STUDY

Requested by the AGRI committee

Research for AGRI Committee - Impacts of the digital economy on the food chain and the CAP

Agriculture and Rural Development

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Research for AGRI Committee - Impacts of the digital economy on the food chain and the CAP

Abstract

The study presents a state-of-the-art overview on digital agriculture, the impacts of new technologies on the agri-food value chains and opportunities for the Common Agricultural Policy (CAP). Using case studies and examples the study demonstrates the needs for further deployment of innovation in the agriculture sector, fostering research and investments in digital agriculture and integrating Agri-tech into the policy agenda.

This document was requested by the European Parliament's Committee on Agriculture and Rural Development.

AUTHORS

WR: Katrine Soma, Marc-Jeroen Bogaardt, Krijn Poppe, Sjaak Wolfert, George Beers, Daoud Urdu[1];
VVA: Monica Pesce, Maria Kirova; Carole Thurston, Consuelo Monfort Belles

Research manager: François NÈGRE
Project and publication assistance: Catherine MORVAN-TAINTENIER
Policy Department for Structural and Cohesion Policies, European Parliament

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ABOUT THE PUBLISHER

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1 WR staff who contributed include: Roel Jongeneel, Robert Hoste, Tamme van der Wal, Ron Wehrens, Trond Selnes, Johan Bremmer, Jos Verstegen, Koos van der Meij, Robert Robbemond, Lan Ge, Tim Timmermans, Marleen Onwezen.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AKIS	Agricultural Knowledge Information System
AR	Augmented Reality
CAP	Common Agricultural Policy
CGIAR	Consultative Group for International Agricultural Research
CSC	Corporate-start-up collaborations
EIP-AGRI	The agricultural European Innovation Partnership
EU	European Union
FaaS	Farming as a Service
FaST	Farm Sustainability Tool for Nutrients
FAO	Food and Agriculture Organisation
GFAR	Global Forum on Agricultural Research and Innovation
GNSS	Global Navigation Satellite System
GODAN	Global Open Data for Agriculture and Nutrition
GPS	Global Positioning System
GRIN	Genetics, Robotics, Information and Nano technologies
IACS	Integrated Administration and Control System
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IoT	Internet of Things
IoF2020	Internet of Food and Farm 2020
LPIS	Land Parcel Identification System

RFID	Radio-Frequency Identification
RDP	The rural development programmes
R&D	Research and Development
SMEs	Small and Medium sized enterprise
VVA	Valdani Vicari & Associati
WECR	Wageningen Economic Research
WR	Wageningen Research
WUR	Wageningen University & Research

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EXECUTIVE SUMMARY

Background

Agriculture is impacted by global trends related to demographics, economics and climate change. New emerging technologies are becoming available that can boost effectiveness and reduce risks. Consequently, a "farm-tech revolution" is emerging within the scope of global trends which generate structural changes in farms and the wider value chain in unexplored ways, comparable to what happened in the 1950s when tractors started to be used more widely, and pesticides were introduced.

Aim

The main aim of this study is to provide an overview of ways in which the "farm-tech revolution" will impact the agricultural sector in the near future, addressing the following research questions:

- What are the key technology advancements of the "farm-tech revolution" to date?
- For particular technology, what are the impacts on the evolution of agri-food chain and the vertical integration of the value chain?
- What do these disruptive technology developments imply for the modernisation of Common Agricultural Policy (CAP)?

Main outcomes

Technology advancements: Technological developments in combination with shifts in power relationships and new business models can cause disruption in agri-food supply chains. Technologies are in this report distinguished into three main categories:

- **Expected high impact on agri-food value chain**: Internet of Things (IoT), Robotization, Artificial Intelligence (AI) and Big Data.
- **Expected medium impact on agri-food value chain:** Blockchain, Global Navigation Satellite System (GNSS) and Virtual Reality (high longer-term impact)
- **Expected low impact on agri-food value chain:** Broadband networks, Information and Communication Technology (ICT) and platforms for e-business, given that they are already established to high extents.

Value-chain impacts:

- Technology advancement includes integration of technologies in systems to enhance traceability. Often IoT, Big Data and AI are used in combination, as well as AI and robotization. Drones are often combined with satellites and Big Data.
- Some applications of technologies target reduction of risks in agricultural production, such as detecting crop diseases early on in production. For instance, use of drones to create detailed soil maps for damage control, benefit the whole value chain. Some technologies target risks associated with emissions and climate change, which impact the society more broadly, including consumers and citizens.
- Other applications of technologies primarily target efficiency in production, such as use of water and energy throughout the value chains. Efficiency impacts the environment and climate positively, as well as productivity.

- Besides impacting vertical integration, digital technologies impact horizontal integration in the food chain, which tends to favour large food suppliers.

CAP impacts: CAP provides farmers with opportunities to adapt to new realities. Modernisation supports existing regional farm systems and specialty crops, as well as inclusiveness, integrated approaches and CAP intervention designed for regional circumstances. Smart farming can reduce environmental impacts and enhance incentives for sustainable production and new business models, with less administrative burdens. Still, there is a risk that administrative burden to farmers increases, and that improved sustainability is not obtained because available data is not used.

INTRODUCTION

The agriculture and food sectors are highly dependent on environmental, demographic and economic variables. Lately they are facing numerous challenges such as climate change, growing demand for production and changing customer needs. The digital economy could enable these sectors to cope with such challenges, bring innovation and generate benefits across the value chain.

The digital economy, or more precisely **digitalisation, is the use of digital technologies to change business models and provide new revenue and value-producing opportunities**. Digitalisation and the creation of many new technologies which evolve at a very high pace appear to be disruptive. **Clayton Christensen popularized the idea of disruptive technologies in the book "The Innovator's Dilemma"[2] published in 1997. Disruptive technologies are those that significantly alter the way businesses or entire industries operate**. Often, these technologies force companies to change their business approach, with risks of losing market share or becoming irrelevant, if they don't. Digital technologies also give a lot of opportunities and possibilities for the creation of smarter agriculture, giving the consumer much more influence. **Industry 4.0** is the next phase in the digitization, driven by four disruptors:

- Rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks.
- The emergence of analytics and business-intelligence capabilities via artificial intelligence.
- New forms of human-machine interaction such as augmented-reality systems and IoT.
- Improvements in transferring digital instructions to the physical world, such as advanced robotics.

In agriculture, these new technologies can and will modernise the sector, foster business innovation and create new business opportunities in areas such as bio-based industries and sustainable ecosystems. However, the magnitude of this transformation and associated impacts on sectors, value chains and Common Agricultural Policy (CAP), are highly variable and will differ, depending on the technology focus. **The main aim of this study is to provide an overview of how "farm-tech revolution" impacts the agricultural sector in the near future**. This study investigates the following three research questions:

1) What are **the key technology advancements in the farm-tech** revolution to date?
2) For each disruptive technology, **what are the impacts on the evolution of agri-food chain and the vertical integration of the value chain**?
3) What do these disruptive technology developments imply for **the modernisation of CAP**?

Based on in-depth research and multi criteria analysis performed for a set of technologies (Annex 1), this study splits the analysis into three different parts, depending on the level of impact on the agri-food chain in the following ways:

First, some technologies with high impact on agri-food value chain are innovative solutions which have already had disruptive impacts in the sector – and may even have more impacts in future. New innovative solutions with a potentially high impact are, for instance, Artificial

[2] https://www.wired.com/insights/2014/12/understanding-the-innovators-dilemma/

intelligence and Automation, because they trigger high extents of potential changes. While in practice different technologies are most often combined, we have in this study specified the following technology categories for the analyses:

- **Internet of things (IoT):** are networks of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.
- **Automation and Robotization:** refers to the automation of a system or process by the use of robotic devices.
- **Artificial Intelligence (AI):** is any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals.
- **Traceability and Big Data:** Big Data ensures traceability by increased data sharing and refers to data sets that are too large and complex for traditional data-processing application software to adequately deal with them.

Second, technologies with medium impact on agri-food value chain are highly innovative and may have a high impact in the long run, but because they are not highly developed in the sector or have not been introduced into the agri-food value chain to cause disruption, they belong to the medium impact category in this study. In the case of Global Navigation Satellite System (GNSS), disruptive and enabling automation, this technology is mostly mature and can easily be extended to smaller farms:

- **Blockchain:** is a growing list of records, called blocks, which are linked using cryptography. A block in a Blockchain contains a cryptographic hash of the previous block, a timestamp, and the transaction data.
- **GNSS:** is used in many applications to determine the position of an asset based on satellite data (e.g. Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), Galileo or BeiDou).
- **Virtual Reality:** is an interactive experience of a real-world environment.

Third, technologies with low impact on agri-food value chain, are identified as service commodities rather than disruptive technologies. They facilitate the implementation of other innovative solutions and are a prerequisite for digitalisation:

- **Broadband networks:** is a network with wide bandwidth for data transmission and can transport multiple signals and traffic types via a medium. Broadband networks are an essential technology that provide online connection.
- **Information and Communication Technology (ICT):** is today considered an enabling commodity technology for creation and/or uptake of more complex technologies such as Cloud Computing, Satellites, Remote sensing, Smartphones.
- **Platforms for e-business:** are software technology solutions that are used as a base for other applications, processes or technologies (mainly digital commerce).

All these new technologies boost today's agriculture industry on its way to becoming a high-tech industry, resulting in the so called **"farm-tech revolution".** This revolution is manifested by the **exponential growth of technologies used for the agriculture sector, changing farming practices**. Besides more resource efficient agricultural production, digital technology is amplifying vertical integration in the food-chain. On the one side, there is **vertical integration of input suppliers to optimize cost, efficiency and complementarity.** On the other side, **vertical integration is increasing due to big food suppliers investing in agri tech**.

New technologies also contribute to modernise and increase the efficiency of the **Common Agricultural Policy (CAP)**. The increase in digital innovation provides new opportunities for monitoring and controlling. For instance, new effective CAP payment options can contribute by means of a sound and transparent monitoring system built on reliable and robust environmental indicators, such as the recent advancements in satellite Remote Sensing and in the European Earth Observation programme Copernicus. Precision agriculture technologies, combined with **new methodologies for cross-linking farmer's information, facilitate a shift from the traditional control of farmers' claims based on sampling, to a continuous and full monitoring that checks compliance to requirements.** This enables verification with less follow-up actions and reduces the administrative burden, especially between payment agencies and farmers. Integrated digital innovations can improve the governance with **more transparency, fairness and likely decrease in disputes**. Currently, new legislation is proposed to make more use of digital technologies for Integrated Administration and Control System (IACS).

1. DIGITAL ECONOMY: STATE OF THE ART

KEY FINDINGS

- Farmers are facing challenges related to a growing demand for production in combination with shifts in power relationships and new business models, unstable yield due to climate conditions and changing customer needs. To overcome these challenges, the agri-food sector can be supported by the introduction of new technologies.
- New technologies transform the current agri-food value chain by facilitating the collaboration between all the players and providing much more information for decision making and consumer awareness
- New technologies can modernise the agri-food sector, foster business innovation and create new business opportunities. Agricultural innovation is beneficial also for public authorities, new players and the environment.
- However, there are a lot of challenges to overcome. Small and medium sized (SMEs) farmers are resisting change. Further, new technologies which are not yet proven to be effective, aging farming population and lack of knowledge when it comes to the usage of the innovative solutions, hamper developments. Moreover, broadband coverage and good internet connection are not evenly distributed within Europe, and especially poor in remote rural areas.
- Digital technologies will influence the role of farmer's suppliers, because farmers often base technological decisions on the recommendations they provide. Farmers must also be convinced that data generated by new technologies is accurate enough to support farmer's decision makingand is accessible via platforms for data sharing. They should be also convinced that digitalization offers opportunities for distribution and retail and influences the relationship with customers.

1.1. Main agri-tech trends

New technologies are changing our business environments and are used across multiple sectors to create value and opportunities, agriculture being part of this change. Macroeconomic trends such as population growth and climate change, as well as the urgency to account for resource efficiency and human health, and declining costs of technology devices, drive advancements of technology applications into the agriculture sector. Agricultural technologies assist the farmers in improving productivity and help them face increasing challenges such as extreme weather, volatile prices, changes in consumer behaviour, natural disasters and diseases.

Demand for technology in agriculture is rising and can assist farmers to face current and future challenges. In search for sustainable solutions, ideally in terms of system changes (e.g. circularity), technology can enable solutions although not always directly solving all problems. **Demand for advanced technology in the agricultural sector is expected to boost in the future. This results from the fact that not only will the overall global population increase (20 million increase by 2050 in Europe compared to 20153), but also the European middle class is increasing, combined with wealthier consumers eating more animal products[4]. Seven of the**

[3] https://ec.europa.eu/eurostat/data/database?node_code=proj
[4] https://europa.eu/european-union/topics/agriculture_en

top twenty countries in the world with the largest gross domestic product in 2017 are European[5], which likely will be followed by relatively high levels of production and consumption. Lower prices of technologies will increase demand, as they can provide new and effective production possibilities. At the same time, even if globally growing[6], agricultural production is highly unstable, because climate change is causing extreme variability in weather conditions with fluctuating frequencies of floods and draughts. The extreme weather phenomena is putting crops at risk. This trend increases the demand for new technologies and digitalisation of the agri-food value chain that can support adaptations to climate change, while at the same time increase productivity. New technologies can possibly facilitate agriculture operations to improve efficiency and reduce the time to markets and along the value chains.

The consumer awareness and demand for organic products is increasing in developed economies, such as Europe. Consumers are becoming more aware of the need for preservation of the environment and the importance of fair trade. Consumers are more concerned about their health and the quality of food they are purchasing; therefore, they are more exigent when it comes to the origin of the product. In terms of organic food, the Western European market experienced growth by 5.4% and the Eastern European sales showed a growth rate of 8.8% between 2015 and 2016. The trend for organic products is supported by the public sector, imposing regulations that enhance traceability or subsidies to support small farmers. Even though demand is booming, the conditions for organic production are yet not sufficient to meet the customers' needs, as organic farmland as a proportion of all farmland area rarely exceeds 15% in most European Union (EU) countries. In addition, organic farming and production without chemicals is costly and gives lower productivity rates, due to the constant requirement for labour working and monitoring production. New technologies such as autonomous robots for harvesting and picking can decrease cost, save time and therefore increase the yield of organic products, as the trend in Europe for organic products is foreseen to grow more rapidly in the next few years[7]. Moreover, advanced data analyses could assist improved early warning systems and advanced preventive management.

Food trends are changing to adapt to consumer and society changes. One of the challenges in the food value chain is the food waste due to short expiry dates. To address this challenge, the Quebec Agri-food Development Centre[8] has developed a technology to increase the shelf life of fresh foods by up to three times. Called HPP (Hydro Protective Process), this green and health-safe technology (which involves dipping a packaged food into a cold-water basin with hydrostatic compression of 87,000 psi) destroys microorganisms in food. Dozens of companies already follow this process, and this technology could become a trend among all food companies in time. Moreover, customers are demanding more information transparency on labels and more natural food. As the number of people with food intolerances or allergies is increasing, the industry is seeing opportunities for new products resulting from ongoing innovation and research and development in food companies (e.g. milk without lactose, bread without gluten). New technologies can also help the producers to provide additional information about their products through an efficient and low-cost system. The growth of online groceries is another trend which will continue to develop and become more consumer driven by means of new technologies, driven by evolving customer lifestyles.

5 IMF, World Economic Outlook Database, April 2018.
6 FAO prediction on global cereal production by 350 million tonnes by 2023.
7 Organic food market in Europe - Statistics and Facts, Statista.
8 http://www.cdbq.net/

Digitalisation allows better cooperation across agri-food value chains. The introduction of new players in the value chain is contributing to the creation of new farming business models. Investments in technology increase, supported by farming cooperatives, big multinational companies or publicly sponsored investments. Due to the high cost of machinery, small size farms turn to **cooperative farming**, to establish consolidated land and share the benefits and cost related to the introduction of new technologies. Notably, the size of farms in the EU is smaller compared to the US. Small-scale farmers have difficulties buying large machinery and choose to rent, or to share. Usually prices surge at the peak time, such as harvest period. To make it easier for farmers to hire a tractor for the time they need it, digital services such as the **Trringo tractor**[9] **or karnott** applications have been introduced in the market. These smartphone applications enable farmers to deploy mechanisation on a 'pay per use' basis and to control the use and cost of their machinery.

New technologies bring changes in farming practices. Digital farming is expected to shift the traditional network of stakeholders around farms. Besides traditional players, such as farmer's suppliers, distributors, retailers and consumers, it is observed that new players (start-ups) enter the network and bring the technologies needed and/or the expertise to analyse the data generated by the agriculture and the food supply chain. These new farming practices can encompass the entire production processes and tools, from equipment such as autonomous tractor or drones, through to the seeds and crop monitoring via sensors. Precision farming is revolutionising the agriculture industry with centimetre accuracy in fields and the ability to manage seeds, fertilizers, water, crops and reduce and target spraying of diseased plants, providing continuous control and supporting decision making.

Biotechnology will shape the future of agriculture. The direct benefit of biotechnology is the possibility to make plants resistant to diseases and even viruses, for which currently there is no cure. This will decrease the volatility of the yield, increase the production and reduce the usage of chemical pesticides[10]. Scientists are currently developing and researching molecular biology and genetic engineering. For example, the technology **CRISPR/Cas**[11] enables modifying of a genome and introduces mutations that are genetically indistinguishable from those resulting from natural breeding. This is a very sensitive and controversial topic to the public. On the one hand, according to scientists[12], the legal approach should be flexible enough to cope with future advances in science and technology in this area. On the other hand, the European Court of Justice ruled that such techniques, whereby organisms are obtained by mutagenesis should be subject to the same strict EU laws that apply to genetically modified organisms.

1.2. Benefits and challenges of new technologies applied in the agriculture sector

In the agriculture sector, these **new technologies** can and **will modernise the sector, foster business innovation and create new business opportunities**. New technologies could be beneficial at all levels of the value chain. The figure below showcases some of the main benefits that new technologies can bring to farmers, consumers, public authorities, the environment and new players.

9 https://www.trringo.com/
10 Crop Farming 2030.
11 https://www.origene.com/products/gene-expression/crisprcas9?&utm_source=bing&utm_medium=cpc&utm_campaign=CRISPR&msclkid=dffcb06f39f718367ac0eb8a5e516515
12 Commission's Group of Chief Scientific Advisors.

Figure 1-1: Benefits of new technologies across different players

Source: *VVA*

New technologies also bring new challenges. Implementing innovation is always disrupting and along with the numerous benefits, the agri-food value chain is also facing some barriers. Some of the main challenges are as follows:

- Many new technologies are used or starting to be used in agriculture, but **the level of implementation in Europe is still very low compared to other regions in the world, such as the US.**
- Primary requirements to enable most of the new technologies, **broadband coverage and good internet connection, are not evenly distributed within Europe**, especially in remote rural areas.
- **Small and medium sized farmers seek cost-effectiveness and reliability on new technologies.** Resistance to change and to the introduction of new technologies in agriculture might be due to the knowledge gap for agriculture needs by new technologies providers[13]. Independent of age or sectors, farmers appear equally sensitive to technologies and their implementation[14]. Their main objective is to gain benefits and reduce costs of labour without disrupting the way they work and negatively impacting their priorities.
- **Small and medium sized farmers have difficulties with investment capabilities.** Investments in new technologies are expensive and it is difficult for SMEs to follow all the technological trends. Insurance schemes are also not sufficient at this stage to protect and cover the risks of technological investments by the farmers. Funding through private-public partnership are therefore developed to address this challenge.
- **Proper governance for 'fair' distribution of information is one of the key challenges for digitizing food-chains**. It is more likely that upstream players in the food-chain adopt

[13] Battigelli F. (2007), Turismo e ambiente nelle aree costiere del Mediterraneo. Regioni a confronto, Forum, Udine.

[14] Statistical study Agrinautes 2018 copyright Terre-net Media. Equipements et usages des agriculteurs sur internet. Realisée par Terre-net Média et Hyltel.

new technologies faster and more effectively. Food-chain partners recognize new opportunities for better alignment of supply and demand, improving food quality, reducing food waste, utilising efficient logistics etc. However, this could become a challenge if information asymmetry is created because some players in the value chain have broader access to valuable data and can strengthen their (market) position at the cost of other, less informed, parties. An example of an action to counterbalance this, is the api-agro platform[15] th0at offers an alternative for free sharing of agricultural data in the French territory with a formal ethics and legal framework.

1.3. Stakeholders' view and issues to be investigated

To distinguish the best ways to organize and regulate the collaboration between partners in the network, the possible future impacts of the use of digital farming technologies on the stakeholders involved in the agri-food value chain must be assessed, as well as the relationships between them.

Farmers' suppliers. Innovative digital technology adoption, particularly precision agriculture, can lead to environmental and sustainable farming benefits resulting from new practices and efficiencies. This is a potentially game changing benefit for the environment and society, because farming and agriculture generally have detrimental effects on the environment and $C0_2$ emissions. **The role of the farm consultants and suppliers will need to change to provide the digitalisation services to farmers and will be critical in the successful adoption, monitoring and ongoing development of 'Smart Farming' and 'Precision Farming'.**

These two concepts are often interchanged: **Smart farming** (also known as Farming 4.0 and digital farming) is the application of information and data technologies for optimising complex farming systems. For example, the integration of smart agricultural technologies and modern data technologies enable seed planting to be adapted to a specific field to ensure an efficient production process. The application of information and data technologies supports farmers in making informed decisions based on concrete data. **Precision farming** is an agricultural concept involving new production and management methods that make intensive use of data about a specific location and crop. Sensor technologies and application methods are used to optimise production processes and growth conditions. On one hand, using digital data can increase resource and cost efficiency as well as reduce environmental impact[16].On the other hand, digital agriculture still must be proven, and optimal business cases should be further developed taking into consideration the important financial investment required.

Digital technologies are starting to benefit and change the role of **farmer's suppliers. They are becoming more tightly integrated into the farm through the availability and implementation of new farm management systems and the adoption of new technologies**. Suppliers and consultants need specific analytical skills to implement and support the new technologies and the analyses of the resulting data. This is creating new opportunities for data analytics specialists and companies. It is acknowledged that humans will always be involved in the entire farming process, but as smart farming evolves it will be at a higher intelligence level, with the operational activities executed by machines[17].

15 http://www.api-agro.fr
16 https://www.biooekonomie-bw.de/en/articles/dossiers/digitisation-in-agriculture-from-precision-farming-to-farming-40/
17 Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153 : 69-80.

For example, in the state Baden-Wurttemberg (Germany[18]) some farm service and supply providers offer tailored solutions for individual farms and provide advice to help farmers, looking at what is efficient, sustainable and economic for a specific customer. Simply supplying input products and farm management software will not be viable for farm supply businesses in the digital farming era, as suppliers will need to develop new collaborations and strategic partnerships to fill knowledge and expertise gaps.

Farmers. A large number of European farmers are digitally connected because of their professional activity[19]. A polling company called BVA conducted a survey with a sample of 1,280 French small and medium size farmers. Based on this survey, it is suggested that farmers are aware of the new technologies and they believe that automation and precision farming is already affecting farming in Europe. It is however less clear how they value these impacts. It is a widespread opinion in farming and counselling circles, such as Chamber of Agriculture, that sensors, enabling the collection of data, will become common in soil, silos and drones, as well as in tractors. Farmers seek new tools that improve performance, guarantee time saving and enhance production. Still, they are sceptical as they cannot afford the risk of failure. Farmers have been negatively impacted in the past periods by technologies implementation, missing appropriate consultation and with unclear performance indicators[20]. Moreover, the practical nature of farmers, dependent on natural resources and cycles, leads them to scepticisms on the ability to predict future farming cycles. Close cooperation with farmers is critically important to implement technology innovation and developments[21].

There is a widespread acknowledgement confirming the need to continue the implementation of more advanced ways to manage farming and breeding. The awareness raising, and dissemination are often carried out by cooperatives or new types of initiatives. Among these new initiatives is, for example, Api-Agro[1], a French public-private consortium who federates and guarantees freedom and good use of agricultural data to add value and innovate towards a performing and responsible agricultural sector. However, **it is understood that a large share of the European farmers will not implement new practices until reliability and cost-benefits are assessed by a trusted partner. These trusted partners may be fellow farmers, cooperatives or reliable and well-known providers.**

The farmers co-operatives form a business model based on sharing benefits, information and tools. They are highly representative for European agricultural sector, which historically used to be a family-based business of small or medium agricultural holdings. Co-operatives are often based in remote rural areas and offer a stable framework for workers and farmers. The emergence of new stakeholders in the framework, such as start-ups providing new digital services via e commerce platforms, will have an impact on the traditional co-operative system.

Distribution and Retail. Digitalization offers opportunities for distribution and retail. The use of digital technology is already extensive in the logistics sector for efficient transport and reliable shipping by keeping track of logistic entities (box, truck, pallet). **By adding more sensors (temperature, humidity, light, movements, sounds) the sector can also track and improve the quality of the products they are shipping, including animal welfare during transport. Digital technologies also make it possible to track food-products when they are distributed.**

[18] https://www.biooekonomie-bw.de/en/articles/dossiers/digitisation-in-agriculture-from-precision-farming-to-farming-40/

[19] Etude Agrinautes 2018. Copyright Terre-Net media 2018. Equipements et usages des agriculteurs sur internet, realisé par Terrenet Media, Hyltel, BVA.

[20] https://www.terre-net.fr/materiel-agricole/tracteur-quad/article/ferme-3-0-l-agriculture-entre-dans-l-ere-du-numerique-207-119982.html

[21] Kruize, J. W. (2017). Advancement of farming by facilitating collaboration: reference architectures and models for farm software ecosystems. Wageningen University.

Across foodservice and grocery retail the impact of the internet has been disruptive. Amazon in 2017 launched a "same day grocery delivery" business, in partnership with grocery retailers, called Amazon Fresh in Europe, which serves high density population areas such as Berlin, Munich, Milan, Hamburg and London, using grocery shop partners in the different cities to deliver the orders. **The target delivery time for orders is within two hours in most cases.**

Innovation in logistics and technology in fresh food, is increasingly focused on the speed of the supply chain. The objective is to develop supply chains that are fast, flexible, transparent and precise. One of the most difficult agri-food products to handle are fruit and vegetables as they have a relatively short shelf life and can deteriorate rapidly. These products require supply chain objectives to be achieved if the product is to reach its destination in prime condition. The organisation "Fruit Logistica" commissioned a report that looks at how the four objectives of **fast, flexible, transparent and precise supply chains** could be achieved. To create faster supply chains, elimination of inefficiencies is needed, requiring an end to end view of the entire supply chain. Duplication of effort needs to be removed, scheduling requests to be precisely coordinated so product is always on the move to its destination, this implies a collaborative working approach. The use of IoT and support systems is essential for this to be achieved, but more important than technology is the fact that suppliers and retailers must collaborate and build a mutually beneficial relationship based on trust. In an anonymous supplier/retailer collaboration case study, this collaborative approach enabled the companies to work together to align processes, which reduced order lead time by half from 48 to 24 hours, which resulted in improved freshness and increased customer satisfaction. The Fruit Logistica approach and report is a practical template for other businesses to adapt and adopt. Other examples are large supermarket chains like Tesco, who were the first in Europe to offer loyalty cards which record purchase details. The Big Data is used to analyse buying trends and forecast product ordering levels and to offer the customer individually customised, special offers to maintain and foster loyalty to their brand.

The subject of food safety and origin is a topic that is relevant to consumers, particularly as there have been several scandals linked to false information. One example is "2 Sisters Food Group" in the UK, which was the largest supplier of chicken to the main supermarkets, supplying a third of all poultry products in the UK. An investigation in 2017 by a national newspaper and ITV news revealed that the company was falsifying the 'kill dates' to extend the shelf life (use before date) of the product. There was no independent monitoring of the processing, which meant a lack of transparency and accountability. Here, in terms of new technology, Blockchain could be a solution to the problem of false records because it has the potential to lock the information exchanged in the supply chain.

Consumers. Digital farming will also influence the relationship between producers and consumers as it allows consumers to learn where their food comes from and how it is produced. Furthermore, consumers can require more information (and justification) about the ways food is produced. However, the customer expectations can sometimes exceed the farmer's capability.

Still, some farms and players move towards a more personally connected agriculture, to position their products differently from post-war mass production and exploitations. This trend is connected to the customers desires for a reasoned and local production (including organic), using processes that respect natural resources and environment.[2]

Start-ups. Agri-Food firms are actively looking for ways to collaborate with start-ups to accelerate the implementation of novel digital solutions in their business activities ranging from monitoring systems to e-commerce.

In the USA, there is a trend in the AgTech sector that has been developing since 2012[22]. According to AgFunder, a US online VC platform, global investments in technologies in the food and agriculture sectors have increased from $500 million in 2012 to $4.4 billion in 2017. In contrast Research and Development (R&D) in the large Agri corporates, Monsanto, Bayer, Syngenta and DuPont reduced by up to 10% in some cases. This has created a lack of new technologies, that are needed to continue to drive productivity growth. **Large Agri corporates are sourcing new innovations from outside the corporation rather than from within, as they invest in AgTech start-ups.** Monsanto for example is the largest investor in Agri research through actively purchasing 'external innovation'. Each of the 'big 6' agriculture input companies, Monsanto, Bayer, DuPont, Syngenta, DOW and BASF have launched in-house Venture Capital funds. This strategy clearly demonstrates the lack of innovation in the large corporates and the acknowledgment that innovation is coming from external sources, including start-up companies and not internal R&D.

In Europe collaborations rather than takeovers between large corporates, start-ups and SMEs are becoming more common[23]. There are mutual benefits to be gained by both parties, SMEs need to collaborate with partners to remain innovative. Large companies acknowledge that collaborations with start-ups enable them to deepen their knowledge and to quickly grasp new opportunities. In the UK, according to Forbes, deals between large UK organisations and SME businesses[24] dropped significantly in 2016, but the value of M&A activity, investment and joint ventures, exceeded the sum spent by corporate businesses on research and development. The article states 'corporate businesses are turning to SME businesses for solutions and technologies that will help them keep pace with the rapid evolution of technological change'. This is due to the large corporate structures and internal procedures, which in many cases are difficult to change, because of the company culture and resistance to change[25]. The successful vehicles for this collaboration are cited as being: access to Accelerators and Hackathons alongside the more traditional Joint Ventures and minority investment stake-holding. Moreover, the recently started Smart Agri Hubs project in Europe aims are consolidating and fostering an EU-wide network and EIT Food has 5 Innovation Hubs across Europe[26].

International, European and national governmental organizations. International, European and national governments support the digitalization of farms, because they expect it to contribute to solving societal problems. These problems include, diminishing the use of water and pesticides, fighting climate change, securing food for the growing population, fostering food safety by tracing unsafe food quickly, development of regional areas that risk losing population, creation of jobs, and a strong and competitive economy in comparison with other continents.

The influence of high-tech companies will increase in the future, such as Alibaba Cloud and Nedap or Lely Industries (milking robots), who influence technology possibilities in Europe, but also internationally, by for instance introducing reality in dairy farms.

Scientific view (academics R&D). Digital farming allows access to unprecedented insight into farm data, which is a rich source that can be used for knowledge creation by a variety of players, such as universities, but also international research centres such as Consultative Group for International

22 The Kodak moment for agriculture giants? Paris Innovation Review, 8th November 2017, Matthew Beckwith.

23 Innovation by Collaboration between Startups and SMEs in Switzerland Fabio Mercandetti, Christine Larbig, Vincenzo Tuozzo, and Thomas Steiner. Dec 2017.

24 https://www.forbes.com/sites/trevorclawson/2017/05/26/as-large-uk-organisations-turn-to-smes-for-innovation-help-is-collaboration-the-new-rd/

25 https://www.forbes.com/sites/trevorclawson/2017/05/26/as-large-uk-organisations-turn-to-smes-for-innovation-help-is-collaboration-the-new-rd/

26 https://eit.europa.eu/eit-community/eit-food

Agricultural Research (CGIAR), Global Forum on Agricultural Research and Innovation (GFAR) and Global Open Data for Agriculture and Nutrition (GODAN).

Many projects range from the fundamental research to the application in-field, including research on genetics, preservation of land and resources, new kind of low carbon diets (consumption decisions to reduce the greenhouse gas emissions), high nutritive products, fully automated farms (see the IronOX case below), the incidents of out-of-field self-guided tractors, reliability and interoperability of tools and data among others.

2. DISRUPTIVE TECHNOLOGIES IN THE AGRI-FOOD VALUE CHAIN

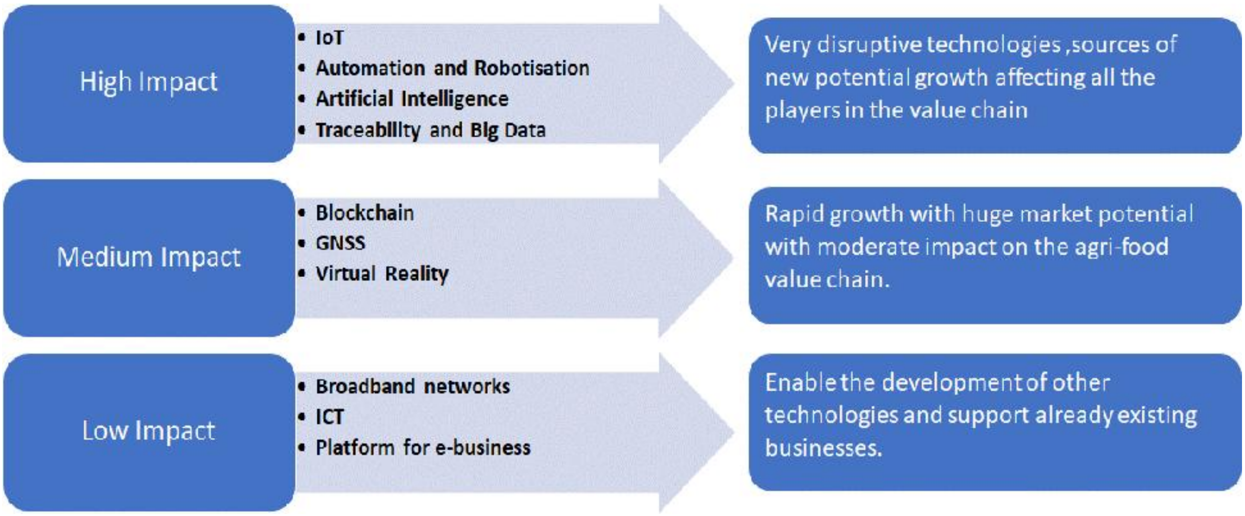
KEY FINDINGS

- Together with Big Data, IoT technology can contribute to improved farm production processes by making available a huge amount and range of data.
- Autonomous systems will control the production in accordance to the market situation, by maximising the profit and minimising the costs in every possible way. They will also impact social benefits by, for instance, taking-over of labour-intensive tasks. Artificial intelligence systems provide rich recommendations and insights for decision makers to further improve production.
- Track and trace agriculture applications from the field through the supply chain and in food processing environments can lead to effective identification and traceability in the food supply chain. The IoT stimulates cooperation between food producers, food storage, logistics and transportation service providers and retail companies, who can work together to ensure efficient delivery of safe(r) food to consumers.
- Use of IoT, Big Data and drones can reduce risks to agricultural production by detecting sicknesses early or designing detailed maps for irrigation purposes, as well as reducing emissions for the benefit of climate change and environmental conditions.
- Blockchains, as well as IoT, Big Data, AI, etc. can increase transparency and trust throughout value chains and provide the possibilities for consumers to influence production to a more sustainable level.

2.1. Overview of the main technologies impacting the agri-food value chain

In this study we distinguish between disruptive drivers and disruptive technologies. First, the disruptive drivers refer to emerging challenges, including the changing environmental conditions (climate change), the uncertain future of demand due to urbanisation and growing population, which make farmers search for technologies that can help them cope with such challenges. Second, disruptive technologies refer to the use of technologies that can cause disruption in a sector, for instance, because supply and prices change, and new contexts throughout value chains developed for competition. This section describes a set of technological developments that cause or can cause disruption in agri-food supply chains. In the near future, IoT, Robotisation, AI and Big Data are expected to cause the highest impacts; Blockchain, GNSS and Virtual reality are expected to cause medium impacts; and broadband networks, ICT and platforms for e-business are expected to have a low impact given that they are already established to a high extent and are seen as critically important to future digitisation developments. An overview is provided in the figure below.

Figure 2-1: Technologies impacting the food-chain and agriculture sector



Source: *VVA*

2.2. Technologies with high impact on agri-food value chain

2.2.1. Internet of Things (IoT)

What is IoT in agriculture? The IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment[27]. IoT makes use of sensors that can record and provide multiplied and growing data volumes, connect multiple objects and devices in production and value chains, and accordingly, large amounts of new real-time data are made accessible[28]. An IoT device can be any traditional device, which becomes connected and therefore able to collect and transmit data. In combination with Big Data, IoT has the potential to transform the agricultural sector, by contributing to improved farm production processes, by making available a huge amount of required data.

The key contribution of IoT is that different types of data, created at different places in the food-chain, can be combined and made accessible for a wide range of applications for different players in and around the food chain. This data can be used to improve control and increase the business efficiency and the overall quality of the value chain processes. For example, sensors and drones are used for crop monitoring, crop spraying, planting, and soil and field analysis.

The structure of IoT in agriculture is based on three layers: the device or perception layer (sensing), the network layer (data transfer), and the application layer (data storage and manipulation). The device or perception layer provides capabilities for automatic identification, sensing and actuating physical objects. It consists of technologies like Wireless Sensor Networks (WSN), Radio Frequency Identification (RFID) and Near Field Communications (NFC). The network layer provides functionality for networking, connectivity and transport capabilities to communicate object information. The application layer facilitates the implementation of the IoT. It provides the intelligence for specific control tasks based on virtual objects. IoT in the agriculture and food domain mostly focus on basic functionalities, including tracking, tracing, monitoring and event management[29].

27 https://www.gartner.com/it-glossary/internet-of-things/
28 Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153: 69-80.
29 Tzounis, A., Katsoulas, N., Bartzanas, T., Kittas, C. (2017). *Internet of Things in agriculture, recent advances and future challenges*. In: Biosystems Engineering. Vol. 164, pp. 31-48. https://doi.org/10.1016/j.biosystemseng.2017.09.007.

What are the future opportunities offered by IoT? The production in agriculture will be further optimised by IoT, as farmlands and greenhouses move from precision to a micro-precision model of agricultural production. Distributed, pervasive computing and precise monitoring of the facilities will provide the optimal growing or living conditions for both vegetables and animals. Autonomous systems will control the production in accordance to the market situation, maximising the profit and minimising the costs in every possible way. Moreover, food supply chains, equipped with WSN and RFID equipment, will be able to monitor each stage in the life of a product, make automatic reasoning in case of a faulty product and increase consumers' feeling of safety, through a transparent product lifecycle information system[30]. This certainly depends on investments, and in the scope of European funded projects that facilitates use of IoT, for instance, in a flagship H2020 project called Internet of Food and Farm 2020 (IoF2020), more than 30M€ are invested in larger uptake of IoT in Agriculture

30 Tzounis et al, 2017.

CASE STUDY 1
Pig health assessment based on sensors

Summary of the case study

In this case, IoT is used in combination with Big Data and AI. It contributes to Smart Pig Health in precision livestock farming in Germany. Use of predictive analytics by machine learning and sensor technology in pig breeding/production will increase pig health and eventually welfare is obtained, use of antibiotics by pigs reduced, and anti-microbial cross resistance (AMR) increased.

Overview and strategic context

Humidity, temperature, noise, water and feed consumption, NH_3, CO_2, H_2S are all criteria impacting on pig health. Currently these criteria are only considered by accident or from time to time (no continuous recording). This IoT-based application aims to implement prediction models to increase pig health while at the same time reduce the use of antibiotics.

Implementation of the case study and challenges

Relevant players in the pig production sector are involved, including two farmers' associations (VzF e.V. and VzF GmbH Erfolg mit Schwein). Other players include a technology provider (MAIS), a Swine Health Service (CALS), and a start-up firm ("innoSEP") specialised in algorithms based on machine learning and AI. The idea is to combine the pig health data with other types of data such as biological data, economic data, slaughtering data, housing data and trade data. With more transparent information, the prediction model will provide better information on diseases and the conditions of pigs at early stages, which should lead to cost reductions in the long term. It is therefore assumed that pig farmers are willing to pay for the new technologies. Also, civil society and the food market will benefit, and may be willing to pay for information about how pigs are kept and treated.

Impacts of the case study on agri-food value chain

The way pigs are kept and how pork is produced is becoming more transparent, which is of interest to markets, customers and the food trade. Increase of pig health and reduction of the use of antibiotics for pigs are important for farmers and the wider population. The services improve pig health and reduce the use of antibiotics.

Impacts of the case study on CAP

Looking at the specific objectives of CAP, the innovative technologies in this case will enhance the farm income and consumer expectations and improve competitiveness. It will also contribute to reducing emissions and thus have positive impacts on the environment and the climate. This case will have a lower impact on the objectives to maintain diverse agriculture across EU and promote socioeconomic development in rural areas.

Timeframe and geographical replicability

The implementation, measurements and calibrations will be conducted on a selected pig farm in Germany in 2019. In 2020 and 2021 the implementation of this technology will be extended to other pig farms in Germany. The technologies experimented can be extended to pig farms in other parts of Europe.

Supporting evidence

http://smartagrihubs.eu/ (Evidence will become available on this website when the project begins; it is now taken from preparatory documentation in the proposals).

2.2.2. Automation and Robotisation

What is automation and robotisation? In general, contemporary robots can be characterised by four central features[31]:

- **Mobility,** which is important to function in human environments such as hospitals and offices.
- **Interactivity** made possible by sensors and actuators (a ‘mover’, a component of the machine responsible for moving and controlling a part of the system), which gather relevant information from the environment and enable a robot to act upon this environment.
- **Communication** made possible by computer interfaces or voice recognition and speech synthesis systems; and
- **Autonomy,** in the sense of an ability to ‘think’ for themselves and make their own decisions to act upon the environment, without direct external control.

Robots in agriculture are represented in dairy farming for example. Cows that are free in the stable come to be milked by the robot. Concretely, the **milking robot** will first identify the cow and will accumulate information on its health (temperature, hormone level, infections, etc.) and on its milk production. The robot then locates the teats and milks the cow while it receives a food supplement. After the cows are trained to go to the robot, they can be milked three times a day, a productivity improvement for farmers. For the farmer there is also a gain of time and flexibility. The use of milking robots also reduces physical labour and staff [30]. Another technology that fits into this category is the use of **drones,** which are being employed in precision agriculture to optimise land productivity and food quality. The drones are equipped with sensors to collect data that can be analysed for more efficient use of chemical inputs (pesticides and fertilisers) and water (drip irrigation). They also allow for selection of interesting traits of plants in the field (e.g. tolerance to drought, salinity or stresses, resistance to pests or diseases) in order to use the selected plants in crop breeding programmes to face challenges such as climate change. The contribution to food safety and crop production is high because they enhance agricultural yields[30].

How are automation and robotisation currently being developed? Robotics has not reached a commercial scale for agricultural applications, apart from milking robots[32]. With declining workforces and increases in production costs, research into robotic weeding and harvesting have received more attention in recent years. However, the fastest available prototype robots for weeding and harvesting are not even close to being able to compete with human-operated systems.

How do automation and robotisation impact on the effectiveness/efficiency of farming production systems? In the period 2014-2015, a survey of 217 Canadian dairy farmers that had adopted milking robots or automatic milking systems showed that the number of employees decreased, and the time spent on milking-related activities also decreased. Also, the farmers reported increased milk yields with little effect on quality[33].

[31] COMEST (2017). Report of COMEST on Robotics Ethics. World Commission on the Ethics of Scientific Knowledge and Technology. UNESCO. Paris.

[32] Shamshiri et al. (2018).

[33] Tse, C., Barkema, H.W., DeVries, T.J., Rushen, J., Pajor, E.A., 2018. *Impact of automatic milking systems on dairy cattle producers’ reports of milking labour management, milk production and milk quality*. In: Animal, 12:12, pp. 2649-2656. doi:10.1017/S1751731118000654.

CASE STUDY 2
Iron OX: AI and robotic operating the hydroponic farm
San Carlos, California, USA

Summary of the case study

A robotic and AI-based farm, which is energy and water efficient, with overall low carbon footprint. Using Iron OX highly developed AI software and robotics arms with 3D sensors the aim was to grow 30 times more per acre than the amount grown by traditional farming.

Overview and strategic context

Iron OX addresses the food security issue, tackling labour shortage, weather variability and traveling long distances by carrying out food production on hydroponic farms with AI software and robotics on the periphery of urban centres. Iron OX provides year-round, consistent varietals of leafy greens and herbs, free of limitations from seasonality and price fluctuations. The AI software, The Brain, analyses the inputs by the robotic arms, giving a submillimetre scale identification of diseases, pest and abnormalities. Human input is allocated in key phases, such as seeding and post-harvesting as in the supervision of The Brain.

Implementation of the case study and challenges

A first 8,000 square foot indoor hydroponic facility, and its offices, is producing leafy greens at a rate of around 26,000 heads a year on its opening year. AI monitoring and the integration of robots are the starting challenges faced by IronOX. The high level of technicality of IronOX farm is an added challenge. The IronOX hydroponic indoor robotic farm provides a model for energy efficiency and uses 90% less water over traditional farming while growing 30 times the number of crops per acre of land. It reduces carbon footprint by reducing transport due to the location of its farms in peri-urban areas. As well the optimisation of logistics and storage, IronOX provides consistent quality, reducing food waste.

Impacts of the case study on agri-food value chain

Due to its impacts on logistics and storage, most relevant is the possibility to introduce time-to-market practices in the value chain. Inputs of water and energy are dramatically reduced and production and prices stability benefit customers. Waste is also reduced.

Impacts of the case study on CAP

The experiences gained in the US on high-tech developments are very relevant to Europe. Looking at the CAP specific objectives, the innovative technologies in this case will improve competitiveness, and will enhance the farm income and consumer expectations. It will also contribute to the effective use of water and energy, and due to peri-urban locations reduce CO2 footprints. This case will have adverse impacts on the objective to maintain diverse agriculture across EU and will not promote socioeconomic development in rural areas.

Timeframe and geographical replicability

The first IronOX hydroponic farm has been functioning and providing vegetables in San Francisco since October 2018. The model is easily replicable and scalable.

Supporting evidence

Press reviews and http://ironox.com

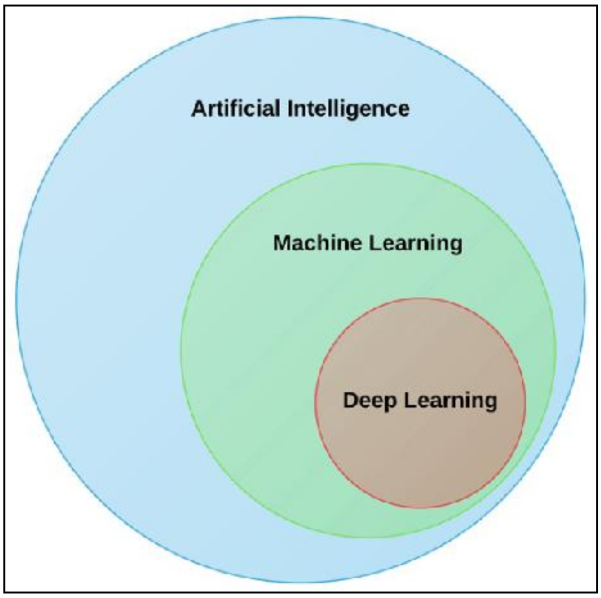
2.2.3. Artificial Intelligence

What is artificial intelligence? According to the European Commission[34] Artificial Intelligence (AI) refers to systems that show intelligent behaviour by analysing their environment and carrying out various tasks – with some degree of autonomy – to achieve specific goals. AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications). Farms across Europe are already using AI to monitor the movement, temperature and feed consumption of their animals. The AI system can then automatically adapt the heating and feeding machinery to help farmers monitor their animals' welfare and to free them up for other tasks. The demand for feed is then adjusted and the value-chain impacted. Mobile phones, navigation systems and many other different sensors constantly gather data or images. AI, particularly machine-learning technologies, can learn from this large amount of data to make predictions and create useful insights for farmers, but also for other players throughout the value chain (EC, 2018). Many AI technologies implement deep learning (DL), by adding more complexity and transforming the data[35]. However, traditionally the driving intelligence behind AI was the machine learning (ML) method, which determines the decisions that are made by AI technologies and discovers hidden patterns or trends that can be used to make predictions[36]. See Figure 2-1.

How is AI being developed? Machine Learning (ML) is defined as the scientific field that gives machines the ability to learn – from 'experience' (training data) – without being strictly programmed to perform a task. ML is being applied in more and more scientific fields. Due to successful applications in various sectors[37], deep learning (DL) has also recently entered the domain of agriculture. One of the applications of DL in agriculture is image recognition, which has overcome a lot of obstacles that limit fast development in robotic and mechanised agro-industry and agriculture[38]. Applications of ML in agricultural production systems can be categorised as (a) crop management, including applications on yield prediction, disease detection, weed detection crop quality, and species recognition; (b) livestock management, including applications on animal welfare and livestock production; (c) water management; and (d) soil management. ML has been applied in multiple applications for mainly crop management, yield prediction and disease detection[39].

[34] Communication from the EC to the EP on Artificial Intelligence for Europe (SWD, 2018); Factsheet on Artificial Intelligence (https://ec.europa.eu/digital-single-market/en/news/factsheet-artificial-intelligence-europe).
[35] (Kamilaris and Prenafeta-Boldu, 2018).
[36] Pierson, L. (2017). *Data Science for Dummies*. John Wiley & Sons, Inc., New Jersey, U.S., pp. 113-114.
[37] Kamilaris, A., Prenafeta-Boldu, F.X., 2018. *Deep learning in agriculture: A survey*. In: Computers and Electronics in Agriculture. 147, pp. 70-90; doi.org/10.1016/j.compag.2018.02.016
[38] Zuh, N., Liu, X., Liu, Z., Hu, K., Wang, Y., Tan, J., Huang, M., Zhu, Q., Ji, X., Jiang, Y., Guo, Y., 2018. *Deep learning for smart agriculture: Concepts, tools, applications, and opportunities*. In: International Journal of Agricultural and Biological Engineering, 11 (4), pp. 32-44. doi:10.25165/j.ijabe.20181104.4475
[39] Liakos, G., Busato, P., Moshou, D., Pearson, S., Bochtis, D., 2018. *Machine Learning in Agriculture: A Review*. In: Sensors. 18, 2674; doi:10.3390/s18082674

Figure 2-2: What is Artificial Intelligence[40]?



What future opportunities can AI provide? By applying ML to sensor data, farm management systems are evolving into real AI systems, providing richer recommendations and insights for the subsequent decisions and actions in order to further improve production. In the future the use of ML models will be even more widespread, allowing for the possibility of integrated and applicable tools[41]. **Deep learning applications have many opportunities**[42] **in smart agriculture such as (1) agriculture information processing; (2) agriculture production system optimal control; (3) smart agriculture machinery equipment; and (4) agricultural economic system management**, where deep learning can be used to model price changes in complex markets with different variables, as there are complex relationships between agricultural product quality and nutrition, human health and the economy.

An interesting application area of DL is the use of aerial imagery by means of drones to monitor the effectiveness of the seeding process, to increase the quality of wine production by harvesting grapes at the right moment for best maturity levels, and to monitor animals considering their overall welfare and identifying possible diseases. DL needs large datasets to perform an analysis, which can be a considerable barrier for use when such datasets are not available.

40 Palmer, Shelly. 2015. Data Science for the C-Sulte. New Yourk. Digital Living Press.
41 (Liakos et al., 2018).
42 Zhu et al. (2018)

CASE STUDY 3
Sensoring and AI algorithms for early crop disease detection

Summary of the case study

This case makes use of AI in combination with IoT, robotisation, drones and satellite in the production of fruits in Portugal and Spain (Iberia). It involves the exploitation of remote sensors and development of AI algorithms to identify disease symptoms, create risk maps and establish data patterns of the symptoms.

Overview and strategic context

Together with weather conditions, diseases can have potentially a very disruptive impact on crops. In this case the data are gathered and analysed to develop early detection, identification and characterisation of phytosanitary diseases, pests and conditions that appear in crops that are relevant in the Iberian region. To minimise the impact of pests, diseases and viruses in a crop this case addresses three elements: the detection of disease symptoms, the detection of vectors that spread the virus or pests that destroy crops, and the identification of weeds that typically host these vectors.

Implementation of the case study and challenges

This case develops algorithms and data collection methods (satellite, drones and sensors) necessary for the implementation of the models and, where necessary, the techniques for collecting data if they do not exist for the following crops in the Iberian region: olives, vineyards and cork trees.. Businesses will be evaluated (by means of drones and sensors), and success, pitfalls and gaps in future services will be identified for future use.

Impacts of the case study on agri-food value chain

Impacts on production qualities of olives, vineyard and cork trees will provide farmers with fewer risks and reduce costs in the long term, which will benefit value chain customers, including consumers, with higher quality products.

Impacts of the case study on CAP

This case study contributes positively to the CAP specific objectives on innovative technologies and farm income. By detecting diseases at early stages, long-term costs will be reduced, ensuring long-term consumer expectations, and improved competitiveness. It will not directly impact public environmental goods, nor climate, diverse agriculture across the EU and socioeconomic development in rural areas.

Timeframe and geographical replicability

The data collection methods and algorithms collected by the combination of technologies can be adapted to other parts of Europe.

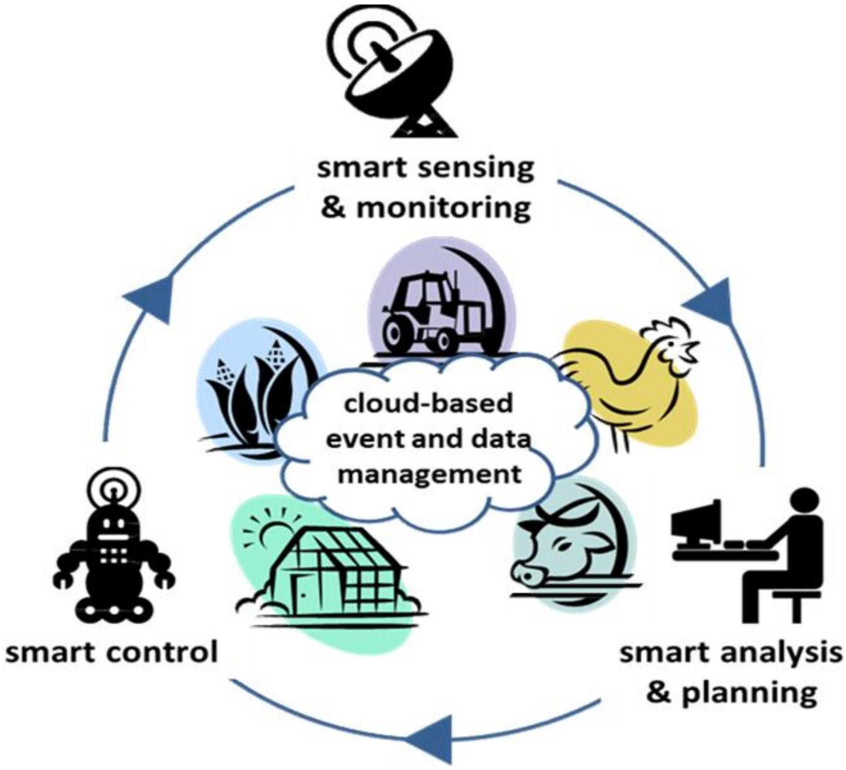
Supporting evidence

http://smartagrihubs.eu/ (Evidence will become available on this website when the project begins, but it is now taken from preparatory documentation in proposals).

2.2.4. Traceability and Big Data

What is traceability and Big Data? The wider uptake of Big Data is likely to change farm structures and the wider food chain in unexplored ways, comparable to the introduction of pesticides and the greater use of tractors in the 1950s[43]. This will involve a major shift in roles and power relations among different players in existing value chains, for example stronger input suppliers and commodity traders. The need for new organisational links and modes of collaboration in the value chains will become more urgent[44].

Figure 2-3: Big Data in Smart Farming



Source: Wolfert et al (2017).

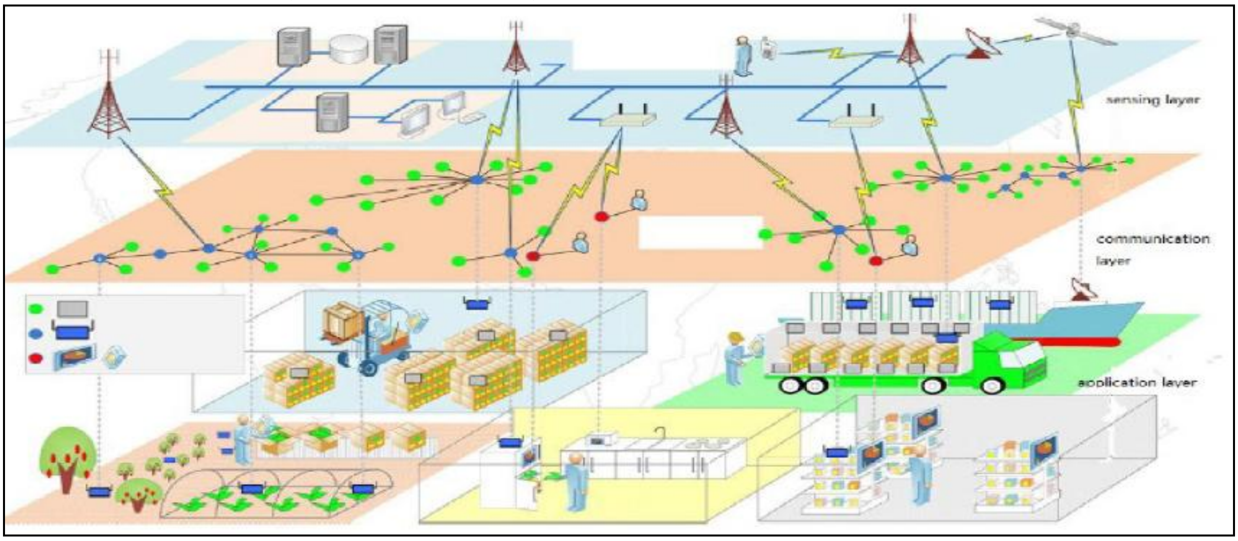
Big Data refers to large amounts of data produced very quickly by a high number of diverse sources. Data can either be created by people or generated by machines, such as sensors gathering climate information, satellite imagery, digital pictures and videos, purchase transaction records, GPS signals, etc.[45] Big Data sets are so large and complex that traditional data-processing application software are inadequate to deal with them. The use of Big Data in agri-food chains has two critical impacts: improvements in on-farm production practices, and improvements in supply chain links to enhance efficiency and effectiveness of the food production and distribution industry[46].

In traceability and Big Data for the agri-food chains the following technologies or applications are used: Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), satellite and remote sensing devices, geographical information and satellite imageries, smart tags, quality sensors, sensor enabled refrigeration, drones, Genetics, Robotics, Information and Nano technologies (GRIN), and Blockchain technology. With these technologies and a backbone system (databases, servers,

43 Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153: 69-80.
44 Sonka, S., 2014. Big Data and the Ag sector:more than lots of numbers. International Food and Agribusiness Management Review 17, 1.
45 Source: https://ec.europa.eu/digital-single-market/en/big-data
46 Scoping Note " Traceability and Big Data" February 15, 2017.

terminals connected by distributed computer networks) data is extracted from the production, storage, transport, sales and consumption stages of the food chain and fused into directly usable information for decision support systems (see Figure 2-3 below).

Figure 2-4: Traceability in the food supply chain in the Internet-of-Things era



Source: Xiarong et al (2015) [47]

Big Data – massive volumes of a variety of data that can be captured, analysed and used for decision-making – are fully dependent on other types of technologies. Big Data stemming for example from IoT gives opportunities to improve food logistics with new technology applications and food logistics management systems. Track and trace agriculture applications from the field through the supply chain and in food processing environments can lead to effective identification and traceability in the food supply chain. Big Data stimulates cooperation between food producers, food storage, logistics and transportation services providers and retail companies that can work together to ensure efficient delivery of safe(r) food to consumers. In terms of tracing and tracking, consumers request greater insight into the production of their food, requiring that more detailed information regarding the product and its processing, needs to be shared with them.

[47] Xiarong, Z., Honghui, F., Hongjin, Z., Zhongjun, F., Hanyu, F. (2015). The Design of the Internet of Things Solution for Food Supply Chain. Paper presented at the 5th International Conference on Education, Management, Information and Medicine (EMIM). April 24-26, 2015, Shenyang, China. https://doi.org/10.2991/emim-15.2015.61

CASE STUDY 4
Data-Intensive Dairy Production

Summary of the case study
In this case Big Data is used for traceability in combination with AI, IoT and Robotisation for the diary value chain in Iberia. The aim is to integrate data to improve data analytics and decision making at all steps through value chain, thus contributing to sustainable, efficient and environmentally respectful dairy production.

Overview and strategic context
One of the main problems in agriculture is the lack of relevant information to perform the production activity. It is crucial to collect all relevant data to improve the management of the livestock. Lots of data are available along the early steps of the dairy production chain (pasture/crop data, animal feed, weather, animal health/welfare, milk automation, etc.) that come in many different formats, from different sources and sensors, and usually are not jointly available.

Implementation of the case study and challenges
This case plans to generate improvements in different steps of the early dairy production chain by exploiting the benefits that digital technologies and data can bring based on the integration of data in the products and services offering of several SMEs[48]. Integration of data to improve data analytics and decision-making take place by first integrating the state-of-the-art algorithms and data analytics schemes in selected products or services of the SMEs involved. Second, testing and technical validation of the different technologies (animal sensing, data analytics, milking automation) will allow improved animal production and sustainability of Galician dairy farms. The tests will take place in the Agrarian Research Center of Mabegondo (INGACAL) and the "Gayoso Castro" Dairy Experimental Farm (USC).

Impacts of the case study on agri-food value chain
Integration of data for improved data analytics targets decision making at all steps through the value chain, to impact overall production efficiency, reducing inputs and supplying more environmentally friendly products to customers.

Impacts of the case study on CAP
Looking at the CAP specific objectives, the innovative technologies in this case will enhance the farm income and improve competitiveness. Through more effective use of input resources, it will also have positive impacts on the environment and climate, and possibly consumer expectations.

Timeframe and geographical replicability
The data-intensive diary production can be applied elsewhere in Europe.

Supporting evidence
http://smartagrihubs.eu/ (Evidence will become available on this website when the project begins, but it is currently taken from preparatory documentation in the proposal)

[48]
- ALLTECH Spain S.L. produces premixes for animal feed and distributes and sells additives for animal feed.
- SERAGRO S.C.G. is a services provider for milk production industry (nutrition services, milk quality service etc.).
- GRADIANT is a private non-profit Research and Technology Organisation which performs applied research and digital technology transfer of ICT to industry.
- ELMEGA S.L. develops engineering solutions for dairy farms, focusing on barns and milking parlours and spare parts. Etc.

CASE STUDY 5
Digitizing Leafy Vegetables

Summary of the case study
In this case Big Data is used together with IoT drones and satellites to analyse soils and microclimate for improved monitoring and optimisation of organic vegetable production in Greece. While this application of Big Data is favourable to production by improving the monitoring of field trials and the running of algorithms for irrigation, weeding and maturity level, consumers will consequently benefit from certified variety and cheaper organic leafy vegetables.

Overview and strategic context
The certification and monitoring of organic products in Europe is time consuming and costly activity and the limitations to the use of pesticides tends to reduce the levels of productivity of such delicate products. The leafy vegetables are a division of the fruits and vegetables sector, which is projected to reach about $62.97 billion by 2020. Moreover, fresh vegetables including leafy vegetables were grown in a 2 million ha area among the European countries.

Implementation of the case study and challenges
The organic producer Marathon (Greece) Bio Products cultivates more than 20 types of leafy vegetables all year around under open field organic certification for Athens supermarkets. Field trials will be conducted using sensors as well as drones to identify weed patches and determine the maturity level of the leafy vegetables for optimum harvesting and for yield estimation. The IoT devices are installed in the field and include weather stations, soil moisture sensors, flow meters and solenoid valves, and data are extracted based on the soils mechanical composition, pH and organic matter content.

Impacts of the case study on agri-food value chain
Impacts on production efficiency, and optimal use of soil offers consumers 20 types of certified leafy vegetables.

Impacts of the case study on CAP
Looking at the CAP specific objectives, the innovative technologies in this case will enhance the farm income, as well as improve competitiveness and consumer expectations. It will use resources very effectively to optimise harvesting, which can have a positive impact on the environment and climate. This case will have a lower impact on the objectives to maintain diverse agriculture across EU and promote socioeconomic development in rural areas.

Timeframe and geographical replicability
The developed services will be offered directly and/or indirectly to them in collaboration with other regions and countries in Europe. The target groups can purchase directly the offered services and equipment. The case study will also provide training to other farms offering similar product lines, potentially offering cluster of products for gaining better market prices.

Supporting evidence
http://smartagrihubs.eu/ (Evidence will become available on this website when the project begins, but is now taken from preparatory documentation in the proposal).

2.3. Technologies with medium impact on agri-food value chain

2.3.1. Blockchain

Blockchain is a **registry of transactions** shared by all the stakeholders via the internet. It is a means of data storage that is **transparent, secure and not under the control of a central body**. The Blockchain saves several transactions, with a non-reverse option. However, it is impossible to delete or change past transactions. It is a peer-to-peer technology, which operates in a decentralised way through nodes. The technology is secured because the information is encrypted. Blockchain can thus enhance trust because of the transparency of the transactions made. It also fosters collaborative and shared economy.

In the past three years, this technology and the various applications in different sectors (e.g. healthcare, telecommunications, energy, logistics) for which it can be used has attracted much interest, but it is mainly known through its use in the financial sector and the way bitcoin payments are operated. **Blockchain is still in a very early stage of development and its future is uncertain** due to the impossibility to control and regulate it given its decentralised character. This makes it very difficult for public authorities to decide on how to respond to this new technology and even more complex to try to regulate it[49].

However, Blockchains are perceived as safe as they are resistant to modification of the data. **Blockchains in agri-food supply chains can support the increase of transparency in supply chains.** Currently, there are many projects and business working on Blockchain technology-based solutions that can be used in agri-food chains. One of them is presented below in the case study on Carrefour in France, where Blockchain technology is used to trace the entire value chain and additional information on some of their products.

Farmers and the agriculture industry in general are under very strict regulations for which they need to provide proof of compliance. These are costly and heavy procedures. In addition, in the case of a problem, it is difficult and time consuming to identify the source of the transaction that caused the problem. For example, in the case of the contaminated eggs in the French market this year[50], a technology such as Blockchain could determine not only where those contaminated eggs were dispatched but also at which level of the value chain the contamination was made. The Blockchain technology could impact the agriculture value chain at each stage. Blockchain can potentially bring more **transparency at all levels:**

- **Find the source of the problem:** trace in a register all the steps of the production value chain of a specific product. The data, which is unmodifiable and undeletable, brings confidence and trust to the consumers.
- **Report a disfunction in the value chain:** with IoT and Smart Contracts, Blockchain could create real time alerts when a problem occurs.
- **Foster confidence between farmers, industries and consumers:** it could show the origin of the products, the production conditions and other information. The technology gives the possibility of accessing information in an open and easy way.

[49] Ge, Lan, Christopher Brewster, Jacco Spek, Anton Smeenk, and Jan Top, 2017. *Blockchain for Agriculture and Food; Findings from the pilot study*. Wageningen, Wageningen Economic Research, Report 2017-112. 34 pp.; 4 fig.; 2 tab.; 18 ref.

[50] https://www.latribune.fr/economie/france/200-000-oeufs-contamines-au-fipronil-ont-ete-mis-sur-le-marche-en-france-746857.html

- **Facilitate audits and controls:** Smart contracts could verify the requirements in an autonomous way, which could reduce the delays and the costs of executing the contracts. This could be used in the context of food certification.[51]

In agriculture there are a lot of risks, many of them related to weather and natural disasters. In the case of heavy natural disasters, in most Member States the public sector supports farmers, but in general the rate of insured and fully covered farmers is very low. Given the high risks relating to environmental disasters, the cost of insurance tends to be high and many farmers, especially small farmers from less economically developed countries, do not take out insurance. Therefore, Blockchain could serve as a form of **insurance for farmers:**

- **Reducing the tariffs**: the management cost of the insurance companies could decrease due to automated and decentralised systems. This could potentially result in a decrease of insurance costs for farmers.
- **Insurance companies can anticipate and better evaluate the risk:** the open access can lead to better understanding of the farmers' situations and provide them with more customised needs in line with the 'know your customer' principle[52].
- **Accelerate the procedures:** Real time data transactions accelerate the process, while refunding procedures could be much faster.

Consumer trust in the industry could decline, as a result of growing awareness of food origin, health issues and sanitary problems. Consumers wish to receive more information not only on the products themselves but also on the entire process behind them. Blockchain could also impact the **upstream market by:**

- Creating **confidence between sellers and buyers** by tracing who is buying what, when and at which price.
- **Facilitating direct sales** from producers to end users, without any additional costs.

[51] Blockchain et Agriculture - Une étude de la Chaire AgroTIC - Octobre 2017.
[52] Know your customer (KYC), is the process of a business verifying the identity of its clients and assessing potential risks.

CASE STUDY 6
Use of Blockchain technology for the traceability of goods and animals

Summary of the case study
Carrefour is one of the world's largest retailers and a leading food distributor, operating more than 12,150 stores and e-commerce sites in more than 30 countries. In 2018 the company launched Europe's first food Blockchain for free-range[53] and plans to extend the technology to eight more product lines before the end of 2018.

Overview and strategic context
Carrefour is looking to lead food transition in Europe, and thus quality, safety and showing where food comes from have become key concerns. Making use of Blockchain technology is a step towards achieving this goal.

Implementation of the case study
To implement this technological solution, each product's label will feature a QR Code. Consumers will be able to scan the code using their smartphones. The scanned QR Code will provide them with detailed and reliable information about the value chain and the process their scanned product followed. For example, for chickens, consumers can find out where and how each animal were reared, the name of the farmer, what feed was used, what treatments were used (antibiotic-free, etc.), where the meat was processed and on which shelves of the store the chicken was stored.

Impacts of the case study on agri-food value chain
The impact would be perceived by breeders, resellers and consumers. It will unlock numerous benefits to the food sector: breeders will be able to showcase their products and expertise, gaining more visibility. Carrefour will be able to use a secured database and guarantee a higher level of food safety, which will increase consumer trust and most likely increase customer numbers and their loyalty.

Impacts of the case study on CAP
This case study has particularly positive impacts on consumer expectations in line with specific CAP objectives. Increased transparency and visibility in the food chain will, at least in the long term, enhance the farm income, as well as improve competitiveness. Depending on consumer demands, this case study can have a positive impact on the objectives concerned with the maintenance of diverse agriculture across the EU and the promotion of socioeconomic development in rural areas.

Timeframe and geographical replicability
Since the first launch of the solution, a major extension of its Blockchain-based product traceability programme was carried out. Internally, the solution was expanded to eggs, cheese, milk, oranges, tomatoes and salmon and will continue to grow. Meanwhile, the industrialisation of the Blockchain technology for the agri-food sector is developed by many players in addition to Carrefour in other geographical areas.

Supporting evidence
http://www.carrefour.com/sites/default/files/cp_carrefour_blockchain_alimentaire_06032018_ven.pdf

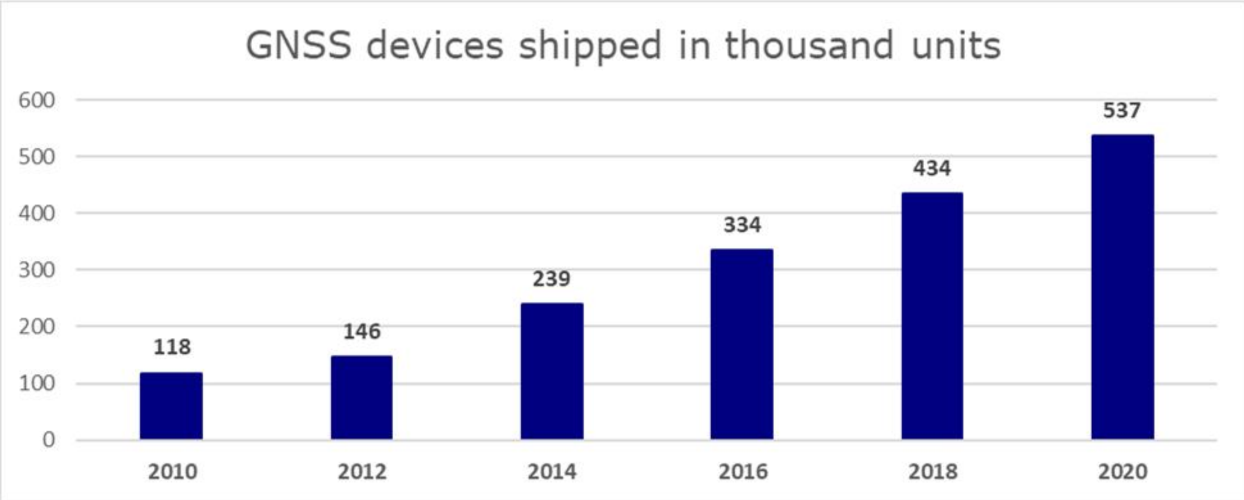
[53] Freerange Carrefour Quality Line Auvergne chicken, one million of which are sold every year.

2.3.2. Global Navigation Satellite System

Global Navigation Satellite System (GNSS) refers to a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers. The receivers then use this data to determine location[54]**.** GNSS include Europe's Galileo, the USA's GPS, Russia's GLONASS and China's BeiDou Navigation Satellite System**.** The performance of GNSS can be improved by regional satellite-based augmentation systems (SBAS), such as the European Geostationary Navigation Overlay Service (EGNOS).

GNSS allows users to know their exact position with greater precision. People use GNSS every day, from the navigation devices in cars to mobile phones. In fact, satellite positioning has become an **essential service that we often take for granted**. In agriculture, GNSS applications are already widely used across all phases of the agricultural life cycle and represent a key enabler for integrated farm management. More accurate GNSS can lead to more precise applications serving agricultural purposes, which is why the technology is constantly being constant developed and new ways of using the data from satellites are emerging. As illustrated in the figure below, by 2020 around 537,000 GNSS devices will be used by the agriculture sector in Europe.

Figure 2-5: Shipments of global navigation satellite (GNSS) in agriculture worldwide 2010-2020



Source: European GNSS Agency.

Galileo, the European GNSS system, the European Geostationary Navigation Overlay Service (EGNOS) and the European Space Based Augmentation System (SBAS) together with Copernicus, the European Earth Observation system, are technologies used to implement agriculture applications. They are being leveraged to be implemented in the Common Agricultural Policy. They can be **used by public authorities for supporting agricultural policy studies on estimating regional production potentials, to monitor and control farmers concerning subsidies on land-use and livestock tracking (e.g. cattle)**.

GNSS is used for precision agriculture, which is the application of different technologies and solutions to manage the variability of agricultural production, to **improve crop yield and reduce environmental impact**. For example, EGNOS is enabling **highly accurate precision agriculture up to the level of 10cm**. **It enhances precision, eliminates waste, saves time, reduces fatigue,**

[54] https://www.gsa.europa.eu/european-gnss/what-gnss

optimises the use of equipment (thus extending its lifetime) and increases crop yields[55]. Currently 82% of European farmers implementing precision farming are relying on EGNOS.

The table below presents a list of applications enabling precision agriculture via GNSS.

Table 2-1: GNSS Agriculture applications

GNSS Applications	Description
Farm machinery guidance	uses GNSS positioning to assist drivers in following the optimal path thanks to a digital display, thus minimising the risk of overlaps.
Automatic steering	completely takes over steering of the farm equipment from the driver, allowing the operator to engage in core agricultural tasks
Variable rate applications	combines GNSS positioning with information from other sensors and digital maps to distribute the right amount of agrichemicals
Yield monitoring	enables site-specific monitoring of harvests, combining the output of a yield sensor with GNSS positioning of the harvester.
Biomass monitoring	enables site-specific monitoring of biomass in an agricultural field, providing up-to-date information on crop development.
Soil condition monitoring	enables updates of soil moisture levels, fertility or diseases to optimise their management. GNSS positioning and software applications identify the exact position of the soil samples sent to laboratories. Data from soil sampling is used in VRT application maps
Livestock tracking and virtual fencing	uses GNSS-enabled portable equipment to track animal's behaviour, leveraging tracking and virtual fencing.
Forest management	makes use of GNSS positioning for different forestry tasks such as the identification and mapping of damaged areas and areas under stress, location of clear-cut areas, sample plots and roads.
Farm machinery monitoring and asset management	uses real-time GNSS information to monitor the location and mechanical status of equipment and to manage work flows efficiently.
Field definition	is the activity of measuring precisely the boundaries and the size of agricultural fields. In the EU, GNSS-based operations using EGNOS and Galileo support a system of area-based subsidies for farmers within the Common Agricultural Policy.

Source: GSA Market report, issue 5

[55] https://www.gsa.europa.eu/segment/agriculture

New trends relying on GNSS are also emerging. Uptake of drones is increasing and growing in popularity in commercial applications, with **agriculture likely to be one of the largest users of drone technology**[56]. This trend is illustrated by a case study.

CASE STUDY 7

Drone-based soil moisture maps to complement satellite and field measurements

Summary of the case study

The case study is based on EU funded project, Mistrale. The project objective is to measure soil moisture from an unmanned aircraft using GNSS. The aim is to provide farmers with soil moisture maps to facilitate their water management.

Overview and strategic context

Agriculture uses around 70% of all freshwater worldwide[57].Taking into consideration the increasing population[58], the water demand is also expected to increase significantly in the coming decades. Therefore, farmers are challenged to produce "more crop per drop". In addition, extreme weather events, such as dry periods or floods, emphasise the challenge for farmers. To overcome these challenges, the farmers would need new tools to monitor and better manage the soil moisture and the use of water. Mistrale set up a service providing soil moisture maps that complement satellite-based and field measurements. These soil moisture maps help farmers to make more efficient decisions on where and when to irrigate. The direct impact would be the saved cost of water consumption for farmers but also the support for environmental care.

Implementation of the case study

Mistrale developed a prototype of a new sensor, GNSS-R, which is integrated on a dedicated unmanned aircraft. This sensor uses GNSS Signals, such as GPS and the Galileo system. It compares the GNSS signals from the satellite directly to the one reflected on the ground. The reflected signals are affected by the soil humidity content, so consequently the moisture can be derived from the signal comparison.

Impacts of the case study on agri-food value chain

It affects farm production by giving insights into where and when to irrigate, based on detailed knowledge about soils. Reduced risks for farmers will lead to greater efficiency and can reduce consumer prices in the long term.

Impacts of the case study on CAPs

Looking at the CAP specific objectives, this case has particularly positive impacts on long term farm income that depends on soil moisture and can improve competitiveness and consumer expectations. Soil moisture is a contributor to environmental and climate, which will be positively impacted.

Timeframe and geographical replicability

The partners in the project[59] are actively working on improving and miniaturising the GNSS-R equipment as well as on integrating it into a dedicated unmanned aircraft system. The solution has the potential to be widely commercialised.

Supporting evidence

http://www.mistrale.eu/

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[56] GNSS Market Report, Issue 5, p.66-73.

[57] http://www.mistrale.eu/Portals/11/FileShare/Photos/poster-MISTRALE-AllEnvi-CVT-v2-print-.pdf

[58] According to the UN Department of Economic and Social Affairs' report "World Population Prospects: The 2015 Revision" the world population is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100.

[59] A consortium led by M3 SYSTEMS which consists of STARLAB, ENAC, GET, L' Avion jaune, and AeroVision. This Mistrale project is funded by the European GNSS Agency under the H2020 programme.

2.3.3. Virtual Reality

Virtual reality (VR) is an artificial, computer-generated simulation or recreation of a real-life environment or situation. It makes users feel like they are experiencing a reality by simulating their vision and hearing. VR is achieved by wearing a headset equipped with the technology.
Currently, it is used in two different ways:

- Gaming and entertainment.
- Training and education for real life environments, where people can learn or practice beforehand.

Figure 2-6: Virtual reality

Figure 2-7: Augmented reality

VR should not be mixed with augmented reality (AR), which is a technology that layers computer-generated enhancements on top of an existing reality to make it more meaningful through the ability to interact with it. AR is developed in the form of an application and used mainly on mobile devices to blend digital components into the real world.

Today, VR is mainly used for entertainment, but more and more applications are found to be very useful in the private and public sector. For example, in the public sector VR is already used for training purposes in police stations or firefighting exercises. This field, however, is still expensive for large-scale implementation, but its future relevance is foreseen.

In agriculture, VR technology is making it possible to take a closer look at crops without needing to go to the fields. **Farmers could thus potentially soon work more in offices rather than in the field**. With a 360-degree camera on a drone and VR headset, **farmers can carry out virtual tours of their fields**. This provides them with a more detailed view (at leaf level rather than just a picture from above), which they can then examine for diseases and other issues. Virtual tours can be especially useful for crops such as corn, where the plants grow tall and become difficult to reach and examine.

Another possible application in the agri-food sector could be the **introduction of new selling services**. Imagine a virtual farm, where customers can visit and choose what they would like to buy directly from that farmer. Moreover, agriculture retailers can offer 360° VR video and new ways of selling products to their farmers. Tractor manufacturers could sell their products with VR, so they can directly show farmers how their new machines work and train them.

CASE STUDY 8
McDonald's use of virtual reality in food education

Summary of the case study
McDonald's launched its *Follow our Foodsteps* campaign, part of Farm Forward, McDonald's UK's long-term programme to address the challenges facing the sector. *Follow our Foodsteps* is offering VR tours of McDonald's partners farms, using 360° videos. The journey starts with farmers and farming, passing by suppliers and process to preparation and cooking.

Overview and strategic context
Consumers have a large knowledge gap related to food sourcing and production across the food and farming industries. At the same time, according to a survey[60] conducted among 2,000 consumers, 74% want to know more about where their food comes from. As one of the largest purchasers of British and Irish farming, McDonald's wants to lift the lid on the passion and skills that exist at every stage of the food value chain.

Implementation of the case study and challenges
The experience linked with VR is built around the following activities:
- '***Top of the Crop' virtual reality challenge***: An Oculus VR headset will invite users to test their skill behind the wheel of a tractor during a potato harvest
- ***Samsung Gear VR headsets with immersive 3600 video***: This series of immersive videos will transport visitors to an organic dairy farm in southwest England and a free-range egg producer in Cumbria.

Impacts of the case study on agri-food value chain
This experience will allow people to follow in the footsteps of farmers, suppliers and other players in the food value chain, bringing knowledge and awareness. It can increase consumer trust in the food they buy and eat. It also challenges stereotypes.

Impacts of the case study on CAPs
Looking at the CAP specific objectives, this case has particularly positive impacts on consumer expectations. Increased transparency and visibility in food production will, at least in the long term, enhance farm income, as well as improve competitiveness. Depending on consumer demands, this case can have a positive impact on the objectives related to the maintenance of diverse agriculture across the EU and the promotion of socioeconomic development in rural areas.

Timeframe and geographical replicability
The Macdonald's model could be replicated by other food corporations to bring awareness and knowledge to the consumer. Beyond that, as a technology, virtual reality is making it possible to have a close look at the crops without the need to go to the fields. Potentially, farmers will soon work in offices rather than in the fields. With a 360° camera on a drone and virtual reality headset, farmers can carry out virtual tours of their fields.

Supporting evidence
https://www.fginsight.com/vip/vip/young-farmers-using-virtual-reality-in-food-education-plan-13460

[60] http://www.mcdonalds.co.uk/ukhome/Aboutus/Newsroom/news_pages/mcdonalds-uk-pioneers-virtual-reality-in-support-of-british-and-irish-farming-inviting-the-public-to-follow-the-foodsteps-of-farmers-suppliers-and-restaurant-teams.html

2.4. Technologies with low impact on agri-food value chain

2.4.1. Broadband networks

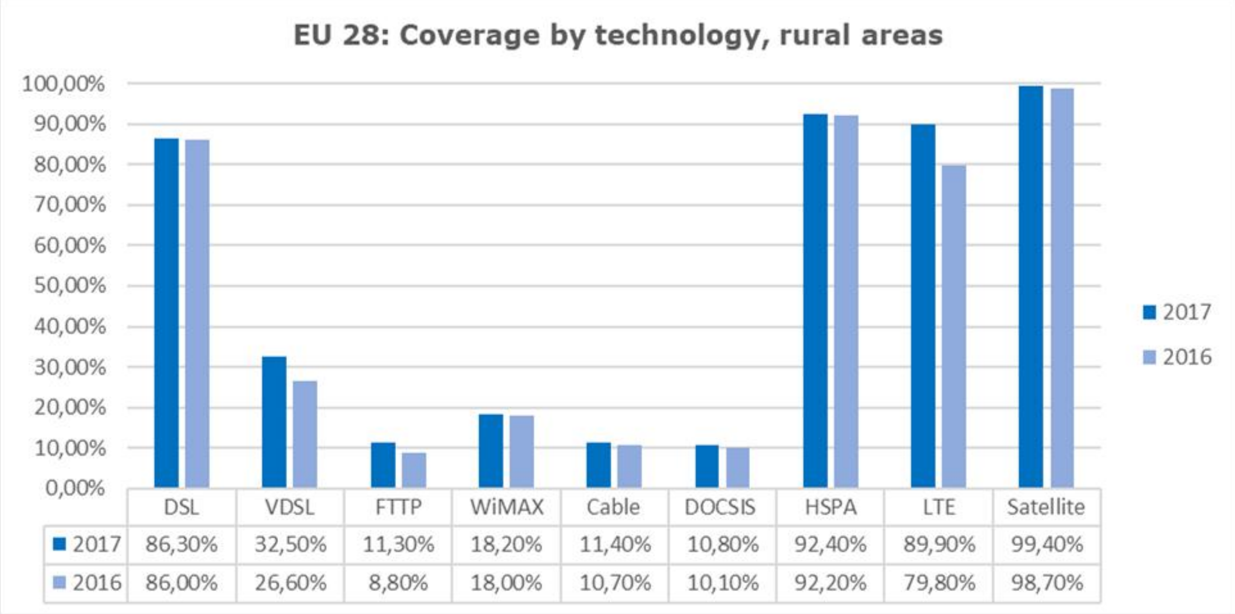
Broadband internet refers to internet access that connects the user to high-speed internet. There are different ways to be connected to broadband: coaxial cable, optical fibre, radio or twisted pair. The most prominent fixed-broadband technology was ADSL in Europe in 2015. Mobile broadband includes 2G, 3G, 4G and upcoming 5G. Each one marks a new generation of mobile broadband with improved download and upload speeds. Most countries in Europe have a different broadband internet provider leading the market. Deutsche Telekom is leading in Germany, while Orange was the leader in France and Movistar had the most connections in Spain. The mobile download speed also differs in the EU. Switzerland has the fastest average connection speed of more than 30 Mbit/s while Czech Republic has an average speed of nearly 8 Mbit/s[61].

Broadband coverage levels – both fixed and mobile – in rural regions remain notably lower than the national coverage, with fixed-broadband networks covering around 92.4% of rural EU households compared to 97.4% of total households. The most widespread fixed-broadband technology in rural areas continued to be DSL, reaching 86.3% of rural EU households by mid-2017. For mobile broadband, HSPA (at least 3G) covers 92.4%, while satellite broadband coverage reaches 99.4% of rural areas. It remains the only option for receiving broadband access in the most sparsely populated and hard-to-reach regions[62].

For newly emerging wireless IoT-applications to be successful – such as the smart potato – high-speed broadband networks such as 5G are certainly required. The smart potato is similar in terms of weight and shape as a real potato and equipped with sensors for humidity, temperature, nutrients and CO_2 measurement. The smart potato is placed among the real potatoes being harvested and naturally removed before the processing phase. With the smart potato, the farmer can collect real-time data about the soil conditions and analyse them, determining which parts of the fields are dry or wet and which potato varieties perform best on specific corners. It also informs farmers on the storage conditions during autumn and winter, before potatoes are delivered to traders or processing companies for e.g. French fries. Especially information on handling potatoes in transport is valuable (ideally potatoes are treated like eggs). This enables farmers to intervene immediately where necessary, bringing precision farming a step closer to reality[63].

61 https://www.statista.com/topics/3729/broadband-in-europe
62 IHS Markit and Point Topic, 2018. Broadband Coverage in Europe 2017. Final Report. UK.
63 https://www.5groningen.nl/themas-en-pilots/use-cases. Also : https://www.nieuweoogst.nu/nieuws/2018/10/03/ultrasnel-draadloos-internet-voor-precisielandbouw-valthermond

Figure 2-8: Broadband coverage by technology in rural areas in Europe in 2017



	DSL	VDSL	FTTP	WiMAX	Cable	DOCSIS	HSPA	LTE	Satellite
2017	86,30%	32,50%	11,30%	18,20%	11,40%	10,80%	92,40%	89,90%	99,40%
2016	86,00%	26,60%	8,80%	18,00%	10,70%	10,10%	92,20%	79,80%	98,70%

Source: Adapted from https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2017

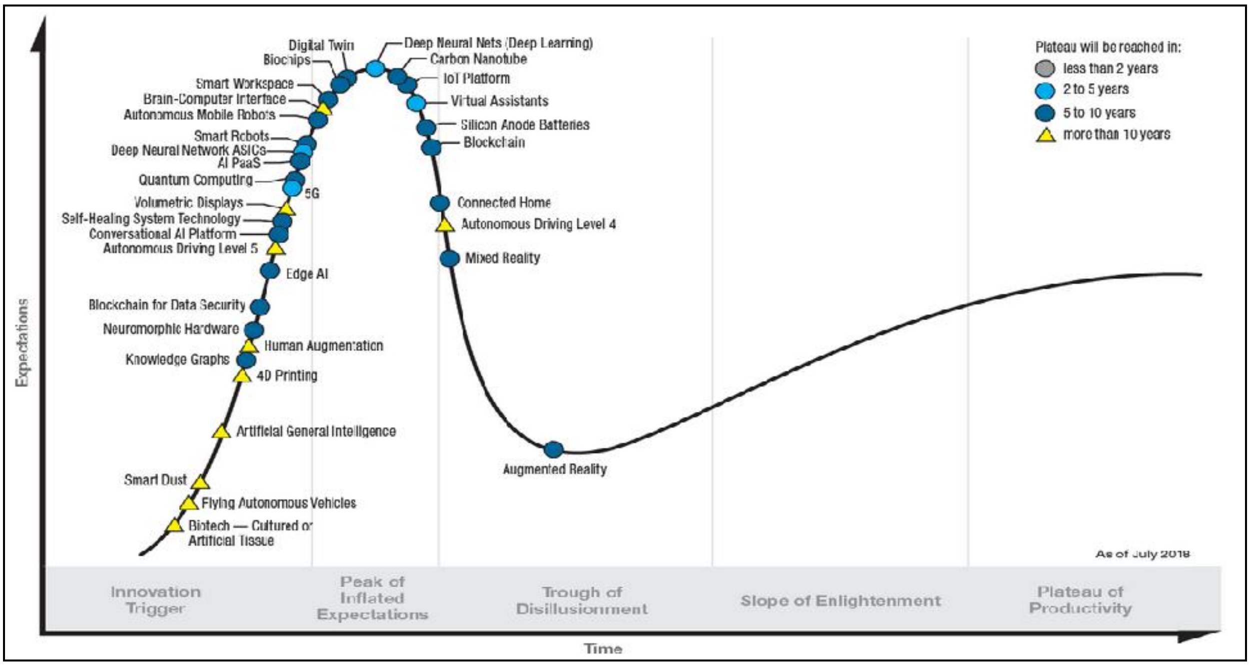
2.4.2. Enabling new Information and Computer Technologies

Information and Communications Technology (ICT) refers to activities or studies involving computers and other electronic technology. The application of ICT in the agriculture sector is also known as **e-agriculture**, which means applying innovative ways to use ICTs in the agri-food domain. ICT in agriculture offers a wide range of solutions and it is a prerequisite for the implementation of new disruptive technologies. ICT is used as an umbrella term encompassing all information and communication technologies including devices, networks, mobile applications and others. It ranges from innovative technologies such as IoT and sensors to other pre-existing technologies such as radios and satellites. ICT is constantly evolving, opening new opportunities for e-agriculture.

To identify new emerging ICT for agriculture, the hype cycle of Gartner – dividing each technology's life cycle into five key phases (see Figure 2-7 below) – could provide insight. The cycle shows the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities. For example, Blockchain has past the peak of inflated expectations and is approaching the phase at which experiments will either be successful or fail. Upcoming technologies like smart dust – tiny sensors with the size of a grain of sand – are currently not quite ready for application due to the difficulty in miniaturisation and the high cost of production[64]. Moreover, much is expected from Digital Twins, a technique that models individual animals, plants, fields or machinery and proposes actions at the moment the actual situation deviates from the modelled outcome, given real-time measurement of the model's parameters.

[64] https://www.raconteur.net/technology/top-5-applications-for-the-industrial-internet-of-things

Figure 2-9: Hype cycle for emerging technologies



Source: https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/

2.4.3. Platforms for e-business

e-Commerce(B2C) and e-Business(B2B) in the agri-food sector. e-Commerce is the online purchase of goods and services from the internet by consumers and e-Business is the exchange of information and purchase of products and services between businesses using the internet. The decision to utilise the internet to trade is influenced by several factors, the main driver being a new route to market for the businesses' products and services. For many 'bricks and mortar' companies building an online sales channels are now a necessity if they are to compete successfully in their markets. The two largest B2B and B2C e-Commerce trading platforms in the world are Alibaba and Amazon. Amazon is the world's largest online retailer and a prominent cloud services provider. Alibaba is a platform that connects Chinese manufacturers with global buyers. It is the world's largest retailer and one of the largest internet companies.

How it developed: The growth of B2C e-Commerce has been exponential with retail sales worldwide amounting to 2.3 trillion dollars in 2017[65]. This is forecast to grow to 4.8 trillion dollars by 2021. The reasons for this growth are: increasing worldwide per capita incomes leading to greater disposable income, growing internet penetration and the exponential growth of smartphone use, which is increasing mobile (m-Commerce) purchases. Consumers no longer require a laptop or computer to purchase. Clothing and footwear are the most popular segments along with electronics[66]. The necessity for retailers to move to online retailing is illustrated by the store closures reported in the USA and UK in 2018, which paints a bleak picture for bricks and mortar stores. Nearly 11,000 stores closed in the USA and in the UK the number is 5,800. The reason is cited as 'the growth of online shopping'[67].

65 https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/
66 B2C e-commerce Market Size, Share 2018-2025, Industry Trend Report, Grand Review Research (sept 2017).
67 https://www.dw.com/en/as-us-uk-retail-apocalypse-deepens-eu-chains-grow-nervous/a-44271346

Worldwide, B2B e-Commerce has also shown strong growth and in 2017 it was worth 1.5 trillion dollars[68], this includes wholesale, retail and manufacturing. In Europe growth of B2B e-Commerce has been slower, but specific platforms have been developed for agriculture and food e-trading and according to the Paris Innovation Review[69], they fall into five general categories: marketplaces, trade and sharing, professionals & private individuals, crowdfunding and peer-to-peer. Marketplaces match the supply and demand of goods and these platforms can target a global market. The products traded range from agricultural equipment to agricultural products. For example, '***Agriaffaires'*** is an agricultural equipment platform established in 2000 by a French company, it specialises in distribution of agricultural equipment, the websites are localised for 25 countries including the UK, Poland and Germany. Moreover, there are collaborative sites for equipment sharing and exchange. One example is '***WeFarmUp'***, which offers equipment for sharing among farmers, which they rent or lease. Collaborative platforms that promote local production and eliminates waste include '***Neighbourly'*** in the UK and '***Foodsharing'*** in Germany. A well-known low-cost implementation using Facebook is the ***REKO network*** in Finland.

How this technology impacts effectiveness/efficiency: Currently in the EU, adoption of Agri-Food e-Commerce has not materialised to any extent at an organisational, regional or country level. Research published in 2017 in the International Food & Agribusiness Management Review (IFAMA) into the reasons for low adoption of this technology in the Agri-food sector, were analysed between internal and external factors. The most relevant internal factors included: low technology competence, organisation size, perceived benefits, target market segment being addressed, and types of products or services being traded. External influences included: competition, market trends, trust and control within the supply chain. **The IFAMA review concluded that regional development of Agri-Food e-trading platforms[70] should be investigated as opposed to national**.

68 https://www.statista.com/outlook/243/100/ecommerce/worldwide#market-marketDriver
69 Agriculture & food: the rise of the digital platforms, 12/2/2016.
70 IFAMA: E-commerce in agri-food sector: a systematic literature review 2017.

CASE STUDY 9
BioSCO (Bioresources Supply Chain Optimiser)

Summary of the case study
BioSCO targets the global market of **bioresources logistics optimisation**. Today, agri-logistics is at best only manually supervised and uses outdated practices, resulting in high costs and a significant carbon footprint. BioSCO's RonGO (Decision Support System) SaaS system has been developed to address the specific problems affecting agri-logistics, including near-to-infinite variable combinations, short crop periods and 'live' commodity and weather constraints. RonGO, as a Decision Support System, delivers real-time logistics optimisation (based on innovative applications of large-scale operational research) and leads to cost savings. Moreover, RonGO substantially reduces carbon footprints by optimising storage building management, as well as reducing mileage and petrol use.

Overview and strategic context
The cost of logistics (i.e. maintenance, transportation and storage) accounts for up to 50% of the crop value. Storage organisations are also undergoing major reorganisations, including mergers between different players, increasing storage on the farm and precision in allotment strategies. For all these reasons, storage planning is becoming more strategic and complex. For example, an average agri-cooperative must choose the best solution from 10,800 different storage plans, which defies human analytical capability. Using algorithms RonGO will model the whole organisation and its operational constraints (flows, costs, capacities, opening hours etc.), presenting the cheapest and most operational solution. The solution will include: ***storage planning***, transportation planning and monitoring via Key Performance Indicators.

Implementation of the case study and challenges
BioSCO developed the RonGO product over for years of R&D. A live test was conducted with two point of contacts in agri-cooperatives, which shared their data and know-how.

Impacts of the case study on agri-food value chain
The innovation introduced by RonGO positively impacts logistics and storage in terms of optimisation, but it also improves the internal processes, reducing the number of meetings and the amount of time required to define a non-optimised storage plan. It also helps to create cost-efficient logistics and storage in agribusiness, reducing transportation requirements, costs and improving the life cycle of goods.

Impacts of the case study on CAP
Looking at the CAP specific objectives, this case has particularly positive impacts on long-term farm income, improved competitiveness and consumer expectations, because BioSCO helps bioresources producers, collectors and users to optimise their logistics and storage, and can reduce supply chain costs by up to 15%. It will also benefit the environment and climate by reducing transportation distances and thus carbon footprints.

Timeframe and geographical replicability
The software is developed to be generic and can be adapted to any kind of economic structure. Optimising the supply chain of wheat in France, or logs in Finland requires the same solution that is easily replicable.

Supporting evidence
Today, BioSCO is the first product to be able to model and optimise agri logistics in real time.

3. IMPACT ANALYSIS OF DISRUPTIVE TECHNOLOGIES CASES ON AGRI-FOOD

KEY FINDINGS

- Some new technologies, such as IoT, Big Data and AI, are contributing to traceability by integrating information of different segments throughout the whole value chain, and by means of effective use of inputs that fit customer needs. Other uses of the same technologies include reduction of environmental and climate risks in production systems, in which customers suffer fewer negative impacts.

- The new technologies are fulfilling the CAP objectives that aim to: meet customer expectations, enhance farm income, improve agricultural competitiveness, provide environmental public goods, and pursue climate mitigation and adaptation. The technologies are less favourable to the two objectives aiming to maintain agricultural diversity across Europe and promote socioeconomic development in rural areas.

3.1. Main findings in the Farm-tech environment

The 'farm-tech' revolution leads to increasing use of technologies in the agriculture sector and changing farm practices. In addition to more resource efficient agricultural production, we can observe that digital technology, and more precisely crop efficiency technologies, are amplifying **vertical integration in the food chain**[71]. On the one hand, vertical integration optimises cost, efficiency and complementarity of input suppliers (seed suppliers, fertiliser suppliers), while on the other hand, **vertical integration tends to favour big food suppliers investing in agri tech**[72]. A recent example is Walmart, an American supermarket chain, which is focused on shortening its supply chain and improving its grocery delivery business, including patenting automated storefronts in and close to people's homes and improving online food shopping[73].

Another trend observed is the **horizontal integration of new players and new types of service providers in the agriculture due to upcoming activities carried out by technology companies in the Agriculture sector**. Whereas vertical integration refers to stronger links between value-chain components, horizontal integration refers to integration of enterprises within the same value-chain component. These companies, such as the international high-tech companies Alibaba Cloud and Nedap, and not the traditional agricultural value-chain companies, have the greatest insights into new technologies and can therefore devise new creative solutions. For instance, the field expertise of traditional agriculture players and the technological knowledge of the new tech players was demonstrated when the established agricultural company John Deere became interested in 'machine learning' applied to agricultural spraying. In 2018, it took over a new Blue River Technology company, which is specialised in computer vision and robotics technology-based equipment for agricultural applications. With such new advanced technology combinations, farmers are required to have

71 https://www2.deloitte.com/content/dam/Deloitte/global/Documents/ConsumerBusiness/dttl_cb_Food%20Value%20Chain_Global%20POV.pdf

72 https://www2.deloitte.com/content/dam/Deloitte/de/Documents/consumer-industrial-products/Deloitte-Tranformation-from-Agriculture-to-AgTech-2016.pdf

73 https://www.cbinsights.com/research/walmart-farming-drones-patent/

extensive knowledge and understanding of the technologies to create new business models. They also need to be part of the valorisation and sharing of data with other players in the value chain. Although the technologies analysed in this study all have impacts on the evolution of the agri-food value chain, their magnitude of impact is different.

Technologies with high impacts on the agri-food value chain will change the way current operations are performed, accelerating the production and distribution processes. In terms of the evolution of the agri-food value chain, **automation and robotisation** will have a very strong impact. However, besides the direct economic impacts and the creation of more qualified employees in automation and robotisation, the needs for employees could overall decline, and might result in fewer jobs in the sector. **IoT, Big Data and traceability** will also have a high impact on 'farm-tech evolution', because they enable the gathering of new data translated into valuable information across the value chain. This creates an entirely new set of possibilities for new business models and support to the environmental and demographic challenges. IoT can optimise use of inputs and improve monitoring possibilities, which not only benefits the farmers directly, but potentially lowers price for the customers and ensures more sustainable and responsible farming procedures that fit customer preferences. Not least AI will foster high impacts, due to the high capacity to analyse data selected by, for instance, IoT. While IoT, Big Data and traceability have already begun to impact the agriculture sector, automation, robotisation and AI still need to be incorporated in the agri-food value chain. Needs for testing, possible regulations and stakeholder acceptance are hampering these developments.

In terms of replicability of these technologies across Europe, infrastructure is critical, and investments are needed. Note that implementation of technology requiring high investments in hardware, such as automation and robotisation, is expensive, compared with IoT, which basically requires a smartphone app or a simple sensor, and is therefore much easier to spread across the sector.

Technologies with medium impact on agri-food value chain are still at very early stages of development and are therefore not ready for larger uptake and replicability**.** For instance, although **Blockchain** is a technology with huge potential and could impact the relationship over the entire value chain of the agri-food sector in future, the expected new future impacts are lower because the technology is not mature yet, the regulatory framework around it is still unclear and trust needs to be built. **GNSS technology** is mainly used as a professional application to support farmers in their production by fostering yield and decreasing the costs of production inputs such as fertilisers. The GNSS technology enables more precise automation and can contribute as a tool for modernising CAP implementation by farmers and monitoring by public authorities. The replicability of the GNSS technology is relatively straightforward, because only a simple installation of a GNSS receiver is often required. **Virtual Reality** is a very innovative technology, with still quite limited use cases in agriculture. Virtual Reality has a high potential to impact the relationship between farmers and consumers and can facilitate farmers operations. However, this technology does not yet have major economic or value chain disrupting effects.

Technologies with low impact on agri-food value chain consist of technologies that are already integrated in the current operations of farmers, retailers and customers. Still, in terms of the evolution of the agri-food value chain, broadband networks and ICT were revolutionary 10-15 years ago, partly replacing paperwork with a computer and immediate access to information made available via the internet. Notably, there is still potential to further develop and evolve these technologies in more remote and rural areas. Overall, current and future impacts are not seen as disruptive but rather necessary for implementation of new disruptive technologies. The economic impacts of these technologies are high, and replicability is straightforward, given increased availability and lower costs.

3.2. Main drivers for the new technology adaptation in agriculture

Beside drivers at farm level, including the wish to improve profitability, environmental legislation, lack of labour (demography), a total of five drivers can be acknowledged as critical for new technology adaptations in agriculture[74]:

1) **New consumer preferences drive the technological uptake** due to an accelerating use of new technologies in the agriculture sector for the purpose of representing ever changing consumer preferences. Increasingly, consumers require more customised products and services, taking into consideration awareness of health, climate and environmental impacts. Consumers are overall increasingly demanding sustainability in their consumption patterns.

2) **The context in which the agri-food value chain is operating can play an accelerator role**, as it is shown that more developed countries with proactive public initiatives and aware customers represent a more supportive context for the uptake of new technologies in the agricultural sector. The possibility to replicate existing success stories and generate benefits across Europe can be influential. The collaboration among Member States and the equally distributed possibilities to participate in innovative solutions, research and development projects or other activities related to new technologies in agriculture has a fundamental accelerating role.

3) **The impacts of new technologies depend on the Big Data and analytics generation and data management**. Thus the sharing of a large amount of data available to support farmer's activities, retail business and customers safety and interest is needed for the generation of positive impacts of new technologies.

4) **Appropriate regulation sets the conditions for a well-functioning innovative agri-food sector.** In general, the EU has well-established agri-food regulation, which protects and builds trust among all the players of the agri-food value chain. Recently, the European Commission issued a legislative proposal that could impact the entire food value chain by obligations to publish scientific studies proving companies' production safety[75]. Another example is the Common Agricultural Policy reform, which will impact the European farmers, not only in terms of subsidies but also in terms of new ways of reporting and of the potential decrease of administrative burden. A policy document was also issued on the European Bio-economy strategy[76] that aims to limit waste and promote the re-use of products. A stable and clear legal framework provides the basis for a lively and innovative context.

5) **Research & Development is needed to ensure the feasibility and trustworthiness of the new technologies that apply to agri-food**. The creation of centres of excellence and digital innovation hubs at EU level can become a very influential factor, supporting the research and development of new technologies in the field of agri-food. The development of new tools that

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74 Thierry Laugrette, Franziska Stockel, Deloitte, From Agriculture to AgTech, An industry transformed beyond molecules and chemicals, 2018.

75 http://europa.eu/rapid/press-release_MEMO-18-2942_en.htm?utm_source=POLITICO.EU&utm_campaign=5e2880886e-EMAIL_CAMPAIGN_2018_12_17_09_55&utm_medium=email&utm_term=0_10959edeb5-5e2880886e-190168305

76 https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en?utm_source=POLITICO.EU&utm_campaign=5e2880886e-EMAIL_CAMPAIGN_2018_12_17_09_55&utm_medium=email&utm_term=0_10959edeb5-5e2880886e-190168305

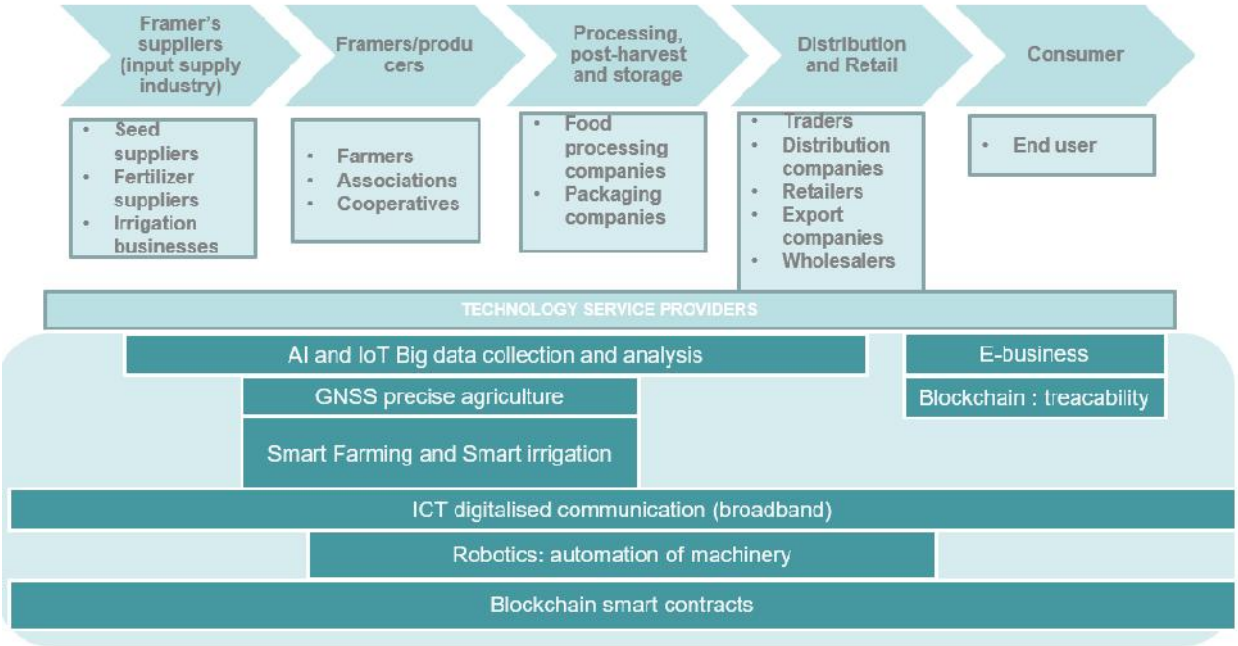
respond to farmers' requirements and ensure food safety and quality for the consumers could impact the developments positively.

3.3. Vertical integration of the agri-food value chain

Recent research shows that the scope of new technologies and digitisation including Big Data applications in smart farming, goes beyond primary production; it is influencing the entire food supply chain[77]. This is because the new digitisation possibilities provide predictive insights in farming operations, drive real-time operational decisions, and redesign business processes for game-changing business models. Consequently, the new technology opportunities provide major shifts in roles and power relations among different players in current agri-food supply chain networks (*ibid.*). Smart sensing and monitoring, smart analyses and planning, smart control and Big Data in the cloud are examples of new forms of data provided by the new technologies that will contribute to vertical integration of the agricultural value chains.

New technologies provide different opportunities at different parts of the value chains (Figure 3-1). Traceability across value chains refers to sharing of information between farm suppliers, farmer producers, processing, post-harvest, storage, distribution, retail and consumers. As addressed in this report, technology suppliers include artificial intelligence, Internet of Things, Big Data, global navigation satellite systems, smart farming, broadband, Blockchain and e-business.

Figure 3-1: Agritech – value chain vertical integration and available technology suppliers



Source: VVA

77 Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153: 69-80.

In general, three categories of data generation can be distinguished[78,79], which could be linked with disruptive technologies that this report analyses: **1) process-mediated, 2) machine-generated and 3) human-sourced. First**, the process-mediated data refers to the traditional business data, such as purchasing inputs, feeding, seeding, applying fertiliser, taking an order, etc. Moreover, transactions, reference tables and relationships, belong to this category. **Second**, the machine-generated data are derived from the vast increasing number of sensors and smart machines used to measure and record farming processes. Internet of Things impact heavily this category due to the availability of a range of sensors that are recording and providing greater data volumes. Internet of Things are connecting multiple objects and devices in farming and the supply chain, and huge amounts of new data that are accessible in real-time are made available. By means of images and videos, sensors and robots are producing new types of data. The impacts on value chain integration are already huge, but they will radically change in the future. **Third**, human-sourced data is the record of human experiences that traditionally was documented in books and works of art, and later in photographs, audios and videos. Lately, however, human-sourced information is almost entirely digitised and stored everywhere from personal computers to social networks, although not yet having a main role in the agricultural value chain data in relation to the marketing aspects[80].

Extents of vertical integration across value chains depend not only on new technologies that are made available to select new data, but also on the whole data chain – from when the data is selected to when the data is used. This process is complicated and could begin with data capture by sensors and continue with storage in cloud-based platforms, transfer by open data, transformation and analytics by yield models and data visualisation, before it is finally used for marketing[81,82]. Challenges associated with a data chain include the availability of: quality data, data capture[83], possibilities for quick and safe access to data at low costs[84], safe, responsible and reliable technology systems[85], possibilities to synergise different data sources[86], and coordination methods that suit new business models[87]. **In addition to technology challenges, governance challenges include dealing with issues of ownership of data and privacy issues.** Dealing with each of these challenges will enhance vertical integration across value chains.

New technologies obviously reduce overall costs when inputs are better managed and reduced, while the outputs are boosted by technology to increase at each stage of the value chain. Additionally, costs for employment can be reduced, for instance, in livestock farming, when smart dairy farms replace labour with robots for feeding cows, cleaning the barn and milking the cows[88],

78 Devlin, B., 2012. The Big Data Zoo—Taming the Beasts: The Need for an Integrated Platform for Enterprise Information. 9sight Consulting.
79 UNECE, 2013. Classification of types of Big Data. http://www1.unece.org/stat/platform/display/bigdata/Classification+of+Types+of+Big+Data
80 Verhoosel, J., van Bekkum, M., Verwaart, T., 2016. HortiCube: a platform for transparent, trusted data sharing in the food supply chain. Proceedings in Food System Dynamics, pp. 384–388.
81 Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153: 69-80.
82 Miller, H.G., Mork, P., 2013. From data to decisions: a value chain for Big Data. IT Professional 15, 57–59.
83 Tien, J.M., 2013. Big Data: unleashing information. J. Syst. Sci. Syst. Eng. 22, 127–151.
84 Zong, Z.L., Fares, R., Romoser, B.,Wood, J., 2014. FastStor: improving the performance of a large scale hybrid storage system via caching and prefetching. Clust. Comput. 17,593–604.
85 Haire, B., 2014. Ag Data: Its Value, Who Owns It and Where's It Going? Southeast Farm Press. http://southeastfarmpress.com/cotton/ag-data-its-value-who-owns-it-andwhere-s-it-going (Accessed: 7 May 2015).
86 Li, P., Wang, J., 2014. Research progress of intelligent management for greenhouse environment information. Nongye Jixie Xuebao = Transactions of the Chinese Society for Agricultural Machinery 45, 236–243.
87 Orts, E., Spigonardo, J., 2014. Sustainability in the Age of Big Data. IGEL/Wharton, University of Pennsylvania, Pennsylvania, US, p. 16.
88 Grobart, S., 2012. Dairy industry in era of Big Data: new gadgets help farmers monitor cows and analyze their milk.

and by the potential of unmanned aerial vehicles (UAVs) throughout the value chain[89]. Improved decision-making possibilities, due to the new technologies, such as drones with infrared cameras, GPS technology, or other formats like sounds or images[90], not only improve the efficiency of the entire supply chain, but also alleviate important societal issues related with, for instance, food security concerns[91]. In table 3-1, a summary of value chain players interested in new data, as well as the short and long-term effects of the case studies presented in Chapter 2, is summarised.

In Table 3-1 an overview of cases is provided, and it is obvious that combinations of technologies are common. Often IoT, Big Data and AI are used in combination (cases 1, 4, 5), and AI is combined with robotisation (case 2 and 3) or drones are combined with satellites (case 3 and 8). Furthermore, Blockchain, virtual reality and new e-business logistics strategies are new technologies that operate independently, and all contribute with new and valuable information across value chains and to customers (case 6, 8 and 9).

Table 3-1: Summary of case studies indicating value-chain interest in data and potential long and short-term impacts

Case - sector and technology	*Impact on value chain*
1) Combination of technologies (IoT, Big Data, AI) sensors detecting pig health and use of antibiotics	Impacts on production qualities of pork – transparency interesting to markets, customers and food trade. Reduced use of antibiotics is a societal goal important to farmers, consumers, citizens. With reduced damage, value chain becomes more effective.
2) Use of AI and robotisation in hydroponic crops	Impacts on logistics and storage. Inputs of water and energy dramatically reduced. Stable production and prices benefit customers. Reduced waste. With large advanced companies, value chain becomes shorter.
3)Combination of technologies (IoT, AI, robotisation, drones, satellite) detecting diseases, pests and viruses on olives, vineyards and cork trees	Impacts on production qualities of olives, vineyards and cork trees. Will be less risky for farmers and reduce costs in the long term and will provide customers with higher-quality products. With less damage, value chain becomes more effective.
4)Combination of technologies (Big Data, AI, IoT) in the diary sector	Impacts on production efficiency, reducing inputs and supplying more environmentally-friendly products to customers. Adapting to changing market demands. With large advanced companies, value chain becomes shorter.
5) Combination of technologies (IoT, Big Data) in leafy vegetable production	Impacts on production efficiency, and optimal use of soil. Supports consumers with 20 types of leafy vegetables. With large advanced companies, value chain becomes shorter.
6) Use of Blockchain for traceability of goods and animals	Impacts on breeders, resellers and customers. It will contribute to transparency throughout the value chain. This can have a positive impact on food security, and thus citizens and society. Connecting production and consumption establishes shorter value chains.
7) Use of drone-based soil moisture maps, and GNSS	Impacts on farm production, by giving insights on where and when to irrigate, given detailed knowledge about soils.

[89] Holmes, M., 2014. Different Industries Debate the Potential of UAVs and the Need for Satellite. Via Satellite Integrating SatelliteToday.com. http://www.satellitetoday.com/technology/2014/10/24/different-industries-debate-the-potential-of-uavs-and-theneed- for-satellite/

[90] Sonka, S., 2015. Big Data: from hype to agricultural tool. Farm Policy Journal 12, 1–9.

[91] Gilpin, L., 2015b. How Big Data Is Going to Help Feed Nine Billion People by 2050 - TechRepublic. http://www.techrepublic.com/article/how-big-data-is-going-to-helpfeed-9-billion-people-by-2050/

	Reduced risks for farmers will eventually ensure efficiency and can reduce consumer prices in the long term. With use of high-quality soils, value chain becomes more effective.
8)Use of virtual reality to educate customers	This can increase customers' trust in farmers, suppliers and other players in the food chain. Connecting production and consumption establishes shorter value chains.
9)Use of Bioresources supply chain optimiser, as e-business	Used alongside optimisation of logistics and storage. Organisational process is impacted. Of interest to customers. With improved logistics and storage, value chain becomes more effective.

The overview of value-chain impacts of the use of new technologies provided in Table 3-1, shows that some technologies are, specifically **targeting reduction of risks in agricultural production,** such as detecting diseases early on in olive production (case 3) and using drones to create detailed soil moisture maps for farmers who want to irrigate effectively and efficiently (case 8). These have impacts on value chains in terms of lowering costs otherwise needed for damage control. **Furthermore, some cases are addressing risks associated with emissions and climate change**, such as pig production (case 1). **Moreover, other cases are mainly targeting efficiency in production and adaptation to changing market demands** in terms of time and water and energy efficiency. This has positive impacts on the environment and climate throughout the value chains, as shown by the examples of hydroponic crops (case 2), dairy production (case 4) and leafy production (case 5)**.** While one case directly provides more information about **logistics throughout value chains**, such as the e-business example (case 9), other cases are **providing new possibilities for customers to get more insights into quality throughout production processes**. This is true for the use of antibiotics in pig production (case 1), use of Blockchain for traceability of goods and animals (case 6), and the use of virtual reality by McDonald's (case 8).

In the literature, it is anticipated that vertical integration across value chains can impact farmers in two extreme ways: 1) farmers become franchisers; or 2) farmers are empowered and open to collaboration and easily switch between suppliers, share data with government and participate in short supply chains rather than integrated long supply chains. The situation is judged to fall between these two extremes depending on the crop, commodity, market structure, etc[92].

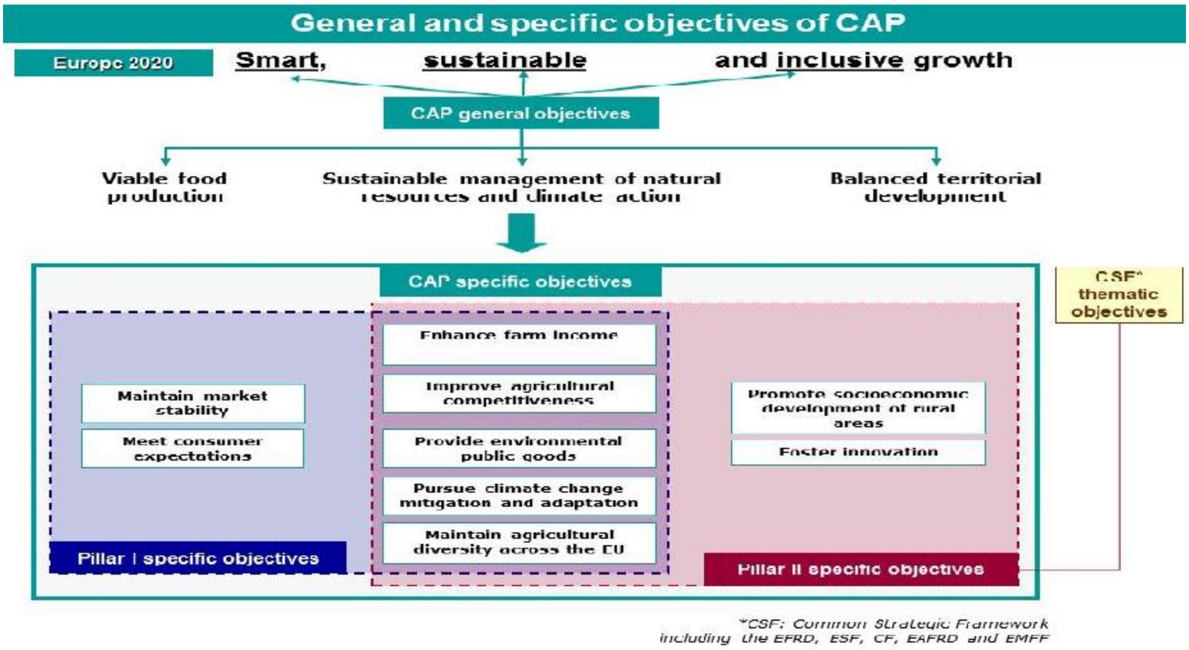
3.4. Digital innovation of Common Agricultural Policy (CAP)

In this section, three sub-sections present the following three topics. First, there is an assessment of the objectives of CAP based on the case studies presented in section 2, second, the main issues around new technologies for CAP modernisation are identified. Third, a SWOT is conducted for modernisation in CAP.

Assessing specific objectives of CAP. To assess technology impacts on CAP, it is of relevance to benchmark against the general and specific objectives of the existing CAP. See Figure 3-2.

[92] Wolfert et al. 2017. Big Data in smart farming–a review. Agricultural Systems 153: 69-80.

Figure 3-2: General and specific objectives of CAP



Source : https://epthinktank.eu/2018/01/16/common-agricultural-policy/

The CAP general objectives aiming for: 1) viable food production, 2) sustainable management of natural resources and climate action, and 3) balanced territorial development, are further divided into specific CAP objectives. In table 3-2 below, the specific objectives in pillar 1 on market measures and pillar 2 on rural development in the existing CAP are addressed one by one through the case studies. The objective 'foster innovation', listed on the lower right side in Figure 3-2, concerns all cases, as this is about illustrating technological innovations in the agricultural sector, including IoT, Big Data, AI, robotisation, Blockchain, GNSS, virtual reality, e-businesses, for this reason it has not been included. The other objectives are included.

Table 3-2: Assessment of Farm-Tech impacts on CAP objectives

CAP specific objectives	Impacts of Farm-Tech Revolution
Maintain market stability	New technologies will typically contribute to market stability when reducing risks associated with pig health and crop diseases (cases 1 and 3), and other conditions such as soils (case 7). Also, when farmers/stakeholders are provided with information about market conditions (e.g. market observatory), which would then add market transparency, it could help farmers to be able to adjust their behaviour in time. This could be the case for Blockchain (case 6)
Meet consumer expectations	Technologies that contribute to competitiveness can potentially contribute to lowering the price of relatively high-quality products, such as the hydroponic crop farm and data intensive dairy cases (2 and 4), which would meet consumer demand. Moreover, increased sharing of information from food chain to consumer groups, such as the Blockchain and virtual reality cases (6 and 8), can give new incentives for producers to adapt to changing demands, for instance, towards climate-friendly or locally-produced food requirements. Also, information about health and emissions related to the pig health case (1) contributes to meeting consumer expectations. The organic vegetable case (5) is specifically developing possibilities for

	cheaper organic vegetables by means of moisture sensors and Big Data.
Enhance farm income	Some technologies target farm income more than others. This is because investment in technology is itself a cost to be covered by extra earnings just to break even. In particular, technologies that put production competitiveness as the main aim, such as the hydroponic crop farm, Big Data leafy vegetables and data intensive dairy cases (2,5 and 4), perform well also for farm income. Use of e-business for logistical optimisation (case 9) will reduce costs through more effective strategies for transporting goods etc. Others, such as AI technologies detecting early crop diseases (case 3), GNSS for optimised use of soil (case 7) and IoT for pig health (case 1) can reduce long-term costs by investing now to avoiding losses in future.
Improve agricultural competitiveness	Some of the technologies put production competitiveness as one of the highest priorities, such as the hydroponic crop farm, Big Data leafy vegetables and data intensive dairy cases (2,5 and 4). Others, such as AI technologies detecting early crop disease case (3) and IoT for pig health (1), increase competitiveness in the long run by investing now to avoid future losses. Use of e-business for logistical optimisation (10) will reduce costs through more effective strategies to transport goods etc., and will have a great impact on competitiveness, as will moisture maps made by GNSS and drones (7).
Provide environmental public goods	Overall, more effective use of natural resources as inputs, will gain environmental public goods such as water, energy use and soil organic matters, given a certain level of output. This implies that the technologies that make competitive production a priority, such as the hydroponic crop farm, Big Data leafy vegetables and data intensive dairy cases (2,5 and 4), contribute to energy use, soil and water by efficiency gains during production. However, other technologies target environmental gains more directly. This includes detection of emissions in the IoT for pig health (1), is more directly targeting emissions from agriculture. Moreover, the technologies advanced for soil moisture, such as GNSS and Big Data for organic vegetables (7,5) are specifically impacting soils. In the case of Blockchain (6), the transparency of traceability information put pressures on producers to shift production to consider public goods.
Pursue climate change mitigation and adaptation	More effective logistics often lead to lower emission levels, at least when transport costs are reduced per output produced (9). Several cases prioritise climate impacts because they aim at energy effective production strategies, such as the hydroponic crop farm and Big Data leafy vegetables (2 and 5). Several of the technology examples target emissions more directly. This includes detection of emissions in the IoT for pig health (1). In the case of Blockchain (6), the transparency of traceability information put pressure on producers to shift production to consider CO_2 footprints. The cases that are not targeting climate do not have negative impacts, rather they are focused on other issues, such as crop diseases (3).
Maintain agricultural diversity across the EU	New advanced technologies are not directly targeting diversity, but can be used for specified purposes, and thus often develop in the direction of monocultures. This is certainly the case for the hydroponic crop farm, Big Data leafy vegetables and data intensive dairy cases (2,5 and 4). For advanced technology targeting, for instance, soil moistures (5,7) or emissions (1), diversity in the form of business size is also not facilitated, because the high costs of investments are not affordable. Therefore, CAP needs to pay special attention to this objective.
Promote	None of the cases is targeting socioeconomic developments in rural areas.

socioeconomic development in rural areas	In the US case it is emphasised that there is a benefit of being in peri-urban areas to lower footprints (2). This argument disfavours this CAP objective. Therefore, CAP needs to pay special attention to this objective.

Modernisation of CAP (cross-cutting objective). The discussion on the modernisation of the CAP is in full swing, and it is important to understand how the CAP will stimulate and benefit from the ongoing digitisation of the agricultural sector. The increase in digital innovation opens new ways of monitoring and control, which could support an effective new model of targeted CAP payments through a sound and transparent monitoring system, built on reliable and robust environmental indicators. Also, recent advancements in satellite Remote Sensing, and in the European Earth Observation programme Copernicus, improve the options for continuous monitoring. In addition, the market availability of new tools and technologies and the increased interoperability between different 'sub' systems, such as open data, farm management and information systems, telemetry on farm machinery and local sensors provide additional incentives to modernise CAP governance.

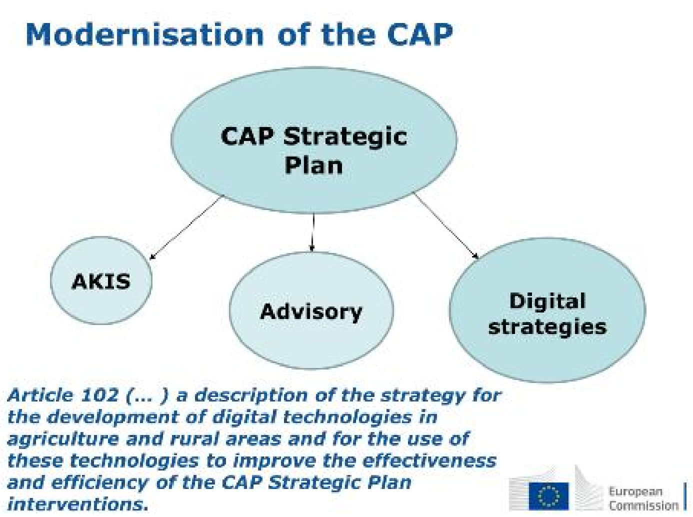
The basic act in CAP includes a cross-cutting objective on "modernising the sector by fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas, and encouraging their uptake". Reflecting the cross-cutting nature of this objective, a series of indicators have been identified that pertain to modernisation.

Specifically, modern technology and innovation are very much needed, together with knowledge exchange to step up the performance of the agriculture sector in economic, environmental and social areas. The new CAP strategic plans will include a section on how to stimulate knowledge exchange and innovation (advisory services, training, research, CAP networks, pilot projects, the agricultural European Innovation Partnership (EIP-AGRI) operational groups etc.) and how to fund them. Under the CAP strategic plans, Member States can deploy series of interventions related to modernisation, such as: investment, cooperation, knowledge exchange – including training.

Member States are asked to describe in their CAP Strategic Plans how they will foster innovation and what they do to support the development of digital technologies by the CAP Strategic Plan. Member States are asked to describe the organisational set-up of the **Agricultural Knowledge and Innovation System (AKIS**), and a description of how farm advice and the CAP networks will work together. Modernisation (including the use of technology) will have impacts on:

- organisational set-up of the AKIS design, in terms of combined organisation and knowledge flows between persons, as well as organisations and institutions who use and produce knowledge for agriculture and interrelated fields;
- advisory services, research and CAP networks, in how they work together within the framework of the AKIS, and in how advice and innovation support services are provided;
- strategy for the development of digital technologies in agriculture and rural areas and for the use of these technologies to improve the effectiveness and efficiency of the CAP Strategic Plan interventions.

Figure 3-3: Modernisation of the CAP



The use of digital technology in the new CAP. Freely available earth observation data captured by the Copernicus Sentinel satellites and other innovative technologies provide significant information on agricultural activities across the EU. The availability of Earth Observation data as well as increasing availability of precision agriculture technologies, that can be combined with new monitoring systems to cross-link farmers' information, will facilitate a shift from the traditional control of farmers' claims based on sampling, to a continuous and full monitoring that checks compliance to requirements that can be verified. The future CAP envisages the development of an "area monitoring system", i.e. a system based on systematic, year-round remote observation of agricultural activities. This will serve the dual purpose of ensuring, at a comparatively **low cost, the availability of EU-wide comprehensive and comparable data for policy monitoring purposes** (agricultural, environmental, climate, etc.) as well as, to the extent possible, replacing classical control methods like on-the-spot checks which should **reduce the administrative burden** and in all likelihood the control burden on farmers - especially between payment agencies and farmers. The Integrated Administration and Control System (IACS) is proposed new legislation that will make more use of digital advances, in using Copernicus data for monitoring and other data sources to do cross checks. This will simplify CAP governance, therefore reducing administrative costs.

A core part of the IACS is its information system called the **Land Parcel Identification System (LPIS).** The data the LPIS holds are geo-referenced polygons of land parcels (units of management or production) and should include information on the type of land cover, as a minimum in terms of broad categories such as arable land, grassland, permanent crops, and broad families of crops, with their area (eligible hectares). Furthermore, the IACS is built upon several other core systems collecting farm data, payment rights, livestock and other information, which overall constitute the AKIS. In addition, the so-called geo-spatial application, a digital application that integrates GIS technology, has proved to be a useful tool to prevent errors in declarations and avoid penalties incurred by farmers and will continue to be the default method of submitting applications post-2020.

Digital innovations can thus make governance more transparent, fairer and likely decrease disputes. Using these technologies will modernise the administration, monitoring and overall operation of the CAP and have multiple benefits for farmers and Member States' administrations. As a result, a reduction of follow-up actions is enabled.

This approach will help farmers to:

- Decrease the complexity of and time spent on submitting applications for CAP aid - some Member States are even considering developing "seamless claim systems".

- Become partners to administrations in the process of checking the fulfilment of eligibility requirements - this means less time spent with inspectors in the field and more opportunities to actively fulfil eligibility conditions.
- Fulfil their CAP obligations thanks to warning alert systems.
- Benefit from synergies with other digital technologies, such as crop monitoring and yield forecasting, to manage their farms better - further automation of activity recording can reduce associated paperwork.

The monitoring approach will also have several benefits for Member States' administrations:

- Automated data processing will enable efficient verification of eligibility criteria with respect to CAP aid schemes and support measures.
- Reduced costs associated with physical inspections in the field.
- Flexible application process, allowing more updated & accurate data through the monitoring process.
- Analysis of geospatial data at regional/national levels for policy performance measurement.

Furthermore, to limit the administrative burden for beneficiaries, Member States will pre-fill the application with as much up-to-date and reliable information as possible, including data from the LPIS, monitoring of agricultural areas, other public databases etc. This can go as far as developing an almost 'claimless system' of application where the farmer would only be asked to confirm the declaration provided by the administration.

In combination, these systems shall contribute to highly efficient monitoring. Improvements in processes and data validation are thus required to reduce the administrative burden and to improve the efficiency of the whole system. More digital inclusiveness allows re-use of (open) data and supports farmers in more accurate and less burdensome claims. In many Member States, digital inclusiveness might lead to a completely pre-populated application of income support, and to an even more advanced 'seamless claim' by properly combining several datasets and using innovative techniques to provide farmers with advisory and validated payments, thus reducing, if not eliminating, sanctions.

Farm Sustainability Tool. The new CAP proposes the obligatory introduction and adoption of a Farm Sustainability Tool for Nutrients (FaST). This tool should help farmers to optimise their use of nutrients, and therefore their income, while protecting water quality and cutting greenhouse gas emissions. The tool will be effective only if farmers see a clear overall advantage in it. Therefore, the only related obligation on farmers (laid down in the system of conditionality) will be to use it, i.e. activate it and input the necessary data for the tool to be operational – i.e. the FaST will not be a tool for authorities to check on farmers and their input levels. The idea is that decision-making support provided through the tool will be clearly beneficial to the farm, ensuring buy-in beyond the traditional 'compliance' model. Moreover, in order to provide a level playing field among farmers EU-wide, Member States should establish a system for making the tool available to farmers and including at least a certain minimum of functionality and features. The FaST has the potential to form part of packages of supported activities that are relatively easy to manage, with the help of technology and (as needed) of advisory systems. The tool with minimum functionality should also serve as a core-basis for additional on-farm digital technology, thereby boosting digital innovation in the sector.

Rural development. The rural development programmes (RDP) pillar refers to several policy measures that include investment support (for both productive and non-productive type of investments) and **innovation and sustainability in agriculture**. Moreover, there are measures that aim at supporting farmer/stakeholder **collaboration** (e.g. could link to European Innovation Partnership) and extension of farm advisory services. Also, these latter measures could contribute to supporting the digitalisation in agriculture.

Jobs and growth. In rural areas, besides primary production, many opportunities are linked with the development of the bio-economy, a sector which is also upgrading by digitisation. New value chains in the bio-economy can create high quality job opportunities. The traditional drawbacks of rural areas – low connectivity in many senses of the word – can be overcome with digital technology opening the countryside to many new business opportunities. **The Smart Village concept** is meant to explore and promote developments in this area.

SWOT analysis of CAP modernisation (see Figure 3-4). To judge the extent to which the impacts of the Farm-Tech Revolution on CAP are positive or negative, SWOT analyses have been conducted based on the impact assessments and cases presented in sections 2 and 3. The description / analysis above makes clear that digitisation will influence agriculture in the years to come. It is a major technological force that reshapes our societies, including agriculture. If the European Commission does leave the adoption of digitalisation strategies to the market, the risk is that smaller crops, regional farm systems and their technology suppliers or rural areas will be left behind as technology providers have an incentive to concentrate on bigger market segments. The European Commission has already paid attention to this in its research and innovation activities and in the new CAP it will actively request Member States to formulate a strategy for the development of digital technologies as part of the modernisation objective of the CAP.

The easy option for Member States is to promote the adoption of digital technologies (like robots or management software) as such. However, a coherent policy approach is to link such investment support with the policies regarding AKIS and the execution of the CAP (and its monitoring and control system) itself. A modernisation strategy that promotes the adoption of digital technologies, with benefits for labour productivity or reducing the environmental impact of farming (precision farming) asks for support of advisors and other AKIS-players in training farmers with the new technology. At the same time the AKIS-players themselves must deal with digitisation. Advisors need digital access to farmers data and researchers need to develop real-time models ('digital twins') that mimic processes in plants and animal husbandry. In a similar way the execution of the new CAP can contribute to digitisation and benefit from developments in digital technology. Satellite data contributes to monitoring in the IACS and its LPIS. This reduces administrative costs. By making such data available as open data or at least authorising farmers to transfer this data to their management software, advisors and partners in the food chain (for certification or logistic purposes), reduced the administrative burden on farmers and enables innovative applications to be developed. To reduce paperwork for farmers (for the CAP as well as certification schemes like GlobalGap) a good interaction of public and private data flows is essential. This helps advisors to spend more time on advising and less on paperwork.

Figure 3-4: SWOT Analysis on CAP modernisation

Modernization of CAP

Strengths

- Modernisation based on digitization is addressed by the CAP and helps farmers to adapt to new realitie
- By not leaving this to market forces only, modernisation will address typical European agricultural characteristics (regional farm systems, specialty crops) and be more inclusive
- Linking modernisation, AKIS actors and the execution of the CAP itself creates a strong cocktail for an integrated approach
- Within National Strategic Plans governments can tune the CAP intervention to regional circumstances.

Weaknesses

- It is not clear how public-private aspects of digitization (as farmers have to report to governments as well as food processors and retailers) are handled
- With the success of the public satellite data and the emphasis of the input suppliers on hardware with sensors, there is a risk that digitization of paper work, from which all farmers could benefit, is undervalued
- Linking modernisation, AKIS actors and digitization of the execution of the CAP requires strong leadership and know how in government agencies, which is not always guaranteed
- The CAP does not fully exploit the possibilities to require CAP beneficiaries (farmers) to hand over data on their sustainability performance to the government, as food processors and retailers (in certification schemes like GlobalGap) require; The CAP should at least introduce this in its Farm Accountancy Data Network to improve the monitoring and impact analysis of the CAP.

Opportunities

- The developments in information and communication technologies provide options for smart farming that reduce the environmental effects of agriculture
- Digitisation will provide AKIS actors, and especially food processors and retailers but potentially also governments, with more data on individual farms that makes better incentives for sustainable production and new business models possible.
- Digitization has the potential to modernize extension services and the advisory process, by reducing CAP-related paperwork and providing access to more data of the individual farmer and more efficient processes of advice (including digital communication).
- Digitization can lead to more services offered on line for rural areas, and make new business models for farmers possible, like short supply chains over long

Threats

- Market forces in digitisation favour larger markets: larger crops and larger countries.
- Market forces can lead to faster structural changes, statistically (as some farms will not invest in new technology but retire a few years earlier than planned) and by making larger farms more competitive: digitisation increases the span of control of farmers (oversight at a distance is possible) and economises on labour (e.g. milking robots).
- Some digitisation platforms will have a tendency to become a monopoly, like dominant players (Google, Uber, AirBNB) outside agriculture
- There is a risk that (public) advisory services and even agriculture in total will not be able to attract the best talents in ICT, given the demand for such human capital in other sectors where margins are bigger.

CONCLUSIONS

The impacts of the "Farm-Tech revolution" in Europe is unclear in terms of the exact transformation it will bring about and what the associated impacts will be on agricultural sectors, value chains and CAP. Accordingly, the main aim of this study is to provide an overview of how "farm-tech revolution" impacts the agricultural sector in the near future.

DRIVERS FOR CHANGE AND ACCELERATORS

Advancements of key technologies are based on influential disruptive drivers and accelerators. Whereas **disruptive drivers refer to challenges** that motivate farmers to search for technologies to solve them, **accelerators refer to positive pushing factors** for adaptation with new technologies in the agri-food sector.

The main disruptive drivers include:

- Changing environmental and climate conditions.
- Uncertain future of demand due to urbanisation.
- Growing population and societal changes.
- Needs for optimising the production due to high cost.

The main accelerators include:

- The consumers' changing preferences and their request for access to more information concerning food products.
- The presence of well-developed infrastructure (broadband networks) and support by legislation that encourage use and uptake of new technologies.
- Data availability and open access to information to facilitate the development of new products, services and business models across the entire value chain.
- Enough investments in Research and Development to support technology advancements in the agricultural sector in Europe.

HOW IS THE FARMTECH REVOLUTION TAKING PLACE

Advancements of new technologies are illustrated in a series of 10 case studies. Most of the new disruptive technologies are used in combination. Often IoT, Big Data and AI are used in combination (cases 1, 4, 5), and combination of AI and robotization (case 2 and 3). Besides, Big Data and IoT are combined with satellites (case 3 and 7). Blockchain, virtual reality and new e-business logistics strategies are new technologies that tend to operate independently, contributing with new and valuable information across value-chains and customers (case 6, 8 and 9).

IMPACTS ON THE VALUE-CHAIN AND GOVERNANCE

Impacts on the value chains can further be drawn by looking at vertical and horizontal integration. Whereas vertical integration refers to stronger links between value-chain components, horizontal integration refers to integration of enterprises within the same value-chain component.

- **Vertical integration:** digital technology, in particular crop efficiency technologies, are amplifying vertical integration in the food-chain, optimizing cost, efficiency and complementarity of input suppliers (seed suppliers, fertilizer suppliers), and tend to favour large food suppliers investing in this integration. Extents of vertical integration across value chains depend not only on new technologies that are made available to select new data, but also on the whole data chain - from when the data is selected to when the data is used. Challenges of vertical integration are not only technological, but also related to governance such as dealing with issues of ownership of data and privacy issues.

- **Horizontal integration:** is a new emerging trend involving new 'tech players' and new types of 'tech service providers', which increasingly become more relevant in the Agriculture sector.

New technologies at each stage of the value chain can reduce overall costs when inputs are optimised and better managed and can boost outputs. Enhanced decision-making possibilities due to the new technologies, not only provide improvements of the efficiency of the entire supply chain, but alleviate important societal issues related with, for instance, food security concerns. Technologies target different issues across the case studies, including:

- **Risks in agricultural production**, such as detecting diseases early on in olive production (case 3) and using drones and satellites to create detailed soil moisture maps to farmers who want to irrigate effectively (case 7), which are lowering costs otherwise needed for damage control.
- **Risks associated with emission and climate change**, such as for pig production (case 1), with impacts also on the society more broadly, including consumers and citizens.
- **Efficiency gains in production and adaptation to changing market demands,** involve for instance more **effective use of water and energy**, thus having positive impacts on the environment and climate, and across the whole value chain. This appears for the hydroponics crops (case 2), diary production (case 4), and leafy production (case 5).
- **Information about logistics throughout value-chains**, such as the e-business example (case 9).
- New possibilities for customers to get more **insights into the qualities throughout production processes**. This is the case for use of antibiotics in pig production (case 1), use of Blockchain for traceability of goods and animals (case 6), and use of virtual reality by McDonald (case 8).

Through transformation processes taking place in the agricultural sector due to the new advanced technologies, some highly important structural changes are taking place, including:

- The EU's technology development is part of the international arena. In carrying out technological change in the agricultural sector, the influence of **international high-tech companies such as Alibaba Cloud**, who influence technology possibilities in Europe[93], but also internationally[94], by for example introducing high tech on smart brains in pig farms, is very relevant. Competing companies exist in Europe, such as Nedap, who realise augmented reality in dairy farm in Europe[95], but also are operating as strong player in the international arena, for instance, in China[96]. Although the exact influence of these multinationals in agriculture and CAP remains low at this point in time, they will certainly become influential to future digitization developments.

93 https://www.pigprogress.net/World-of-Pigs1/Articles/2018/11/Alibaba-signs-contracts-with-Danish-Crown-and-JBS-356836E/
94 https://www.pigprogress.net/World-of-Pigs1/Articles/2018/6/Alibaba-Cloud-launches-smart-brain-for-pig-farms-299059E/
95 https://www.nedap-livestockmanagement.com/nedap-brings-augmented-reality-dairy-farm/
96 https://www.nieuweoogst.nu/nieuws/2018/11/21/nedap-stapt-in-big-data-met-chinese-partners

- The agricultural sector in Europe consists of two world views: the one supporting traditional way of day-to-day business, and the one pushing towards directions of digitization, efficiency and technology development. An important player, which should not be underestimated in future, who contributes to bridge the two world views, are **the cooperatives.** The role of cooperatives, at least in France, Italy and Spain, but also in other countries, as facilitator and knowledge brokers in future developments, should be considered as a great asset and opportunity to reduce risks of mass objections to modernization of the agricultural sector.

DIGITALISATION AND THE CAP

In general, to foster innovation by introducing new technologies in the food-value chain is part of the **CAP objectives**. More specifically, each of the 10 use cases in this study applies new technology that can be linked with some of the specific CAP objectives. For instance, new sensors and IoT monitoring devices contribute to **maintaining the market stability**; availability and transparency of data **can meet consumers expectations**; technology such as robotisation of machines can **enhance farmers income** by reducing the production costs and **improve the agriculture competitiveness**. GNSS and IoT technologies are used to create more effective use of resources such as energy, water, fertilizer, thus adapting to **climate change and preserving the environment.**

Modernization of CAP via digital innovations can make governance more transparent, fairer and likely decrease disputes. Using new technologies will modernise the administration, monitoring and overall operation of the CAP and have multiple benefits for farmers and Member States' administrations. New technologies can be used to modernise and facilitate the CAP at different levels, for instance to:

- **Provide new monitoring and control procedures**: To shift from the traditional control of farmers' claims based on sampling, to a continuous and full monitoring that checks compliance to requirements that can be verified. Recent advancements in satellite Remote Sensing, and in the European Earth Observation programme Copernicus, improve the options for continuous monitoring.
- **Provide new ways of payments:** To ensure CAP payments go through a sound and transparent monitoring system, built on reliable and robust environmental indicators. Completely pre-populated application of income support enables more advanced 'seamless claim' by properly combining several datasets and using innovative techniques to provide farmers with advisory and validated payments, thus reducing, if not eliminating, sanctions.
- **Provide decision-making support tool to farmers (Farm Sustainability Tool)**: To assist farmers to adopt the new CAP decision-making tool to optimise their use of nutrients, and therefore their income, while protecting water quality and reducing greenhouse gas emissions.

ANNEX 1: Methodological Note

The methodological note has for objective to illustrate the methodology used for the elaboration of the disruptive technology analysis in this report. The methodology followed can be summarised in the following steps:

- **An extensive literature review of more than 100 scientific papers** permitted the Consortium to collect more than of 60 potential case studies related to the agri-food chain and technology.
- **A multi criteria assessment was performed for all the collected potential case studies, in order to select the most impacting and interesting ones** to be developed and presented in the report. In addition, the in-depth multi-criteria analysis permitted the consortium to create a segmentation between the disruptive technologies by high, medium and low impact. For each of the potential case studies the selection was based on the criteria presented by Table 3-4;
- **Final selection of 10 case studies to be integrated in the report:** The selection of the 9-11 case studies is based on quantitative and qualitative assessment. The case studies are ranked by "biggest coverage of technologies" and "biggest impact on Value chain, farmtech revolution, Vertical integration and CAP objectives" of the score obtained from the MCA. In addition to this quantitative method for selection, a qualitative selection was made based on the expertise of the consortium, which finalised the selection.

Table 3-2: Final selection of case studies

Ref.	Technology	Topic	VC coverage	Comment
1	Big data, IoT, AI,	Pig health assessment based on sensors SmartPigHealth, DE	Farmers/Producers; Processing, post harvest and storage; Distribution and retail	
2	Big data, IoT, AI,	Ammonia Emission Monitoring Network – AEMON; BE, NL	Input supply industry; Farmers/Producers; Processing, post harvest and storage	Not part of the top quantitative selection, but of particular interest for environmental impact with good coverage of technologies and VC coverage
3	IoT, AI, Robotisation	Sensoring and AI algorithms for early crop disease detection – SAIA, PT, ES	Input supply industry,Farmers/Producers; Processing, post harvest and storage	
4	Big data, IoT, AI, Robotisation	Data-Intensive Dairy Production, ES	Input supply industry; Farmers/Producers; Processing, post harvest and storage	

5	IoT, Robotisatio, Image recognition	Implementation of ICT in aquaculture AquacultuER4.0, IT	Input supply industry;Farmers/Producers	
6	Big data, IoT, AI,	Digitizing Leafy Vegetables, GR	Farmers/Producers;Processing, post harvest and storage; Distribution and retail;Consumers	
7	Blockchain	Use of blockchain technology for the traceability of goods and animals , FR	all	Not part of the top quantitative selection, but important to represent an application of a very innoovative technology
8	GNSS and Drone	Drone-based soil moisture maps to complement satellite and field measurements, EU	Farmers/Producers	Not part of the top quantitative selection, but great use case for drone and GNSS application, whih are critical for the new precise agriculture approach
9	AR	Virtual reality: corn following soyabeans	Farmers/Producers;Processing, post harvest and storage	Not part of the top quantitative selection, but important to represent an application of a very innoovative technology
10	all	Biosco: logistique, FR	Input supply industry;Farmers/Producers; Processing, post harvest and storage	

Table 3-4: Criteria used for MCA

Assessment Criteria	1
Description of the case study	Farm Sustainability Audit
Link to the case study source	
Geographic coverage	UK, IE
Case study characterization (yes='1'/no=' ')	
Category 1: Technologies	
1.Broadband network and services	
2.Tracebility and Big Data	1
3.Internet-of-Things	
4.Information and Computer Technologies	1
5.Artificial Intelligence	
6.Blockchain technology	
7.Robotization	
8.Global navigation satellite system (GNSS)	
9.e-Business	
10.Augmented Reality	
11.Others (please specify)	
Category 2: Size of enterprises	
12.*(drop down list)*	Large
Category 3: Value chain coverage	
13.Input supply industry	
14.Farmers/Producers	1
15.Processing, post harvest and storage	1
16.Distribution and retail	
17.Consumers	
Category 4: Products	
18.Horticulture (vegetables and fruit)	
19.Diary	1
20.Meat (pigs, poultry)	1
21.Arable	
22.Fishery, aquaculture	
23.Others (please specify)	
Category 5: Timeframe for the implementation	
24.*(drop down list)*	Short term
Total Score	6
Case study impacts (*=a little impact, **= some impact, *=quite some impact,**	
Category 6: Farmtech revolution	
25.Greater use of knowledge and innovation	*
26.Using new digital data-driven services and products for on-farm production (farmer does things that were previously not available/affordable)	**
27.Investment in new technology and machines	*
28.Using existing digitised farm supply and services and products for on-farm production (farmer does the same things better)	0
29.Start ups providing technology and service providers	0
30.Stages (awareness phase, data collecting phase, data driven action)	*
31.Decision making (operational, tactical, strategical)	***
32.Data users in the supply chain	*
33.Data users for food supply actors	*
34.Inclusiveness - extended numbers of enterprises take part	*
Category 7: Vertical integration of the value chain through…	
35.Digitalisation level	*
36.New distribution channels	0
37.Traceability across value-chains	0
38.Labelling schemes	*
39.Replicability (easiness to transfer to other enterprises, across value-chains)	*
40.Platforms (cooperatives, farmer organizations, manufacturers, etc.)	**
41.Credibility - related to environmental and social care	0
Category 8: CAP objectives	
42.Ensure fair income	0
43.Increase Competitiveness	*
44.Rebalance power in food chain	*
45.Climate Change action	0
46.Environmental care	0
47.Preserve Landscape&Biodiversity	0
48.Support Generational renewal	0
49.Vibrant rural areas	0
50.Protect food and health quality	**

ANNEX 2: Additional case studies

CASE STUDY 10

Summary of the case study

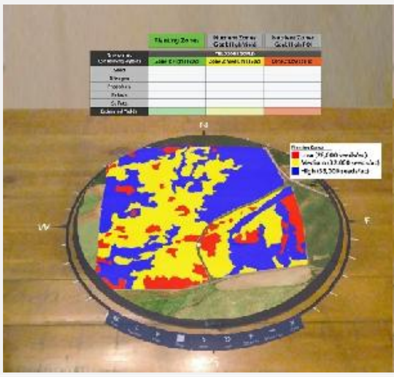
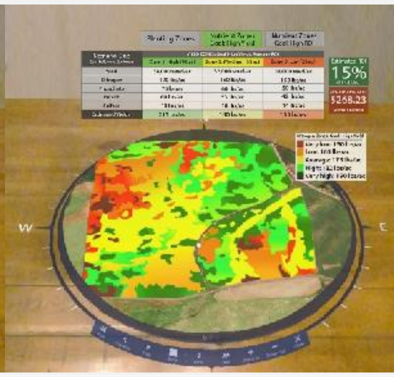
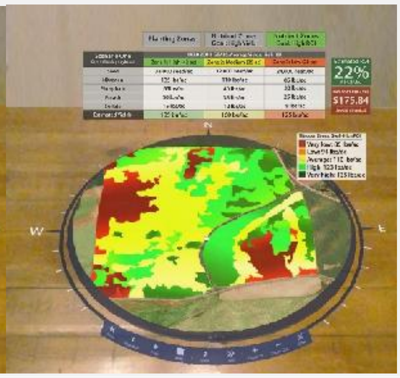
Augmented reality. Scenarios with high yield crops, average yields and optimal biomass.

Overview and strategic context

In the past, farmers would treat fields in a uniform manner. However, the advent of the Global Positioning System, coupled with precision farming technologies, now allows growers to collect data on a much smaller scale. This benefits farmers by allowing them to treat specific areas of a field according to its unique makeup.

Implementation of the case study

Three scenarios are implemented by using the augmented reality. Scenario 1 aims to achieve high yields (resulting in additional input costs per acre) while achieving an average return on investment. This option contains a higher risk than normal, but if the weather cooperates and commodity prices rise, this option may generate exceptional revenue.

Scenario 1: High yields *Scenario 2: Average yields* *Scenario 3:* Biomass

Scenario 2 aims to achieve average yields with lower input costs, resulting in a higher return on investment. Although targeted yields are not as high as those in Scenario 1, the farmer may desire to keep input costs lower on this field, so he or she can target additional investments on higher-producing fields. As the grower and service providers discuss scenarios, they may choose to alter the plans.

Scenario 3: Biomass. Throughout the season, growers and agronomists keep a close eye on the progress of their crops. On this field, a drone flew over the plant canopy and utilised multispectral imagery to measure the crop's biomass and vigour. From these zones, the agronomist was able to monitor expected yield outcomes and treat problem areas.

In addition, farms are now coupling algorithms and IoT devices to more closely monitor changes in field conditions such as climate, soil and plant health. Various growth stages of the crop are displayed while the agronomist confirms areas where crop threats have been detected. The agronomist records the threats, and recommendations are immediately delivered to the farmer and his preferred retailer for application. By optimising crop threat detection and shortening response times, farmers can alleviate yield loss.

Impacts of the case study on agri-food value chain

The agriculture vertical has experienced many pain points in its attempts to deliver value through data-driven platforms. The pain points, which have cost the industry billions of dollars, is why the food value chain is so interested in the agribusiness alliance between Microsoft and EY. This partnership brings together best-of-class technical capabilities with a deep understanding of the business case for helping companies achieve their data platform goals.

Impacts of the case study on CAP

Looking at the CAP specific objectives, this case has particularly positive impacts on farm income. Moreover, increased transparency and visibility in the food chain will also improve competitiveness. It will have less impact on the objectives to maintain diverse agriculture across EU and promote the socioeconomic development in rural areas.

Timeframe and geographical replicability

This technology could be used by other farms across Europe.

Supporting evidence

This demo was developed in partnership with EY (Ernest & Young), Taqtile, Slantrange and Microsoft.

CASE STUDY 11
Ammonia Emission Monitoring Network

Summary of the case study
In this case, AI is combined with IoT and Big Data in animal housing systems in livestock production in Belgium and the Netherlands. The main objective of this case is to develop an NH_3-emission and climate monitoring and control technique for naturally and mechanically ventilated animal houses, aiming for optimised indoor climate control and potential emission reduction.

Overview and strategic context
Theoretical, technological and tacit knowledge will be combined to develop a collaborative sensor system fitting the needs of the animals and farmer, while being scientifically substantiated to increase the products market value in the light of current and future environmental and animal welfare legislation. The effect of pollutants, such as dust, ammonia (NH_3) and greenhouse gasses (GHG), produced as a by-product of intensive animal husbandry is twofold. On the one hand those pollutants will deteriorate the **internal climate**, having negative effects on the health of the farmer and the animals, though little conclusive proof of the effect on the economic gains can be found. Countries such as the Netherlands and Belgium are actively working on implementing regulations to improve the quality of the living environment of farm animals. On the other hand, simply evacuating pollutants from the stable without abatement techniques results in **damage to the environment**, and agriculture is known to be the largest source of NH_3 emissions. European countries are obliged to reduce or maintain the emission level according to the National Emission Ceilings Directive. Furthermore, the complexity of the problem increases when considering, for instance, the thermal comfort of the animals and energy consumption.

Implementation of the case study and challenges
Modern farms adopt either natural ventilation or mechanical ventilation depending on the building structure. Due to the innate difference between how the air flows are manipulated, air property (composition, temperature, humidity, etc.) and available techniques for emission/air quality monitoring differ greatly between the two ventilation systems. Thus, although the monitoring system to be developed could have a unique base structure, multiple variant versions are required to cope with different work conditions and purposes. This case consists of three main components: gas measurement, climate control and wireless sensor network. In this case emission measurement will focus on ammonia with a possible extension to GHGs, where climate monitoring will look at a broader range of parameters such as CO_2, NH_3, temperature and relative humidity. The biggest challenge lies with NH_3 measurement. Performance of sensors with different TRL and sensing principle will be tested. A low-cost sensor, tested within ISense project (ILVO), will be incorporated in this case. Via sensor fusion technique different sensors could be used together and thereby compensate for their respective bottlenecks. Secondly, ventilation control and the effect on indoor emission/air quality will be investigated in two steps. In step 1 notifications or alarms (depending on importance and urgency) will be given to the farmer when necessary so that the farmers can act manually. In step 2, an automated control scheme which employs dynamic control techniques will be developed and tested. Finally, a wireless sensor network that links the sensor measurement and ventilation control will be tested.

Impacts of the case study on agri-food value chain

This case impacts the value chain in at least two ways. First, the internal climate can have indirect impact on production conditions and thus quality of products and satisfy value-chain customers including consumer interests. Second, positive impacts in terms of reduced environmental damage by lowering pollution levels impact consumers, and the citizens and society broadly speaking, by reducing climate footprint.

Impacts of the case study on CAP

Looking at the CAP specific objectives, the innovative technologies in this case will greatly enhance the objectives of climate and environmental goods (emissions from agriculture). Given long-term sustainability investments, positive impact on competitiveness and consumer expectations will be obtained. Given the high costs of technologies, farm income will reduce in the short term. This case will have a lower impact on the objectives on maintenance of diverse agriculture across EU and the promotion of socioeconomic development in rural areas.

Timeframe and geographical replicability

The NH_3-emission and climate monitoring and control technique for naturally and mechanically ventilated animal houses can be adapted to other parts of Europe.

Supporting evidence

http://smartagrihubs.eu/ (Will become available on this web-site when project begins, now taken from preparatory documentation in proposal documents).

The study presents a state-of-the-art overview on digital agriculture, the impacts of new technologies on the agri-food value chains and opportunities for the Common Agricultural Policy (CAP). Using case studies and examples the study demonstrates the needs for further deployment of innovation in the agriculture sector, fostering research and investments in digital agriculture and integrating Agri-tech into the policy agenda.

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