KEY DIGITAL GAME CHANGERS SHAPING THE FUTURE OF AGRICULTURE IN 2040

VIEWS FROM DESIRA'S RURAL DIGITALISATION FORUM EXPERTS

February 2021

Author(s): Lies Debryune (ILVO), Gianluca Brunori (University of Pisa), Blanca Casares (AEIDL), and Enrique Nieto (AEIDL)

1. INTRODUCTION

This document is a contribution from the EU-fuded project DESIRA to the debate on the 'Long-term vision for rural areas' (LTVRA) offering a multi-actor research and innovation perspective and evidence. We focus on a question, 'How can digitalisation shape and influence the future of the agricultural sector in 2040?' in order to contribute to a sustainable, resilient and fair society.

In June 2019, the University of Pisa, together with 24 European organisations, launched a four-year **Horizon 2020 project ,DESIRA - Digitisation: Economic and Social Impact in Rural Areas.** DESIRA has established a European Rural Digitalisation Forum (RDF): an open EU-wide community of stakeholders with a common interest to work, learn and share knowledge about digitalisation in three domains: agriculture, forestry and rural areas. DESIRA's RDF also coordinates four virtual Working Groups (WGs), dedicated to i) Agriculture, ii) Forestry, iii) Rural Areas/Life and iv) Policy, formed by experts from within the project, Living Lab members and high-level external experts.

This document on **Key Digital Game Changers shaping the future of agriculture in 2040** has been developed within the framework of the WG on Agriculture of DESIRA as a **contribution to the Long-Term Vision for Rural Areas** exercise, recently launched by the European Commission (EC). This document offers the DESIRA perspective on a desirable future for digital agriculture, based on research performed in the context of the project, and on a survey sent out to a wide range of stakeholders to obtain their views on the main elements presented here. A desirable future is one where the direction and scale of change contributes to a sustainable, resilient and fair society, from a global perspective. In support of this, we have framed our analysis of the socio-economic impact of digitalisation within DESIRA in terms of the UN (United Nations) Sustainable Development Goals (SDGs).

In this document, we propose three guiding principles to support a desirable future for digital agriculture, i.e. bridging the digital divide, co-creating solutions, and developing adaptive governance models. It is argued that a systemic perspective, carefully considering socio-economic impacts in processes of digitalisation, will be crucial to achieve a desirable digital future for agriculture.

We start with the state of play of digitalisation, focusing in particular on socio-economic impacts, including challenges and opportunities of digitalisation nowadays in agriculture. We then present a number of digital technologies which are considered as potential key 'game changers' (Rijswijk *et al.*, 2020) in the field of agriculture for the next decades and include examples on how some of these technologies are already used today. To conclude, the three guiding principles are explained and actions are proposed for each one of them, to ensure that in future processes of digitalisation the aforementioned threats are carefully considered, and the most can be made of the presented opportunities.

This document follows the understanding that **digitalisation is the means to an end, and not the end itself.**

In the preparation of this document, **DESIRA has sought the opinion of experts and capitalised on the knowledge already developed in the project** to contribute to the Communication on the LTVRA that the EC will publish in 2021. During the months of October and November 2020, there has been a response from 53 experts from 16 EU Member States and 3 non-EU countries, of which 23 completed the survey for agriculture.

## 2. The state of play of digitalisation in agriculture

Digitalisation is understood as "*the sociotechnical processes surrounding the use of multiple digital technologies. Such technologies have an impact on social and institutional contexts, which in turn increasingly require and depend on these digital technologies*" (Tilson et al., 2010). Thus, it extends beyond digitisation, which refers to the transformation of physical into digital entities. While digitisation mainly refers to the implementation of one or a few digital technologies at farm-level, digitalisation extends beyond the level of a single business. Both digitisation and digitalisation are considered here as part of the digital transformation, whereby, over time the options of digital technology use, the associated complexity and their related, either positive or negative, impacts on society continuously increase (Rijswijk et al., 2020). In DESIRA, socio-economic impact has been defined as the opportunities and threats of digitalisation, which has "*deep repercussions on people's lives, generating losers (the ones marginalised by the changes), opponents (who resist and elaborate alternative rules of the game), and winners (who benefit from the change)*".

As presented in more detail in the Synthesis Report on the Inventory and Taxonomy of Digital Game Changers (Bacco et al., 2020), several areas of impact and many possible effects or outcomes can be indicated in relation to digital transformation of agriculture and rural areas (see Figure 1). While it is still non-exhaustive, it provides an overview of possible impacts, structured along four main domains (social, economic, environment and governance), and lists a number of possible outcomes for each of the mentioned impacts. For example, in the economic domain, digitalisation has an impact on companies (organisations) determining a higher decision-making autonomy in the production process as an outcome; in the environmental domain, the area of impact ecosystem services has as an outcome the capability of reducing pollution emissions, thus having an impact on climate, etc.

More specifically for the field of agriculture, opportunities and threats were identified in relation to five main themes based on the survey answers, i.e. i) on-farm sustainability and farm management, ii) access to knowledge, iii) access to markets, iv) data management and power relations, and v) the digital divide. These five main themes in some respect overlap and certainly interact, and as such are not mutually exclusive.

One of the main opportunities seen for the introduction of digital technologies is in relation to the overall farm performance, covering a diverse range of sustainability aspects (people, planet and profit). It is perceived to support sustainable intensification of agriculture, by improving yields, increasing resource efficiency, and therefore farm income, while at the same time reducing detrimental effects on the environment. Opportunities are also seen for improved access to markets and consumers, potentially supporting the empowerment of farmers.

However, for the majority of aspects, the expected outcomes of digitalisation are more contested and considered highly context-specific. For example, for labour some indicate that digitalisation will lead to an improved work-life balance, and more opportunities for female farm workers because of less physically demanding work. Nevertheless, others indicate a number of concerns, indicating more negative outcomes for seasonal or migrant workers who are often employed to perform manual, tedious and repetitive tasks, e.g. fruit picking, and indicate there might be investments required in the form of re-skilling. Also, for access to knowledge, the expectations differ. Some see mostly positive associations, like improved access
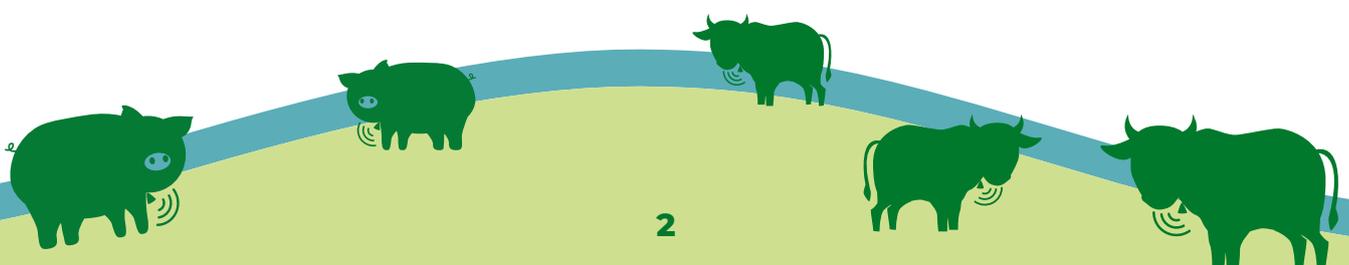
to data and information, which can support decision-making, and access to new services, e.g. e-consultancy. Yet others are less certain about the effect on decision-making, and have concerns about loss of experiential, practical knowledge, about, for instance, land and production management, which in turn will also affect farmer and farming identity. It was mentioned that, overall, capacity building is a basic requirement to achieve the full potential of digital tools and technologies' use. As a third example, there is the effect of robots on family farming: more

positive views indicate this will help overcome shortages in the labour force, while others fear that robotic automation will foster either concentration or marginalisation of small family farms.

Finally, there are also a number of threats identified. A first important one is linked to the digital divide. It is suggested that this exists in different ways: there is the expected divide between the digitally skilled and digitally illiterate, between

Figure 1. Domains and areas of expected socio-economic impacts
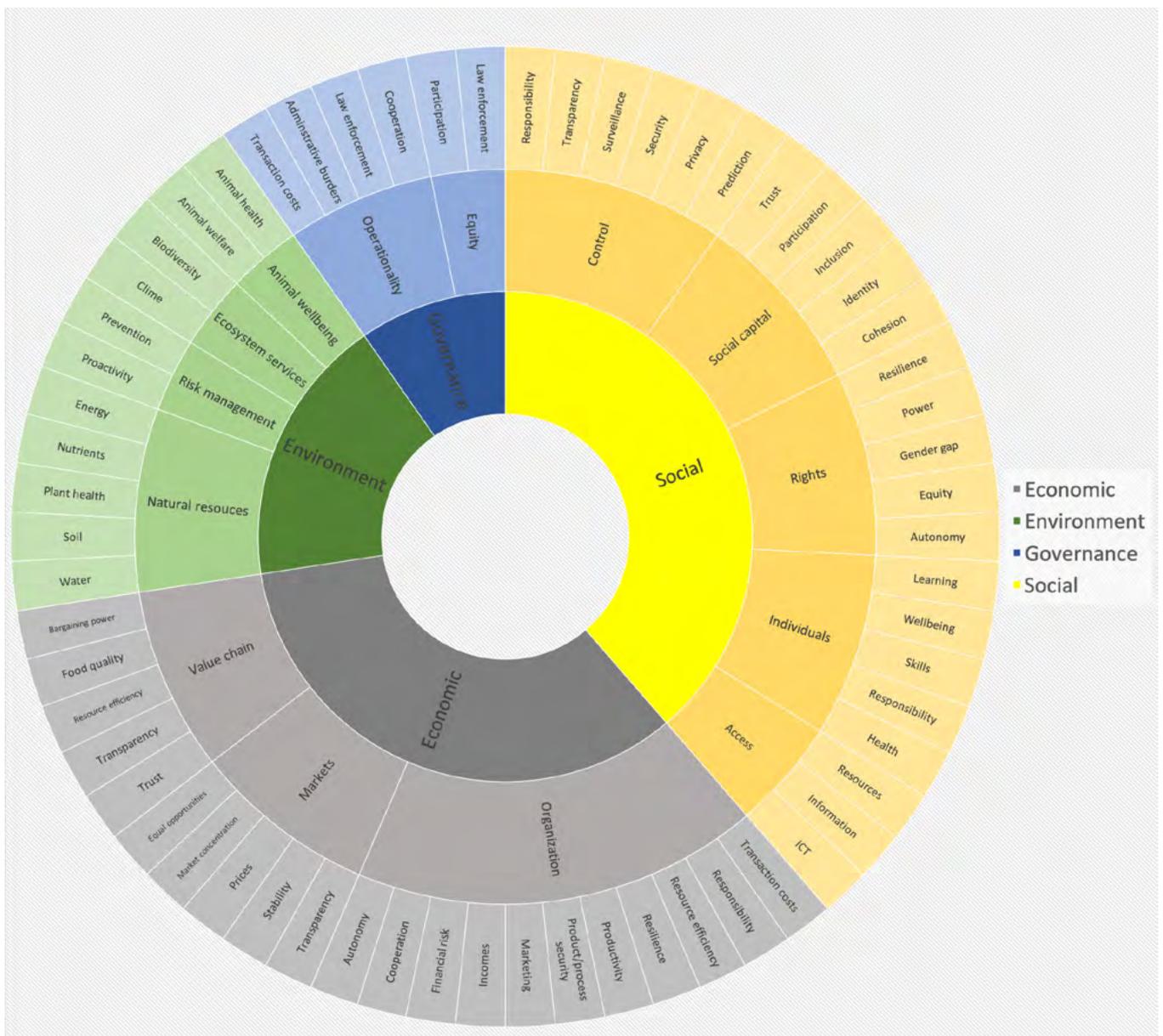
Source: Bacco *et al.*, 2020

those with access to the right infrastructure (e.g. broadband) and those without, and between large, intensive farming businesses and smaller and/or more extensive farms. Specifically, in relation to the latter, there are some concerns that the digital transformation will favour the model of large-scale, intensive farming, while others also see opportunities for the use of digital technologies in more extensive, agro-ecological farming models, to support the reduced use of chemical inputs. A second main threat was found in relation to overall data management, where there are concerns around data ownership and power relations, and data security (e.g. ransomware).

Numerous concerns were raised around the compatibility of different systems, indicating that various platforms are not linked, leading to poor interoperability, and that a holistic perspective is often lacking. Poor interoperability of different systems will also lead to the creation of new dependencies, and there are concerns that some digital applications may also simply become an obligation (related to certification). Linked to this, the cost associated with the use of different systems and technologies was mentioned as an important threat.

3. Identification of key digital game changers for 2040 and examples of contexts or application scenarios

> We are in the middle of the fourth industrial revolution, with digital technologies transforming whole sectors, and this process will continue to drive disruptive changes.

When thinking about digital game changers, it is important to note here that there is a close link between digital technologies -and tools using these technologies - and so-called application scenarios. An application scenario can be defined as the context in which a given goal can be accomplished by using digital tools. In DESIRA, application scenarios have been built by grouping digital tools according to the function they serve. For instance, wthe scenario livestock in agriculture groups all digital tools that can be used to support animal husbandry activities, which differ from those that can be used for machinery (Bacco *et al.*, 2020).

Depending on the application scenario and the challenges they are engaging with there is potential for both highly sophisticated digital solutions and for more simple digital technologies, with some technologies being more effective for a particular challenge. Also, some application scenarios are simply more suitable for digital intervention, so what might be a game changer for one context or scenario, might not be for another. Therefore, we tend to refer to such digital technologies as potential game changers. Finally, it is important to recognise and understand that digital technologies amplify their game-changing potential when jointly used (*integration*). As an example of this, the use of Augmented Reality/Virtual Reality (AR/VR), in combination with 3D printing is expected to facilitate prototyping and the development of tools and machinery that perfectly meets individual needs, but also autonomous machinery is an example of such integration, where robotics are combined with Internet of Things (IoT).

In the Synthesis Report on the Inventory and Taxonomy of Digital Game Changers, an overview is given for 10 technologies, which are considered as potentially game changing for agriculture, forestry and rural areas (see Table 1).

A similar overview of the potential of technologies was mentioned by survey respondents, with responses grouped into five main types of key digital game changers when thinking about agriculture by 2040, i.e. use of digital technologies in the field of precision agriculture (including local and remote sensing, and autonomous systems and robotics), blockchain, Artificial Intelligence (AI), data technologies, and mass access Information and Communication Technologies (ICT) services. We also provide some examples of contexts and scenarios in which these technologies are already being used.

As mentioned in Section 2, one of the main opportunities for digitalisation is seen in relation to improving and optimising on-farm management and decision-making. So, a number of digital technologies are cited by survey respondents as key digital game changers due to their contributions to these opportunities. Survey respondents listed a collection of digital tools and technologies, of which the combined use in the field of precision agriculture is expected to be game-changing for agriculture. Technologies that were mentioned include drones, satellite images, sensors (local and remote), IoT, Global Positioning Systems (GPS) equipped machinery, and robotics and autonomous machinery.

Additional explanation for the experts' high expectations for these digital technologies are illustrated in DESIRA's Deliverable 1.3 (Bacco *et al.*, 2020).
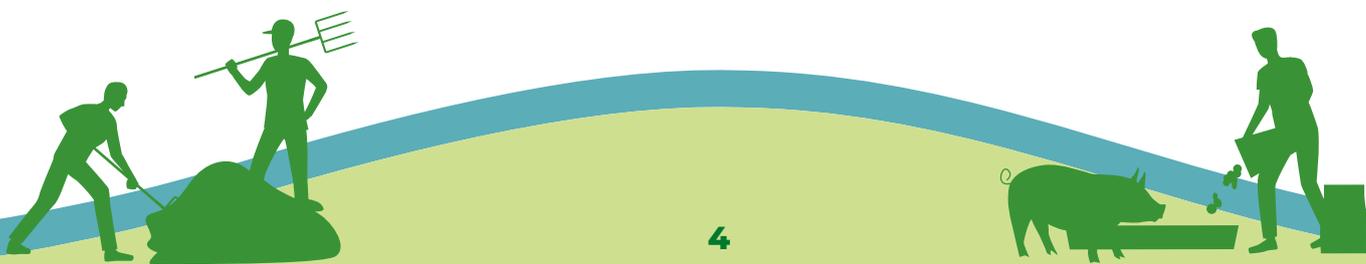
Table 1. Potentiality of game-changing digital technologies

Digital technology	Example in agriculture	Expected positive impact
Social media and social network & web-based technology	Access to online services and connection with the market	Access to information; Access to consumers for farmers; Peer-to-peer learning
Cloud / edge computing	Field-level storage and computing data	Provision of remotely deployed services; better support to real-time sensitive scenarios
Local and remote sensing	Advanced monitoring capabilities applied to crops and livestock to increase the production, assess health status, and other	Better knowledge of the farm agro-ecosystem
Distributed ledger (in some cases also referred to as blockchain)	Traceability and smart contracts; insurances	Reduction of transaction costs: creation of trust in the value chain
Data analytics	Information from sensed data to support decision-making. Physiological, and phenotype modelling	Higher productivity; reduction of losses; reduction of inputs
Augmented reality / virtual reality (AR/VR)	Education and training tools; decision support systems	Better knowledge of the farm agro-ecosystem
3D printing	Design and printing of custom parts and small equipment	Decentralisation of technology; Easier access to small farmers
Artificial intelligence (narrow AI: including machine learning and machine vision techniques, Natural Language Processing (NLP), robotic automation)	Decision support and management system; planning and simulation; Image recognition (pest diseases)	Higher productivity; reduction of losses; reduction of inputs
Autonomous systems and robotics (integrated systems using several technologies together)	Semi and fully autonomous systems for data collection and agricultural practices	Improved knowledge of the Farm agro-ecosystem; reduction of labour costs; replacement of unpleasant or dangerous work

Source: Adapted from Bacco *et al.* 2020

The strong relation between social media and social inclusion is illustrated by several Practice Abstracts (PAs) developed by DESIRA[1]. For these digital tools and technologies to meet their potential in supporting improved decision-making, there is a need for AI and data analytics. While it is expected that data analytics will increasingly shape the way farmers manage on-farm decision-making, the same is also expected for other businesses in the agri-food supply chain. So, advances in this field will extend beyond the level of the farm, and can also contribute to ensuring food integrity and quality, and public decision-making for broader societal challenges. This in turn might also influence (food system) governance and might force policy-makers to intervene and structure how technologies are used by the different food systems and societal actors.

In the field of food integrity and quality, distributed ledgers and blockchain are frequently mentioned as a key digital game changer of growing importance. It is expected that such technologies will contribute to improved quality assurance and traceability and the reduction of transaction costs, by allowing data to be collected, stored and easily accessed in an unchangeable format, at each level of the agrifood chain. However, these technical possibilities will not change the game, if the governance is organised by traditional actors.

Last, but certainly not least, there is great potential seen in 'mass access ICT services and applications', such as the use of web platforms and social media (e.g. WhatsApp groups). Their role is maybe taken more for granted, and less considered next to the more sophisticated high-tech solutions mentioned before. However, considering their easy access and broad uptake, they are nevertheless potentially game changing, having a wide impact in rural areas. It is expected that they can radically change the advisory and knowledge landscape (by facilitating peer-to-peer interactions, and providing alternatives to the traditional face-to-face advice), and the way different actors in the agrifood chain (including consumers) interact. They are an important step in bringing agriculture into the digital age, because of the low threshold for accessing such technologies.

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1 DESIRA Practice Abstracts https://desira2020.eu/resources/practice-abstracts/

BeeKing - digital apiary management

BeeKing is a digital note-taking and work-planning mobile application aimed at improving the efficiency of apiary management for beekeepers. The tool allows the recording of a beekeeper's observations and actions at the apiary, with the help of voice recognition technology on a smartphone and near-field communication (NFC) sensors attached to hives. The users can consult and organise the registered data, and interact with other beekeepers on the internet support platform.

More information

Hands Free Hectare

It is a system of automated digital tools applied in arable farming. Hands Free Hectare was a project of precision farming led by researchers at Harper Adams University working alongside leading company Precision Decisions Ltd. They were the first in the world to successfully use only drones and autonomous vehicles to grow and harvest a cereal crop (barley) over a hectare of land. Their work has now been extended into the ongoing Hands Free Farm, a 35-hectare farm where the same team continues to develop and improve the technologies and outcomes.

More information

iFarming - livestock integrated farm management system

The iFarming system is a tool or management system used worldwide, and developed specifically with intensive livestock farming in mind, such as poultry or pigs. The iFarming tools are used to automate barn management, including ventilation, feeding and herd management, and to integrate them into one farm management system. This enables farmers to increase productivity, while improving livestock housing conditions.

More information

Agricolus DSS - Decision Support System (DSS) that collects, analyses and interprets data from forecast models, crop scouting and remote sensing

Agricolus is a Decision Support System (DSS), which provides farmers with information to help prevent and fight the main diseases of olives, tobacco, grape vines, corn and other crops. The system is designed to: i) prevent plant disease, ii) support decisions on the application of sanitary products, and iii) gather and compare data related to productivity, treatments and infections of fields and crops. Agricolus is a cloud platform accessible from both web and mobile devices. It operates as a monitoring tool providing meteo-climatic data (collected using IoT sensors) and innovative forecast models of the spread of phytopathologies on crops at plot and farm level. The forecast models provide precise information suggesting the best time to apply treatment and also on which specific part of the land area.

More information

CAPSAT- using satellite data to use in CAP compliance control

The CAPSAT initiative aims to provide the farmer with a tool for sending data to the government using geotagged pictures. This tool, proposed by the Flemish government and currently under development, is intended to support compliance with the Common Agricultural Policy (CAP) objectives. This is achieved through a smartphone application where farmers can upload geotagged pictures at farm level as evidence of compliance with EU regulations linked to CAP.

More information

OSIPPPIT – Web Farmers market

OSIPPPIT is a free web application that aims to help farmers use digital tools to sell local products to a large number of consumers in the area of Istria County, Croatia. The application offers an online market and an interactive map. The users are small farmers, members of farm associations, and consumers of agricultural products: households, restaurants, educational centres, hospitals, tourist establishments and other public institutions. The application enables buyers to search for home-made products and locate them on a map. The producers can present their products, increase their visibility, and help consumers make online orders by choosing delivery and payment methods. The app also provides direct online communication between the farmer and the consumer, along with destination guidelines for tourists.

More information

INNOSETA Platform: innovative spraying equipment training and advising

INNOSETA (Innovative Spraying Equipment Training Advising) is a project funded by Horizon 2020, which has developed a freely accessible repository of innovative spraying technology, training material, projects and papers tailored to the needs of the spraying community. This project supports the transfer of knowledge to practice in the field of application and management of phytosanitary products. In the research framework of INNOSETA, extension and advisory services play an intermediate role in negotiating with other actors to create a relevant knowledge and innovation network.

More information
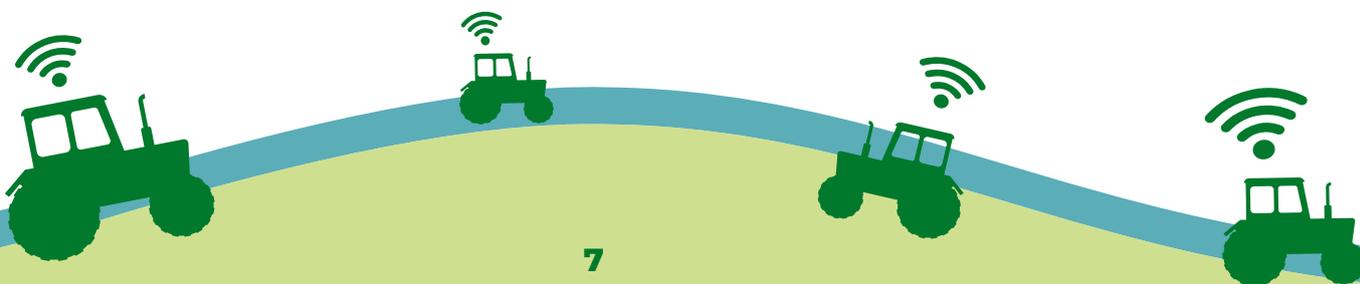
4. Recommended actions to make the best out of digitalisation

Given their potentially game-changing nature, digital technologies can be a relevant topic of discussion in relation to the development of plausible and desirable futures. In such discussions, it is important to consider also for whom are these desirable futures. We see a desirable future as one where the direction and scale of change contributes to a sustainable, resilient and fair society, extending thus beyond farm and even agricultural system level, from a global perspective. The key question is thus, will digital technologies contribute to building desirable futures, or will they get us further away from them?

The potential of digital technologies, in other words, cannot be taken for granted nor can we delegate our future to the processes of digitalisation. For achieving a desirable future, a thorough and well-conceived consideration of the concerns and threats that are raised around the use of digital tools and technologies, will be necessary. We assume that these concerns can create an 'innovation environment' that stimulates researchers, developers, agricultural extensionists, and farmers to shape technological solutions that go in the desired direction.

In our view, future developments should follow three guiding principles in order to achieve a desirable future for digital agriculture: bridging the digital divide, co-creating solutions, and developing adaptive governance models.

4.1 Bridging the digital divide

Inclusion is a key element when considering a desirable future. Despite significantly higher growth rates and progress in relation to the Digital Agenda for Europe, the goal of providing every single European household with 30 Mbit/s access was yet to be reached by 2018. The divide between urban and rural areas remains large (De Clercq *et al.*, 2020). Different actions are suggested to help in bridging this divide:

- First, the need for **capacity building** is clearly emphasised. Training should be offered for further development of digital skills/reskilling, not only to farmers and farm workers, but equally to farm advisors/intermediaries. This should be considered both at the level of formal learning (e.g. incorporation in agronomic curricula) and informal learning (e.g. peer-to-peer learning, Community of Practice).

- Second, as digital technologies are assemblages of different technologies - each of which requires different levels of expertise – there is a **need for 'connectors' or innovation brokers**, who can act as 'free actors' and help rural actors to identify the appropriate technological solutions and to link them together. These can be employed in many types of organisations or by the self-employed.

- Third, the call for **improved infrastructure and connectivity** is unmistakable, and is a crucial enabler, or even basic requirement, to close the gap. Without suitable infrastructure, there is no future for digital agriculture, without data connectivity it is feared that only major technology companies will have access to game changing information.

- Finally, there is a call for the development of digital technologies and tools that cover the range of farmers (and farming systems) which exist, and that we would like to continue to exist in the future. It should be ensured that **digital solutions address the needs of various farmers and farming systems** and not just high-end users or large-scale, intensive systems.
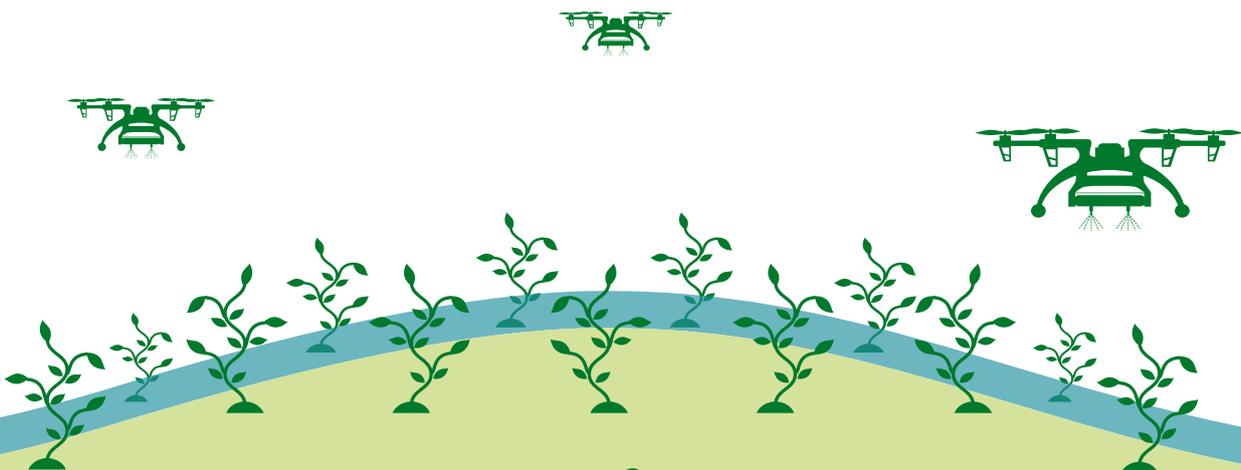
4.2 Co-creating solutions

As mentioned, digital technologies are expected to have a number of both (un)seen and (un)known impacts, and there are concerns that they will favour mostly intensive, large-scale farming systems. In response to the aforementioned socio-economic and ethical concerns, and to ensure that solutions are developed not only to meet end-users needs, but also overarching sustainability goals (e.g. the SDG framework), there is a need for a transdisciplinary and collaborative approach in the conceptualisation and design of these. Discussions about interoperability, developing open data standards for agricultural/food systems, and data sharing between different users could also be part of such an approach. By including a wider range of actors in this discussion, it might reduce the risk of a single stakeholder controlling all the data. It could also support new forms of cooperation to ensure "data smallholders" maintain access to their data. Not only the 'usual suspects' should be included, but also concerned artists, youth activists and other people that experience quick changes in either rural or urban contexts, who can contribute to this game changing transition. As stated by one of the survey respondents, "*We have to keep in mind that digital tools are only tools and one way among another to reach a goal, so digitalisation doesn't have to be an end in itself.*"

In this light, the Responsible Research and Innovation (RRI) approach has been suggested. RRI is intended to anticipate the impacts and, possibly unintended, consequences. RRI implies that researchers design their solutions starting from users' needs and from analysing the problems to be addressed, and not from the technology. In such an approach, problems and solutions are identified together, with researchers, developers and users, collaborating throughout the process. We recommend that innovation policies encourage these co-construction processes.

4.3 Developing adaptive governance

As a third guiding principle for achieving the desired future, there is a clear need for inclusive governance models. This will be crucial in overcoming specific concerns around misuse of data and power imbalances. To achieve this, governance will need to shift from reactive to proactive models.

Proper governance models already in the early stages of development of digital solutions should be considered, which to some extent could be done also by integrating policy-makers in the co-creation process. Deep knowledge of the stakeholders' roles, business chances/threats, ways of communication, etc., are needed to fully understand the truth behind the stories and to suggest useful next steps to governance models that balance power.

REFERENCES

Bacco, M., Paolo, B., Brunori, G., Debruyne, L., Ferrari, A., Gotta, A., Koltsida, P., Lepore, F., Orsini, A., Rolandi, S., Scotti, I., Toli, E. (2020). Synthesis Report on the Taxonomy and Inventory of Digital Game Changers. http://desira2020.eu/wp-content/uploads/2020/11/D1.3-Taxonomyinventory-Digital-Game-Changers.pdf

De Clercq, M., Buysse, J., & D'Haese, M. (2020). The state of rural digitalisation in Europe. Draft briefing. https://desira2020.eu/wp-content/uploads/2020/11/Briefing_Digitalisation-in-Europe.pdf

DESIRA (2020). First set of Practice Abstracts. https://desira2020.eu/wp-content/uploads/2020/11/D1.4-First-set-Practice-Abstracts.pdf and the individual PAs http://desira2020.eu/resources/practice-abstracts/

Rijswijk, K., Bulten, E., Klerkx, L., Dessein, J., Debruyne, L., Brunori, G., Scotti, I., Bacco, M., Currie, M., Bartolini, F., van der Velden, D., Rolandi, S., and Metta, M. (2020). Digital Transformation of Agriculture, Forestry and Rural Areas – Developing a future proof Socio-Cyber-Physical System. ç

Rijswijk, K., Bulten, E., Klerkx, L, den Dulk, L, Dessein, J, & Debruyne, L. (2020). Digital Game Changers (DGCs): The potential to generate disruption. Conceptual Briefing. https://desira2020.eu/wp-content/uploads/2020/11/Briefing_Digital-Game-Changers.pdf

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Research Commentary — Digital infrastructures: The missing IS research agenda. Information Systems Research, 21(4), 748-759.

www.desira2020.eu