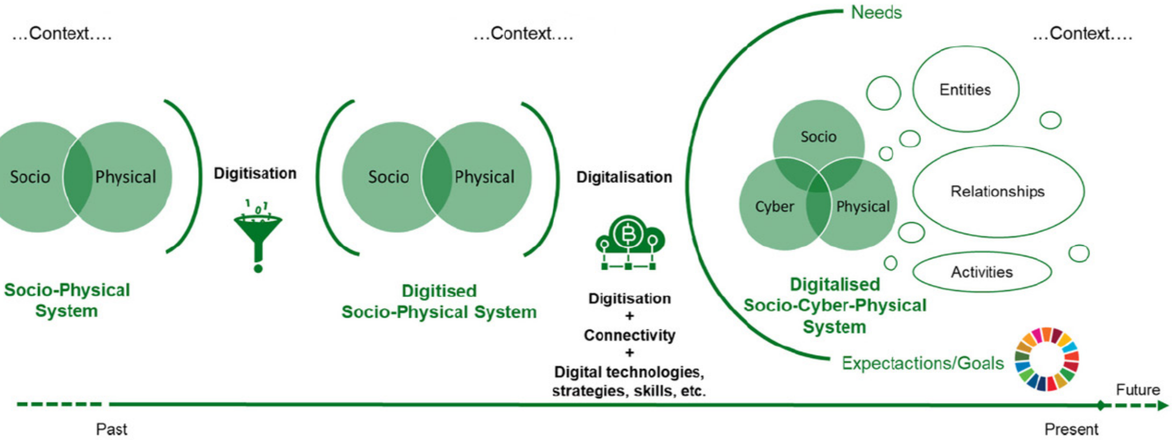
In Metta et al. (2022) it was highlighted that there is a difference between digitalisation in specialized agriculture and digitalisation in multifunctional agriculture. In multifunctional digital agricultural systems, more stakeholders are involved and looking at digitalisation in these more complex systems help to understand the tensions and synergies between productivist and non-productivist functions (see e.g., Klerkx and Rose, 2020; Schnebelin et al., 2021) and thus supports responsible digitalisation in agriculture. Because of the latter and because more top-down conceptualisations exist that do not take into account the RRI concept, theoretically the application of the SCPS framework can be justified.

4.3.1 SCPS Framework and timescale

Within DESIRA, further research was conducted on the SCPS framework and described in "An integrated socio-cyber-physical system framework to assess responsible digitalisation in agriculture: A first application with Living Labs in Europe" by Metta et al. (2022). Metta et al. (2022) argue that the framework can be applied on different time-scales, in the past, present or future, and also on different levels, i.e., on farms, sectors, or supply chains. This flexibility is described to meet the context-specificity of participatory settings, because SCPS can be specific by focussing on e.g., single actors or can be scaled-up to get a broader view on e.g., involved stakeholders of the extended LL network and also allow LLs to decide for themselves on what timescale they want to focus. From the Participatory Theory Building interviews, it became apparent that the flexibility of the framework was however perceived as a burden by the interviewed actors from the LLs.

Metta et al. (2022, p.14) revised the SCPS framework "to facilitate an in-depth, participatory, and reflexive analyses of impacts at levels of system entities, relationships, and activities." Since the digital transformation process of moving from digitisation to digitalisation may also be a change in scale, theoretically the flexibility of the concept is an important characteristic. Therefore, a timeline to the SCPS concept was added to take its evolutionary nature into account (see Figure 14). They also found that by "starting from a specific problem or opportunity, selected as subject of the LLs' focal question, we were able to understand how socio-cyber-physical entities have assembled and brought about changes at level of needs, entities, their relationships, and activities."

Fig. 14: Integrated conceptual framework to assess impacts and support responsible digitalisation (Metta et al., 2022)



4.3.2 Similar Theories and their Relation to SCPS

To further reflect on the added value of the SCPS framework in the following the framework is compared to similar frameworks applied in Sustainable Transition Studies (STS). The initial CAF gives a logical explanation of a system and the three domains, etc. However, during the PTB the question arose if the SCPS framework adds anything to existing system frameworks, because there seem to be many similar frameworks.

In the LTVRA (Long Term Vision for Rural Areas, EC, 2021) the concept of digital innovation ecosystem (to support and accelerate the digital transformation in rural areas) was used to explain how, together with other factors, digital innovation enhances the digital maturity of rural area. In the long-term vision, the concept includes social, physical, and cyber entities, and is thus comparable to the SCPS framework. The digital innovation ecosystem was also applied in Chae (2019), emphasising the complex nature of the network of digital innovation ecosystems. It also focusses on the interaction between social and technological entities in the system.

In STS, concepts similar to the SCPS and the digital innovation ecosystem concept are used to explain the development and the interactions of entities within a system. The socio-technical system and cyber-technical system, as described in the initial CAF also follow this approach. The only difference between those system concepts seems to be the broader definitions on which entities are part of the system, but the underlying mechanisms are the same. Therefore, the question arises what the SCPS framework adds to the previously described concept of digital innovation ecosystem, which will be addressed in the following paragraph.

4.3.3 Conclusion on Empirically grounded SCPS

The initial framework of SCPS lacks validation or justification. The framework shows that digital technologies are used to sense and interact with the social and physical world through data. It thus sheds light on the interactions between the three entities of social, cyber, and physical actors. However, as explained earlier, the concept of interaction is seen in every system theory (for example, the socio-technical system framework is used to explain interactions between people and the digital technology) which could be why it is not clear to users why this theory should be used over other system frameworks. But this does not necessarily mean that there is no good reason to apply the framework in practice.

Overall, the SCPS framework helped to understand the characteristics of the system in the LL or the system that the LL is part of. However, it was questioned if the theory adds to conventional systems thinking and the theory was perceived as rather fuzzy. Metta et al. (2022) found that the LLs focal questions differed in time-scale and scale of the system. Generally, the flexibility of the SCPS framework in time and scope helps to adjust the framework to the needs of the LL. This is why no limitations have been added to the framework in terms of time and scope. The framework is, however, mainly useful as a descriptive concept. In order to attach meaning and interpretation, SCPCS description should be accompanied by a focal question and other concepts such as socio-economic impact or digital game changers as has been done within the DESIRA LL.

Moreover, in this chapter we compared other system frameworks to the SCPS framework. The different systems framework can only be distinguished by their entities, which have individual characteristics. An important basic premise within DESIRA is the linking of RRI with the SCPS framework as a necessary condition for social innovation processes, which sheds light on the importance of the social dimension of digitalisation.

5 Digital Game Changers

5.1 Disruption and digital transformation

In the Collins dictionary the definition of the term disruption is described as follows: "When there is disruption of an event, system, or process, it is prevented from continuing or operating in a normal way". Disruption interrupts the normal way systems work. When a system undergoes disruption, all elements of a system are reorganized: some entities become obsolete, new entities are embodied, the material and immaterial flows change, and relations and interactions between entities are reshaped. Also the outcomes change, both in diversity, quantity and in quality. Disruption is an "outcome that can be measured not just by its process but by both its results and its process" (Millar, Lockett, & Ladd, 2017, p. 254).

Technologies are important drivers of disruption (Downes, 2009). The Gartner Glossary (Gartner, n.d.) defines digital disruption as follows: "Digital disruption is an effect that changes the fundamental expectations and behaviours in a culture, market, industry or process that is caused by, or expressed through, digital capabilities, channels or assets". When introduced into current socio-technical systems, they have disruptive effects, as they profoundly affect daily practices and the roles that people, animals, and things play, e.g. robots can replace or complement human labour; smartphones replace computers, cameras, clocks, voice recorders. In other words, a disruptive (digital) technology may potentially lead to a disruptive innovation process (Millar et al., 2017), e.g. digital transformation.

Digital transformation involves, in many cases radical technological, social, institutional, economic, and/or environmental change at the level of either individuals, organisations, a (subset) of an industry or even at a societal level (Kilkki, Mäntylä, Karhu, Hämmäinen, & Ailisto, 2017). Schuelke-Leech (2018) categorizes the levels at which disruption takes place: First order disruption is a localized change within an industry or market (e.g. this could be at business level); And second order disruption entails changes across multiple industries and affects social norms, relationships and institutions (e.g. at national or global level). In this project digitisation can be seen as first order disruption, and digitalisation as second order disruption, both contributing to digital transformation.

From a business perspective, disruption is often described as an opportunity, e.g. being disruptive gives a business advantage (Kilkki et al., 2017). Here digital technologies can support in creating more efficiency and efficacy, resulting in more productivity, profitability, and ideally sustainability. Fitting with this perspective is the idea that disruptive technologies and/or processes will, for example, be cheaper and of better quality, therefore more competitive and attractive to new customers, better supported by regulation, and more sustainable in terms of resource use (Millar et al., 2017). This perspective is often held by new companies and start-ups, or incumbent firms with a clear strategy towards the disruption (Phillips, Relf-Eckstein, Jobe, & Wixted, 2019).

However, disruption is often also seen as negative but unavoidable, i.e. digital technologies are constantly being developed and improved and there is no choice but to use them, for example due to changing context and requirements of stakeholders (Scholz et al., 2018). Disruption is then perceived as something that is external, without the ability to influence it, especially because disruptive technologies are often only identified ex-post (Dotsika & Watkins, 2017). This is often the case when organisations are not yet sure of what the disruption might entail and how to anticipate on it, let alone have a strategy to cope with, or make use of the disruption (see for example Rijswijk, Klerkx, & Turner, 2019). Furthermore, disruption may also have a number of ‘unseens’ and ‘unknowns’ which are not visible yet when a digital transformation starts to unfold (Scholz et al., 2018). In other words, while it is acknowledged that disruption contributes to the volatility, uncertainty, complexity, and ambiguity of a given situation (Millar et al., 2017; Pandit, Joshi, Sahay, & Gupta, 2018), not everyone is able to understand and respond to that in an early stage (Dufva & Dufva, 2018; Rijswijk, Klerkx, & Turner, 2019).

5.2 Game Changers

In everyday language, game changers are defined in many ways: it can be a person, a product, a policy, a great idea, or anything that changes ‘the game’. The concept of game changers can thus be applied to whatever generates a deep change in the normal routines: daily habits, social relations, working patterns. What becomes clear of the regular use of the term ‘game changer’ is that something has such an influence on a certain system in a certain environment that thereafter they are significantly different. If we consider a technical system, a game changer is an entity, a rule, an activity, that significantly changes how the system operates, as well as its inputs, its outputs, and its outcomes. Taking this into consideration, a way to describe digital technologies and digital transformation, besides disruptive, is *game-changing*.

When looking into the scientific literature game changers is a term that is often used without a clear definition, e.g. similar to the use of the term game changers in everyday language. Broadly, we can distinguish here **external game changers**, and **internal game changers**. External game changers are part of the system’s environment, and in the literature seen as shocks having an impact on ones’ activities. Avelino, Wittmayer, Kemp, and Haxeltine (2017, p. 1), taking a system transformation perspective, describe game changers as “macro-trends that are perceived to change the rules of the game, i.e., to change how society is organized and defined by today’s understandings, values, institutions, and social relationships.” (See also Avelino et al., 2019). Examples are the economic crisis, climate change, natural disasters and, for example, terrorist attacks, such as 9-11 (Campos et al., 2016; Loorbach et al., 2016; Westley, McGowan, Antadze, Blacklock, & Tjornbo, 2016). Some of these events had an impact at global scale, others on national or regional level. Thereby also, logically, impacting on communities, businesses, and individuals.

Others see game-changers either being internal, e.g. within the system, using agency to develop great ideas or new combinations. Others see it more coming from inside companies. For example, game-changing is used in the management literature with reference to disruptive business models, which may be connected also to new technologies. Abell (1980) quoted by Markides (2013), defines a business model as the sum of answers that a company gives to three questions: Who should I target as customers? What products or services should I be offering them? How should I do this in an efficient way? Game-changing business models are those that give significantly different answers from competitors: “significant shifts in market share and company fortunes took place not by trying to play the game better than the competition but by playing a different game—in a sense, by avoiding head-on competition." (Markides, 2013, p.1). An internal game changer is therefore an entity or activity embodied into the system.

In DESIRA, we consider an interaction between internal and external game changers, in the sense that they are connected and may amplify each other – hence, following ideas from complex adaptive systems thinking emergence of new natural, technological, or social phenomena may occur or game changers may trigger cascading effects (Burnes, 2005; Küppers, 2002; Loorbach, Frantzeskaki, & Avelino, 2017; Plowman et al., 2007). Such processes of emergence and cascading effects are not fully predictable, as there are many self-organising elements involved which are only steerable to a limited extent. Often, the individual elements in SCPS may not be game-changing per se, but the sum of the parts is game changing, as game changers are often multidimensional, meaning that there are links between for example social and environmental aspects (Loorbach et al., 2016; Olsson, Moore, Westley, & McCarthy, 2017). Following new technologies, or business models often new rules and regulations start to occur; new processes, products and services are being developed; new infrastructures arise; new interactions, networks and relationships are being formed; etc. and this all requires new (combinations of) knowledge, skills and capabilities (Herrero et al., 2020; Klerkx & Rose, 2020).

Game changers are generally considered disruptive, but it is often a question whether they are disruptive for good or bad, according to whom, and for whom or what? For example climate change, as an external game changer, is largely perceived as negative from a social, economic, and environmental perspective, and with a global impact. At the same time it might indeed be positively game changing (internally) for research on climate change adaptation (Campos et al., 2016).

Given the multidimensionality of game changers, it also becomes clear that understanding game changers requires a participatory and transdisciplinary approach (Campos et al., 2016; Swilling, 2016). Additionally, awareness and reflexivity are required, as the game changer notion may indeed have winners or losers, thus it can reproduce or strengthen the game that initially was undergoing a change (Avelino et al., 2017).

5.3 Digital Game Changers

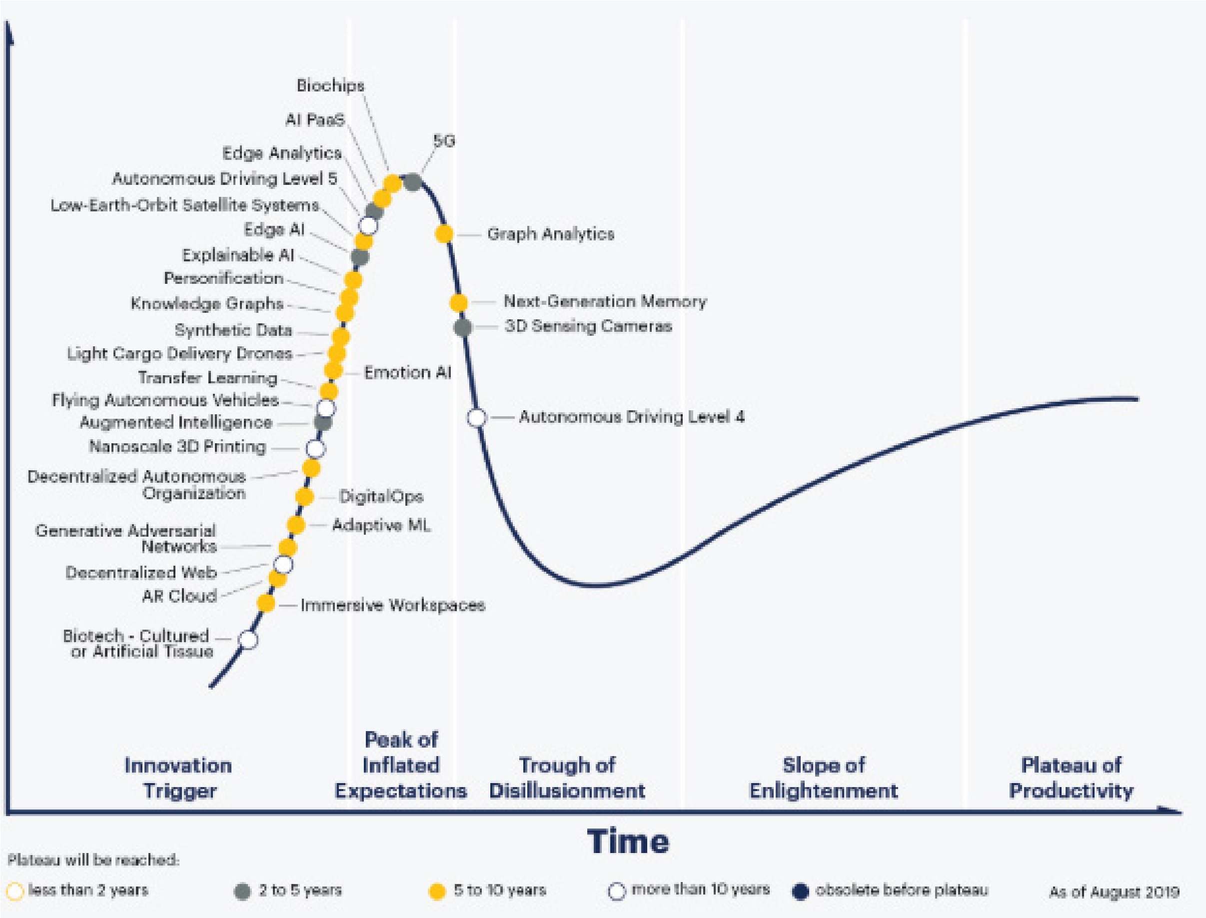
As described above digital transformation can be disruptive and game-changing. When seeing game changers as macro-events, based on the definition of Avelino et al. (2017), digital transformation can therefore be referred to as an external game changer since it can change market offerings, business processes, or models through the availability of digital technologies. However, according to Nambisan, Lyytinen, Majchrzak, and Song (2017), disruption can be related to the use of digital technologies within the system. In other words, digital technologies can be seen as *potential* internal digital game changers (DGCs). Game changing technologies interfere and may have different anticipated and unanticipated outcomes in the social world (Klerkx & Rose, 2020; Scholz et al., 2018), in terms of relationships, markets, institutional arrangements, practices. Potential, since not every digital technology will indeed be game changing in every geographical, temporal, or functional context. In the DESIRA proposal DGCs have been defined as "digital technologies that deeply reconfigure routines, rules, actors and artefacts of social and economic life" (DESIRA, 2018, p. 4). In addition, the social and economic life are explained as the business models, consumption, and shopping styles, service provision, as well as learning processes and innovation. Thus, the deepest socio-economic impact of digital transformation occurs when social, economic, legal systems are not ready to deal with digital technologies. Digital game changers are thus digital technologies that change the rules of a game.

In many cases, technology gives huge advantages to early adopters because transformation occurs into a regulatory void. According to Downes, 2009 the 'law of disruption' implies that "technology changes exponentially, but social, economic, and legal systems change incrementally". This has happened, for example, to the cultural sector when sharing applications were launched on the web that allowed bypassing copyright rules. Gartner (2019) provides a yearly forecast with an overview of emerging digital technologies, how they will progress, and the duration before reaching the so-called 'plateau of productivity', i.e. when they have become commonplace (see Figure 15). These emerging technologies include for example Big Data; artificial intelligence (AI); Internet of Things (IoT); augmented reality; 5G networks; virtual assistants to support daily live and work; and digital twins to create virtual models of reality; 4D printing; autonomous and smart robotics; and various levels of autonomous driving (Alm et al., 2016; Gartner, 2019).

The identification of the game (i.e. the system itself, or the domains, or - social, economic, environmental, institutional, etc. - aspects of those domains in the system) helps to understand that disruption may occur at several levels of complexity. A first level of disruption relates to the cyber domain or the broader technical system: when a new digital technology is developed, many technical systems become obsolete. This is the case of analogue cameras, magnetic tapes, vinyl records. Further levels of disruption occur when the disruption impacts on the interaction within the social domain and affects for example legislation that is not (yet) prepared to regulate it.

Often these emerging digital and potentially disruptive or game changing technologies depend on each other to function optimally, e.g. without connectivity there is no IoT. Moreover, they allow for combining knowledge, data, and processes of diverse physical machines that were previously disconnected (Yoo, Boland, Lyytinen, & Majchrzak, 2012) and have increasing autonomy, combining monitoring, controlling and optimisation activities (Porter & Heppelmann, 2014).

Fig. 15: Hype Cycle for emerging technologies (Gartner, 2019)



Regarding **agriculture**, the FAO states in their recent report on digital agriculture that it will not only change how farmers farm, but will change "fundamentally every part of the agri-food value chain" p.2 (Trendov, Varas, & Zeng, 2019, p. 2). Digital agriculture can thus be considered as a potentially disruptive innovation (Bronson & Knezevic, 2016; Kelly et al., 2017), providing both opportunities and threats to all parties within agriculture, forestry and rural areas. Klerkx and Rose (2020, p. 2) note in their review article that many articles now allude to the potential game changing capacities of digital technologies:

> *"The scientific literature on digital agriculture has primarily focused on the technical aspects of applying these technologies for improving agricultural practices and productivity (Rutten et al., 2013; Wathes et al., 2008), as well as improving post-farmgate processes, such as postharvest quality monitoring in logistic process and real-time traceability (Wolfert et al., 2017). By now, there is a large body of predominantly natural and design science oriented literature on (potential) applications of digital technologies in agriculture. This is evidenced by an increasing number of review articles on topics such as precision farming, big data analysis, drones, artificial intelligence and robotics, 3D printing, artificial intelligence, IoT, and the transformative potential of these digital technologies for agricultural production systems, value chains and food systems (de Amorim et al., 2019; Dick et al., 2019; El Bilali and Allahyari, 2018a; Hunt and Daughtry,*

2018; Kamilaris et al., 2017; Mogili and Deepak, 2018; Patrício and Rieder, 2018; Portanguen et al., 2019; Shamshiri et al., 2018; Skvortsov et al., 2018; Smith, 2018; Verdouw et al., 2013, Verdouw et al., 2016a, Verdouw et al., 2016b; Voon et al., 2019; Weersink et al., 2018; Zhang and Wei, 2017; Zhao et al., 2019)."

In **forestry**, similar technologies have been observed, for example using remote sensing and drones for plantation management decisions, and robotics for plantation management and tree harvesting. While the literature on game changing technologies in forestry is less extensive than in agriculture, it is now also emerging (Bayne, Damesin, & Evans, 2017; Bayne & Parker, 2012; Müller et al., 2019; Ogilvie et al., 2019; Parker, Bayne, & Clinton, 2016; Torresan et al., 2017; Watanabe et al., 2018; Zou, Jing, Chen, Lu, & Song, 2019)

For **rural areas**, as an authoritative review by Salemink, Strijker, and Bosworth (2017) describes, as well as other works in rural sociology (Pant & Odame, 2017; Philip & Williams, 2019; Roberts, Beel, Philip, & Townsend, 2017), game-changing technologies mainly relate to ICTs enhancing access and connectivity, such as wired and mobile broadband, and optic fibre internet in rural areas. In addition to this, also phenomenon like rural makerspaces are emerging in which technologies such as 3D printing are employed (Ensign & Leupold, 2018) as well as platform technologies for social exchanges in rural areas (Chowdhury & Odame, 2013).

In DESIRA, the taxonomy of game-changing technologies (see work package 1, task 1.2) will further unravel what actual game-changing technologies are manifesting and in what way they can be considered game-changing, as the game-changing technologies mentioned here are potential, as their game-changing properties may differ across systems and are dependent on the specific context (see also section 2 and 4).

The previous sections show that disruption and game changers are closely linked despite being used as concepts in different disciplines. We also see that digital transformation fits within both concepts. Therefore we describe digital transformation as an external game changer, e.g. as a macro event or second order disruption. In this process (cumulative) digital technologies may have potential internal game changing effects. I.e. not every digital technology will indeed be game changing in every geographical, temporal or functional context.

For DESIRA the game that was analysed is the socio-economic situation in the context of 20 Living Labs on agriculture, forestry and rural areas in Europe. Despite zooming in on the socio-economic situation we also take other aspects into account (e.g. institutional, environmental), as game changers are often multidimensional (see also Section 4 on socio-economic impact and in particular de Sustainable Development Goals, and Section 2.4 on the Socio-Cyber-Physical System). Moreover, it requires a transdisciplinary, participatory process.

Game-changing and disruption are key to understand the socio-economic impact of technologies. Here we want to flag that:

1. disruption occurs at different levels of complexity;
2. the level of disruption that technologies generate depends on how disruption in one domain is transmitted in other domains;
3. disruption can be generated by external as well as internal game-changers.

Some key characteristics of a digital game changer can be identified: it is based on the use of digital technologies, and has the potential to become widespread because of low costs (with respect to those in the past) or because it comes for free. Software-only solutions typically spread faster than those also involving hardware because the digital world operates at faster speeds than the physical one: that is why Facebook or Twitter took very little to enter our lives, or why solutions for online working are becoming increasingly popular. According to Aris, four fundamental questions need answering: is the new technology meeting a need (in a specific field)? Is it easy to use? Is it affordable? Is the right set of technologies in place? Answering yes to all those questions is a good hint to identify potential digital game changers to appear. For instance, drones are meeting the need of having improved monitoring abilities, and they are proving increasingly easy to use at affordable costs; the technological system was ready, while the legal part of the social system (consider the use of the aerial space, privacy concerns, potential damages due to falling, and so on) was not really in place, but it is catching up rather fast because of the diffusion of those objects due to their large versatility.

Box 4: Examples of potential Digital Game Changers

Cultured meat could be a game changer for the beef industry independently on its efficiency. If accepted by consumers and economically viable, cultured meat could make the beef industry obsolete.

Robotics can replace human labour, and this may increase dramatically the productivity of a firm. This is a positive outcome for the adopting firm. However, adopters of this technologies may gain a strong advantage against non-adopters. Non-adopters, less competitive, are expelled from the market. This generates unemployment and difficult reemployment of jobless people. In a context where there is a program for support, training and reemployment of jobless people, the transition can be smooth, and disruption limits itself to the technical and economic sphere. When this does not occur, higher level disruption occurs.

One example of this gap between speeds of change between domains is copyright systems. With the possibility of digitizing texts, images, and music, replication and circulation have become costless. The legal system built upon paper and vinyl was not ready to regulate the digital circulation of copyrighted material, so everybody could have easy access to digitalized copies without being caught by enforcing authorities. Even when enforcing authorities have adapted their surveillance systems, the easiness of circulation of information imposes a revision of the regulation to let the technology be beneficial to society.

Another example is UBER: the app that allows simple car owners to run a taxi, that allow travellers to order a taxi, to track its position, to pay a fixed rate, and evaluate the driver has disrupted the taxi services that operated in a regime of quasi-monopoly. When legislation has restricted the freedom of Uber taxi drivers the system has found an equilibrium.

As a last example, the use of Unmanned Aerial Vehicles (UAVs) or drones in several fields is having a large impact, thus provoking disruptions. Consider the use of UAVs in agricultural application to monitor fields from above in real time, or to their use in monitoring the health of ancient buildings: monitoring from above provides a different point of view, offers digital imagery that can be analysed for different purposes, can remove the need for scaffolding, all at acceptable costs with respect to similar services in the past. That is why they are being so largely used and firms providing such services are thriving.

5.4 Empirically grounded Digital Game Changers Concept

From the initial CAF it becomes clear that a digital game changer is disruptive in nature and that it facilitates digital transformation. The definition of digital game changers is rather broad in that a digital game changer can be a concept or a specific tool or any combination of things that change the game (the game can be understood as the way the system operates). Game changers may have different impacts, that are often unforeseen, can block or support other processes in the SCPS and may trigger a cascade of events. These characteristics ascribe complexity to the concept of digital game changers. The concept of game changers was used in the LLs in the context of the futuring exercise.

In the LLs, the digital game changer concepts was reflected upon. The LL facilitators realised that the question should not be 'how digital is a digital game changer?' but rather 'how game-changing is a digital agent?' Thus, they realized that the technology in itself is only relevant when the context the digital technology is embedded in fits the needs of other actors (like e.g. local growers.

However, in the LLs, the concept of digital game changers was seldomly used, amongst others because the game changers that have been found to impact the LLs were more often social actors rather than digital game changers. According to one LL facilitator, more and more technological innovations are categorized as digital innovations or digital game changers, while it is perceived that the digital component is relatively small. At least regarding the LLs that were interviewed, we could conclude that digital technology had little influence in their context and that social actors played a bigger role. Nevertheless, since the LLs applied digital technology, it may rather be that they underestimate the influence of the technology, as was already found when the LL assessed the cyber-entities of their SCPS. To make social actors aware of what digital technology entails, the right taxonomies, check-lists, or guiding questions could help (as has been described in section 3.2).

Another reflection on DGC is that even 'simple' digital technology or digital options can be very game changing depending on context. This shows that there is no correlation between the complexity of the digital technology and the impact of the DGC.

5.4.1 Drivers of Change

In the DESIRA project the concept of drivers of change (DOC) also played an important role, which is why it is included in this empirically grounded-CAF. In the scenario studies of the LLs the concept of DOC was used to describe external drivers such as demographic changes or political shifts that impact the LL and create change, either positively or negatively. DOC can therefore be interpreted as similar to what the initial CAF described as external game changers.

DGC as a possible solution

Switzerland and Germany: robotics as a DGC for the DOC of labour shortage

Labour shortage was an often identified demographic Driver of Change in the scenario studies carried out in the LL. In the LL of both Switzerland and Germany, labour shortage can be seen as a DOC. Labour shortages create problems in (local) economies that drives stakeholders to look for alternative solutions to remain profitable. In this case, robotics can be seen as a DGC that is a solution to this problem where a digital technology changes the game in a local economy, where automation is able to 'fix' a problem of shortage of human labour.

In Switzerland, weeding robots were identified as a way to deal with labour shortages in the organic vegetable sector. Similarly, in Germany robotics more generally replace agricultural labour. Although these examples appear only positive, it should be kept in mind that robotics and automation replacing human labour also comes with downsides, as for example observed in Italy where high use of technology was observed as going hand in hand with population decrease. Whether or not a DGC is an appropriate solution for a 'problematic' DOC therefore always remains context-specific.

In the LLs, DOC were operationalised using the STEEP methodology describing the social, technological, economic, environmental and political factors that influence change within the LL. This analysis was useful in determining the DOC relevant to the LL and look at their mutual dependencies, similar to the interactions of the entities in the SCPS. The STEEP methodology is widely recognised and was therefore chosen to operationalize the DOC in the DESIRA project. A limitation of this methodology is that it does not offer room for hybridity of DOCs. DOCs are attributed to a single category of factors, even if in reality we see several hybrid DOCs, for instance socio-economic.

DOC is a broad concept describing external factors that impact the LLs, whereas DGC are specifically about digital technologies and how these can 'change the game'. Regarding the STEEP methodology, DGC are thus categorized under technological factors that lead to change. But more specifically DGC are about the data-driven change processes. DOC can then pose a challenge (e.g. labour shortage) that DGC can potentially provide a solution for. For LL participants, the concept of DOC was much easier to understand compared to DGC. DOC were therefore more prominently used and defined with LL participants. This can also be attributed to the issue of LL actors who find it difficult to determine which entities are cyber-entities.

In the foresight exercise that LL carried out, drivers of change were considered as the component of different scenario (positive vs negative). For example, in the LL Toscana Nord in Italy depopulation was the key component of positive and negative scenario. In the first case, digitalisation would involve farmers in the management of hydrogeological risk, providing them with digital tools to signal the risk and to organize maintenance intervention. In the second case, in a scenario where farmers have abandoned land, digitalisation would provide a full remotely controlled system.

5.4.2 The game changing effect of digital technologies according to Living Labs

The influence of cyber-entities in the LLs was not directly apparent by the LL stakeholders. In our experience with interviewing LLs stakeholders, opening the black box of digitalisation was one of the first steps to encourage the assessment of digitalisation processes. In addressing the question of how to meet a sustainable development problem or opportunity, cyber-entities widely adopted in contemporary society, like social media, geotagging in online maps, or cloud storing could emerge as influential or, at least, recognised as an established component of socio-cyber-physical relationships. Indeed, many interviewees did initially not notice, but then they realised and explicitly listed various cyber-entities that were already part of the system under analysis for many years or that have been increasingly used in more recent days.

During interviews or focus-group discussions, taxonomies, check-lists, or guiding questions were deployed by LL researchers to stimulate stakeholders in self-inquiring and identifying any relevant digital technologies, tasks, and infrastructure already in use for the subject under their focal question. These analytical tools enhanced data collection even from those stakeholders who initially under-estimated the influence of digitalisation (literacy, use) or are deeply concerned on the use of digital means. At the same time, the presence (or absence) of cyber-entities is the starting point to analyse why certain technologies are present in the system and who benefits and who bears the costs of digitalisation.

LL report have shown that game changers are mainly those easy to use and cheap. Given that most rural actors don’t work in offices and have a high level of mobility, for them mobile phones are the most suitable tools for connecting. Social media such as WhatsApp help them reorganize their work in real time and coordinate with others. Other social media give them visibility on the market. In general, we can say that social media have been mentioned as breaking rural isolation and improving the organizational capacity of rural actors.

5.4.3 Agency of Digital Game Changers

To attribute the (possible) game changing characteristic to digital technology, means that we attribute agency to the digital technology. One of the lessons learned during the DESIRA project is that only the way social actants use the technology determines if the technology has positive or negative consequences. However, when a digital technology is implemented, it is programmed to do its work. Indirectly the technology thus has agency and can be seen as the prolonged arm of social actors, whose intentions in programming the technology determine the impact of the technology. In a SCPS, in which the social entities (like the other entities) are so embedded in the system where it is difficult to get change going, there is a path dependency regarding digital technology that also limits the agency of new entrants in the system. To become digital game changers, digital technology promoted by powerful actors or incumbent institutions has a higher chance of success. There is thus overlap between social agency and digital game changers.

Furthermore, since digital game changers have agency, they impact the SCPS. This again shows the narrow connection of the different concepts that are part of this conceptual and analytical framework. The concept of socio-economic impact is described in the following.

5.4.4 Digital game lockers

In our applied research, we learned that the transformative capacity of digitalisation can fail or reinforce existing path dependencies and lock-in effects. The failures of technological transitions are already well documented in the scientific and non-scientific literature (Wells & Nieuwenhuis, 2012). In D2.2, situations were highlighted where no or zero impacts of digitalisation were found for various reasons. In some cases, digital technologies were still in their piloting or early adoption stage, in others, effects were minimal simply because effects take time to appear. Zero or minimal effects emerge also as result of deviations between digitalisation and identified needs of stakeholders in a given (organisational, temporal and spatial) situation.

Digital game 'locker'

Precision farming activities, like the sensor-controlled hoeing machinery studied in lettuce production in Switzerland, can bring savings in terms of time and human labour in organic farming, but can also have negative effects on the maintenance of good agronomic and environmental conditions (GAECs) due to the weight of machinery (e.g., soil compaction) or the abandonment of effective crop rotation practices.

In Finland, dairy cooperatives or corporations can further strengthen their competitive market position through integrated management systems, or absorb most public funds available for Research, Development and Innovation, thus forcing small and independent dairy farmers to quit or adapt to centrally governed data-driven AKIS.

Mirroring the concept of DGCs, after working with LL and revising macro-level policies, we can speak about a "digital game locker" when digital transformations are not disruptive, but a continuity of the present system and instrumental to mantain business-as-usual situations. These locks-in or path dependencies effects are hard to measure and identify as they require critical, longitudinal, and multidisciplinary studies. In our Living Labs, we did not collect a rich pool of examples at micro-level, but two examples are included in the accompanying text box above.

6 Socio-economic impact

In the DESIRA proposal 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)" (DESIRA, 2018, p. 5).

6.1 Three conditions of impact: access, design, and system complexity

Impact can have multiple dimensions: we can group them into economic, social, and environmental dimensions or articulate them into more detailed categories (see next section). In each of the three dimensions, impact can depend on three conditions: access, design, and system complexity. Table 4 summarises the socio-economic opportunities and threats of digitisation related to these conditions:

Tab. 2: Socio-economic impact of digitisation (Adapted from DESIRA, 2018, p. 9)

	Opportunities	Threats
Access	Increase equal access to digital technology	Digital divide
Design	Solutions that anticipate unintended consequences	Design-related risk
System Complexity	Synergies between digital game changers	Digital traps

The first and most commonly known condition for benefitting from digitalisation are related to *access*, i.e. "the distribution of physical, social and human capital necessary to get access to digital opportunities" (DESIRA, 2018, p. 5). With as a result that some (groups of) people do not have access to digital technologies, leading to social and economic marginalisation (DESIRA, 2018) and uneven socio-economic development (Rotz, Gravely, et al., 2019; Salemink et al., 2017). Assessment of access conditions should consider potential users of the systems and those who may be excluded from it. What are the social, physical and cyber conditions necessary to access the technology or its outputs? How have the outcomes of the system been distributed as an effect of the change in the system?

Another condition for benefiting from digital technologies is related to the *design* of these technologies. Digital technologies are designed to realise a given (desired) outcome, i.e. to have intended consequences. However, digital technologies that aim to improve productivity, profitability and sustainability (Global e-Sustainability Initiative & Deloitte, 2019) can also have unintended consequences. In some cases, these outcomes can be harmful to people or to the environment, as in the case of weapons or technologies intended to discriminate, steal, or trick. For example, an irrigation system can be designed to save water and optimise the timing of irrigation. If the irrigation system is not designed properly, the application of this technology may have harmful outcomes, such as waste of water or interruption of water irrigation. Design-related impacts may also be related to the vulnerability of the system to environmental conditions, such as heat, wind, humidity. Moreover, they can be vulnerable to espionage or cyber-attacks. Poor design can lead to privacy breaches, data appropriation, sabotage. A recent example: Zoom, one of the most used teleconferencing systems the use of which has grown from 10 million to 300 million users, has generated strong security concerns, as unwanted actors have entered video meetings and disrupted them. After these attacks, Zoom has released a new version of its app.

A third condition is *system complexity*. The more digitisation proceeds, the stronger the need to connect system entities to each other. Increasing connectivity adds to complexity because of the multiplicity of ways that each entity interacts with others. Complexity raises a number of issues on which each outcome of the system can depend, and decreases the manageability of the system. According to Perrow (2011) complexity of a system combined with too tight coupling (strong cause/effect links between entities) leads to vulnerability of systems and to domino effects. With systems that have a low level or a poor integration it is likely that adaptation is challenging and may have negative socio-economic consequences, or *digital traps*. The higher the integration level and the quality thereof "the better the outcomes of innovation" (p.6). Assessing system complexity should consider the outcomes of changes of entities and activities of a system in relation to the connections with other entities and other domains. For example, new operating systems of a laptop are not fit to old computers, and this implies that old computers become obsolete. When devices need to communicate with each other, emerging problems can be only fixed by specialists. In complex systems, choice of the right technology may be a problem in itself, as it requires skills and time.

Further and more elaborate cases of complexity relate to the cross-dominion implications. For example, social exclusion related to digitalisation can be caused by lack of access to the Internet and the cost of an application (*access* conditions), or the design of a technology with a gender or racial bias or intrusive forms of conditionality (see the UN report on e-government, UN 2019) (*design* conditions), or to the difficulty to make all parts of a system work (for example, the electronic Identification code for access to the health service) (*complexity* conditions). The integration between digital technologies and the social organisation (e.g. institutions, leadership, skills) may add to complexity. For example, social networks and connectivity can amplify social disparities such as exclusion, bullying, criminal organisation. In relation to agriculture, forestry and rural areas the three conditions (access, design and system complexity) often come with a number of potential threats and opportunities commonly described in the literature.

Poor access to digital opportunities by certain groups of people (often based on location) create a *digital divide* (Rotz, Duncan, et al., 2019), which hampers the socio-economic development of certain areas and people. This divide is often a divide between urban and rural areas, but this divide also exists among rural areas (Townsend, Sathiaseelan, Fairhurst, & Wallace, 2013). Across Europe, rural areas are lagging behind when it comes to digital connectivity and accessibility. Only 40% of rural households in Europe have next generation access (fibre-based, high-speed broadband services), compared to 76% of total European households (European Commission, 2017). Among EU countries, the rural-urban gap differs across countries, with only a 2% gap in the Netherlands compared to a

25% gap in Bulgaria (Trendov et al., 2019). Rural areas are dependent on lower internet speeds and less reliable connections (Skerratt, 2010). Lack of digital access and/or connectivity puts pressure on social and economic development of rural areas, essentially excluding rural areas from completely participating in temporary society (Salemink et al., 2017; Trendov et al., 2019) because they have less or no access to services such as eHealth (Hage, Roo, van Offenbeek, & Boonstra, 2013), eGovernment (Quinn, 2010; Trendov et al., 2019), (public) transportation services (Velaga, Beecroft, Nelson, Corsar, & Edwards, 2012), educational services (Trendov et al., 2019) and entertainment and leisure (Townsend et al., 2013). But rural areas are also disadvantaged because there is limited or no market competition (amongst others due to unattractive investment conditions such as physical distance and lower population density) (European Commission, 2013; Malecki, 2003; Salemink et al., 2017). This widens the gap between rural areas with unattractive business opportunities and urban areas with growing markets and increasing business investments (Townsend et al., 2013). Digital technologies and mobile services in particular have great potential in realising socio-economic benefits for (remote) rural areas, especially related to health, agriculture and financial sectors (Boekestijn, 2017). Broadband connections for rural communities can be a solution to reduce inequalities and can ensure that rural areas enjoy the benefits of better connectivity (Roberts et al., 2017; Townsend et al., 2013). Others warn that digital technological advancement in rural areas can also have adverse effects such as excluding rural people within their own communities if they do not use new digital technologies or devices (Kilpeläinen & Seppänen, 2014). Moreover, limited access does not only relate to the availability of technologies, for example internet connectivity, but also to the ability to adopt and use these technologies (Salemink et al., 2017; Townsend et al., 2013) . Due to the large variety of technologies and applications, as well as the related adoption and (abilities to) usage, the digital divide represents a broad range of access problems (Salemink et al., 2017). The digital divide may thus reinforce existing power differences, for example between farmers and suppliers, as well as social and economic differences in relation to labour and skills (Bronson & Knezevic, 2016; Townsend et al., 2013; van der Burg, Bogaardt, & Wolfert, 2019).

Design-related risks are the (unintended) consequences of unequal distribution of power and risks created by the innovation itself, resulting in winners and losers (DESIRA, 2018, p. 6). Examples of design-related risks are disappearance of the need for human skills (and subsequent potential unemployment) due to automation, discrimination based on profiling or loss of privacy (Scholz et al., 2018). These risks also apply to digital technologies in agriculture, forestry and rural areas, for example robotics in precision farming taking over human work or risks regarding privacy and data protection in forest and farm management applications. However, there are also design-related risks that apply more specifically to agriculture, forestry and rural areas. Agricultural advisors play an important facilitating role in the digitalisation of rural areas and agriculture (Eastwood, Ayre, Nettle, & Dela Rue, 2019), because they are critical for diffusing digital innovation (Fielke, Taylor, & Jakku, 2020). Digitalisation will likely increase connectivity of humans and technologies, driving and driven by growing connectivity (Fielke et al., 2020). However, digitalisation of agricultural knowledge and advice networks is also likely to create a challenge in balancing various agricultural stakeholder's priorities (Fielke et al., 2020). As Bronson (2018) warns: certain digital innovation in agriculture (e.g. big data or the way algorithms are designed) may reinforce power among agricultural businesses by their very design, serving already rich and powerful parties. Moreover, there are often societal concerns regarding the introduction of digital technology in agriculture, forestry and rural areas. For example, public concerns about privacy and safety of digital biosecurity measures to protect forest health (Ogilvie et al., 2019). User-centred design and participatory design methods where end-users as well as those affected by digital technology are included upfront in the design of new technologies has been suggested as an important measure to combat design-related risks, improve outcomes and anticipate unintended consequences (Bronson, 2018; Ogilvie et al., 2019; Rose & Chilvers, 2018). Of course, there are also design related opportunities of digitisation, i.e. solutions that anticipate unintended consequences (DESIRA, 2018). Specific to agriculture, opportunities of digitalisation typically centre around increased efficiency, such as automation, precision mechanisation or improved decision-making (Fielke et al., 2020). To be able to anticipate unintended consequences, it is important to identify potential winners, losers and opponents of a digital technology and take their considerations into account. This implies the importance of applying the principles of Responsible Research and Innovation.

Examples of *digital traps*, in relation to agriculture, forestry and rural areas, are the blurring roles of knowledge providing organisation, technology suppliers and farmers (Eastwood et al., 2017), but also "information overload, digital addiction, virality of fake news, cyberbullying and cybercrime and loss of human control over machines" (DESIRA proposal, p.6). For many companies and other organisations, complexity challenges are related to incompatibility or lack of standardisation of software and lack of data storage (European Innovation Partnership AGRI, 2015; Higgins, Bryant, Howell, & Battersby, 2017); uncertainty around the value of data (Poppe et al., 2013); suitability of existing large databases (Magee, Lee, Giuliano, & Munro, 2006; Philip Chen & Zhang, 2014); lack of trust in the quality of industry databases (Cooper & Green, 2015; Minet et al., 2017) and data ownership issues (Bronson & Knezevic, 2016; European Innovation Partnership AGRI, 2015; Poppe et al., 2013). We can already observe that existing digital technologies are changing business models, market integration, coordination among businesses, configuration of Agricultural Knowledge and Innovation Systems (AKIS) but also interaction with policy organisations (Poppe et al., 2013, DESIRA proposal, p. 24). In agriculture, there are already many tools to deal with these complexities, for example decision support systems are widely used among both farmers and their advisors (Rose et al., 2016). While less developed, forestry and rural areas are developing such tools as well. Positive socio-economic impacts related to systems complexity is that complexity allows synergies between digital game changers (DESIRA proposal, p. 10), because system complexity implies integration between both technologies as well as social organisation (DESIRA proposal, p.7).

6.2 Empirically grounded concept of socio-economic impact

Socio-economic impact in the context of the DESIRA project was initially described as the opportunities and threats of digitalisation that may create winners or losers. There are three conditions that influence socio-economic impact, which are access, design, and complexity. Moreover, the SDGs are described as an important goal that concentrate on the socio-economic impact.

In the course of the DESIRA project, Rolandi et al. (2021) have worked on a framework that provides a classification of impact caused by digital technologies to better understand the socio-economic impact of digital technology. According to them the "adoption [of digital technology] deeply transforms the wide context in which both routines and interactions take place due to their connection with multiple elements of the socioeconomic system" (p.2). This interconnectedness of digital technology in the socioeconomic system is said to often promote the status quo. In order to concentrate more on socially just transitions in agriculture, forestry, and rural areas the authors proposed a way to generate a more comprehensive and detailed overview of impacts of digital technologies. This so-called taxonomy includes social, economic, governance, and environmental factors that help researchers to have a broad but in-depth study on the impact of digital technologies in a given socio-economic system.

From the PTB it emerges that the concept of socio-economic impact was perceived as rather underdeveloped. Most criticism is directed towards the impact assessment, based on the SDGs, which is believed to address macro targets and are therefore not suited for the local targets of LLs. The impact assessment is said not to showcase the reality of the LLs, because there is a difference between lived realities of stakeholders and macro targets identified at national/EU level.

Since LL facilitators found it a challenge to discuss farm sustainability in its broad sense, instead of only focussing on economic sustainability, the concepts of access, design, and complexity in real world setting get more attention in this section to support a more thorough exploration of the socio-economic impact on local level. As it was highlighted during the workshop at the GA in January 2023, the LLs concentrated mostly on three positive impacts of digital technology when they discussed the digital transformation. However, by using the more concrete concepts of access, design, and complexity is said to help to shed light on the more negative effects also. By concentrating on the negative impacts of digitalisation as well, policies may be created that try to avoid these acknowledged negative impacts.

6.2.1 Access, design and complexity in real-world settings

The concepts of access, design, and complexity were applied in more detail in the LLs. However, mostly the concepts of access and design were found to be useful in the LLs. The concept of complexity was found to be difficult to implement and operationalise in practice. The fuzziness of complex systems and the perceived vague definition add to this difficulty. However, the SCPS framework and the concept of DGC are there to help actors to grasps the complexity. The concept of complexity was thus more indirectly addressed. The concepts of access and design were easier to grasp and identify within the LLs directly.

In the context of socio-economic impact, there is a discrepancy between the impact that digital technology is believed or wished to have and the actual socio-economic impacts. The actual benefits depend, among others, on interoperability of digital tools, as for example the machine-to-machine communication and data sharing between farm equipment and management information systems, but also on availability of technical experts to resolve issues, etc. The empirical work of the DESIRA project has evidenced the need to take the complexity of digital ecosystems and the subsequent role of interoperability especially serious. In this light, the work of Bacco et al. (2020) proposes the concept of *application scenarios* which describes the notion that there are different contexts in which a given objective can be achieved by using digital tool(s) and taking into account the technical requirements around which digital tools should be designed. In the LLs, the issue of complexity primarily came up in the realisation that complexities are often overlooked and underestimated. Overlooking complexity can lead to negative and real consequences. For example, if the interconnectedness between a sensor, cloud and a person (e.g. farmer, advisor) are not recognised and organised within a SCPS, this can lead to unintended negative consequences such as unusable data, privacy issues or no return on investment. System complexity is therefore also about connecting access, design, and complexity and creating conditions in which threats are minimised and opportunities are maximised.

Poor interoperability in dystopian futures

More data is not always perceived as better, as evidenced by dystopian descriptions of future scenarios with challenges around poor interoperability. In several Living Labs, complexity of digital transformation became visible in challenges around interoperability. Where data-sharing that is perceived as the norm was described in positive scenarios, negative scenarios included notions of poor interoperability between multiple services and data portals. In France, in order to achieve a successful agro-ecological transition, a need for improved communication between digital objects was expressed to promote their uses and exploitation of the data collected.

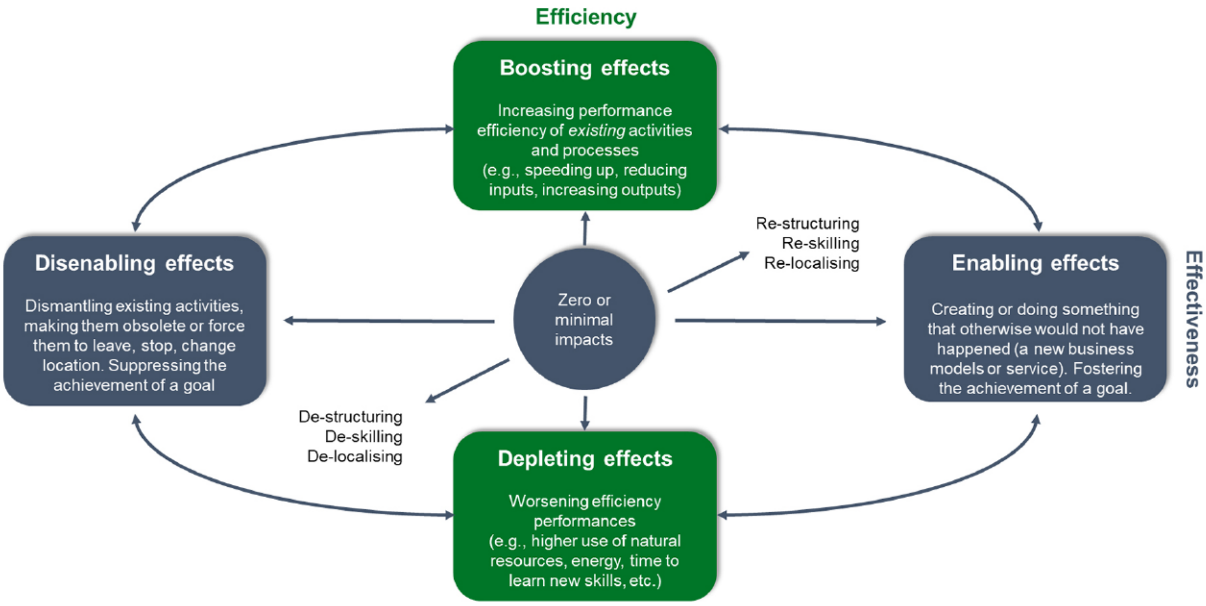
Within DESIRA, the work of Metta et al. (2022) shows that a distinction can be made between enabling, disenabling, boosting, and depleting impacts of digital transformation in agriculture, forestry, and rural areas. This distinction specifies that there can be effects and trade-offs in terms of these different types of impact of digital technologies. The framework therefore contributes to responsible digitalisation in agriculture where design, access, and system complexity are kept in view and equally considered.

6.2.2 Enabling and disenabling, boosting, and depleting effects

The comparative analysis of LL reports (deliverable 2.2) has allowed us to identify four categories of effects of digitalisation (Figure 16):

- boosting effects refer to efficiency improvements brough by digitalisation on existing activities and processes performed by socio-cyber-physical systems.
- depleting effects refer to efficiency worsening brought by digitalisation on existing activities and processes performed by SCPS.
- enabling effects refer to the creation of new activities, products and services that serve a specific function or a given goal, as well as the ability offered by digitalisation to do things which otherwise could not be performed
- disenabling effects refer to the dismantling of existing activities that serve a specific function or are used to achieve a given goal, making them obsolete or force to leave, stop, change location

Fig. 16: Impacts of digitalisation on SCPS activities (Source: D2.2)



6.2.3 Winners and Losers

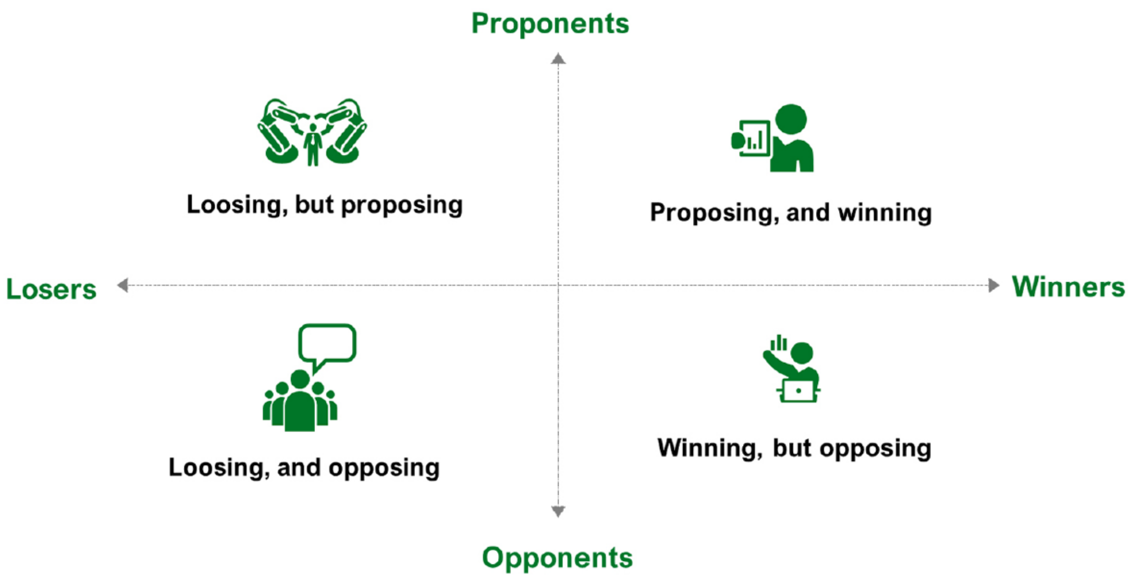
Winners and losers of digital transformations

Finland Privacy as a concern

While digital technologies can provide many solutions, there are also deep concerns, even among proponents of digital solutions. In many future scenarios, data privacy was considered a challenge that needs to be tackled and was seen as a technological consideration. For example, in Finland, the focus was on the digitalisation in the bioeconomy. How will digitalisation influence this progress? Thinking about the future, LL participants feared that absence of digital privacy will give more and more power to big corporations and subsequently strip individuals of data ownership and control.

Within digital transformation processes, winners are those who gain the benefits of a transformation, while losers face negative consequences of the transformation. Within the DESIRA LL, the discussion about and reflection on winners and losers became rather reductive because in the context of the project, there are few opponents to digitalisation. This resulted in overlooked negative consequences of digital technologies and therefore fail to minimise these consequences for losers. Note that speaking about winners and losers can unjustly give the impression that these are absolutes, while in reality groups of stakeholders can be considered winners in one regard and losers in another. For example, farmers using online tools to facilitate the organisation of their direct selling or on-farm community-gatherings can be seen as winners in the transformation because digital tools make it easier to organise their business and reach potential customers. However, these same farmers can simultaneously also be losers if they must bear additional costs while the added value is still captured by data owners or supply chain intermediators. Animals and nature in general might be further 'objectified', 'genetically engineered', and 'dominated' by precision farming innovations instead of enhancing their welfare and social agency (e.g. in biodynamic or social farming) and could in that case also be considered losers. Under different conditions, the same entities can win or lose, oppose or propose. Understanding these conditions is key to reconcile tensions between private, public, and individual objectives and rights, and foster a just and sustainable digital transformation.

Fig. 17: Digitalisation and entities: strategies and actions for a just digital transformation (Source: D2.2)



7 Sustainable Development Goals

One particular area of socio-economic impact are the Sustainable Development Goals (SDGs). Succeeding the Millennium Development Goals (2000-2015), the SDGs (2015-2030) make up the 2030 Agenda for Sustainable Development, as defined by the United Nations (2015). The United Nations Member States adopted the SDGs as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. 'Leaving no one behind' is the pledge of the Agenda 2030. It is a set of 17 goals, that are structured around five pillars (5Ps): people, prosperity, planet, peace and justice, and partnership. The 17 SDGs are integrated - that is, they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability (UNDP, n.d.). They combine the challenge of coping with planetary boundaries (Rockström et al., 2009) – a safe operating space – with the challenge of dealing with social concerns – a just operating space – into creating a 'safe and just operating space' (Hajer et al., 2015).

The relevance of the SDGs in the context of digital transformation is threefold. First, developing digital technology is prominent in the Agenda 2030, in particular in SDG 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation) and in related mechanisms that support the multi-stakeholder collaboration such as the Technology Facilitation Mechanism and the Science Technology and Innovation (STI) Forum. The latter aims at ensuring inclusiveness and equality, including gender equality (SDG 5, see for more on gender section 4.3). The development of digital technology is also a prerequisite for Member States in order to build sufficient digital government capacity that allows to achieve the SDGs (Janowski, 2016).

Second, digital transformation may have an impact (see also https://www.diplomacy.edu/blog/digital-technology-sdgs) on the SDGs, in a positive or negative way: they may contribute to or hinder meeting the SDGs. There is ample, though often uncritical, literature on how the digital transformation can accelerate the SDGs (ITUNewsMagazine, 2017). It shows amongst others how digital transformation can lower food waste (Jagtap & Rahimifard, 2019), promote smart water management (Yildiz & Ansmann, 2019), impact on gender equality (Sorgner et al., 2017), citizen empowerment (Kouroubali & Katehakis, 2019), protection of biodiversity (Nagendra, 2001) or smart grids and smart sustainable cities (Mehmood et al., 2017). Counterproductive effects of digital transformation often relate to (unforeseen) processes of social and economic exclusion of more vulnerable actors, hence drifting away from the pledge of 'leaving no one behind', especially when policies do not sufficiently anticipate this. Many of these effects are still vague, although it is clear that automation of the labour market and the accompanying more flexible ways of working will impact upon the lower skilled or less flexible employees (Freddi, 2018; Mönnig, Maier, & Zika, 2019). The integrational character of the SDGs also warrants for trade-offs: contributing to a particular SDG (say SDG 9: industry, innovation and infrastructure) might negatively impact upon another SDG (say SDG 10: reduced inequalities, or SDG 8: decent work and economic growth).

Third, the SDGs call for action is based on an 'outside in' approach (GRI, UN Global Compact, & WBCSD, 2015) by looking at what is needed externally (required by society) from a global perspective and setting goals accordingly, businesses will bridge the gap between their *current* performance and *required* performance. The SDGs represent an unprecedented political consensus on what level of progress is desired at the global level. This has far reaching consequences for digital transformation. It implies that digital technology has to be designed in such a way that it performs in a desired way, i.e. within the 'safe and just operating space' that the SDGs delineate. In this way, and adding to the first element of the SDGs about having *impact on* the SDGs, the SDGs now become a compass for the design of digital technology and the digital transformation: the SDGs steer the development of the future of agriculture, forestry and rural areas, and the possible position and role of digitalisation within it.

7.1 Empirically grounded SDG concept

Since the idea of sustainable development is common ground in scientific and political contexts, a number of guidelines, frameworks and tools were developed to assess the sustainability of technologies, processes and systems. Since almost 30 years, several approaches to conceptualize sustainable development have been developed and applied such as the three or four pillar model or the pillar-overarching integrative approaches. The three-pillar model is dominating political and scientific practice although it is criticized for its lacking theoretical profoundness in justifying sustainable development as overall guiding principle, its systematic neglecting of interdependencies between the pillars, and an insufficient consideration of the postulate of justice and fairness.

For the definition of additional indicators with relevance to scientific debates and societal and political decision-making, a theoretically well founded and operable conceptual approach for analyses and assessments is required. The Integrative Concept of Sustainable Development (ICOS) that was developed within the German Helmholtz Association is such a concept and is used in this work as a methodological framework to derive a coherent system of sustainability indicators. In contrast to other concepts structured along the economic, ecological and social dimension, ICOS is based upon three constitutive elements of sustainable development, which basically characterize the key documents of sustainable development like the Brundtland report, the Rio Declaration and the Agenda 21:

1. Inter- and intra-generational justice, both equally weighted, as theoretical and ethical fundament. Justice is understood as distributional justice with respect to rights and obligations, benefits and burdens.
2. A global perspective, by addressing key challenges of the global community and developing goals and strategies to achieve them. It also includes a strategic justification to translate globally defined goals into the national and regional context.
3. An enlightened anthropocentric approach including an obligation of humankind to interact cautiously with nature based on a well-understood self-interest.

These constitutive elements of ICOS are translated into three general goals and preconditions of sustainable development:

1. Securing human existence, including basic needs and the capability of human beings to shape their lives on their own.
2. Maintaining society's productive potential, which consists of natural, man-made, human and knowledge capital.
3. Preserving society's options for development and action, addressing immaterial needs such as integration in cultural and social contexts, which complement material needs.

Through an iterative, participatory process, a final set of 65 Socio-Economic Sustainability Indicators to assess the impact of digitalisation in agriculture, forestry, and rural areas have been created (see Deliverable 2.3). These indicators were then used in the context of the DESIRA project to qualitatively measure the impact of digitalisation across 21 Living Labs towards the DESIRA sustainability targets.

The final set of SESI presented in this report can be used to monitor and measure the impacts of digitalisation in agriculture, forestry, and rural areas in other research contexts. This assessment provides a snapshot into the current and near-future impacts of digitalisation in the DESIRA domains. Furthermore, these results can be compared across spatial and temporal contexts.

7.2 Gender

Given that the SDGs are connected and strive towards sustainability, the gender aspect (and intersectionality more broadly) is an essential part of the SDGs. The gender aspect has been made explicit in SDG 5: improving gender equality, and in SDG10: reducing inequalities. Therefore it is also crucial for the DESIRA project to investigate gender aspect around the access, design and system complexity of digital technology use, in order to fully understand the socio-economic impact of digital transformation.

It has been found that digital engagements and digital capital can play a key role in a range of outcomes for individuals and that those individuals who are more digitally included enjoy more advantages than those who are not; and as time progresses forms of digital exclusion change (Robinson et al., 2015). Which is closely linked to the earlier mentioned digital divide. Additionally, the *gender digital divide* is used to refer to gender differences in access to resources and digital technology. Research considering the gender digital divide began focusing on identifying gaps and differences, but in the last decade has moved onto explore the consequences of such a divide (Robinson et al., 2015).

Generally, women use digital tools less than men and are at a disadvantage when learning about digital technology (Cooper, 2006) and as such there are gendered processes associated with jobs and technology (Robinson et al., 2015). Moreover it has been found that users' behaviour online is an extension of their offline roles (Colley & Maltby, 2008) and women additionally tend to underestimate their digital literacy in comparison to men (Hargittai & Shaw, 2015). In Europe, in 2017 women had a rate of basic ICT skills (55%) lower than males (60%) (Eurostat, 2017). While the gender digital divide exist all over the world, it is especially prevalent in developing countries (Antonio & Tuffley, 2014).

Access to digital technologies thus plays a big role in the digital gender divide. According to Hilbert (2011), lower access is related to unfavourable conditions of employment, education and income: in other words, the digital gap is an outcome of the broader gender gap. Vice versa, the gender digital divide also further broadens the gender gap. According to the World Economic Forum (2016) expected job losses due to digitalisation are likely to amplify the current gender gap. For example, in sectors such as banking and retailing, where the percentage of female employees is higher, there will be strong job losses (Hauer, 2017). Nevertheless, even in developing countries, the gap has closed in terms of access (Blank & Groselj, 2014; Ono & Zavodny, 2003). This is, however, somewhat misleading as women have lower frequency of use, intensity of use and a narrower range of digital activities (Haight, Quan-Haase, & Corbett, 2014).

Another key element of the gender digital divide is the actual design of digital technologies. Who design the technologies implicitly or explicitly bases this design on their own norms, values and biases. Yet for example software development seems to be a profession from which women are disappearing in Europe and the USA (Tassabehji, Harding, Lee, & Dominguez-Pery). There seems to be a general assumption that women are less suited for coding and writing of algorithms (Miltner; Tassabehji et al.). This is in line with the general view of women in STEM professions (Beede et al., 2011; Leung, 2019).

Thus there are a number of hurdles that account for this gender digital divide, ranging from access conditions, affordability, lack of education and technological literacy to socio-cultural norms and values that cause gender-based digital exclusion (OECD, 2018). However, it is also expected that ICTs can contribute to reducing the gender gap. Strong social networks appears to affect access to the internet positively for women in rural India (Venkatesh, Shaw, Sykes, Wamba, & Macharia, 2017) and rural Spain (Correa, Pavez, & Contreras, 2017) for example, which has led women to be more entrepreneurial than men. At the same time there is the aim at EU level of empowering women to take op job opportunities in the ICT sector to enhance the high growth potential of that sector (Morrow, 2015). Apart from job opportunities for women in the ICT sector, there is some hope that digital transformation will help with the reconciliation of work and family life, as in the case of telework, but the real impact will depend on the contractual arrangements in place and on enabling conditions (Lohman, 2015). Another field of attention is the role of digital transformation on access to decision-making and to education (SIDA, 2015).

With regards to agriculture, forestry and rural areas, thus far the debate on gender and digital transformation has mainly been linked to the following questions: In what ways can digital transformation be used as a source of empowerment for women in agriculture, forestry and rural areas? What are the links between gender and social capital in agriculture, forestry and rural areas? (DESIRA, 2018).

The Responsible Research and Innovation approach (see Chapter 2) helps to be aware and further identify relevant gender equality questions regarding digital transformation, as well as other (potential) digital divides linked to a broader range of inequalities and intersectionality. In the LL, a poor link between digitalisation and SDG 5 (Gender) was found. Gender bias can restrict access to digital tools that regulations, policy and collective action could help relieve.

8 Discussion and conclusion

The conceptual framework developed in a participatory manner is based on interviews conducted in the Living Labs to include the added value from a Living Lab perspective, but also on input from the general assembly in Gent in 2023 and empirically work done in the work packages. As described in this empirically grounded CAF, especially the SCPS framework was applied in practice. However, it also became clear that most of the concepts from the initial CAF were perceived as complex and some LL facilitators had problems with the multi-dimensionality of the concepts, while others expressed that they found it difficult to operationalise the concepts. Therefore, this empirically grounded CAF included additional concepts and insights to facilitate an in-depth analysis of digital technologies' socio-economic impacts.

From the work on the theories and concept that showed to be important for local realities of LLs, it emerges that the complexity of the system should receive more attention. This is because complexity is difficult to understand and there are several tools, like for example the taxonomy of the impact proposed by Bacco et al. (2020), that help us to better understand and describe the socio-cyber-physical system.

In the course of the DESIRA project it become even more apparent how important the RRI framework is. Technology is neutral and the way we use it, determines if it will cause good or bad results. The RRI lens helped to look more at the implications for the social actors in the socio-cyber-physical system and opened an entire world, leading us to realize that all these different domains are so interconnected. Even though the CAF can be seen as a product that protected us researchers and Living Lab stakeholders and functioned as a solid but simple foundation. Digitalisation in rural areas is so intertwined with a lot of other topics that it is reasonable to conclude that the broad theories of SCPS and RRI help us to get a better grasp on the complicated structure and influence of the system. Whether stakeholders should be involved in the theory building processes is up for debate and can be an element for future research. Participatory theory building implies that there is a broader participation in theory building, but it remains fairly open who need to be included in this process and how participants should be able to contribute to theory. In this project, PTB has remained limited to discussions between researchers and to reflections based on empirical data.

In applying a SCPS framework to understand complex transformations, researchers and participants struggled to make sense of the multi-faceted, ambiguous nature of digitalisation and its impacts. This remains one of the barriers to move these participatory assessments from academic to change-making agents. The challenge to envisage and implement concrete follow-up actions in terms of policies, technologies, networking, and civil society mobilisations can be seen in different areas.

Conceptually speaking, having a focus on micro- or meso-level assessments (e.g., land management in North Tuscany) require deep knowledge, socio-technical confidence, and policy capacity to extrapolate detailed observations and bottom-up lessons to drive macro-level changes, for instance at level of National or European law making (e.g., European Digital Services Act, the Common Agricultural Policy, etc.). As far as possible, DESIRA LLs tried to integrate their assessment efforts to concrete regulations (e.g., Ciliberti et. Al., 2022) or market initiatives, thus reducing the distances from research to actions, however, these outcomes are generally hard to grasp immediately or depend on many circumstances.

Politically speaking, actions can fail to emerge from digitalisation impact assessments when the political legitimacy and steam of multi-stakeholder platforms like LLs does not manage to pass through existing decision-making and political apparatus. Nevertheless, the capacity building, collective and individual learning, and societal dialogue dimensions of these assessment processes should be acknowledged as much as the findings and follow-up actions uptake.

Finally, being descriptive in nature, the SCPS framework lacks the normative lenses to qualify digitalisation beyond its presumed links or contributions to the Sustainable Development Goals, and therefore propose concrete policy changes that alter the natural flow and mainstream trajectories of digitalisation. Like other socio-technical assessments, a normative analysis of digitalisation could have narrowed, but probability also enriched and deepened the insights and findings towards more explicit hypothesis, assumptions, theories, progressive policy objectives. Key questions like the impacts of digitalisation on farmers' autonomy and capacity to escape capitalist agri-food structures, impacts on rural resilience or vulnerability from international geopolitical conflicts over natural resources and digital infrastructure, impacts on women and minority groups' agency in front and back-office digital work, and other justice-oriented assessments remained indeed blurred in the conceptual framework and its operative application (e.g., LLs' focal questions).

The initial CAF includes high level theories and concepts that LL actors found difficult to use or apply in practice. The translation of the theory to practice was perceived as rather radical. In order to generate actionable knowledge which does right to the knowledge that is needed on local scale, the LLs (or local actors) should be included in the conceptualisation process from the beginning.

In any case, the lessons learned in the LLs during the DESIRA project can be used to create concepts and theories that are more mid-level theories , that take into account mechanisms that could be observed in the LLs and that are generalized for further research in other LLs or similar innovation hubs, to this end the empirically grounded CAF was formulated.

Annex 1. Underpinning sociological theories: Actor-Network Theory and Social Practice Theory

There are sociological frameworks which focus specifically on the relations among humans and technologies, i.e. material and organisational constraints, and propose a social theory to analyse the society and its functioning. One such theory is the **Actor-Network Theory** (ANT) (Latour, 2005)[2], which questions the interaction between human and material entities, postulating that the activities and outcomes in socio-technical systems depend on the whole set of connections established by entities themselves, while social actors (i.e. human entities with agency) do not necessarily have a prominent role in the system. In the ANT, we should rethink natural events, social phenomena and the discourse about them. They are not seen as separate objects, but as hybrids made and scrutinized by the public interaction of people, things and concepts. In short, everything in the social worlds exists – and is continuously changed – by networks of relationships among material and semiotic elements (Dolwick, 2009). Latour (1993) argues that for example climate change or pandemics are a mix of politics, science, popular and specialist discourse so that a nature/culture dualism needs to be questioned.

Here, non-human entities (e.g., ideas, technology, natural entities, etc.) and human entities (e.g., social movement, social actors, etc.) are so called *actants*, and are on the same level of importance in the configuration of specific, situated social order. Together they form an actor network, whereby it is important how the actants interact, what is the relation between them, and the meaning subjects attribute to the elements involved in the *actor-network*. When the entities are connected, they act as a whole and their relations with one another shape any other single element in this network (Latour, 2005). Following the ANT thinking, a SCPS can thus also be seen as an actor-network, and as described in section 2.4, all the entities and domains involved in a SCPS are at the same level of importance. What is relevant is how the entities in a network, or system interact and are in relation.

Callon (1986) observes that there is a need for a *translation process*, in order for entities to coherently assemble, i.e. how an entity can become part of an actor-network. Moreover, an actor-network only exists due to constant making and re-making. This means that relations need to be repeatedly 'performed' or the network will dissolve. It also suggests that systems of connections are not intrinsically coherent, and they contain conflicts. Social relations, in other words, are only ever in process and must be performed continuously (Callon, 1986). Callon (1986) thus describes how actants influence the socio-technical system activities, routines, etc., depending on the translation process.

The different performances of technological innovation, for example, depend on how some actors (institutions, for example) define the nature of the problem and a possible technical solution (problematization). A fast internet connection can be established as a solution to economic issues in rural areas. Around this technological solution, different subjects – such as economic actors, local institutions, civil society organizations, etc. – with different interests, values and aims, are activated by modifying the initial solution (interessement). In this case, for example, farmers, tech companies, internet providers, local institutions, etc., express pros and contras related to the fast internet connection pressing to change it. Once a stable solution has been defined, the different actors work to

2 Other social theories following with a similar focus are the Cyborg perspective (Haraway, 1991) and the Social Practice Theory (Schatzki, 1996; 2016)

perform the implementation of the technological novelty (enrolment) so that it can change the socio-technical system as it was set in the mediation process (mobilization). In short, the translation process can describe how an entity (e.g., organizational forms, new technologies, natural events, etc.) become a game-changer concerning the actor-network (that can be a socio-technical system).

In this line game changers can be seen as everything that transforms the activities, relations, interactions, and outcomes. Still, how these game changers are incorporated and transform the social-technical system depends on the mediation processes put in place by social actors.

Close to the ANT perspective is the **Social Practice Theory** (SPT). Starting particularly from the concept of practice proposed by Schatzki (1996, 2019), Shove and Pantzar (2005) designed a scheme to define the dynamic of social change taking in account elements that constitute a social practice: materials (objects, technologies, etc.), meaning (social values, norms, imagines, etc.) and competencies (skills, know-how, etc.). Focusing on the making and breaking linkages among these elements, SPT analyses the social life of an innovation. Specifically, a practice changes when different links between the entities of which it is composed change because links define the practice. In this sense, it is crucial to understand what kind of link is made among a new event, technology, ideas, etc., with others' entities. From this perspective, we can argue that the practice of writing changed dramatically with the introduction of word processing software because there were previous skills (e.g. typing on analogue typewriters) and it perceived as linked to relevant social values (such as productive efficiency, aesthetic canons, etc.). For examples see Hand and Shove (2007); Shove and Pantzar (2005).

Similarly to the ANT, the SPT suggests us that everything can be a game changer, and the chance that an entity becomes relevant in social change is related to the ongoing process of *normalization*. It refers to the analysis of in which way social practice changes and stabilizes by the time, which links contribute to it and which interpretation of the shift is prominent.

Annex 2. Interview protocols and list of codes for the participatory theory work

First round of interviews:

- In your opinion, what worked well during the WS, in relation to the use of the main concepts?
  - How did you use the concepts of the CAF in the LL and what terminology did you use? (think of the SCP system, digitalization/digitization, digital game changers etc.)
  - Were your expectations for using these concepts met? And in what way?
- In your opinion, what did not work?
  - How/What would you change this to make it work next time?
- What were the main positive and negative points of feedback obtained from the participants, and what were suggestions for improvement?
- Did you observe LL participants using/adopting this terminology too and if they did, in what way (same or different meaning/understanding)?

Second round of interviews:

Introduction

Based on discussions during the reflections workshop, we have identified three main focal points for PTB linked to WP3.

They are:

- How is the **DGC concept** used, understood, and applied in practice? Where and how is the connection made with the technological drivers of change as part of the scenario planning methodology? What types of technologies do people see as (potential) DGCs (finding examples)?
- There was the question around (social) implications that come into view (especially linked to social aspects) of using new technologies through using the SCP concept. This is about finding stories related to power relations, gender, (in)justice, …., which can be linked to the **concept of socio-economic impact**.
- Enriched understanding of the concepts **system complexity, access and design**. What are the key issues at stake for each of these concepts, and how does this differ across LLs?

Through the discussions during the scenario planning workshops, reflections can be gathered around these three main focal points. This will not require specific changes to the proposed scenario planning methodology. However, it may require asking some triggering or clarifying questions during the actual workshop, to more clearly elucidate participants' perceptions on the different elements.

In the following sections, some short background (based on the CAF) is provided for each focal point, together with a number of related interview questions. These are the questions that will be used for the interview after the workshops between the PTB team and LL coordinators. Some of the interview questions are indicated in bold-italic. These interview questions can also be used, with slightly adapted formulation, during the workshops to trigger discussion/reflection with the participants. It is important to take notes/record discussions carefully, with the different focal points in mind.

Focal point 1: use of the Digital Game Changers concept in practice

Digital Game Changers refers to both hardware and software components of digital technologies that deeply reconfigure routines, rules, actors and artefacts of social and economic life.

In the scenario planning methodology *DGCs are described as a particular type of driver of change (DOC)*. Drivers of Change are dynamic factors that shape the future. There are two broad categories, namely: i) *critical uncertainties*, i.e. DOCs which are unstable and difficult to estimate in terms of their future effects, which may be either external (not to be controlled by actors in the scenario) or internal (to be influenced by actors in the scenario) to the scenario environment, including behaviours and choices of influential actors; and ii) *predetermined factors*, i.e. DOC which are relatively stable and predictable over the period under consideration.

Link to the scenario workshop methodology: Information on this is expected to emerge during the discussion of the scenario outlines, but possibly also already during the preparation of the workshop ("Identify drivers of change (DOC): possibly with some validation from key members of the LL")

Interview questions (follow-up interview with the LL coordinator)

- How were the abovementioned concept(s) used during the scenario workshops? What terminology was used?
- In your view, how did participants understand and engage with these concepts?
- How did you identify/classify the DOC? Who was involved in this identification?
- How do you see the connection between the DOC's and the DGCs?
- How did these concepts affect your understanding of the living lab and the context of the living lab?
- What was the relevance/importance of DGCs in comparison to other DOC? What was the role they played in the different scenarios (e.g. critical uncertainty vs. predetermined factor), and did this change significantly between the draft scenario outlines and the final scenarios developed during the workshops? If so, in what way, and what/who triggered/initiated the change?
- ***What digital technologies were seen as DOC/DGCs? How were they perceived by different actors (more positive or more negative perceptions/associations; more stable/unstable; within our outside of the scope of control – also note for different perceptions in different actors)?***

Focal point 2: Implications and impacts of using new technologies

As indicated in the definition for DGCs, digital technologies have the potential to deeply reconfigure routines, rules, actors and artefacts of social and economic life. In the CAF/DESIRA proposal, this impact has been further defined as "the opportunities and threats of digitisation which has deep repercussions on people's lives, and generates losers (marginalized by the changes), opponents (who resist and elaborate alternative rules of the game), and winners (who benefit from the change). We want to further our understanding about these reconfigurations/repercussions, and thus the socio-economic impact of processes of digitisation and digitalisation.

Link to the scenario workshop methodology: Examples and stories can be captured during discussions/ stories around the review of past events (actual impacts), and during the further development of the scenario outlines (anticipated impacts).

Interview questions (follow-up interview with the LL coordinator)

- ***What were social (and/or economic) reconfigurations and changes through use of new technologies identified by different actors (distinguish between changes/reconfigurations that actually happened, and anticipated changes/reconfigurations)?***
  - ***How are these reconfigurations perceived by the participants?***
  - Did you introduce examples of such reconfigurations into the workshop? If so, which ones?
- Did you use the concept of winners/losers/opponents/proponents in the living lab (in the workshop or in later analysis)
  - How did this concept affect your understanding of the impact and implications of using new technologies in the context of your living lab?
  - ***Who were identified by the participants as winners/losers/opponents/proponents in your LL)?***

Focal point 3: Conditions influencing impact

As described in the CAF, impact can depend on three conditions: access, design and system complexity. **Access (i.e. the distribution of physical, social and human capital necessary to get access to digital opportunities) determines how much a given person/type of actor or stakeholder can benefit from digital technologies**. Lack of access can lead to exclusion, and marginalisation of the excluded. The assessment of access should consider who are potential actors of the system, and who will be possibly excluded; what the different (social, physical, cyber) requirements for accessing the technology or its outputs; how are the outcomes of the system distributed; … Second, there is the design of digital technologies. **Digital technologies are designed to achieve certain outcomes (i.e. have intended consequences). However, poor design can also lead to unintended, and possibly harmful, consequences.** When thinking about design, different kind of vulnerabilities need to be considered (fundamentally flawed design; vulnerable to physical elements (heat, wind, …); vulnerable to social elements (espionage, cyber-attacks, …)). Third, we have system complexity. The more digitisation proceeds, the stronger the need to connect system entities to each other. Increasing connectivity adds to complexity because of the multiplicity of ways that each entity interacts with others. Complexity raises a number of issues on which each outcome of the system can depend, and decreases the manageability of the system. Assessing system complexity should consider the outcomes of changes of entities and activities of a system in relation to the connections with other entities and other domains. For example, new operating systems of a laptop are not fit to old computers, and this implies that old computers become obsolete. When devices need to communicate with each other, emerging problems can be only fixed by specialists. In complex systems, choice of the right technology may be a problem in itself, as it requires skills and time.

All three conditions pose threats and opportunities when considering the socio-economic impact of digitisation and digitalisation:

	Opportunities	Threats
Access	Increase equal access to digital technology	Digital divide
Design	Solutions that anticipate unintended consequences	Design-related risks
System Complexity	Synergies between digital game changers	Digital traps

As such, the discussions around the conditions are very closely linked to the discussions in the previous section. While the previous section aims to capture more specifically different kinds of socio-economic impact, this section zooms in on the conditions affecting the impact. It is expected that during the workshop, discussion on this (i.e. impact and conditions affecting impact) will be intertwined. It is also expected that certain conditions will be more prominent in some LLs than others.

Link to the scenario workshop methodology: Information is expected to emerge during the development of the scenario outlines, and also during the backcasting exercise.

Interview questions (follow-up interview with the LL coordinator)

- How did you use these concepts in the living lab? During the workshop or for analysis?
- How did you go about using this concept in a future-oriented scenario? What were steps you took to understand how these conditions would be affected?
- ***What were possible opportunities/threats mentioned regarding access?*** Were there differences in participants in how these were perceived?
- ***What were possible opportunities/threats mentioned regarding design?*** Were there differences in participants in how these were perceived?
- ***What were possible opportunities/threats mentioned regarding system complexity?*** Were there differences in participants in how these were perceived?
- Which of the elements of this concept is most vital for your living lab? And how is it vital in understanding the living lab?
- What are possibly other conditions affecting digitization/digitalization in the context of this LL?

List of codes for analysis of PTB results:

- CAF Concepts:
  - Digital Game Changers
  - Digitisation & Digitalisation
  - Socio-Cyber-Physical System
  - Socio-economic and sustainability impacts
  - Access, Design & Complexity
  - Drivers of Change
  - Winners, Losers, Proponents, Opponents,
- Further additions
- Translation of concepts – link to stakeholders

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