UNIVERSITÀ POLITECNICA DELLE MARCHE
Department of Agricultural, Food and Environmental Sciences (D3A)
Doctoral School on Agriculture, Food and Environmental Sciences – XIX (19° Edition)
AGR 01- Agricultural Economics and Rural Appraisal

Understanding the phenomenon of Digital Transformation in the Agrifood sector: Drivers, Actors, Benefits and Costs

Ph.D. Dissertation of:
Giorgia Bucci

Supervisor:
Prof. Adele Finco

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Prof. Giuseppe Corti
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Academic Year 2019-2020

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Acknowledgments

"Non dovrà sorprendermi, in qualche mattina di nebbia e di sole, il pensiero che quanto ho avuto è stato un dono, un grande dono?"

(Cesare Pavese, Il mestiere di vivere)

Undertaking this Ph.D. has been a truly life-changing experience for me and it would not have been possible to do without the guidance of my supervisor Prof. Adele Finco and Dott. Deborah Bentivoglio. I am incredibly grateful to them for their advice, support and trust, and their help, interest and PATIENCE (!), both in professional and personal matters, during all this time of work together.

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Finally, since "*No man is an island…*" thank to all the people I met during this journey. I could not do it on my own.

To my supportive family (thus including Bucci Nikita, the dog), and to my closest friends (better known as "AMIKE"), thank you, everyone, for putting up with me.

Abstract

This work aims to understand the main benefits, drivers and actors of Digital Transformation in the Agrifood sector. This phenomenon plays a crucial role for agribusiness, especially in leading to a more productive, sustainable, and environmentally responsible food production. The study focused on the potential application of Precision Agriculture Technologies (PATs) among Italian farm managers. This research has been divided into eight research projects aiming to investigate four major issues: (1) factors affecting the intention to adopt PATs; (2) sustainability of the investments in those technologies, (3) the role of the farmer as a Manager in the farm's innovation process, and (4) the role of the provider in the technology adoption process. The proposed methodology is original because it accounts for the data acquisition process of the combination of quantitative and qualitative approaches. As results, this work shows how (i) the adoption of PATs in Italy still depends on the socio-economic characteristics of the farm; (ii) the use of precision farming technology could enhance the profitability of the farm by improving the farm yield, reducing variables cost and improving the farm management; (iii) how the managerial capabilities of the farmer are fundamental to uptake the process of digital transformation; (iv) a strict collaboration between technology providers and farmers could lead to a successful introduction of a technology.

Keywords. Digital Transformation, Precision Agriculture, Sustainability, Economic Profitability, Network, Farm Manager, Technology Provider

Table of Contents

Premise

There is this new Colgate advertisement, in which a young farmer speaks, smiling at the camera, and says "*When they say I a'm not a real businessman, I smile*"
The advertising message is to believe in the strength of the smile, but the point is another: Why shouldn't a farmer be considered a businessman?
Probably because in today's society, there is still the belief that that of the farmer is more a mission than a profession that provides a real income, still anchored to tradition, and not very innovative.
Well, this thesis tells precisely this change, the passage from traditional agriculture to a technological and innovative one thanks to the introduction of Precision Agriculture Technologies.
Forget the ox cart and immerse yourself in smart farming, where sensors, drones and robots automatically manage the farm. Digital technologies have the potential to revolutionize

agriculture by helping farmers work more precisely, efficiently and sustainably. Factors such as climate change, urbanization, population growthand food increasingly demand have propelled the industry into seeking more innovative approaches for protecting and improving crop yield.

Some examples? The Dutch firm, Connecterra, has developed technology that follows the movements and activities of cows. The high-tech system, powered by AI and motion sensors, is called “The Intelligent Dairy Farmer’s Assistant.”The company says information about the cows can be collected and seen on a cellphone or other mobile device. A text message can also inform farmers of concerns involving the animals. In France, the vineyards are managed by TED, a highly precise weeding tool developed by Naio Technology. Its main asset is that it frees the hands and minds of wine growers so that they can spend more time on tasks with a higher value-add. What about Italy?

While the United States, the United Kingdom and Australia are the nations most rapidly adopting precision agriculture technologies, things start to move quickly in Italy only in these last 2-3 year. “The success of agricultural businesses increasingly depends on the ability to collect and use the large amount of data generated, especially in terms of cost control and increase in production quality”, explained Andrea Bacchetti, director of the Observatory of Agrifood.

Are you curious to know some of the Italian experiences in the field of technology?

Then,

Enjoy the reading!

Introduction

Digital Transformation is a complex phenomenon, which affects the technological, organizational, and social aspects (Reis et al., 2018). It refers not only to the diffusion of the technology itself but also to the investments that firms need to make in digital skills, organizational changes, process innovation, new systems, innovative business models and business processes (Castelo-Branco et al., 2019; Vial et al., 2019; Chiarello et al., 2018; Li et al., 2018; Schmidt et al., 2015). In fact, in the Era of Digital Transformation, companies are facing several challenges in an environment of digital disruption: Internet of Things, Artificial Intelligence, Big Data, robotics, and other disruptive technological innovations are revolutionizing both organizations and society (Chandy et al., 2017; Brem and Voigt, 2009). Since the emerging digital technologies are creating new opportunities on the market, firms have to face the problem of balancing the risk of rushing into the new market with high technology investment costs, potential losses from cannibalizing existing business, and the uncertainty occurring in the emerging market (Kim et al., 2019). However, global challenges such as the world's growing population, climate change and global warming, biodiversity loss, are some of the issues for the economy that could be solved by applying new, advanced digital technologies. This is particularly true for the Agrifood sector, including the Agricultural Production and Food Industry, one of the most critical sectors and foundations of the European Union economy (European Commission, 2021).

According to the Food and Agriculture Organization of the United States (FAO, 2019), the demands of a growing population and unsustainable agriculture are compromising access to natural resources and the Covid-19 pandemic is intensifying the vulnerabilities and inadequacies of global food production. In fact, the coronavirus crisis has shaken Europe at every level - including the farm sector. The restrictive measures taken by most EU member states to respond to Covid-19 outbreak have left many European farmers facing manpower shortages, making it difficult for EU farmers to either plant or harvest products - which is disrupting the sector across the continent.

For this reason, the issues mentioned above have propelled the Agrifood sector into seeking more innovative approaches for produce more with fewer resources and, in this sense, Digital Technologies have the potential to revolutionize the way of doing agriculture by helping farmers and food operators to work more efficiently and sustainably (George et al., 2020; Schneider, 2019).

Thus, policy and governments highlight this issue and turn to create strategies for the development and growth of economic, environmental, and social sustainability and the Agrifood sector plays a particularly significant role in these three aspects. This thought prompted the study on the part of Digital Technologies in achieving sustainability in the Agrifood context (ElMassah and Mohieldin, 2020; Hrustek, 2020; Bucci et al., 2019, Radulescu et al., 2019). Within the Agrifood sector, Digital Technologies develop more than others through Precision Agriculture's application. Precision Agriculture a relatively new concept. It emerged in the early ‘90s when this technique was only focused on studying and managing spatial in-field variability. There is no broadly accepted definition of Precision Agriculture and starting from 1990 to date, several definitions were provided (Table 1).

Table 1: Definitions of Precision Agriculture over years

Year	Authors	Definition
1994	Pierce et al.	The intent of precision agriculture is to match agricultural inputs and practices to localized conditions within a field to do the right thing, in the right place, at the right time, and in the right way
1994	Robert et al.	The Right time, the Right amount and the Right place
1996	Stafford, John V	The targeting of inputs to arable crop production according to crop requirement on a localized basis
1996	Johansen	Careful tailoring of soil and crop management to fit the different conditions found in each field
1996	Kitchen	Information gathering, management planning, and field operations that improve the understanding and management of soil and landscape resources so the cropping inputs of management practices are utilized more efficiently than with conventional “one-fits-all” strategies
1997	The National Research Council	Precision agriculture is a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production
1997	Pierce and Sadler	Site-specific management (SSM) for agriculture is the management of soils and crops according to localized conditions within a field

1997	Lowenberg-DeBoer, J., and Swinton, S. M.	The SSM is information technology applied to agriculture. Technically, SSM is similar to spatial information technology being developed for many other sectors of the U.S. economy (e.g. vehicle tracking, surveying, navigation, forestry management).
1998	Olson, Kent	Precision agriculture is the application of a holistic management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with agricultural production, marketing, finance, and personnel
1999	Pierce & Nowak	Precision agriculture is the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality
2000	McBratney and Taylor	Simplified, PA is the use of new information technologies together with agronomic experience to site-specifically: i) maximize production efficiency ii) maximize quality iii) minimize environmental impact iv) minimize risk
2000	Robert, P. C.	It (PA) has been defined in many ways but basically it is information technology. PA is not just the injection of new technologies but it is rather an information revolution, made possible by new technologies that result in a higher level, a more precise farm management system
2000	Whelan & McBratney	Matching resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field
2001	Plant, R.E.	Site-specific management (SSM; also called, precision agriculture) is the management of agricultural crops at a spatial scale smaller than that of the whole field
2004	Dobermann et al.	Precision farming is a systems approach to managing soils and crops to reduce decision uncertainty through better understanding and management of spatial and temporal variability
2005	McBratney, Whelan, Ancev and Bouma	One generic definition could be ‘‘that kind of agriculture that increases the number of (correct) decisions per unit area of land per unit time with associated net benefits’’
2007	Whelan	Site-Specific Crop Management (SSCM) is “A form of PA whereby decisions on resource application and crop management practices are improved to better match soil and crop requirements as they vary in the field”

2008	Khosla	(Applying inputs at the) Right time, the Right amount and the Right place (Robert, 1994). Later, the International Plant Nutrition Institute added another "R" to that list, "the Right Source", and more recently, Khosla (2008) proposed an additional "R", the Right manner
2010	Adamchuk and Gebbers	Precision agriculture, or information-based management of agricultural production systems
2016	Fountas, S., Aggelopoulou, K., and Gemtos, T. A	Precision Agriculture (PA) can be defined as the management of spatial and temporal variability in the fields using Information and Communications Technologies (ICT)

In 2019, the International Society of Precision Agriculture (ISPA) finally provided a comprehensive definition of Precision Agriculture as "a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combined it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.", thus linking this technique to the issue of Sustainability.

Today the concept of Precision Agriculture is constantly evolving due to the introduction of increasingly advanced technologies. With the advent of Information and Communication Technologies and the Internet of Things, Agriculture becomes Smart. While Precision Agriculture is just considering in-field variability, Smart Farming goes beyond that by basing management tasks on location and data, enhanced by context and situation awareness, triggered by real-time events (Trivelli et al., 2019; Wolfert et al., 2017).

Finally, starting from the twenty-first century, the digital paradigm has brought a new way of thinking about innovation within the farm through the introduction of automation, key factors of Digital Farming, which describes the evolution in agriculture and agricultural engineering from Precision Agriculture. It uses all available information and expertise to enable the automation of sustainable agriculture practices. In this sense, Digital Farming is the result of these three related technology fields:

- **Management Information Systems**: Planned systems for collecting, processing, storing, and disseminating data in the form needed to carry out a farm's operations and functions.

- **Precision Agriculture**: Management of spatial and temporal variability to improve economic returns following inputs and reduce environmental impact.
- **Agricultural automation and robotics**: The process of applying robotics, automatic control and artificial intelligence techniques at all levels of agricultural production, including farm-bots and farm drones

Nowadays in Europe, Precision Agriculture's adoption is challenged by differences in geographical location/climate, cropping systems, technical developments, social issues, diversity in field sizes and farm-scale and diversity of farm and production-chain structures. Precision Agriculture's applications contribute to creating new business opportunities and work for highly skilled persons offers a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection, on-farm quality of life, and rural economic development. (Sott et al., 2020; Michailidis et al., 2010; Gandorfer et al., 2017; Lombardo et al., 2017). Despite these advantages, Precision Agriculture is adopted only by innovative farmers and the intelligent usage of Precision Agriculture Technologies is still relatively limited, which is especially true for Italy, where these technologies are adopted only by 1% of farmers (MIPAAF, 2017).

According to Rogers' Theory (1962), the adoption of an innovation follows an S curve when plotted over a length of time. Adopters are innovators, early adopters, early majority, late majority, and laggards (Figure 1).

The causes of poor agricultural performance are essentially due to low technological development and could be solved by developing and improving these lacks. However, in general, innovation is a complex process and the adoption of new technologies in agriculture is not often immediate (Pierpaoli et al.2013).

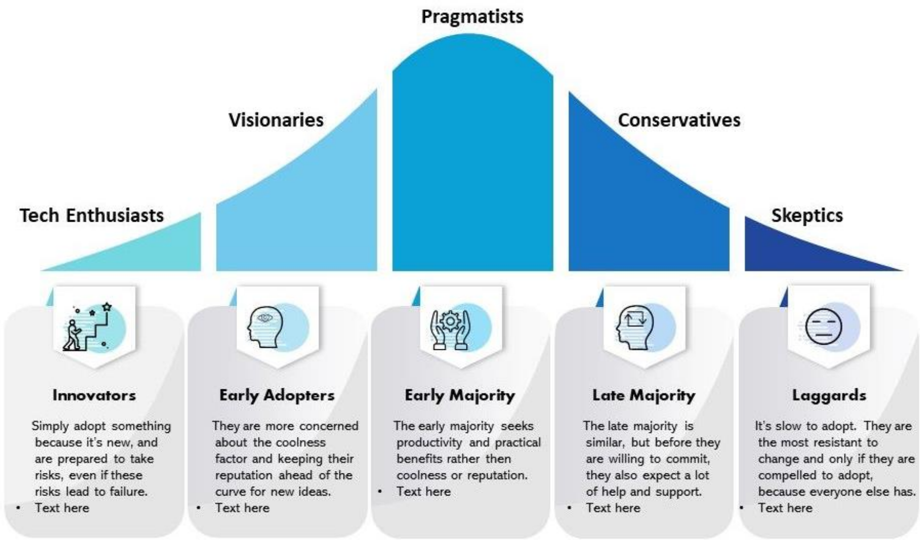

Figure 1. The model of diffusion of innovation by Rogers (1962)

Indeed, the difficulty of applying innovative technologies is because farming operators meet complex decision-making problems. To optimize agricultural process/operations, farmers need to consider various conditions and inputs (water, nutrients, fertilizers, weather, etc.) that can influence the entire agricultural system. Finally, the institutional setup is another crucial factor to be understanding to innovation activity. In particular, an agricultural policy that supports the income of farmers could influence the innovation process. There is a strong connection between public support for innovative research and programs that support farm income. This could explain the need for new investments in innovation for the Agrifood sector (Lajoie-O'Malley et al., 2020). It is generally accepted that profitability is the main driver for investing in new PA equipment and systems (Tinker and Morris, 2011). There is a link between knowledge, technology, and production increments (Foresight, 2011). It has been demonstrated that better understanding and technology can increase crop yields, while investment in research and development is critical to producing more food in an environmentally sustainable manner. Precision agriculture (PA) offers farmers the opportunity to improve efficiency in managing resources and optimizing process inputs, thus

increasing their whole farm’s profitability. Despite these well-known benefits, the adoption of PA technologies (PATs) is still challenging due to the farms' socio-economic barriers and unique characteristics: cropping systems, technical developments, field sizes, and farm scale. The economic aspect is undoubtedly one of the most important aspects to consider before adopting PATs. In most cases, farmers are reluctant to introduce precision farming systems since the costs and uncertainty about the profitability and advantages need to be addressed. This chapter aims to explore how PATs could affect the profitability of two representative Italian farms specializing in the production of cereals, making this a case study. In detail, an economic analysis was applied to determine the farm's profitability, which showed that the adoption of PAT’s increased the yield of durum and soft wheat and significantly reduced the cost of mechanical operations and technical means.
The lack of comprehensive knowledge of the recent Digital Transformation phenomenon in the Italian agri-food sector gave rise to this research that aims to understand better when the phenomenon started, how much is developed, yielding valuable insights to help understand the dynamics of adoption of new digital technologies in Italy.

This dissertation addresses the issues and knowledge gaps discussed above. Specifically, it focuses on answering the following set of research questions:

- ❖ Q1: What are the main factors affecting the adoption of Precision Agriculture Technologies?
- ❖ Q2: How sustainable is the investments in Precision Agriculture Technologies?
- ❖ Q3: What is the role of the Farm Manager in the innovation process?
- ❖ Q4: How do relationships with Technology providers influence the process of technology adoption?

To solve these four issues, this Ph.D. Thesis proceeds with the following Chapters (Figure 2) that correspond to papers:

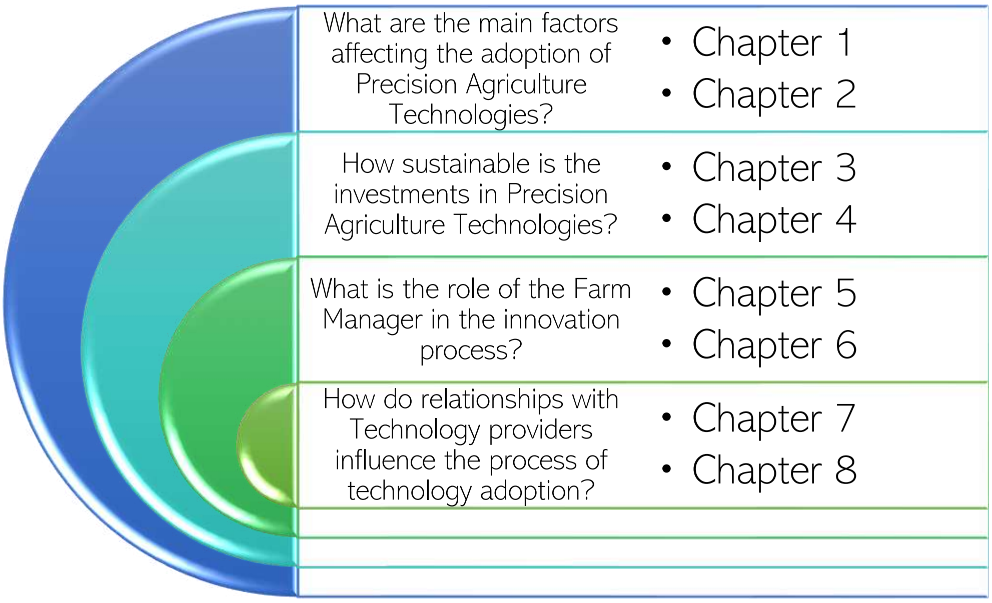

Figure 2: Main structure of the thesis

- **Chapter 1**: "Precision agriculture as a driver for sustainable farming systems: state of the art in literature and research," published in 2018 on Quality, Access To Success, 19(S1), 114-121.
- **Chapter 2**: "Factors affecting ICT adoption in agriculture: A case study in Italy," published in 2019 on Quality, Access To Success, 20(S2), 122-129.
- **Chapter 3**: "Measuring a farm's profitability after adopting precision agriculture technologies: A case study from Italy," published in 2020 on ACTA IMEKO, 9(3), 65-74
- **Chapter 4**: The economic results of investing in precision agriculture in durum wheat production: A case study in central Italy, Submitted on Agricultural Economics – Czech
- **Chapter 5**: "The role of managers or owners of SMEs in driving the digitalization process in the agri-food sector" published in 2020 in the book. How is Digitalization

Affecting Agri-food?: New Business Models, Strategies and Organizational Forms, 37.

- **Chapter 6**: “Network's dynamics for innovation adoption in the agricultural sector: the case of precision agriculture,” To be published on Revista de Economia e Sociologia Rural (under review)
- **Chapter 7**: “Digital Farming under the technology provider’s perspective: insights from a Grounded Theory Method.”
- **Chapter 8:** “Implementing the Sustainable Development Goals with a digital platform: experiences from the vitivinicultural sector,” published in 2020 on 2020 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor) (pp. 119-123). IEEE

The first step of the research consisted of an overview of the topic (Chapter 1) and recognizing the potential areas of application of Precision Agriculture in Italy by applying a linear regression (Chapter 2). Then, the second step of the research followed two main qualitative approaches and relative methodologies.

To evaluate the sustainability of the investment in Precision Agriculture, the case study research approach has been chosen as the first qualitative research method (Chapter 3 and Chapter 4). For each case study provided by two innovative farms of Central Italy, we applied economic analysis, including (i) Cost-Benefit Analysis, (ii) Income Statement, (iii) Sensitivity Analysis, and (iv) Break-even analysis. A related, more complete dissertation is available through the following chapters.

After the economic assessment of Precision Agriculture Technologies, research has focused on understanding: (i) how digital technologies are introduced within the farm; (ii) what are the main actors involved in this process, and finally (iii) how these actors interact within a network. While the process of technology adoption by farmers has been widely studied through quantitative research (e.g., Theory of Planned Behaviour and its extension in Technological Acceptance Model) (Adnan et al., 2019; Michels et al., 2019), over the last two decades, there has been an increasing interest in the use of a more qualitative approach.

Then, given the need to study the phenomenon from a different perspective, we applied two main qualitative research methods, which allow describing, understanding, and interpreting phenomena to achieve a deep understanding of the various factors involved.

Qualitative content analysis provides knowledge and understanding of the phenomenon under study since it is considered the study of recorded human communications (Babbie, 2001) with a "systematic, objective, quantitative analysis of message characteristics" (Neuendorf, 2002).

The Grounded Theory Method (GTM) involves a systematic and inductive approach for conducting an inquiry to construct new theories from data (Charmaz, 2008) systematically obtained and analyzed using comparative analysis. Through the combined application of these two methodologies, it was possible to study: the role of the farm as a manager (Chapter 5), how the farm manager is involved in a network (Chapter 6) and the role of technology providers in the adoption of digital technologies (Chapter 7). These qualitative methodologies was deeply studied during the Ph.D. visiting at the University of Wageningen, on the Department of Business Management and Organization, supervised by Wilfred Dolfsma, Professor of Business Management & Organisation at Wageningen University & Research and Maria Carmela Annosi, Assistant Professor at the Business Management and Organization group. The thesis ends with a case study involving farmers and Evolvea s.r.l., the company that co-funded this Ph.D., in the design of a digital solution applied to the viticulture sector (Chapter 8).

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Chapter 1

Precision agriculture as a driver for sustainable farming systems: state of the art in literature and research

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ABSTRACT

In 2017, the food and beverages industry was reconfirmed as the European Union's most significant manufacturing sector, in terms of employment, turnover and added value. However, almost all the companies are small and medium size enterprises (SMEs), showing a slow rate of adoption of innovations and precision agriculture technologies. With the advent of the digital age, new opportunities are opening for the agri-food SMEs to enhance their competitiveness through the application of technological innovations in the supply chain, from farm to fork. Given the wide range of available technology and its increasingly rapid development, the paper presents an overview of worldwide development and status of precision agriculture, starting from 2000 until to date. In dealing with the state-of-the-art, the paper confirms that technological applications in food production are of relevance in ensuring sustainable management of farming systems.

KEY WORDS

Precision agriculture, ICT, innovation, sustainability, review

INTRODUCTION

Nowadays innovation is a central driver of economic growth and productivity. The capacity to innovate is a strategic tool for those firms that want to maintain their competitive position in the global market (Laforet and Tann, 2006). This is especially true for the agri-food sector that is the largest manufacturing sector within the EU and is one of the main drivers of the EU economy, contributing to both economic output and employment (Traill, 1998). According to FoodDrinkEurope's Report, in 2017 the food and drink industry have generated 4.24 million employees throughout the EU, over €1 trillion turnover and a positive trade balance of €30 billion. Nevertheless, the agri-food sector has traditionally been viewed as a low-tech sector with slow rates of innovation respect to others (Dalla Corte et al., 2015; Bentivoglio et al., 2016). Agri-food enterprises operate in a complex and dynamic environment. To meet increasing demands of consumers, government and business partners, enterprises continuously have to work on innovations of products, processes and ways of cooperation (Harsh et al. 1981). Nevertheless, it is not only the research that leads to innovation but also users of technology. This fact is used in EU programs and policy to promote digital technologies as part of the Competitiveness and Innovation (Wozniakowski, and Jalowiecki, 2013). Today, companies are confronting something new and different: digitalization. Referring to the adoption of powerful and accessible, technologies like social, mobile, cloud, analytics, internet of things, cognitive computing, and biometrics, digitalization is a transformation that companies can undergo to take advantage of the opportunities these technologies create. A digital company, which decides to embrace new technologies, deliver enhanced products, services, and customer engagement. Starting from the twenty-first century, digital paradigm has brought with it a new way of thinking about innovation within the firms through the introduction of the Internet of Things (IoT) and the Information and Communications Technology (ICT) that are the keys factors of digital transformation technologies. These two concepts are distinct from each other's but related, in order to clarify the differences between the terms, some definitions will be provided later. Today the Internet of Things is one of the main topic of interest for the industry but it is a relatively new concept. Coined by Kevin Ashton in the early 2000's, the IoT concept describes a system where the Internet is connected to the physical world via ubiquitous sensors, meaning that, some objects in daily life equipped with identifiers and wireless connectivity, are able to communicate with others, and to be managed by computers. After then, several definitions for IoT have been provided by Santucci (2009), Quarterly (2010) and Evans (2011). All of them agree in conceiving the IoT system as a network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. The Internet of Things in fact, links the objects of the real world with the virtual world, thus enabling anytime, anywhere connectivity for anything and not only for anyone. (Patel et al., 2016). IoT is an environment where objects, animals or people are equipped with unique identifiers capable of data transmission over Internet network without the need for human-human or human computer interaction. Within this technological ecosystem, information is carried at phenomenal speeds within and across various communication networks known as Information and Communication Technology networks (ICT). ICT is the digital processing and utilization of information. It comprises the storage, retrieval, conversion, and transmission of information by the use of electronic computers. According to Rouse (2005), ICT includes any communication device or application in addition to computers, encompassing: radio, television, cellular phones, network hardware and software, satellite systems too. Even the UNESCO, recognized the relevance of ICT as an information technology useful to process and communicate information, making knowledge available to all. Nowadays, IoT and ICT applications are pervasive in society and abundantly present in many businesses not traditionally included in the ICT sector and are they are responsible for the growth of production and revenue (Basu and Ferald, 2008; Miller and Atkinson, 2014). These technologies are very promising in several fields such as manufacturing, government, education, energy management, health care, smart cities, and smart transportation up to the agriculture as well as logistic and supply chain management. (Zhuhadar et al; 2017; Fernando, 2018). With the spread of digital technologies, agriculture has turned "smart" too, in order to boost company competitiveness, transparency of production processes and the improvement of end-products quality, with an enormous advantage for the whole production chain. Based on the concept to "produce more with less", Precision agriculture could be the solution to feed a population that is growing faster than land supply, while ensuring a sustainable use of natural resources. Because of the strategic position of the agri-food sector in the European Union, the main objective of the paper is to provide an updated overview of the application of precision agriculture of the best precision farming techniques that ensure sustainable management of primary production. The study is organized as follows: Section 1 affords an overview of the policy framework. Section 2 explores briefly some of the emerging technologies framed in the whole food supply-chain and finally, in Section 3 a systematic review on precision farming and its sustainability is addressed. It is divided into two parts: first, the methods applied in the review are presented; then the selected studies are presented and discussed, providing the reader with a summary of the advantages and disadvantages, which derive from the application of precision farming system.

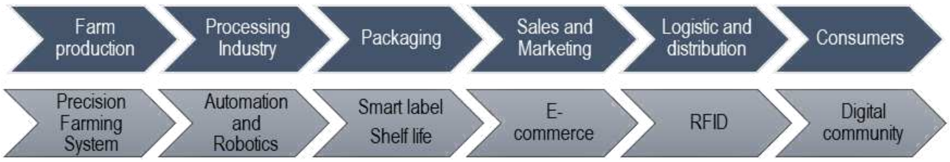
1. TECNOLOGICAL INNOVATION POLICIES IN AGRIFOOD SECTOR

As part of the Europe 2020 Strategy, The Digital Agenda for Europe was adopted in 2010 as one of the seven flagship initiatives of the Europe 2020 strategy to stimulate the digital economy and address societal challenges posed by information and communications technologies (ICT). Issues of IoT are part of the Digital Agenda (European Commission, 2016), whose main objective is to develop a Digital Single Market in order to generate smart, sustainable and inclusive growth in Europe by achieving the digital single market, enhancing interoperability and standards and promoting digital inclusion through investments in research and innovation. Started in 2010, the Digital Agenda for Europe is aimed at boosting Europe’s economy by delivering sustainable economic and social benefits from a Digital Single Market, which has a strong potential to contribute to the growth of rural areas and support innovation in European agriculture. According to Europe's Digital Progress Report 2017, Denmark, Finland, Sweden and the Netherlands have the most advanced digital economies in the EU followed by Luxembourg, Belgium, the UK and Ireland. Whereas, Romania, Bulgaria, Greece and Italy have the lowest scores on the index (Bodislav and Bran, 2017). Size is a major factor facilitating the digital transformation of enterprises. SMEs are slowly closing the gap with large companies, and there are a lot of opportunities still to be exploited. In fact, in addition to European Policies, an important role for the dissemination of IoT-ICT based technologies lies with Horizon 2020. In its first three years of implementation, Horizon 2020 has allocated EUR 4 billion of EU funding to 1369 projects in the field of ICT, attracting 4832 organizations. SMEs represent 40 % of participating organizations and their participation varies according to pillar and Work Programme Area. They are present in the 'Focus Area IoT', in the Societal Challenges and within LEIT ICT in "Micro-and Nanoelectronic technologies"," Content Technologies and Information Management" and in "Factories of the Future".

IoT has also stimulated the factories and the governments to launch an evolutionary journey toward the fourth industrial revolution called Industry 4.0. (Shrouf et al., 2014). The term 'Industrie 4.0' was coined in Germany at the Hannover Fair in 2011 as part of a Governmental strategy for the computerization of factories in order to mitigate for increasing competition from overseas. McKinsey defines Industry 4.0 as digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyberphysical systems, and analysis of all relevant data. It is driven by four clusters of disruptive technologies. The first consists of data, computational power, and connectivity. Analytics and intelligence form the second, while human-machine interaction is the third, comprising, for instance, touch interfaces and augmented reality. Digital-to-physical conversion is the fourth. Industry 4.0 can be perceived as a strategy for being competitive in the future. Introducing the concept of Smart Factory and Smart Products (Wang et al., 2016), Industry 4.0 is focused on the optimization of value chains due to autonomously controlled and dynamic production (Mrugalska and Wyrwicka, 2017) The forerunners in this filed were Germany and the United States: the first, more focused on automation and firm's innovation, the latter more oriented towards digitization and collaborative platforms. The European Union immediately adopted the German approach with the aim, according to the Oettinger Plan, of bringing back the GDP generated by the EU manufacturing to 20% by 2020 (in 2014 it stood at 15%). In this context numerous national and European and national initiatives born during in the last years. The European Platform of national initiatives, launched in March 2017, is at the core of the coordination effort. Overall, 15 European countries such as Austria, Belgium, Czech Republic, Germany, Denmark, Spain, France, Hungary, Italy Lithuania, Luxembourg, Netherlands, Poland, Portugal and Sweden, have activated national initiatives. Italy has launched an Industry 4.0 strategy too, with the aim of modernizing Italy's manufacturing sector, mainly through the adoption of digital technologies and digital business models. The Industria 4.0 National Plan represents a major opportunity for all companies that are ready to take advantage of the unprecedented incentives offered by the Fourth Industrial Revolution. The Plan, consisting of 20 billion euros, provides for a wide array of consistent and complementary measures promoting investment in innovation and competitiveness, including a super and hyper amortization of 140% and 250%, a 50% tax credit on R&D investments and incentives on investments in start-ups and innovative small businesses. In addition, in agri-food sector, an ad hoc program has been launched, which is Agriculture 4.0, focusing on three main innovation trajectories: Precision agriculture, Traceability and Sustainability.

2. THE ROLE OF DIGITAL TECHNOLOGIES IN AGRI-FOOD SUPPLY CHAIN

The agri-food sector can deliver sustainable solutions to current and future global challenges such as assuring a safe and sustainable provision of quality food, fostering resource efficiency, developing the circular economy and combating climate change. In this context, digital transformation plays a crucial role for agribusiness in farming sector and especially in rural areas, in which, as Salemink et al. (2015) showed, there is need of improved digital connectivity to compensate for their remoteness. Primary Business Processes are those involved in the creation of the product, its marketing and delivery to the buyer (Porter, 1985). Supporting Business Processes facilitates the development, deployment and maintenance of resources required in primary processes. The business processes of farming significantly differ between different types of production, e.g. livestock farming, arable farming and greenhouse cultivation. A common feature is that agricultural production is depending on natural conditions, such as climate (day length and temperature), soil, pests, diseases and weather (Nuthall, 2011). In this sense, the integration of wireless sensors with agricultural mobile apps and cloud platforms helps in collecting vital information pertaining to the environmental conditions (temperature, rainfall, humidity, wind speed, pest infestation, soil humus content or nutrients), besides others, linked with a farmland, can be used to improve and automate farming techniques, take informed decisions to improve quality and quantity, and minimize risks and wastes. For instance, the adoption of modern farming technologies, including those based on robots, the Internet of Things (IoT) and Big Data, has great potential in leading to a more productive, sustainable, and environmentally responsible food production. Smart farming systems can help farmers improve decision-making and develop more efficient operations and management (Gu and Jing, 2011). Today's food supply chain (FSC) is extremely distributed and complex. It has large geographical and temporal scale, complex operation processes, and large number of stakeholders (Xu et al., 2014). The complexity has caused many issues in the quality management, operational efficiency, and public food safety. IoT technologies offer promising potentials to address the traceability and controllability challenges. It can cover the FSC in the so-called farm-to-plate manner, from precision agriculture, to food production, processing, storage, distribution, and consuming. Ramundo et al., (2016), identified all the current technologies applied in the whole part of the agri-food supply chain (Figure 1).



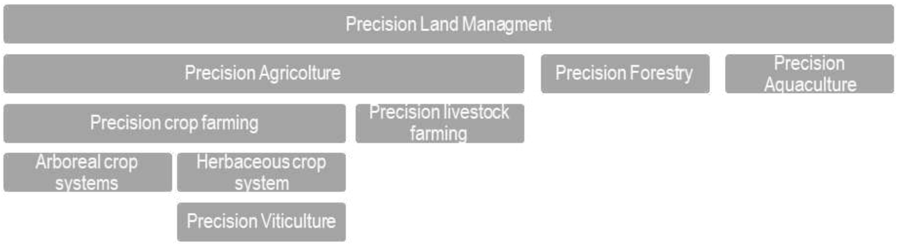
(Source: Ramundo et al., 2016)

Figure 1. Technological innovations in the agri-food chain

The development of e-commerce (Antonescu et al., 2017) and the RFID tag for logistics and traceability, are only very few examples of the potential applications of these technologies in the agri-food sector. However, it is evident how the development of new technologies concentrated above all in the first step of the supply chain, the farm production, through the Precision Agriculture Technologies, (PAT) which are fundamental for establishing sustainable patterns of agricultural production.

3. PRECISION AGRICULTURE TECHNOLOGIES: STATE OF ART IN LITTERATURE AND RESEARCH

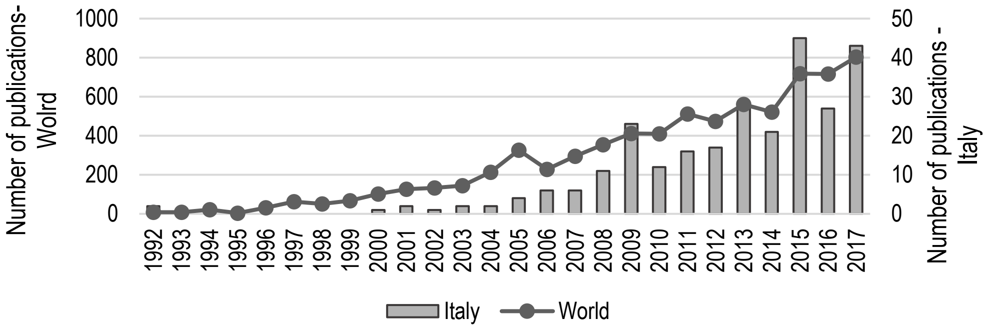
The current paragraph aims to provide a review of recent literature about precision agriculture technologies. As Auernhammer and Demmel (2016) highlighted, Precision Agriculture can be considered one of the different types of precision land management, which also includes precision forestry and aquaculture (Figure 2).



(Source: Casa, 2016)

Figure 2. Precision Land Management architecture

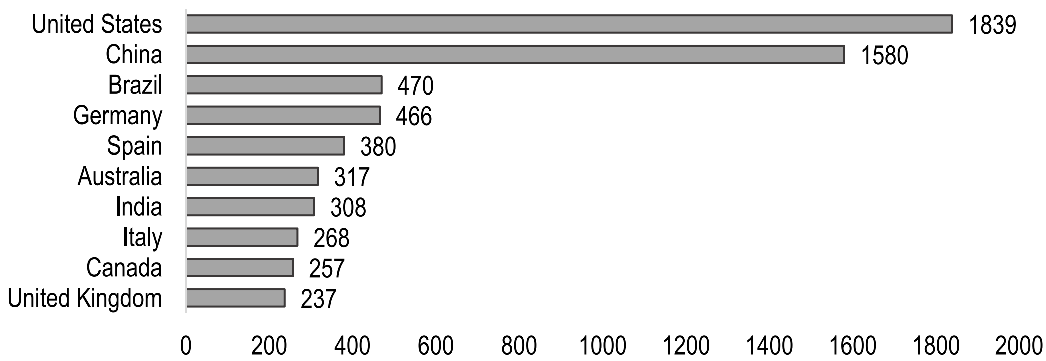
Precision Agriculture could be further divided into two categories: precision crop farming and precision livestock farming. The first is the application of precision farming technologies to manage spatial and temporal variability for improving crop performance and environmental quality. The latter, (PLF) means the use of advanced technologies to optimize the contribution of each animal. Through this "per animal" approach, the farmer aims to deliver better results in livestock farming. PLF is a technology that applies the principles of process engineering to livestock farming and has the potential to support of: efficient utilization of feed and nutrients, early warning of bad health reduction in pollutant emission (Morgan-Davies et al., 2018; Hostiou et al., 2017). Precision Agriculture could be used as a synonym for precision cultivation, applied to both arboreal and herbaceous systems. Nowadays the development and adoption of PA technologies and methodologies in viticulture (termed Precision Viticulture, PV) represents one of the most important specializations for the Mediterranean countries. Being a sector with high technological innovation, scientific research carries out a fundamental role in the development of precision agriculture. The number of scientific publications produced is constantly increasing internationally and in Italy from the 90s to today (Figure 3).



(Source: Our elaboration, 2018)

Figure 3. Number of annual scientific publications, in the world and in Italy, on precision agriculture, extracted utilizing the keywords "precision agriculture" in Scopus

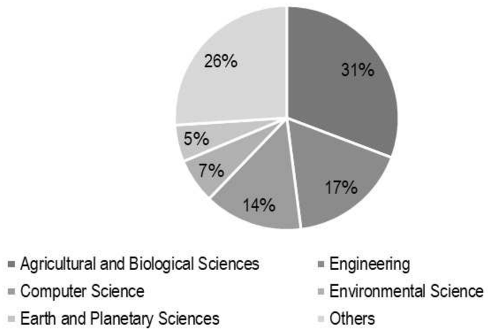
Research on Precision Agriculture in Italy, though not having been able to count on comparable financing to those of other countries, such as United States and China, has good scientific productivity, which places it at eighth place worldwide as the number of publications scientific (Figure 4).



(Source: Our elaboration, 2018)

Figure 4. Number of scientific publications by country

At worldwide level, about 31% of the publications concern agronomic aspects, 17% engineering aspects, 14% Information technology and 7% environmental (Figure 5).



(Source: Our elaboration, 2018)

Figure 5. Number of scientific publications by subject area

Based on this framework, a systematic review of the literature was performed on the sustainability of precision agriculture technologies. The methodological approach of the work is briefly described. Two keywords were chosen in Scopus to obtain a range of papers to be analyzed. The keywords selected were: “precision agriculture” and “sustainability”. This database was chosen because of its wide coverage of relevant literature and advanced bibliometric features such as suggesting related literature or citations. The choice of the review period (2000-2018) was a practical one and took into consideration the fact that precision agriculture is a rather recent phenomenon. From the database 217 peer-reviewed articles were retrieved. These were scanned for relevance by identifying passages that were addressing the research questions. As a result of the screening, we considered the most relevant. The results of the analysis are shown below. As defined as a whole farm management approach using information, technology, satellite positioning (GNSS) data, remote sensing and proximal data gathering, Precision Agriculture (PA) involves the application of technologies and agronomic principles to manage spatial and temporal variation associated with all aspects of agricultural production in order to improve crop performance, optimizing returns on inputs, and environmental quality, reducing environmental impacts. (Rees et al., 2018; Garibaldi et al., 2017). In addition, European Commission (2017) recognized another five additional benefits of smart agriculture that are:

increased production, real time data and production information, better quality, improved livestock health and lowered production cost. one of the main benefits that comes from the precision agriculture technologies consists in water efficiency, save irrigation water and enhance crop irrigation water productivity (Luo et al., 2016). The adoption of site-specific (SS) management practices is fundamental, not only to improve crop yield, but also for a more efficient use of resources, increasing the environmental sustainability of the agricultural production (Ortuani et al., 2016). Precision irrigation and precision nitrogen fertilization are widely seen as an excellent method to save water and fertilizer and maximize yield. (Zhao et al., 2017). However, several authors (Adeyemi et al., 2017; González Perea et al., 2017; West, and Kovacs, 2017); have shown that the use of these technologies alone are not sufficient to increase the efficiency of the entire production process. The development of decision support systems (DSS) into precision irrigation and fertilization management will enable significant advances in increasing the efficiency of current irrigation and fertilization approaches. An example can be provided by the work of Lundström and Lindblom, (2018), which describe a decision support system called CropSAT developed for calculation of variable rate application files for nitrogen fertilization from satellite images. In the case study, results revealed that social contexts could support farmers' development of cognitive strategies for use of agricultural decision support systems, e.g. CropSAT, and could thus facilitate decision-making and learning through development of enhanced professional vision that hopefully may increase farmers' situated knowledge and care. In Europe the main successful applications of precision agriculture concern intensive crop production such us grain (Yost, 2017), maize and soybean. In fruit and vegetable farming the recent rapid adoption of machine vision methods allows growers to grade products and to monitor food quality and safety, with automation systems recording parameters related to product quality. Additionally, tracking of field operations such as chemicals sprayed and use of fertilizer can be possible to provide complete fruit and vegetable processing methods. This information can be disclosed to consumers for risk management and for food traceability as well as to producers for precision agriculture to get higher quality and larger yields with optimized inputs. However, driven by the high value of the crop and the importance of quality, several research projects already exist in wine production areas of the world including France (Mazetto et al., 2010) Spain, and Italy too (Borgogno and Gajetti, 2017) Grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential wine qualities. The parcels with greatest opportunities for PV are those which reveal a high degree of yield variation. Another example of precision agriculture specialized application is that in olive groves localized in the Mediterranean areas: it's the case of Italy, Spain Greece and Egypt too. According to van Evert et al., (2017), IoT applications make possible a site-specific management in olive orchards, leading to an increase in productivity and product quality. In addition, in order to maximize environmental benefits, Nawaz et Ahmad, (2015); Choudhary et al., (2018), confirmed that precision agriculture technologies can be integrated into conservation agriculture techniques in a novel approach with a series of practices that strives for acceptable profits together with high and sustained production levels while concurrently conserving the environment. The applications of precision farming on family farms and rural farm communities may slow down or stop the trend of people leaving rural areas in the EU for better life in cities because it creates new business opportunities and work for highly skilled persons offers a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection, on-farm quality of life, and rural economic development. (Lombardo et al., 2017) Despite these advantages, precision agriculture is adopted only by innovative farmers and the intelligent usage of precision farming data is still rather limited. Adoption of precision farming in southeast Europe has been very low due to the small size of farms, infrequent contact of farmers with new technology, no awareness of the precision agricultural practices, and the high cost of initial investment. In Italy, for example, only 1% of the agricultural surface is managed through precision farming techniques. (MiPAAF, 2017). In addition to cost and farm size, other factors reported to influence the adoption of precision farming in Europe are socio-economic factors (farmers′ age and education level, and cost of labor, land and capital), agro-ecological factors (soil quality, land ownership), institutional factors (pressure for sustainability), informational factors (hiring consultants), farmer perception (prospect of increased profit) and technological factors (use of IT) (Tey and Brindal, 2012). The complexity of precision farming is, in part, due to a required change in mode of working for farmers, transitioning from experiential decision-making to data-driven processes, and this causes uncertainty around the potential costs and benefits of the technology (Kutter et al., 2011). Another crucial element is that precision farming technologies are primarily developed and supplied by private companies who often lack the farm systems expertise or knowledge networks to adequately support on-farm use and adaptation (Eastwood et al., 2016). There is thus subsequent uncertainty on how to implement the technology on farm as well as off-farm, for example data transfer between on-farm and industry-level databases (Kamphuis et al., 2015). As a consequence, precision farming technologies require support structures to facilitate learning and reduction of uncertainty in the implementation and adaptation process. While Precision Agriculture is just taking in-field variability into account, Smart Farming goes beyond that by basing management tasks not only on location but also on data, enhanced by context- and situation awareness, triggered by real-time events (Wolfert et al., 2017). A number of studies (Cook et al., 1996; Stafford, 2000Zhang et al., 2002; Godwin et al., 2003; Ancev et al., 2004; Mcbratney et al., 2005; Balafoutis et al., 2017) have reported the economic impact deriving from application of PA. According to Godwin et al., (2001), the main cost related to the application of PA are associated with: precision farming monitoring and control systems; precision farming equipment and precision farming management. According to OECD, (2016) a review of 234 studies published from 1988 to 2005 showed that precision agriculture was found to be profitable in an average of 68% of cases (Griffin and Lowenberg-DeBoer, 2005). Profitability depends on the extent of spatial variability of soil conditions, the size of a field and uncertainty about output and input prices (Murat and Madhu 2003).

4. CONCLUSION

Technological development and digitization make possible big leaps in resource efficiency enhancing an environment and climate smart agriculture which reduces the environment-/climate impact of farming, increase resilience and soil health and decrease costs for farmers. However, the uptake of new technologies in farming remains below expectations and unevenly spread throughout the EU, and there is a particular need to address small and medium-sized farms' access to technology. The number and types of challenges associated with smart farming ranges across various agricultural production systems, and infrastructural limitations apply when it comes to IoT implementation. Innovation will be accelerated by creating a framework in which farmers, cooperatives, extension professionals, scientists and the private sector can effectively collaborate and co-create knowledge. Farmers are essential participants in the research process, to identify research priorities, to collaborate with scientists in conducting research, and to adopt and disseminate the results of research. Technical solutions should allow farmers to produce more efficiently, leaving more time for managing, for instance through technical solutions for monitoring and controlling emissions. These solutions should enable farmers to show the quality, the sustainability and the safety of their product to consumers and policy makers. Future research based on deeper analyses, will draw an overview on all the technologies involved in all the stages of the supply chain.

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Chapter 2

Factors affecting ICT adoption in agriculture: A case study in Italy

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ABSTRACT

In the last decade, Precision Agriculture technologies (PATs) are one of the most widespread innovations in the agricultural sector. Precision Agriculture (PA) allows farmers to manage their fields for maximum output by using data and digitized farming equipment to apply the right inputs, in the right place, at the right time. Nowadays, PATs became almost commonplace in America and Australia, compared to Europe and Italy, in which their application is still limited. Considering this context, this research aims: (I) to give an overview of the state of art of PA; (II) to summarize which factors more affect the adoption of PATs in Italy (III) to understand the determinants of technological innovation through a Regression model. Results reveal that the technological adoption of Italian agriculture meets several obstacles, linked to the cultural barrier to innovate with the difficulty of investing in and appreciating the benefits of precision technologies.

KEY WORDS:

ICT, Precision Agriculture, Technology Adoption, Innovation, Regression, Sustainability

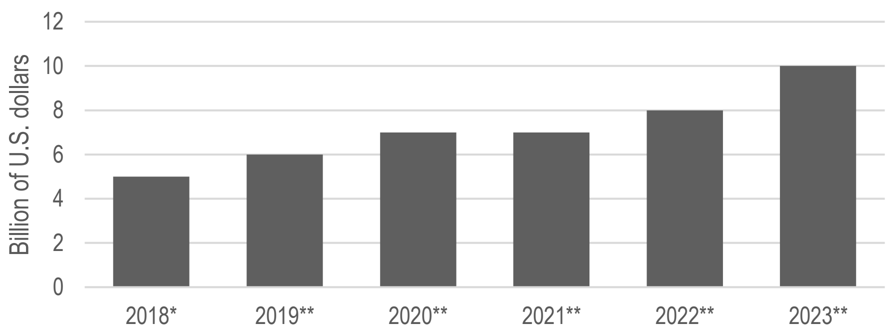
INTRODUCTION

The traditional vision of a static agriculture and not inclined to change can be today overturned thanks to the multiple opportunities offered by digitalization, which is proposing to agriculture new, innovative ways to grow and develop, by investing in modern Precision Agriculture Technologies (PATs). Precision Agriculture (PA) is a business management strategy that uses information technology to acquire data that leads to decisions aimed at agricultural production (Reichardt and Jürgens, 2009; Gebbers,and Adamchuk, 2010; Casa, 2016). A synthetic but more effective definition of PA is provided by Pierce and Nowak (1999), which describe the PA as a management practice that allows "doing the right thing, in the right place, at the right time". This definition does not limit to the range of action of technologies only to the agronomic context, but it identifies PA as a whole farm management strategy, based on the observation, measurement and response of the set of variables quantitative-qualitative that are involved in the productive system. Today the concept of Precision Agriculture is changing due to the advent of the Internet of Things (IoT) and the Information and Communication Technologies (ICT): from Precision Agriculture it is starting to talk of Smart Farming. While Precision Agriculture just takes in-field variability into account, Smart Farming goes beyond that, by basing management tasks not only on location but also on data, enhanced by context and situation awareness, triggered by real-time events. From the farmer's point of view, Smart Farming should provide the farmer with added value in the form of better decision making or more efficient exploitation operations and management (Wolfert et al., 2017). The recurrent expressions such as "Smart Farming", "Digital Farming", "Internet of Farming" and "Agriculture 4.0" (in analogy to Industry 4.0), are not always understood as synonyms of Precision Agriculture (PA) but are used in literature to underline the evolution of PA towards forms of farms management in which the most recent technologies (IoT and Big Data) and data management are involved. (Kaloxylos et al., 2014; Zambon et al., 2019). The first application of precision agriculture dates back to 1929, when Linsley and Baue developed the first prescription map for the study of soil pH variability, but its broader development took place only from the 1980s with the diffusion in agriculture of Global Positioning System (GPS) and Geographical Information System (GIS) technologies. From that moment, PA developed in many directions and the term PA had become quite complex, covering many technological solutions (Perdersen and Lind,2018).

According to a more sustainable vision of agricultural production (Di Vita et al., 2013; Rusciano et al., 2017; Blanc et al., 2018), the use of precision agriculture technology could trigger a big transition in agriculture, also the manufacturers of machines and inputs agree: their innovations focus no longer on mere productivity, but on a greener and cleaner agricultural production – of course keeping in mind the economic sustainability on the farm. Another interesting aspect of precision agriculture is that it creates new jobs in the rural area: all these high-tech equipment needs to be operated, maintained and repaired. Also, sensor systems, drones and robots need to be connected and their data must be analysed and translated in actionable knowledge Because of the significant role the agriculture sector plays, the government of European countries ensures that they go all the way to subsidize PATs for farmers and also encourage entrepreneurs to go into farming. The European Union's response to the need for a program to support the dissemination of technologies is the Digital Agenda, presented by the European Commission as one of the seven flagship initiatives of the Europe 2020 strategy (Bentivoglio et al., 2016; Marotta et al., 2017; Finco et al., 2018). The Digital Agenda proposes to make the most of the potential Information and Communication Technologies to foster innovation, economic growth and progress (Bucci, 2018). The Rural Development Program has implemented policies to support innovation and the adoption of techniques for technological improvement through the agricultural European Innovation Partnership (EIP-AGRI) works to foster competitive and sustainable farming and forestry that achieves more and better from less. Rural Development will in particular support Operational Groups within a country or region (Torquati et al., 2016). From the national point of view, the Ministry of and the Ministry of Agricultural, Food, Forestry Policies and Tourism, (MiPAAFT) and Ministry of Education, University and Research (MIUR) are the institutions that are involved in stimulating innovation and research in the agri-food sector and are positioned as interlocutors with the European Union. On the basis of this the MIUR has elaborated a National Operational Program-PON Research and Innovation 2014-2020 in support of research in the agricultural and agri-food sector to promote innovation and transfer of knowledge; in addition, the National Decree of the Mipaaf no.33671 of 12/22/2017 approved the "guidelines for the development of precision farming in Italy", whose general objective is to optimize and strengthen agricultural production, and to do so more and more sustainably. The national strategy for Italy is to reach 10% of the utilized agricultural area cultivated through the use of precision farming means and technologies by 2021 (MiPAAFT, 2017). In line with the literature, computer use is found to be a precursor factor for the adoption of PATs. Thus, the objective of this study is to investigate the relationship between computerization of Italian farms and its determinants through a multiple linear regression. This paper is organized as follows. After a brief literature overview of the worldwide precision agriculture market in section 1, section 2 factors present the most common factors affecting technology adoption in agriculture; section 4 introduces the methodology and the case study. Section 4 then discusses the results. Finally, section 5 presents our conclusions.

1. PRECISION AGRICULTURE MARKET: A FUTURE PERSPECTIVE

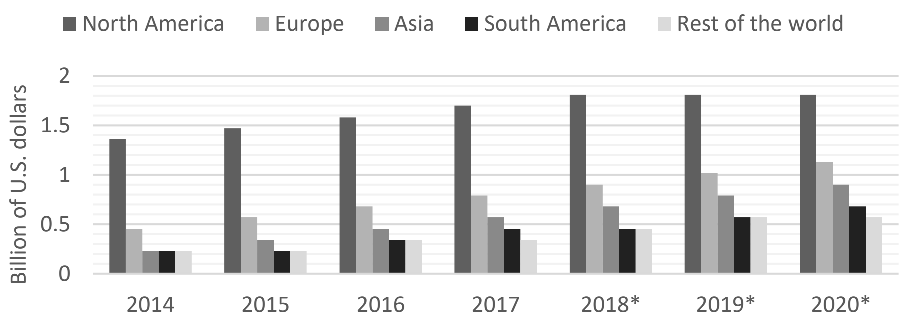
Smart agriculture is a trend topic in the academic research (Pallottino et al. 2018) as well as it is becoming an increasingly commonplace among farmers (Fountas et al., 2015) and high-tech farming with sensors is quickly becoming standard practice. This positive trend can be found by assessing the increasing development of the PA market: according to Markets and Markets report 2018, Precision Agriculture market is expected to grow from approximately 5 million U.S. dollars in 2018 to 10 billion U.S. dollars by 2023 with an increase of 50% (Figure 1).



(Source: MarketsandMarket, 2018)

Figure 1. Forecasted market value (*) of precision farming worldwide (2018- 2023)

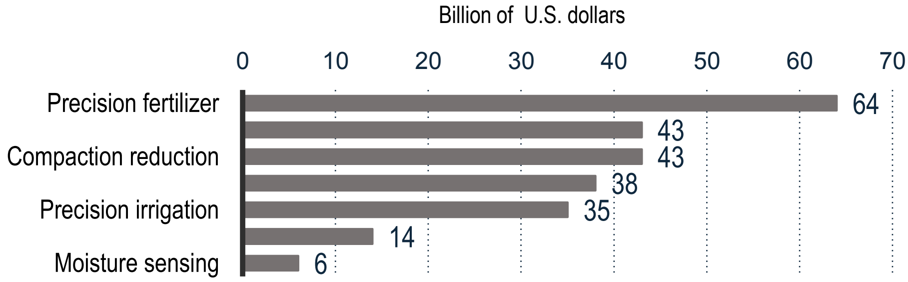
The rapid growth of the precision farming market can be attributed to various factors, such as the increasing adoption of automation and control devices and sensing and monitoring devices by farmers. It is also expected that the cost of precision farming technology will decrease in the next couple of years, mainly because of the declining prices of major hardware components. As a result, the precision farming market is expected to witness high growth during the forecast period. North America accounted for a major share of the smart agriculture market, followed by Europe and Asia (Figure 2), even if these technologies are spreading among the Developing Countries such as Brazil, Argentina, India and Malaysia. Moreover, in the next future, China is estimated to become the worldwide leader.



(Source: Bergers, 2014)

Figure 2. Forecasted (*) market size of precision farming worldwide (2014-2020)

The precision farming technique depends on specialized equipment, IT, and software services. This farming technique involves a broad range of technologies including robotics & automation, imagery & sensors, and big data, as well as digitization. From a technological point of view, PATs solutions with a wider growth expectancy on the market are expected to be those technologies related to the field phase, such as precision fertilizer and precision planting (Figure 3). The adoption of site-specific crop management would reduce the cost of nitrogen fertilizers, improve crop yields, reduce the usage of pesticides, provide better farm records that are essential for sale, and provide better information for management decisions (Grand View Research, 2018).



(Source: Goldman Sachs, 2016)

Figure 3. Estimated addressable market for precision farming worldwide by 2050 by technology

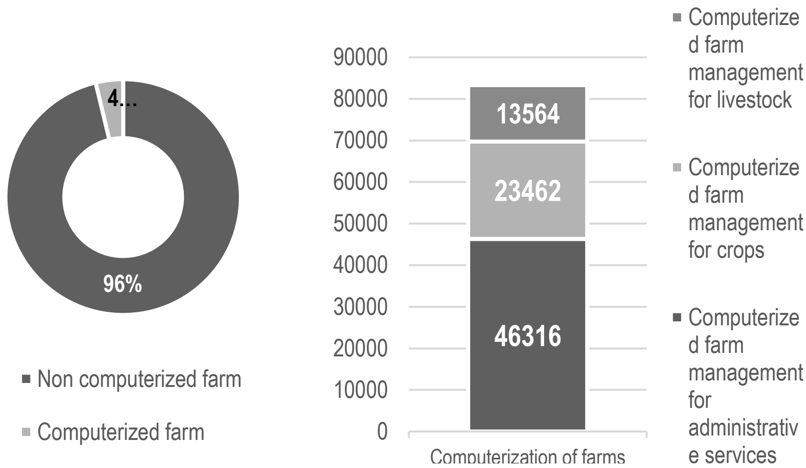
The biggest players in the Precision Farming market include the amerincan companies Americans Deere & Company (US), (Trimble) (US), AGCO (US), AgJunction (US), Raven Industries (US), AG Leader Technology (US), Precision Planting (US), SST Development Group (US), Teejet Technologies (US), Topcon Positioning Systems (US), DICKEY-john Corporation (US), CropMetrics (US), Agribotix (US), The Climate Corporation (US), Descartes Labs (US), Autocopter Corp (US), Granular (US), Autonomous Tractor Corporation (US), Decisive Farming (Canada) and the European companies such as DeLaval (Sweden), GEA Group (Germany), ec2ce (Spain), Gamaya (Switzerland). According to the Global Precision Farming Market Research Report (2018), only 20% of the total acreage in the United States and 58% of the producers implement precision agricultural technologies. To date, compared to the United States, the use of Precision Agriculture technologies is still limited in Europe and Italy. Nevertheless, this value is strongly affected by the size of the farms, with higher benefits for larger farms because of economies of scale. European farms are considerably smaller than USA farms with an average of 175 ha in the USA compared to just 16 ha in Europe (Census of Agriculture 2012; Eurostat Farm structure statistics 2013), and size is believed to be one of the causes of a low diffusion of PA technologies in Europe (Carli et al., 2017).

2. FACILITIES AND BARRIERS INFLUENCING THE ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN AGRICULTURE: A BRIEF OVERVIEW

Precision agriculture is designed to help making the agricultural production a more sustainable activity. Policy makers, farmers' organisations and technology providers believe that, if farmers use precision agriculture they will improve on their economic performance and farms activity, while maintaining the whole sustainability of their activity. Precision agriculture is a win-win strategy, even if that is true that the adoption of precision agriculture still happens slowly. This occurs because in the choice to adopt technologies, farmers do not only base solely on the net benefits of the investment in technology, but also on perceptions related to innovation and social factors (Long, and Coninx, 2016; Carli et al., 2017). Accordingly, it is important to improve our understanding of how and why farmers come to the decision to adopt PA technologies. To delve into this issue, a brief overview of the factors affecting the use of technological innovations is carry out. An exhaustive classification of the factors that most determine the adoption of PATs has been provided by Tey and Brindal, (2012). They grouped factors within seven categories: (1) socioeconomic factors, (2) agro-ecological factors, (3) institutional factors, (4) informational factors, (5) farmer perception, (6) behavioral factors and (7) technological factors. Another study developed by Long et al., (2016), illustrates the key barriers that need to be overcome for the spread of precision farming technologies, applied in the European agricultural context. According to this study, there are both barriers for the technology user, in our case the farmers, and barriers for the technology providers. One of these, can be identified with the market, where a technological innovation is having to compete against established products (Costa-Campi et al., 2014). In addition, current policy or administrative systems may not be supportive of technological innovations, especially where they represent a radical innovation (Weiss and Bonvillian, 2013). The adoption of precision agriculture has shown to positively affect the performance of farms, even though its benefits vary according to the size of farms and their location: PA has been relatively widely adopted by larger farms in Central and Northern Europe, the USA and Australia, where the main reason to adopt Precision Agriculture is to maximize profitability. The adoption of Precision Agriculture is challenged by differences in geographical location/climate, cropping systems, technical developments, social issues, diversity in field sizes and farm scale and diversity of farm and production-chain structures. The applications of precision farming create new business opportunities and work for highly skilled persons offers a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection, on-farm quality of life, and rural economic development. (Lombardo et al., 2017). Despite these advantages, precision agriculture is adopted only by innovative farmers and the intelligent usage of precision farming data is still rather limited. Adoption of precision farming in southeast Europe, including Italy, has been very low due to the small size of farms, infrequent contact of farmers with new technology, no awareness of the precision agricultural practices, and the high cost of initial investment. Italy started to embrace precision farming techniques and several research activities are being carried out (Costa et al., 2018). In Italy, where it has been spreading throughout the country for some years, precision farming is mainly used in vineyards, hazel groves, cereal crops, tomatoes and rice fields (Pallottino et al., 2018). The complexity of precision farming is, in part, due to a required change in the mode of working for farmers, transitioning from experiential decision-making to data-driven processes, and this causes uncertainty around the potential costs and benefits of the technology (Kutter et al., 2011).

3. DATA AND METHODS

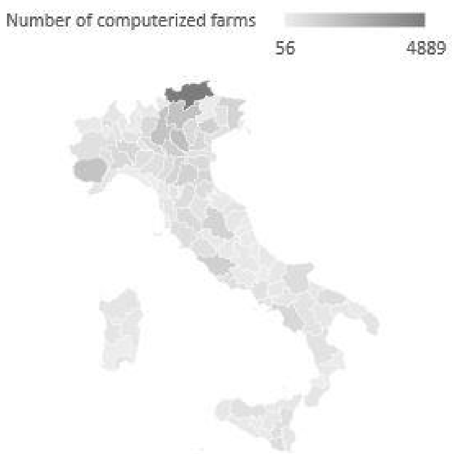
One of the main difficulties of this study is related to the lack of an official statistic on the diffusion of precision agriculture in Italy because of there is currently no official census of precision farmers in Italy. Nevertheless, there are many examples of cases study on the application of precision farming techniques (Mazzetto et al., 2010; Castaldi et al., 2017; Altobelli et al., 2018; Lundström and Lindblom, 2018). To overcome this limit, starting from the major factors that influence technologies adoption in agriculture, found in the previous literature, we estimated the technological innovation of farm, starting from data related to computerization of farms in the ISTAT database, (2010) assuming that a computerized farm is more inclined to use precision agriculture technologies. In fact, according to literature since computer technology is the integral part of precision agriculture (Roberts et al. 2004), the computer use is a predictor for the adoption of PATs (Daberkow and McBride, 2003; Isgin et al. 2008). According to Istat, computerization, understood as the computerized management of business processes, concerns only 4% of Italian farms (Figure 4).



(Source: Authors' elaboration based on ISTAT 2010)

Figure 4. Computerized farms in Italy

Computerization is more frequently used for the management of administrative data (56%), crops (28%) and livestock management (16%). Computerized farms are more concentrated in the North of Italy. The top 10 provinces for the largest number of computerized farms in their territory, are Bolzano, Torino, Verona, Trento, Brescia, Cuneo, Mantova, Roma, Treviso and Bologna (Figure 5).



(Source: Authors' elaboration based on ISTAT 2010)

Figure 5: Computerization of farms by province

In order to identify the determinants of computerization of farms, a multiple linear regression method was applied. A regression analysis is useful to understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. In our analysis "Computerization", mean as the number of computerized farms by province, was taken as the dependent variable; while the following factors, related respectively to the farms and farm owners' characteristics, were put in the model as independent variables:

1) Farm's characteristics:
    - Farm's size (sizes class: 0 - 9.9 ha; 10 - 29.9 ha; 30 - 49.9 ha; 50 -99.9 ha; > 100 ha)
    - Production Standard
    - Internet access
    - Web Page
2) Farm owner's characteristics:
    - Age (Number of farm owners by age: < 40; 41 – 64; > 65)
    - Educational level (primary or middle school diploma; diploma or degree)
    - Sex (Male; Female)

For each variable, 110 observations were collected, corresponding to the number of Italian provinces, according to Istat (2010). The general model can be written as follows:

$$Computerization_{Farms} = f(Size\ 1 + Size\ 2 + Size\ 3 + Size\ 4 + Size\ 5 + Production\ Standard + Internet\ access + Web\ page + Age\ 1 + Age\ 2 + Age\ 3 + Ed\ Lv\ 1 + Ed\ Lv2$$

Descriptive statistics of the independent variables are reported in Table 1.

Table 1: Descriptive statistics

Independent Variable	**Description**
Size 1	Number of farms by province for size class (0 - 9.9 ha)
Size2	Number of farms by province for size class (10 - 29.9 ha)
Size 3	Number of farms by province for size class (30 - 49.9 ha)
Size 4	Number of farms by province for size class (50 -99.9 ha)
Size 5	Number of farms by province for size class (> 100 ha)
Production Standard	Production standard by province (€)
Internet access	Number of farms by province with Internet access
Web page	Number of farms by province with a web page
Age 1	Number of farm owners by age < 40
Age 2	Number of farm owners by age 41 - 64
Age 3	Number of farm owners by age > 65
Level 1	Number of farm owners by province without higher qualification, with primary or middle school diploma
Level 2	Number of farm owners by province with diploma or degree
Male	Number of male farm owners by province

Female	Number of female farm owners by province

(Source: Authors' elaboration, 2018)

4. RESULT AND DISCUSSION

Table 2 shows the results of the regression model. Factors affecting successful adoption of management information systems in farms are: (1) Internet access, (2) Web page, (3) Production standard, (4) Age1 and Age 2, (5) Educational Lv 1 and Educational Lv 2.

Results indicated that Internet access and the use of a web page are the basic requirements which lead to the computerization of farms. Although Standard Production is a significant variable ($p>0.01$), however, the value of its coefficient is very low, highlighting that a variation of 1 of the computerization, would bring about almost zero variation in standard production. On the other hand, the farm size (Size) does not seem to have any influence on computerization. But the most interesting results concern the characteristics of the farm owner. Age and educational level have been shown to be significant explanatory factors. In particular, old age has a negative relationship with the adoption of computerization. There is a significant difference ($p>0.01$) in adult (Age 2) and old (Age 3) farmers 'propensity to computerization: the respective coefficient indicate that adult farmers had, slightly, more familiarity with technologies than old farmers. Similarly, farmers' level of education significantly affects ($p>0.01$) the computerization of farms: farmers with a degree or diploma (Education Lv 2) are more likely to computerize the company compared to the others, with a lower Educational level (Education Lv1). This has been considered a consequence of older farmers having shorter planning horizons, diminished incentives to change and less exposure to PATs (Roberts et al. 2004). Younger higher educated farmers, in contrast, have a longer career horizon and are more technologically orientated (Larson et al. 2008). They may be more motivated to try PATs than their older counterparts. The results would thus appear to be consistent with one of the oldest social science theories, the theory of diffusion of innovations, by Rogers (1962), innovation does not happen simultaneously in a social system; rather it is a process whereby some people, the innovators, are more apt to adopt the innovation than others, the laggards. Innovators are willing to take risks, have the highest social status, have financial liquidity, are social and have the closest contact to scientific sources and interaction with other innovators. On the opposite side, the laggards, with the lowest social status are the oldest among the adopters, and they typically have an aversion to change-agents and tend to be focused on traditions. These two figures seem to perfectly embody the existing gap between young and old farmers.

Table 2: Factors affecting the computerization of farms

Variable	**Coefficent**	**Standard Error**	**P value**
constant	-125.3377	59.01071	0.036
Size 1	-.9011169	.816197	0.272
Size 2	-.9220556	.8155177	0.261
Size 3	-.4716435	.8221719	0.568
Size 4	-1.119548	.9000788	0.217
Size 5	-1.098680	.8450861	0.197
ProdStand	4.99E-07	5.57E-08	0.000**
Internet	1.114382	.2994532	0.000**
Webpage	.3182767	.1473278	0.033*
Age 1	-.038447	.677071	0.571
Age 2	.0002502	.00008	0.002**
Age3	-.0782089	.0273704	0.005**
Education Lv 1	.0092728	.026198	0.724
Education Lv 2	.0709397	.0263702	0.008**
Male	.9171631	.8238685	0.268
Female	.8234216	.8228139	0.320
R^2	0.9059		

Note: Asterisks denote levels of significance * $p< 0.05$ ** $p< 0.01$

(Source: Authors' elaboration, 2018)

5. CONCLUSION

Technological development and digitization make possible big leaps in resource efficiency enhancing an environment and climate smart agriculture which reduces the environment-/climate impact of farming, increase resilience and soil health and decrease costs for farmers. However, the uptake of new technologies in farming remains below expectations and unevenly spread throughout the EU, and there is a particular need to address small and medium-sized farms' access to technology. Farmers recognize that the only way to remain competitive is to improve the sustainability of this sector: this requires technological innovation at all stages and aspects of the food supply chain. To facilitate AP adoption, policies initiatives have been fostered in Europe countries since the 2000s: European Innovation Partnership "Agricultural Productivity and Sustainability" (EIP-AGRI), Digital Agenda for Europe, Agriculture 4.0 are just the most recent examples of policies for innovation which are stated to address social, environmental, as well as economic issues. The application of Precision Agriculture solutions seems to depend on some key factors including socioeconomic factors, agro-ecological factors, institutional factors, informational factors, farmer perception, behavioral factors and technological factors. One of the main reasons for low AP adoption is the resistance of farmers to investing economic resources in technologies that they are not able to use. The existence of information asymmetry between supply and demand clearly emerges, which does not allow us to fully grasp these aspects, thus becoming an obstacle to the spread of Precision Agriculture. Machinery and equipment are increasingly technologically advanced and (potentially) integrated, but often farmers lack information and technical expertise to consciously choose the most appropriate solutions for their farms. This paves the way for wrong investments, which in turn feed the cultural barriers towards. This aspect could represent a challenge for technology companies to develop "farmer-friendly solutions", more affordable and easy to use. In addition, results of our study indicate that the level of farms computerization, which is the precursor factor of PAT adoption, it is more closely linked to the socio-economic characteristics of the farm's owners, in particular, it depends from the level of education and the age. It is expected that those innovative farmers will be the ones most likely to adopt in the future precision agriculture technologies. Further research may focus on other variables, to better understand farmers' attitudes and willingness to adopt such technological tools.

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Chapter 3

Measuring a farm's profitability after adopting precision agriculture technologies: A case study from Italy

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ABSTRACT

Precision agriculture (PA) offers the opportunity for farmers to improve both efficiency in managing resources and optimisation of process inputs, thus increasing their whole farm's profitability. Despite these well-known benefits, the adoption of PA technologies (PATs) is still challenging due to socio-economic barriers and unique characteristics of the farms: cropping systems, technical developments, field sizes and farm scale. The economic aspect is undoubtedly one of the most important aspects to consider before adopting PATs. In most of the cases, farmers are reluctant to introduce precision farming systems since the costs and uncertainty about the profitability and advantages need to be addressed. This study aims to explore how PATs could affect the profitability of a representative Italian farm specialising in the production of cereals, making this a case study. In detail, an economic analysis was applied to determine the profitability of the farm, which showed that the adoption of PAT's increased the yield of durum and soft wheat and significantly reduced the cost of mechanical operations and technical means. Therefore, the potential gains from the adoption of PATs challenges policymakers to design targeted interventions which could encourage their uptake. This paper is an extended version of the original contribution presented to the 2019

IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor) in Portici, Italy.

Keywords: Precision Agriculture, Measurement; Cost-benefit analysis; Profitability, Case study research

1. INTRODUCTION

As a means of producing on-site data to guide decision-making, precision agriculture (PA) is a whole-farm management approach that allows for managing crops growth for better yield and quality through measuring physical parameters and collecting data [1]. Starting in the 1990s, several definitions of PA have been given in the literature, [2]-[6], but all the authors agree that this practice allows the site-specific management of the agronomic inputs and practices within a field through accurate measurements [7]. In detail, we can consider PA as integrated information and as a production-based farming system, designed to deliver high-end technology solutions to increase farm production efficiency and profitability while minimising environmental impacts. PA technologies (PATs) are all those innovations that incorporate recent advances in modern agriculture, providing evidence for lower production costs, increased farming efficiency and reduced impacts. Accuracy and precision are two relevant factors to consider when taking data measurements. They both reflect how close a measurement is to an actual value, but accuracy refers to how close a measurement is to a known or accepted value, while precision reflects how reproducible measurements are.

For a long time in the field of PATs, digital devices, which can take more accurate and precise measurements, generally corresponded to higher investment costs. This economic constraint initially caused a limited diffusion of PA. Today, however, there are a wide range of different low-cost devices is available on the market that allow for meeting measurement accuracy requirements. Further, policymakers at the national and European level have established a set of measures and initiatives to encourage and facilitate the purchase and use of digital technologies, including PATs, throughout the agri-food supply chain (Figure 1).

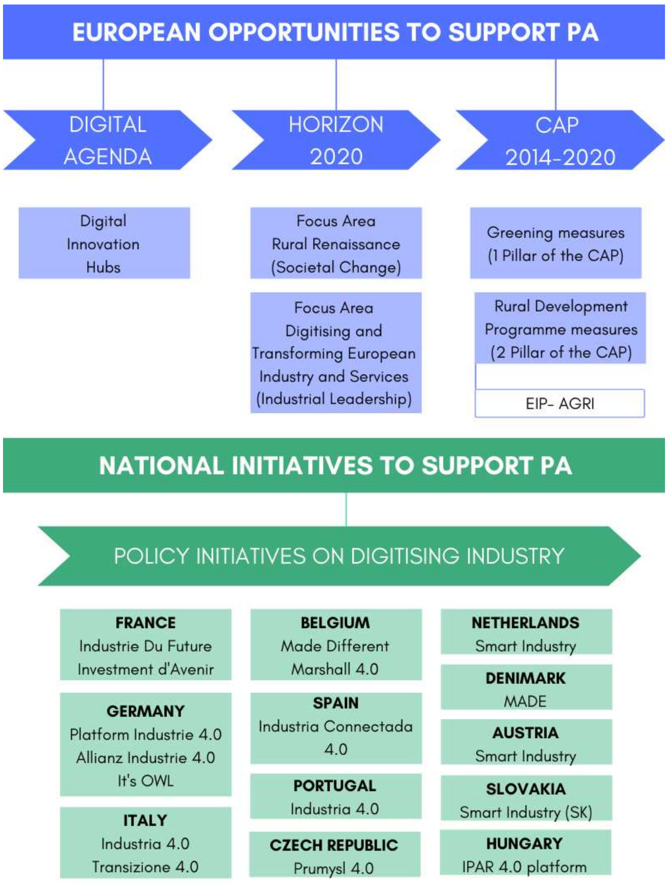

Figure 1. Policy instruments for PATs adoption

From European level, on 19 April 2016, the European Commission launched the first industry-related initiative known as the Digital Single Market strategy, part of the Digital Agenda, aiming to make the agriculture sector and rural areas of Europe digitised and data-empowered. Another fundamental contribution to the diffusion of these technologies is mainly provided under Horizon 2020 through the Societal Challenges and Industrial Leadership pillars.

However, when we refer to implementation and adoption of PATs by end-users, and then by farmers, this is mostly channelled through the EU's Common Agricultural Policy (CAP). For instance, different rural development measures under pillar II of CAP can foster the development of these technologies. PA can contribute to meeting the requirements put forward within the greening measures (pillar I of CAP) in which farmers receive payment to undertake practices that benefit the environment and the climate.

At the national level, each member state of the EU has developed Industry 4.0 policies to strengthen industrial competitiveness and modernise the manufacturing and agriculture sectors. This policy especially supports the digitalisation of agriculture based on the development and introduction of new tools and machines in the production process.

However, even if there are affordable PATs available on the market and policy support for the acquisition of the technologies, the application remains circumscribed at few farms. In fact, in addition to the cost of investment, the adoption of the PATs has encountered other difficulties, such as additional application or management costs and investment on new equipment, employee training for using the technologies and uncertainties found within the farming community [8]-[14]. Given these premises, this paper discusses the economic benefits of PA, as they concern the accuracy of the measurements taken by different technologies, while trying to answer the following question: "What is the economic effectiveness deriving from the adoption of high-accuracy PATs?". To reach this goal, we attempt to quantify the economic benefits of PA based on a case study – a representative cereal farm in central Italy that manages the whole-farm system with a mixed approach of conservation agriculture and precision farming. The case study method allows researchers to explore and investigate a contemporary real-life phenomenon through a detailed contextual analysis of a limited number of events or conditions and their relationships. The methodology adopted for evaluating the profitability, the cost–benefit analysis, derives from the introduction of PATs. This paper extends a previous study presented during the 2019 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor) in Portici, Italy. Here, a more extensive and detailed economic analysis is provided by the authors. The remainder of the paper is organised as follows: section 2 shows the primary precision farming tools and their adoption. Section 3 presents a brief literature review on the profitability of PA. Section 4 provides the methodology and data, and section 5 discusses the results. Finally, the conclusions and some policy implications are detailed in section 6.

2. PRECISION AGRICULTURE TECHNIQUES AND TECHNOLOGIES

Rather than referring to the development of new digital technologies, PA refers to the need to collect geo-referenced information necessary to monitor or manage spatially variable agricultural fields. In fact, PA is a management concept based on observing, measuring and responding to intra-field variability in crops through the use of technology. PATs allow farmers to recognise variations in the fields and to apply variable-rate treatments with a greater degree of precision than before [15]-[16]. The management of PA can be divided into four phases (Figure 2):

1. Understanding and identifying variability
2. Determination of homogenous zones
3. Decisional Phase
4. Agricultural Operation Management

Each of these phases requires specific technology. To achieve a better understanding of within-field variability, there is a set of different instruments and tools that allow farmers to generate and manage big data from the field. The development and implementation of PA has been made initially possible by combining the Global Positioning System (GPS) and geographic information systems. These technologies allow the combination of real-time data collection with positional information. Remote and proximal sensing are the two most common techniques used for the acquisition of information related to variability within crop fields. Satellite, airborne or UAV platforms, using different type of cameras, are the most popular technologies used in agriculture.

In terms of proximal sensing, in which the sensor is close to the object to be monitored, it is possible to directly analyse soil and crop data in real-time. Typical examples of proximal sensing are as follows:

- Watermark and Sentek soil moisture sensors – used measuring soil humidity.
- The Green Seeker system – used to measure the normalised difference vegetation index and to quantify crop variability via optical sensors;
- On-harvester grain quality sensors – sued to estimate protein, oil and moisture within the grain by using infra-red spectroscopy.

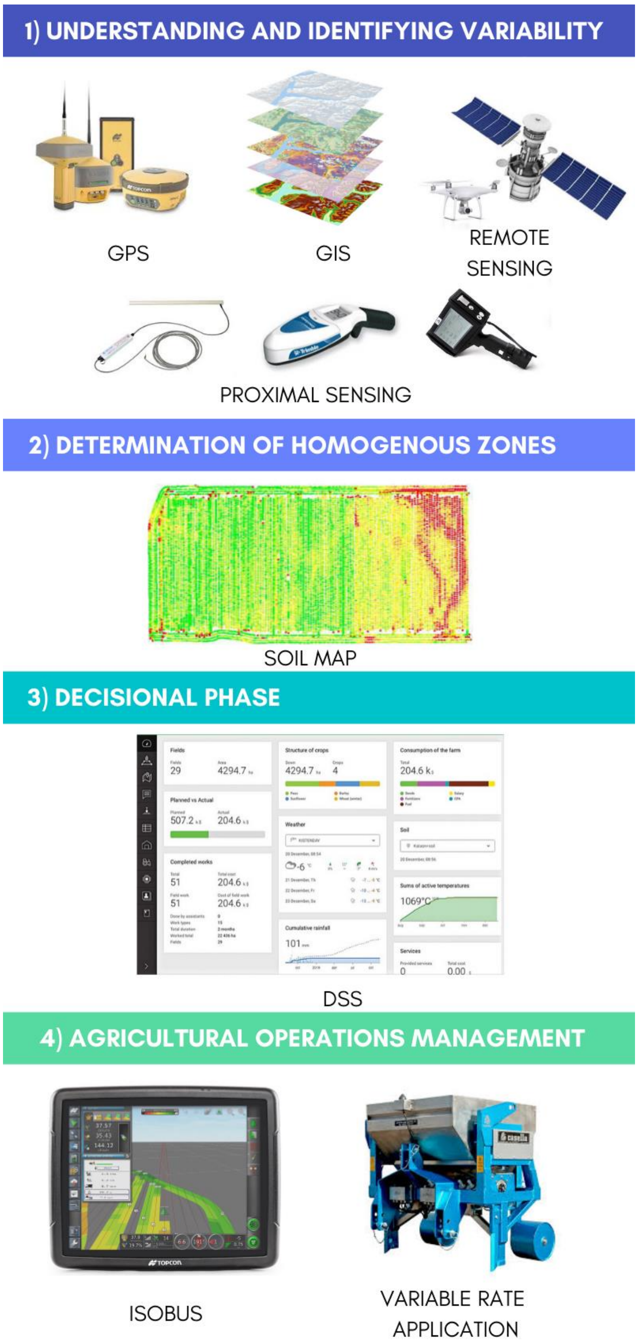

Figure 2: Technologies for Precision Agriculture

By collecting this data from different sensors, farmer can be aware of the spatial and temporal variability of the fields, as represented through maps, and it is possible to recognise homogeneous areas within a field that could be treated in a diversified way. All the data collected from the sensors and maps can be stored in a decision support system (DSS), a software-based system that allows farmers to analyse all the agricultural data and consider them as inputs for the decision-making process [17]. After the decision phase, the farmer is therefore ready to intervene in the field through the use of advanced agricultural machinery with serial control and communications data network (commonly referred to as "ISO Bus" or "ISOBUS"), the standard protocol that makes it possible to manage the communication between tractors, software and equipment of major manufacturers, allowing the exchange of data and information with a universal language through a single control console in the tractor's cab [18]. Another suitable application for agricultural operations management is variable-rate technology, which provides the capability to vary the rate of soil- and crop-applied inputs for site-specific applications. These technologies consent the recording of spatial differences in relevant factors to crop growth, such as the quality of soil, availability of water and fertilisers, and crop yield. This greatly improves the efficiency of resources and adjustability of biological-technical systems as well as leads to reduced waste of inputs.

Other studies highlight how positioning accuracy represents a key factor for the precise management of agricultural operations [19], [20]. In the engineering field, accuracy refers to how close a measurement is to the true value, but a more rigid definition is applied by the International Organization for Standardization (ISO), which defines accuracy as a measurement with both true and consistent results. The ISO definition means that an accurate measurement has no systematic error and no random error. A key component of the precision farming management approach is the use of a wide array of digital devices that allow taking accurate agricultural measurements, including GPS guidance, sensors, control systems, robotics, drones, autonomous vehicles, variable rate technology, GPS-based soil sampling, automated hardware, telematics and software.

PA applications can be classified into three categories, taking into account the different degree of accuracy in the positioning systems [21]:

- Low accuracy (meter level) – used for asset management, tracking and tracing;

- Medium accuracy (sub-meter level) – used for tractor guidance, via manual control, for lower accuracy operations such as spraying, spreading, harvesting bulk crops and area measurement/field mapping;
- High accuracy (cm level) – used for auto-steering systems on tractors and self-propelled machines, like harvesters and sprayers.

These technologies also differ in cost and the knowledge or skills required to use the tool. Proximity sensors, depending on the type of sensor, have a commercial price between 50–60 € (Watermark sensor) up to 1,000 € (Sentek Sensor). A drone for professional agricultural use has an average cost of 5,000 €, while a tractor ISOBUS application via the automatic steering systems can cost up to 20,000 €. Considering these relatively high costs and the skills needed to manage technologies, which not all farms still have, technology providers are increasingly making these technologies available as services. This is the case for yield maps or DSSs, which are generally made available in the form of annual fees, depending on the services requested. The use of technologies as a service is a way to reduce the costs of technology and to spread their use among farmers who possess knowledge gaps regarding management of the equipment.

Focusing on the adoption of PATs at worldwide level, the US is the top player in this sector, followed by Australia and Canada. Nevertheless, the percentage of PA adoption has increased in Europe, with a rate of 15–20 %. Based on region, the EU PA market is segmented into the UK, Germany, Spain and France. In Italy, only 1 % of the agricultural surface is managed through precision farming techniques.

The work of [22], focused on the level of adoption of PA among Italian farmers, showed that PATs adopters were characterised by an average farm size of 143 ha, showing that farmers are more likely to manage big farms with AP. In line with these results, it is possible to highlight that PA follows the model of a capital-intensive technology, characterised by both high entry and large fixed transaction costs, and by an overly long payback period. However, although the adoption rate of technology among farmers is still low due to these socio-economic barriers [23]-[26], the market for smart agriculture technologies is growing since technology providers are increasingly developing solutions that can cover the entire field of the agri-food supply chain (AFSC). In particular, most of the solutions cover the first step of

AFSC, the production phase, from cultivation to storage of the product to processors. According to a recent survey, currently, the available technologies on the market are those that support the growing phase of the crop (79 %) followed by seeding/plantation phase (37 %) and harvesting (33 %) [27].

The most widespread technologies on the market are related to the soil mapping (29 %), machine control (27 %) and precision interventions (21 %), such as planting, fertilising and distributing pesticides. The remaining part of these technologies are reserved for farm and crop management and monitoring (18 % and 5 %, respectively). The main crops treated with PA are fruit and vegetables (38 %), cereals (35 %), grapes (23 %) and olives (4 %) [28]-[30]. For fruit and vegetable crops, machine vision methods allow growers to grade products as well as monitor food quality and safety with automation systems recording parameters related to product quality (colour, size, shape, external defects, sugar content, acidity, etc.). Additionally, the tracking of field operations, such as the chemicals sprayed and use of fertilisers, can provide for a complete fruit and vegetable processing method. The use of PATs on arable land is one of the most successful applications and is the most advanced amongst farmers. The technology allows farmers to control the number of inputs in arable lands, such as the optimised amounts of fertilisers like nitrogen, phosphorus and potassium. The development and adoption of PATs and methodologies in grape and olive orchards are more recent than in arable lands. For these high-value crops, precise irrigation methods are developing rapidly to save water while improving yields and fruit quality; for example, grape quality and yield maps are of great importance during harvest to avoid mixing grapes of different potential wine qualities [31]. The "Guidelines for the development of precision agriculture in Italy" [32] calls for expanding management through precision agriculture to up to 10 % of the agricultural area cultivated nationally by 2021. Therefore, it becomes essential to identify the factors limiting their diffusion and to analyse profitability from using these technologies.

3. THE PROFITABILITY OF PRECISION AGRICULTURE: A BRIEF REVIEW

Three different PA research focus areas are represented in the literature [33]: studies aiming to prove the profitability and the positive environmental impacts of PA [34]-[38], studies investigating the technical aspects of product development and process improvement, and studies focusing on the implementation of PA at the single-farm level. In the first research focus area, PA has the potential to help farmers improve input allocation decisions, thereby lowering production costs or increasing outputs and, potentially, increasing profits. However, there is still scant knowledge about the relative magnitude of the overall costs and benefits of PATs on individual farms.

Previous studies [39]-[44] tried to evaluate the savings and revenues caused by PA, but only by considering either the average savings from the application of a single technology or a specific growth phase of the crop (Table 1)

According to [45], the impact of PATs on agricultural production is expected in two areas:

- Profitability for farmers;
- Ecological and environmental benefits to the public.

However, both the profitability and the environmental benefits of PA continues to be difficult to predict, evaluate and measure [46], [47]. According to the literature, the profitability of PA depends on different aspects, including farm size, the type of crop, the technology adopted, the degree of spatial variability of soil attributes (e.g. soil types, fertility and organic matter) and yield response [48]-[53]. Studies on PAT adoption emphasise that adopters tend to operate a larger agricultural area and subsequently generate a higher income. This indicates the ability to accommodate some risk in investment of newer and larger technologies. Some studies have highlighted that farms specialising in high-income crops, such as vineyards and olive groves, are more likely to adopt PATs.

The major benefits of PA management derive from the increase of crop yields and reduced inputs as well as more efficient farm management with improved communication possibilities and higher quality of work with machine-guided systems. The implementation of precision farming concepts may mitigate production risks because inputs are applied only where they are needed. While risk mitigation with precision farming is intuitive, the implementation of precision farming typically requires substantial investments that may increase financial risk [54]. Investments in precision farming are further associated with the irreversibility of the capital cost, which should be taken into account where appropriate; farmers might prefer to wait for better information on the costs and benefits of the new technology before investing in precision farming technologies [55]. While the costs of precision farming technologies can, inmany cases, be estimated precisely, it is more challenging to evaluate the benefit of the system in management

Table 1. Economic benefits of PA

Year	**Author**	**PATs**	**Case study**	**Crop**	**Average savings**
2000	Bongiovanni & Lowenberg-DeBoer	RTV for fertilisation	USA	Soya and corn	17.60 €/ha
2003	Godwin et al.	Assisted/Semi-Automatic Driving	UK	Arable crops	25 €/ha
2003	Godwin et al.	CTF	UK	Soft Wheat	From 18 to 45.5 €/ha
2009	Biermacher et al.	RTV for fertilisation	USA	Soft Wheat	13.2 €/ha
2010	Wagner et al.	RTV for fertilisation	DE	Soft Wheat	16 €/ha
2011	Robertson et al.	RTV for fertilisation	AUS	Arable crops	9.4 €/ha
2012	Shockley et al	RTV for seeding	USA	Soya and corn	31.67 €/ha

The willingness of farmers to trust the technology is a fundamental behavioural factor in achieving positive results. Several studies found that a low level of trust in the technology could be a key limitation for PAT adoption when compared to other factors. Thus, farmers are waiting for research results on the profitability of various PATs before deciding to invest significantly to adopt new technologies. On the one hand, PA is aimed at large holdings with a farm and capital structure that enables them to invest in expensive systems. On the other hand, it is a means to move farm management back to small-scale farming processes with detailed knowledge about small units and management zones. It enables farmers to treat each unit, whether it is a piece of land or an animal, with the same care as farmers did in previous times. This development is facilitated by the help of smart technologies that allow the farmer to gain detailed knowledge about the field and subsequently treat the field accordingly. Despite these advantages, PA is adopted only by innovative farmers and the intelligent usage of precision farming data is still rather limited. The introduction and uptake of technologies require new skills and knowledge for farmers and advisers. Raising awareness and organising training on a regional/local level is essential, especially to reach small and medium-sized farms where the use of digital technologies is not always thought of as profitable

However, taking advantage of PATs will depend not only on the willingness of farmers to adopt new technologies but also on each farm's potential, in terms of scale economies, since profit margin increases with farm size. This concept is widely explained in the work of [56], which analysed the socio-cultural and complexity factors that affect the probability of an Italian farmer adopting new PATs. The authors found that the farmers most prone to technological innovation all had similar characteristics: big size farms (average dimension equal to 143 hectares) and young managers with the highest level of education.

4. DATA AND METHODS

To determine the profitability of applying PA, a case study was conducted. According to [57], the case study research method is 'an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used.' Due to the limited availability of other cases for replication, in this study, we adopt a single-case design. While not reflecting a statistical representation, a single-case study can contribute to scientific development through a deep understanding of a still-rare context of inquiry, such as that of adopting PATs in the Italian agriculture sector.

Cost–benefit analysis was selected evaluate the economic implications of adopting PATs and was carried out on an innovative farm specialising cereals production located in the centre of Italy. This study, conducted in 2019, takes into consideration durum wheat and soft wheat production on an agricultural area of 537 flatland hectares applying a conservative production system (i.e., sod seeding). The farmer was interviewed and asked to characterise the farming practices before and after the adoption of PATs. Also, specific questions were asked to find out the technological investments. From 2010 to 2016, the farm has invested in highly accurate PATs, costing approximately 184.000 €, to be used to make decisions with greater precision and to optimise crop yields. The main investments include assisted steering (ISOBUS); services for georeferencing, production and soil mapping system; a variable rate fertiliser spreader; machinery for weeding; and treatment with variable dosage distribution. The description of the phases of the cost-benefits analysis are follows:

1) Definition of the time horizon under study:

- 2005–2009 – pre-adoption period;
- 2010–2016 – progressive investment period in the PA technological ‘package’;
- 2013–2017 – post-adoption (progressive) period of the PA package.

2) Definition of average land productivity (both for durum wheat and soft wheat):

- for pre-adoption period (2005–2009);
- for post-adoption period (2013–2017).

3) Definition of a 10-year amortisation schedule (and related constant annual payment) of the PA technology ‘package’. This phase is aimed at defining the annual capital cost of the investment in PA.

4) Definition of the pre-adoption average total cost:

- per hectare (ha);
- per product unit, in tonne (t).

5) Estimation of the post-adoption monetary savings at a level of average total cost induced by PA adoption:

- per hectare (ha);
- per product unit (t).

6) Estimation of the post-adoption average total cost (ATC):

- per hectare (ha);
- per product unit (t).

7) Definition of the market price time series (2012–2019) for durum and soft wheat.

8) Estimation of the operating margin generated by the adoption of the PA package:

- per hectare (ha);
- per product unit (t).

9) Sensitivity analysis on the cost–benefit analysis results so as to evaluate the economic and financial effectiveness of the investment, according to the changes in

- production scale;
- unit product cost;
- land productivity.

5. RESULTS

Comparing the pre-adoption and post-adoption period of PATs, the main empirical evidence is relating to two main issues:

- the variation in land productivity;
- the change in cost.

Relating to the first aspect, as shown in Table 2, an increase in the average land productivity in the post-adoption period is observed.

In particular, the post-adoption land productivity enhancement is considerably greater in the case of soft wheat (+ 23.3 %) compared to the durum wheat (+ 14.2 %). Consequently, we decided to assess separately the supposed effect of PA in terms of economic effectiveness for both durum and for soft wheat.

In analysing the crop yield trends, it is not possible to establish with certainty whether this productivity enhancement is due to the technological change. We are aware that crop productivity is influenced by a complex set of factors, such as climatic conditions or the type of grain variety, certainly not only by the possible introduction of a specific technology.

Table 2: Variation of crop yields over the entire study period

Crop	Pre-adoption 2005/2009 Average yield (tonne/ha)	Post-adoption 2013/2017 Average yield (tonne/ha)	Increase (tonne/ha)	Increase (%)
Durum W.	5	5.71	0.71	14.2
Soft W.	5.93	7.31	1.38	23.3

However, it must be noted that the increase in land productivity is measured over a five-year post-adoption period on average, which is a fairly reliable period to assume the presence of some level of impact from the introduced technology. Indeed, the improvement of crop yields could be associated with both the direct and indirect effects of PATs. The direct effects derive from the optimisation of production processes. The indirect effects derive from greater knowledge about the state of soils and crops. In this way, the farmer can make more timely decisions. In fact, the farmer in this case study stated that the georeferenced mapping of both the farmlands and working time allowed them to quantify how much of the farm area was actually worked upon due to overlapping errors from different cultivation operations. Further, both the mapping of production and the soil analysis allowed the farmer to optimise seeds, fertilisers and herbicides according to the real need of the plants and the productivity of the soils.

To evaluate the effect on production costs due to the introduction of PATs, the pre-adoption and post-adoption ATC have been estimated and then compared. In summary, Table 3 shows a comprehensive picture of the PA cost-benefit analysis results.

The pre-adoption ATC equalled 794.56 €/ha for durum wheat and equivalent to 768.98 €/ha for soft wheat. Further, the average saving (AS) on ATC in the post-adoption period, hypothetically attributable to the cost efficiency of the PATs, was found to be 77.55 €/ha, a cost reduction of 10.08 % on average compared to ATC in the pre-adoption period. In particular, through the use of fertiliser spreaders, machines for weeding and treatments, and seeders with variable dosage distribution, it was possible to reduce the cost of mechanical operations (labour, diesel, lubricants, etc.) and technical means (spreading seeds, fertilisers and pesticides).

Table 3: Cost-benefits analysis results

Cost	Soft W.	Durum W.
ATC pre-adoption (per hectare)	768.98 €/ha	794.56 €/ha
Average saving on ATC (per hectare)	- 77.55 €/ha	- 77.55 €/ha
Incidence capital cost (per hectare)	44.08 €/ha	44.08 €/ha
Incidence capital cost (per tonne)	6.0 €/tonne	7.7 €/tonne
Average saving on ATC due to PA cost efficiency (per hectare)	- 33.47 €/ha	- 33.47 €/ha
Average saving on ATC due to PA cost efficiency (per tonne)	- 4.6 €/tonne	- 5.9 €/tonne
Total average saving on ATC (per tonne): cost efficiency plus productivity effect	- 29.0 €/tonne	- 25.5 €/tonne
ATC pre-adoption (per tonne)	**129.6 €/tonne**	**158.6 €/tonne**
ATC post-adoption (per tonne)	**100.7 €/tonne**	**133.1 €/tonne**

However, in order to evaluate the net savings due to PA adoption, the capital cost (CC) of the technology introduced has to be estimated and then discounted from the average savings on the operating production costs. Thus, a 10-year amortisation schedule at a 5 % annual interest rate (plus related constant annual payments) of the introduced PATs package has been calculated. We calculated a CC of the total investment in PATs to be 44.08 €/ha, calculated based on the agricultural area invested in the cereal production within the case study, i.e. 537 ha. We then calculated the net savings (NS) per hectare on the production cost, hypothetically due to the technology package introduced, as follows:

AS – CC = NS = 33.47 €/ha (1)

Thus, when CC is deducted from the total cost reduction (or AS) between pre- and post-adoption ATCs, a reduction of 10.08 %, the total NS is 4.3 %/ha. The first interesting notion is that this net effect of PA in terms of cost efficiency is relatively modest and in line with the previous studies examined in the literature review. A possible explanation is the fact that the case study farm is an entrepreneurial farm, already fully functional before PA adoption with a high level of efficiency with respect to the cost of production per unit of land. That said, the most significant effect attributed to PA seems to concern productivity.

Finally, to measure the net gains per unit of production in the post-adoption period, the operating margin (OM) per tonne of production has been calculated as the percentage difference between the average revenue (AR) – corresponding to the average market price for the period considered – and the ATC as follows:

$$OM (\%) = (AR - ATC)/AR \quad (2)$$

Table 4 shows the main indicators from the PA cost–benefit analysis. The OM increases from 40.5 % in the pre-adoption period to 50.1 % in the post-adoption period for soft wheat while it increases from 42.9 % in the pre-adoption period to 55.7 % in the post-adoption period for durum wheat. This performance is due almost entirely to the increase in land productivity registered for the post-adoption period.

Table 4: Main economic indicators

Indicators	**Soft W.**	**Durum W.**
Land productivity increase post-adoption	23.18 %	14.13 %
Average saving on ATC (%)	10.08 %	10.08 %
Average saving on ATC (%) net of the CC	4.3 %	4.3 %
Total average saving on ATC (per tonne): cost efficiency plus land productivity effect (%)	- 22 %	- 16 %
OM per tonne (%) pre-adoption	**40.5 %**	**42.9 %**
OM per tonne (%) post-adoption	**50.1 %**	**55.7 %**

Net gains in monetary terms pre-adoption	114.8 €/tonne	98.7 €/tonne
Net gains in monetary terms post-adoption	140.3 €/tonne	127.7 €/tonne
Net gains in monetary terms due to PA	**25.49 €/tonne**	**28.97 €/tonne**

The OM is the summary result of this cost–benefit analysis; therefore, it seems important to offer some assessments on the basic meaning of this measurement. Looking at Figure 3, it is possible to visualise in a comparative way the net gains derived from the production of wheat in the pre-adoption period and the post-adoption period. The first interesting note is that we analyzed a farm able to generate income both for the pre-adoption (thus regardless of the PA adoption) and the post-adoption period respect to Italian conventional cereal farms that are rarely effective. The second interesting note is that in the post-adoption period, the NS increases, in monetary terms, by 9.6 % for soft wheat and 12.8 % for durum wheat.

This means, in absolute terms, the net gains in monetary terms is higher in the case of soft wheat (in both the pre-adoption and post-adoption periods). The increase of the operating margin due to PA (in %) for durum wheat could be due to a more favourable average level of the durum wheat market price in the post-adoption period (as compared to the soft wheat market price).

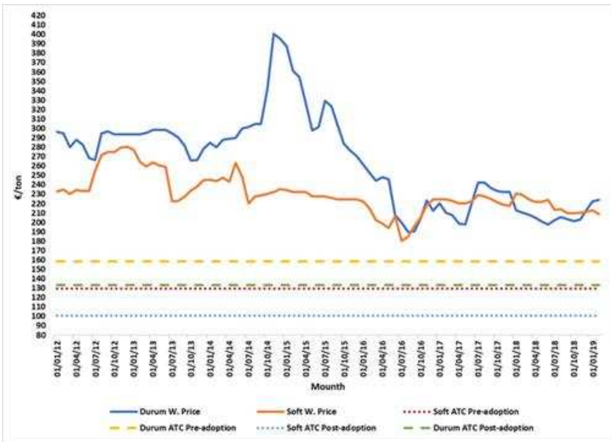

Figure 3: Prices and ATCs for soft and durum wheat

A further consideration which may deserve more attention is the following: the present case study is a cooperative farm that dedicates more than 500 ha to the production of wheat. This means that the farm is a 'large farm' and that it can be roughly considered a case of minimum efficient scale, with respect to a fixed investment like the PATs package. For this specific case study, we observed that the impact of CC on the unit of production turns out to be minimised thanks to the optimal farm dimensions. However, if the farm size decreases, the impact of CC on the unit of product will increase accordingly. This occurs because, as we have verified, the cost of the PATs package can be considered, with good approximation, a fixed cost, not reducible depending on the reduction of the firm size. Based on this hypothesis, we performed a sensitivity analysis to explore the variation of the CC impact on ATC per unit of production with respect to changes in farm size.

The goal of this sensitivity analysis was to identify the minimum farm size needed to balance the farm budget, with respect to the post-adoption market price levels.

Table 5 shows the results of the sensitivity analysis performed on the balanced minimum farm size, assuming as constant all the variables considered in the present case study – i.e., the CC invested in the PATs package, the ATC of production per hectare, the average saving on ATC per hectare and the productivity levels; only production scale changed. The minimum production scale necessary to balance the farm budget appears to be strongly influenced by land productivity. Accordingly, based on a post-adoption soft wheat productivity level that is 22 % greater than durum wheat (7.3 t vs. 5.7 t), the 'virtual' minimum production scale necessary to balance the firm budget results in 60 ha for durum wheat and 30 ha for soft wheat.

Table 5: Minimum farm size in balance

Indicators	**Soft scale 30 ha**	**Durum scale 60 ha**
Incidence capital cost/ha	790.0 €/ha	395.0 €/ha
Incidence capital cost/tonne	108.1 € tonne	69.1 €/tonne
ATC post-adoption (ha)	1,481.4 €/ha	1,112.0 €/ha
ATC post-adoption (tonne)	202.7 €/tonne	194.5 €/tonne

It is interesting to note that the minimum farm size required to balance the budget – in this case, regardless of the distinction between soft and durum wheat – is significantly smaller compared to the size of the real case study farm. This means that PATs could be financially sustainable even for 'medium' production scales when keeping the cost efficiency and productivity levels, as expressed by the study case farm, fixed.

Finally, as a further point of reference related to the minimum production scale necessary to obtain a positive result by adopting PATs, Table 6 illustrates a simulation consisting of the results of a sensitivity analysis to identify the minimum farm size needed to balance the farm budget with respect to PAT adoption by a cereal farm producing durum wheat in a hilly area. Thus, the fundamental analytical elements that distinguish this 'virtual' farm from our real case study are as follows:

- Hilly area (vs. flat land for the case study);
- Minimum tillage (vs. no tillage for the case study).
- Unit cost of production equal to 170 € / t (vs 133.1 € / t for the case study);
- Land productivity equal to 5 t / ha (vs. 5.7 t / ha for the case study)

The results show that the minimum farm size necessary to balance the farm budget is considerably greater than the minimum farm size for the case study farm (200 ha in a hilly area versus 60 ha in a flat area).

This result is indicative of how the economic effect of PATs changes as the environmental conditions, in which the production takes place, change. Particularly, in this hypothetical scenario characterised by minimum tillage of a hilly area, the unit production cost is assumed to be 35 % greater than the unit production cost of the case study farm, and the land productivity level is assumed to be 15 % lower. Based on these results, one can conclude that PA adoption in a hilly area using minimum tillage could be worth the investment only for large farms (> 200 ha) or for cooperative systems capable of bringing together many producers in a common management organisation.

Table 6: Table 5: Minimum farm size in balance in a hilly area

Indicators based on ATC condition of minimum tillage average cost (ha) and hilly area	**Durum 200 ha**
Incidence capital cost/ha	118.5 €/ha
Incidence capital cost/tonne	23.7 €/tonne
ATC cost post-adoption (ha)	968.5 €/ha
ATC post-adoption (tonne)	193.7 €/tonne

6. CONCLUSION

PA may offer important opportunities toward more sustainable agriculture. However, the diffusion of PATs in the agricultural sector is still insufficient due to the scarce knowledge regarding economic and environmental benefits that PATs may have. In this regard, the case study in this work contributes to the body of research aimed at identifying important points of reference for cost-effectiveness and efficiency in PA-derived production inputs. The case study shows how a large farm can effectively exploit the returns to scale associated with adopting PATs packages, generating income as a consequence. Indeed, PA requires a large investment of capital, time and learning. Thus, costs associated with PATs may prevent smaller farms from being able to invest in these technologies. In this context, the farm-scale is a crucial variable in the analysis tools to evaluate the adoption and profitability of PATs. However, insofar as how PATs were able to reconcile production requirements and environmental protection, questions arise on how best to support PA adoption. It is clear that there are still no specific measures for the diffusion of PATs in the agriculture sector, but there are generic measures of sector innovation and digitisation of the agri-food chain.

While several studies have begun to demonstrate the economic effectiveness of PATs, the assessment and quantification of the environmental benefits are almost totally lacking in the literature. Some farmers do consider these benefits as part of their overall viability decision, but this is based upon their personal values. Apart from general qualitative statements, there is no quantified environmental benefit assessment that can underpin an investment decision; this appears to be a significant omission that could be addressed by developing a methodology and/or tool for the management decision-making process.

Finally, in PA, there is often a large knowledge gap between the technology companies and the farmers, and not enough effort is being spent on closing this gap. Future research will be focused on relationships between these providers and users.

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Chapter 4

The economic results of investing in precision agriculture in durum wheat production: A case study in central Italy

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Abstract:

Today, Precision Agriculture Technologies (PATs) can be considered a tool for the management of the farm which allows the agricultural entrepreneur to optimize inputs, reduce costs and offer the best quantitative and qualitative agricultural products. In Italy, the number of digital farmers is still low, therefore it is not yet possible to assess with certainty the actual economic benefits that technologies bring to the farm. To bridge this gap, the paper proposes, through the analysis of a case study, an assessment of the economic efficiency of an Italian cereal farm that has invested in precision agriculture. The results show that, unlike what is reported in the literature, the farm, after the technological adoption, keeps both the yield and the variable costs stable. However, the major benefit is recorded in the decrease in labour costs (-20%) and in the reduction of pesticides (-53%). The increase in the quantity of nitrogen (+ 11%) and of seed distributed in the field (+ 5%) shows how the farm, in the face of a significant increase in total costs due to the capital invested in technology, aims to intensify production, rather than reduce agricultural inputs.

Keywords: break-even; case study; durum wheat; economic profitability; precision agriculture, sensitivity analysis; sustainability.

INTRODUCTION

In Europe, the cereals sector is not only facing challenges structurally, but also financially and climatically, which have been responsible for the decline in income experienced by cereal producers in recent years: volatility of the market, scarce land availability, and climate change issues. The Italian agricultural context stands out for the presence of traditional low-tech farms, which operate within a political framework, characterized by income support and protected markets. In order to gain competitiveness and sustainability with an increase in yields accompanied by a reduction in their operating costs, European Union (EU) grain growers started to digitalize agriculture through the introduction of precision agriculture technologies. This transformation represents an epochal challenge that cannot be taken up by all the farms in the sector because, as already said, it is accompanied by a substantial complexification of farm management.

Thus, this dynamic leads to a progressive exit from the market of smaller farms with the concentration of arable land management into larger production units. It must be clear that the need to increase the production scale depends on the need to invest substantial amounts of financial resources in multi-year assets to fulfil the modernization required by the market under increasing technical and environmental constraints.

The overall effect of this remarkable process of structural change requires farmers not only to invest in technological change but also (and consequently) to train in order to increase their skills in terms of management control thus leading to competitive advantage and superior performance (Dent 1990). The Precision Agriculture Technologies (PATs) have to be considered as tools to efficaciously manage the farm, their declared objective being to save production inputs with positive effects in terms of productivity, ecological footprint, and cost-saving. Most of the studies evaluating the economic efficiency of PATs, starting from the hypothesis that the expected effects of Precision Agriculture (PA) adoption include the improvement of the crop operating margin due to the reduction in variable costs and, possibly, the increase in yields (Šilha et al. 2002; Klerkx et al. 2019; Cizek et al. 2019; Radulescuu et al. 2019; Shafi, et al. 2019; Syrucek et al. 2019; Trivelli et al., 2019; Cisternas et al. 2020; Jung et al. 2021).

On this premise, we propose a cost-benefit analysis case study carried out through analytical accounting with the aim of assessing the economic efficiency of a PATs investment. Theoretically, the environmental and economic benefits of these technologies are two sides of the same coin.

Nevertheless, in Italy we are in a phase of adoption of the PATs by pioneering farms. This trend is confirmed by the recent studies of Blasch et al. (2020), Vecchio et al. (2020) and Pallottino et al. (2018), which refer to the Italian context. Indeed, these studies highlight that high chances for the adoption of PATs can be expected mainly from innovative farmers who showed a particularly strong interest in various benefits of PATs , such as increases in yields and water and fertilizer savings (Marucci et al. 2017; Morari et al. 2018; Caffaro et al. 2020; Ofori et al. 2020). However, considering that the phenomenon of PA adoption is thus still at an early stage, especially in the case of small and medium farms (Tyrychtr et al. 2015; Bucci et al. 2019; Bucci et al. 2020; Giua et al. 2020), it is not currently possible to directly observe the economic effect of these technologies.

Thus, consistently with this assertion, the case study we investigate is an Italian farm, situated in the Marche Region in central Italy, considered a pioneer farm in terms of its level of management control skills, propensity to modernization, structural change, and willingness to accept the current environmental and market challenges with which the cereal sector will have to deal with. In other words, the case study we propose should be considered a frontier farm relative to the farming context under investigation, not an average one.

Even knowing that the case study research approach determines a lack of power in terms of generalizability of the research results, however, it must be considered that the internalization of the PATs by Italian farms is a contemporary event, consequently the PA cost-benefits analysis must necessarily be carried out through case studies.

A large amount of studies report the positive effect of technology adoption among farmers (Bongiovanni and Lowenberg-DeBoer 2004; Adrian et al. 2005; Paustian and Theuvsen 2017; Hrustek 2020). However, related to the economic benefits, much of the literature research (Babcock and Pautsch 1998; James and Godwin 2003) focuses on the economic savings from agricultural inputs (fertilizer; pesticide; water etc.) recorded only after one growing season and excludes the initial investment costs (depreciation costs) in machinery and technology made by the farm manager.

For this reason, to get an accurate analysis of the profitability of precision agricultural technologies, there is the need to apply an economic and financial evaluation taking into particular account PA investment in multi-year assets. Based on the assumption that not all farms are able to cope with technological change, this article intends to answer the following research questions:

1. What is the economic impact derived from the adoption of precision agriculture?
2. What are the main characteristics of farms that decide to invest in precision agriculture?

Thus, the paper aims to assess the competitiveness of an Italian cereal farm managed with precision agriculture technologies for a period of seven years, by describing all the economic changes that occurred before and after the technology adoption with economic indicators. Then the empirical results will be compared to the evidence gathered from the Farm Accountancy Data Network (FADN) to increase the robustness of the results extensions and of checks concerning statistical methods and data reliability. The remainder of the paper is divided as follows: Section 2 presents materials and methods; then the results are presented in Section 3 and Section 4 ends with conclusions

2. MATERIAL AND METHODS

Using the case study method, proposed by Yin (1994), we evaluated the economic results of a cereal farm that invested in precision farming technologies. Specifically, it was chosen to apply the single case study, since the farm represents a case study with unusual characteristics as compared to the national agricultural context which is characterized by small low-tech farms. In contrast the farm in question is a large cereal farm, located in central Italy, with a total area of 200 hectares, of which 87 are cultivated with durum wheat.

Also, the farm is equipped with a technological package, which includes, in line with the subdivision made by Schwarz et al. (2011):

1. Guidance systems (driver assistance, machine guidance, controlled traffic farming)
2. Recording technologies, (soil mapping, soil moisture mapping, canopy mapping, yield mapping)
3. Reacting technologies, (variable-rate irrigation and weeding and variable rate application of seeds, fertilizers, and pesticides)

These technologies were purchased from 2003 to 2019, for a total cost of about EUR 548 000

These technologies allow the farm manager to collect information to be used to make informed decisions related to farming practices, including financial and managerial operations (Fountas et al., 2015). The current precision farming types of machinery are presented in Table 1.

Table 1: Major Investments in Precision Farming Technologies

Precision agriculture investments for crop farming	**Type of technology**	**Year of purchase**	**Replacement Value (€)**
AGCO challenger ISOBUS-ready tractor	Guidance system	2011	200.000,00 €
Mazzotti MAF 5400 self-propelled sprayer with GPS guidance system	Guidance system & Reacting technology	2018	200.000,00 €
Jhon Deere ISOBUS-ready no till seeder	Guidance system	2018	67.000,00 €
Sulki ISOBUS-ready fertilizer sprayer	Reacting technology	2018	24.000,00 €
Parrot Drone	Recording technology	2018	5.000,00 €
Trimble in-cab terminal and satellite receiver combination for GPS guidance system and variable and rate distribution system	Guidance system & Reacting technology	2019	15.000,00 €

For the purposes of the case study, we collected information and data concerning the economic sphere of the farm necessary to analyse the profitability of durum wheat. For the economic analysis, we considered two distinct periods:

- 2013-2017 of a pre-adoption phase of PATs
- 2018- 2019 of a post-adoption phase, since the whole farm, by virtue of the investments made, is fully managed through precision agriculture technologies.

There is the need to clarify that, the post-adoption phase is asymmetrical compared to the pre-adoption one. In fact, the economic results of a five-year pre-adoption period (2013-2017) are only compared to two-year of the post-adoption period (2018-2019).

The economic analysis was carried out according to the following steps by mean of analytical accounting:

1. The definition of an income statement for the period 2013-2019 carried out with the active collaboration of the farm's management;
2. The evaluation of the principal economic indicators;
3. The comparison of the main economic indicators of the case study with the representative medians of these indicators with respect to the FADN sample cereal farm population, representative of central Italy;
4. Break-even and sensitivity analysis.

4. RESULTS

The main results are presented in 3 main subparagraphs:

4.1 Economic Results

Figure 1 shows the trend of costs and revenues, related to the price of durum wheat from seed. Starting from the revenues, they incur a reduction between the pre-adoption period and the post-adoption period, except for the year 2015 when a calamitous event occurred. The decrease in revenues is attributable to cyclical effects that primarily concern the market price (the price of seed grains), but also from the increase in total costs over time which is mainly due to the investments made in AP. Given the competitiveness of the durum wheat market, evidenced by the general tendency to compress the price of commodities, the farm had to necessarily invest in increasingly efficient technologies to maintain a competitive position on the market (technological treadmill). Indeed, the profitability of the cereal sector strongly depends on the volume of production achieved, on the quality of the seeds, and therefore on the resulting market price. The cereal farm represents an exception since it has been able to implement competitive strategies able to cope with market conditions (e.g., the selling price of the product), becoming, thanks to the qualitative parameters of production, a price-taker on the seed market.

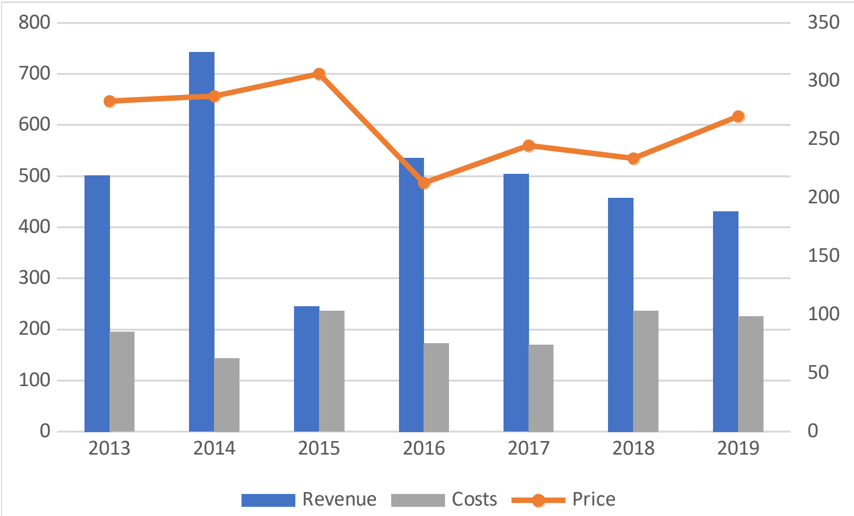

Figure 1: Trend of Cost and Revenue for Durum Wheat

By analysing the amount of total costs, we observe a growth trend in the post-adoption period. Below we analysed the different cost items that made up the total costs to understand the reasons for this variation (Figure 2). Starting from Variable Costs (VC), they are the cost category that affects revenues most of all. In detail, Figure 3 further breaks down the individual variable cost items.

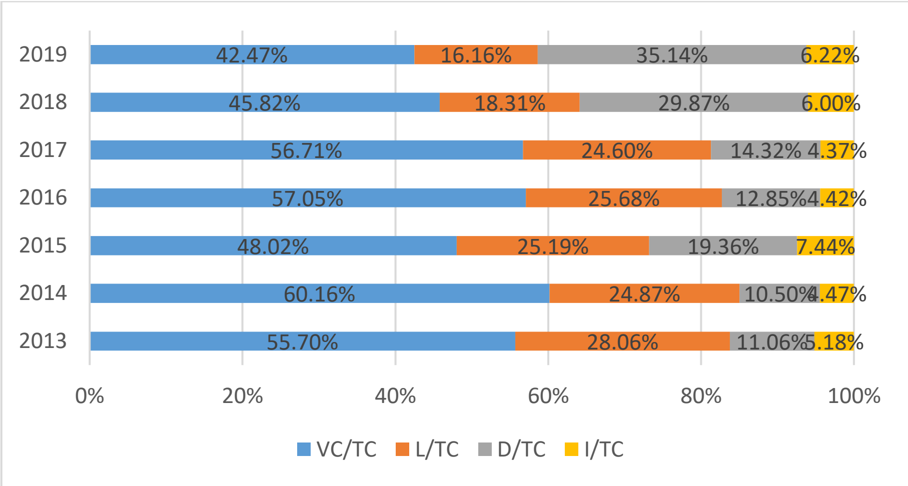

Figure 2:Incidence of the single cost categories on the total costs

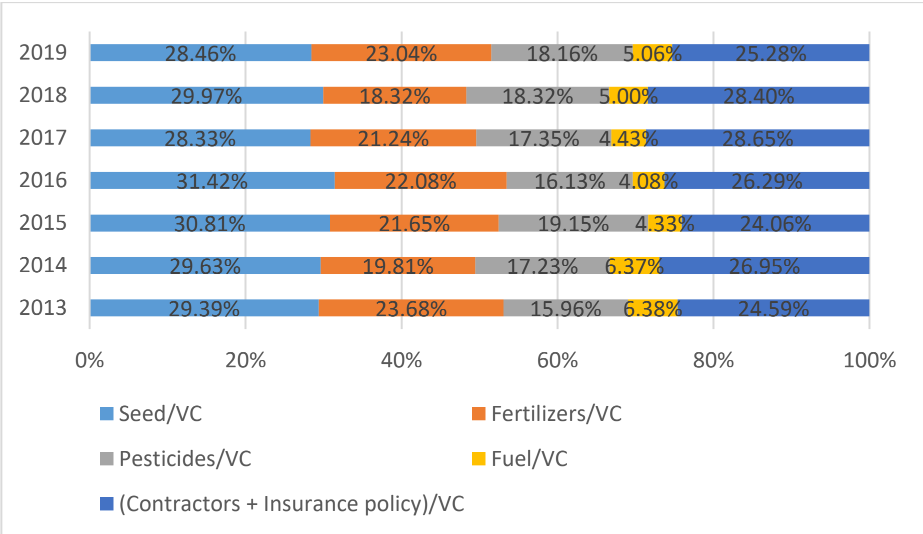

Figure 3: Incidence of the single variable cost categories on the total variables costs

The cost for the seed represents the cost category that mainly affects variable costs (on average about 30%). This shows how seed companies play an important role in the cereal supply chain, capable of influencing the market prices of seeds. This mechanism can have a negative impact on cereal producers, leading to an increase in production costs and the exit of farms that are no longer competitive. It is interesting to note how the cost of fertilizers and pesticides, in second and third position for importance, remain stable over time, even after the process of technological adoption. However, by analysing the quantities of inputs distributed in the field, it emerges that the farm's technological evolution has generated the optimization of the management of crop inputs, in terms of the quantity distributed in the field. The purpose of precision agriculture is not always to reduce the quantities of agricultural inputs consumed, rather it is above all to optimize their use, to generate positive effects in terms of production yields and product quality and, therefore, in terms of revenues. Furthermore, it should be remembered that these costs strongly depend on the market price of inputs, which is often volatile and cannot be influenced by precision farming techniques, so it is certainly more effective to focus attention on the quantities of inputs used. Although the VC have remained almost unchanged, the quantity of inputs distributed in the field has undergone variations (Table 2).

Table 2: Variation in the quantity of inputs

	Seeds (kg/ha)	Fertilizers (kg/ha)	Pesticides (kg/ha)	Fuel (l/ha)
2013-2017 PRE ADOPTION PHASE	225,39	402,00	3,81	46,80
2018-2019 POST ADOPTION PHASE	225,00	450,00	2,50	43

In particular, while the amount of seed distributed remained unchanged, after the introduction of variable rate fertilization, an increase in the amount of nitrogen added to durum wheat was detected (+ 11%). These results differ from the literature, which more generally highlights a reduction in terms of distributed nitrogen (Koch, et al. 2004; Tekin 2010; Biggar et al. 2013; Lin et al. 2020). It should also be pointed out that in the case study implemented, a strategy of distributive efficiency of nitrogen fertilizer, after the Automatic Resistivity Profiling analysis, made it possible to accurately identify those field areas subjected to nitrogen deficiency, as well as those characterized by excess, so as to intervene in a targeted manner. Concerning the quantities of pesticides, it can be observed that there was a decrease in quantities in the post-adoption period decreased (-53%): this decrease is mainly due to the use of precision sprayers. These results are in line with the literature: several authors state that precision agriculture (in particular, variable rate chemical weeding) leads to savings in crop protection products in cereal farming (Gerhards and Sökefeld 2003; Timmermann et al. 2003). In the post-adoption phase, there was also a decrease in the quantities of fuel consumed (-28%). This was possible thanks to the new machines purchased, which have a better operating capacity than the previous ones and, among other things, are all equipped with the most advanced satellite guidance systems, which allow for overlaps to be minimized. It should be emphasized that the optimization of the management of crop inputs discussed above has a very positive effect on the environmental sustainability of precision agriculture as it can result in a reduction in greenhouse gas emissions attributed to agricultural systems. Returning to the description of the main cost items, it is worth noting that labour cost (L) represents the second most important item from 2013 to 2017, and on average it affects revenues by 18%, and then after the introduction of the technology, the cost of labour is drastically reduced. This means that the farm, through the use of various PATs, has managed to make the use of the workforce in the wheat production process more efficient, consequently allowing more efficient use of human resources within other farm activities (nursery activity).

Depreciation of capital (D) is the third most important category from 2013 to 2017: it affects revenues, on average, by 16% (minimum value of 6% in 2014 and a maximum value of 31% in 2019). Interest (I) ranks last in importance for the entire period analysed and on average affects revenues by 4% (minimum value of 2% in 2014 and maximum value of 6% in 2019). Considering that the capital cost of farm implements equipped with IT capabilities is fairly high there was a substantial increase in the value of amortization quotas, given by the sum of D with I. This increase is due to investments in AP technologies made by the farm in 2018, which allowed the company to innovate. The gap between the total revenue curve and the Value Added curve (VA) is the largest because VC represent the main cost category for the entire period analysed. Instead, the absolute minimum difference is observed between the

EBIT curve (Earnings Before Interests and Taxes, that is, the result before financial charges) and that of net income (NI), because I is the last category that affected the cost for the entire period studied.

In 2019, the EBIT curve is more distant from the VA than in previous years. This phenomenon is due to the substantial increase in D, which occurred because of the huge capital investments made in 2018. By consequence, 2018 was the only year in which it registered a negative Operating Margin.

4.2 Comparison with FADN

In order to have a benchmark with the scenario of Italian cereal farms, this sub-section provides a comparison of the economic results provided by the case study with the sample farms from the FADN Database (Table 3). Among the datasets of the FADN, we selected two classes of farms: Farms with a size > 40 hectares; and of these, we also considered the most efficient farms as those which make up 25% of this group (40 ha Top 25%). The comparison of the case study data will be carried out with the Top 25%, considering that the case study is particularly efficient.

Table 3: Comparison with FADN Database

Results	**> 40 ha**	**> 40 ha top 25%**	**Case Study**	
			Media 2013-2017	**Media 2018-2019**
UAA Durum Wheat (ha)	14.3	15.2	89,3	82,5
Crop yields (median) (t/ha)	4.1	4.7	5.5	5.4
Price (€/ton)	182	222	262, 67	
TC per hectare (median) (€/ha)	725.76	691.74.56	1.062,49	1.329,66
TC per ton (median) (€/ton.)	171.40	136.38	194,09	246,44

Variable costs per hectare (median) (€/ha)	379.68	341.57	585,99 €	586,68
Variable costs per ton (median) (€/ton)	93.80	74.20	106,38	108,89
Nitrogen (kg/ha)	51.6	46.6	120,38	135,68
Gross Margin (€/ha)	350.5	575.81	958,07	837,85
Gross Margin per hectare (median) including EU subsides (€/ha)	662.78	928.01	1.374,07	1.271,78
Incidence labour + capital cost per hectare (€/ha)	308.96	299.51	476,50	742,98
EU subsides (PAC) (€/ha)	310,62	352.2	416,00	433,93
Operating Margin per hectare (median) + EU subsides (€/ha)	352.16	628.5	897,57	528,80
Opertating Margin (€/ha)	41.54	376.3	481,57	94,87
EU subsides/Operating Margin + EU subsides (%)	0.88	0.56	0,49	0,92

Below, we will analyse the individual items of Table 3. Starting from the Utilized Agricultural Area (UAA), the case study has on average 87 ha of UAA, showing variations that are not relevant in the period of pre- and post-adoption of technology: pre-adoption (89.3 ha) and post-adoption (82.5 ha). For the period considered (2013-2019), it is important to underline that the total area of wheat cultivated is not constant over time, but it undertakes variations that do not depend on the technologies adopted but rather on the managerial decision on crop rotation and the demand for the product. However, the farm area of the case study is five times larger (82.5 ha) than the FADN sample (15.2 ha). This implies that, as reported by Balafoutist et al. (2017) and by Meyer-Aurich et al. (2008), the availability of large-sized fields allows for more efficient depreciation of the machine capital. With regard to the yield, the company recorded a yield of 5.5 (t / ha) in the pre-adoption period and 5.4 (t /ha) in the post-adoption period, while the FADN companies are characterized by an average yield of 4.7 (t / ha). The average yield in 2019 is in line with the historical average (5.6 t/ha against 5.5 t/ha), so it can be deduced that the technological evolution implemented in 2018 for the moment has not had direct effects on the quantities produced, but it is expected that at full capacity the company will reach higher yield levels. This result confirms that the farm is characterized by productivity above the average of Italian cereal farms, even before the introduction of the technology package. As already mentioned in the previous paragraph, farm efficiency can also be found in the managerial choices made in relation to the sale of durum wheat. The table shows that the average price obtained by the case study is on average 262 EUR/ton vs the 222 EUR/ton of FADN companies. Indeed, to get a better price on the market, the farm does not choose to allocate production to wheat as a food commodity, but it chooses to allocate the product for the production of seeds, thus obtaining a higher average price in part thanks to pre-harvest contracts stipulated with leading semi-seed companies.

Regarding the total costs (TC), the case study recorded an increase (+ 25%) after the post-adoption phase due to investments in digital technologies, and thus in the capitalization of the farm. Adoption of PATs naturally leads to greater expenditures on machinery and equipment because these technologies are capital intensive. By comparing this result with the FADN sample, TC has almost doubled (+ 48%). Concerning the variable costs, there are no significant decreases in variable costs for the case study before the adoption (586 EUR/ha) while the variables cost of FADN farms amounts to 341.57 EUR/ha.

The increase in variable costs of the case study, compared to the FADN sample, is due to the intensification of agricultural practices after the introduction of technology: indeed, after 2018, both the quantity of nitrogen distributed in the field and the cost of nitrogen increased. In addition, the increase in the quantity of nitrogen (+ 12%) is in line with the quantity of seed distributed in the field (+5%). The quantity distributed by the case study (135 kg/ha) is more than doubled compared to the distribution made by the FADN farm (46.6kg/ha). This result highlights how the efficiency of precision agriculture is due to the efficiency of the spatial distribution of the inputs according to the needs of the crop, rather than the savings of the inputs. The efficiency in the distribution of inputs, made possible by the collection of information provided by the precision agriculture technologies, leads to sustainable intensification, thus contributing to the farming efficiency and environmentally friendly farming practices: indeed, the nitrogen input is brought into the field only where needed (Meyer-Aurich et al. 2010; Lindblom et al. 2017). In order to reach an efficient farming system, the farm decided to adopt an input-intensive system, rather than an input-saving one. Turning to terms of profitability, the farm's gross margin increases by 66% compared to the FADN sample, attesting how the farm was already efficient in the pre-adoption phase. Paradoxically, the decrease in the gross margin after the adoption of the technology package is manifested by the increase in fixed costs due to the capitalization of the farm. Consequently, if we subtract the costs of labour and capital factors from the gross margin, we obtain a very low operating margin (94.87 EUR / ha) both with respect to the pre-adoption phase and with respect to the FADN sample.

In summary, in the face of production and management efficiency, including in terms of the market, the investment costs in precision agriculture have a considerable impact in lowering the level of profitability. The operational results, however, must take into account the subsidies of the Common Agricultural Policy (CAP) from which the farm benefits. The subsidies that vary between EUR 416 / ha and EUR 433 / ha allow the farm to retain performance levels of profitability compared to the FADN sample (EUR 528 / ha to EUR 628 / ha).

4.3 Break-even and Sensitivity Analysis

The last part of the analysis concerned break-even and the sensitivity analysis. The break-even point (BEP) analysis was performed for the evaluation of the economic convenience of investments in precision agriculture technologies. BEP is a technique that tends to determine the equilibrium point between total costs and total revenues and that allows us to predict the economic results in correspondence with production outputs (i.e., the quantities produced or sold and therefore, in our case, the yield) or sales price or production costs. In this way, it becomes possible to understand how the variables considered the impact on the farm's economic results.

Adopting precision agriculture technologies by farmers depends on several factors including variation in yields or in the market price. The purpose of this break-even point was to evaluate the minimum yield and price that the company must maintain in order to amortize the cost of the technologies.

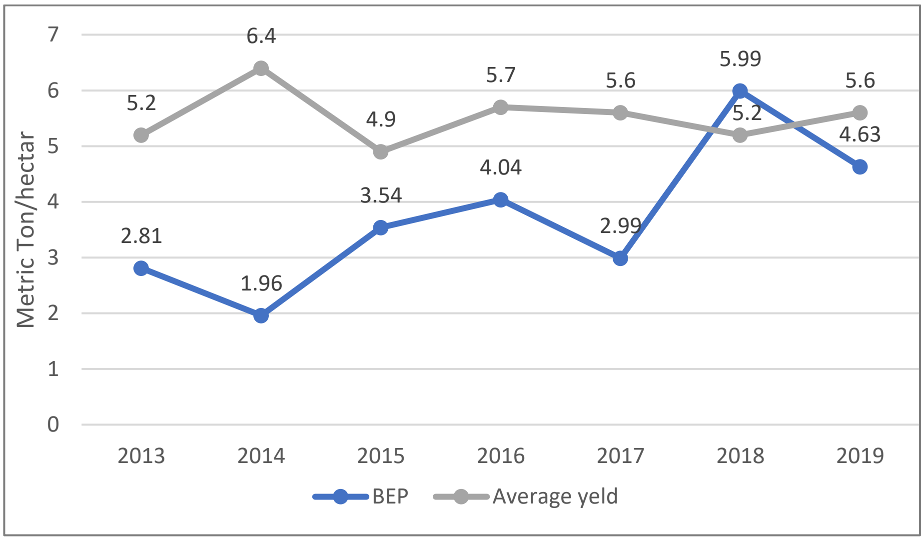

Figure 4: Break-even yield (t/ha) of durum wheat on sample farm

Figure 4 relates the BEP of the yield together with the actual yield of the case study. It is evident that the farm yield largely exceeds the BEP in all years except 2018. Indeed, only in 2018 was there was a negative NI and, to obtain balanced economic results, a yield equal to 5.99 would be necessary instead of the 5.2 t / ha actually produced, to reach the equilibrium point. In the remaining years, the farm yield was always largely sufficient to ensure a positive NI, since the farm was very efficient from the point of view of the production per hectare. Therefore, it is possible to say that currently there is no need for the agricultural entrepreneur to increase the yield of his productions.

In parallel, Figure 5 shows the trend of the BEP price together with the actual sale price of the farm. Similar considerations to those made with regard to Figure 5, emerged from this figure. Indeed, only in 2018 the BEP exceeds the actual price (EUR 252.05 / ton against EUR 234 / ton), as it is the only year in which there was a negative NI. However, contrary to what was stated in the comment of the BEP yield, by virtue of the increase in the quality of the product, the entrepreneur would like to reach an increase in the sale price of durum wheat from seed.

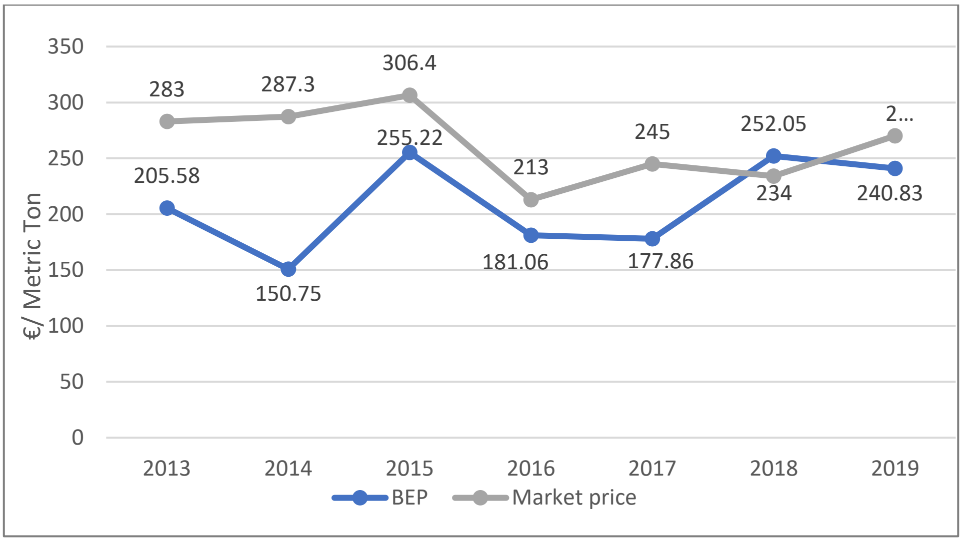

Figure 5: Break even price (€/t) of durum wheat on sample farm

In summary, the farm is in a profitable position in the existing yield and price obtained in the study area. The research concludes with a sensitivity analysis conducted on the results of the income statement of the post-innovation period (2019) in order to assess the economic and financial effectiveness of the innovative investments made in 2018. The sensitivity analysis, in general, allows series of alternatives to be taken into consideration, understood as entrepreneurial choices, with the aim of identifying which parameters can be modified in such a way as to achieve the set economic objectives.

The results of the sensitivity analysis make it possible to examine the effects of the innovations introduced on the profitability of the post-innovation period and, above all, indicate which levers can be realistically acted upon to possibly improve this profitability. For the following analysis, the effects have evaluated 4 parameters: yield, sales price, variable costs, and farm size. The sensitivity analysis revealed how much the production yield or the selling price or the cultivated area should be increased or how much the variable production costs should be decreased in order to raise the NI up to at least equalize the target profitability (Table 4).

Table 4: Durum wheat Sensitivity Analysis

	Yield (Ton/ha)	**Market price (€/ Ton)**	**Cost of the product unit (€/ Ton)**	**Size (ha)**
Actual Amount (2018-2019)	5,4	252	97,78	82,5
Target amount	6,03	298,96	54,45	131,82
Variation	+ 11,6%	+ 18,6%	-44,31%	58,78 %

The table shows that if we wanted to obtain a NI in the post-adoption period greater than or equal to that of the pre-adoption period, we would have to reach a production yield of approximately 6.03 t / ha (compared to 5.4 t / ha effective) or a sales price of approximately EUR 289.96 / t (compared to the actual 252 EUR / t) or variable costs of approximately EUR 54.45 / t (compared to EUR 97.78 / t effective) and a cultivated area of approximately 131.82 ha (compared to the actual 82.5 ha). Therefore, it is clear that in the "post-innovation" period the desired positive effects of innovation in terms of profitability require more than one year to manifest themselves. It is conceivable that the new PATs introduced within the farm can lead, over time, to an increase in the sale price (following the increase in product quality) and / or to reduce the variable production costs (thanks to the optimization management of crop inputs). Instead, the production yield depends almost exclusively on varietal and pedoclimatic factors, while an extension of the cultivated areas is difficult to hypothesize as the dynamics of the land market hinder its implementation (although the current farm structure, especially in terms of work and capital, could also support an increase in the scale of production).

The table shows that, if we wanted to obtain a NI in the post-adoption period greater than or equal to that of the pre-adoption period, we would have to reach a production yield of approximately 6.03 t / ha (compared to 5.4 t / ha effective) or a sales price of approximately € 289.96 / t (compared to the actual 252.00 € / t) or variable costs of approximately € 54.45 / t (compared to € 97.78.29 / t effective) and a cultivated area of approximately 131.82 ha (compared to the actual 82.5 ha). Therefore, it is clear that, in the "post-innovation" period, the desired positive effects of innovation in terms of profitability require more than one year to manifest themselves. It is conceivable that the new AP technologies introduced within the farm can lead, over time, to an increase in the sale price (following the increase in product quality) and / or to reduce the variable production costs (thanks to the optimization management of crop inputs). Instead, the production yield depends almost exclusively on varietal and pedoclimatic factors, while an extension of the cultivated areas is difficult to hypothesize as the dynamics of the land market hinder its implementation (although the current farm structure, especially in terms of work and capital, could also support an increase in the scale of production).

CONCLUSION

To date, PA in Italy still has a certain degree of resistance on the part of agricultural entrepreneurs due to the difficulty of understanding that the economic advantages of technology applied to agriculture are not immediate, but that their effects occur mainly in the long term. Through the case study, it was possible to evaluate the effect over time of precision agriculture technologies, which have brought an economic and environmental benefit, due to the efficiency of the use of crop inputs and the organization of business activities. Indeed, if on the one hand the adoption of new technologies has represented for the farm an increase in fixed costs (depreciation of the capital) deriving from the investments made, on the other hand, the adoption of these technologies has ensured greater efficiency and greater speed of execution of agricultural operations, with significant savings in the labour force and the optimization of inputs.

Some considerations must be made regarding the positivity that emerges from the adoption of precision agriculture concerning the labour saving, quality and traceability of production, and the positive environmental effect of precision agriculture. It is clear that labour capital is the only factor that, thanks to the adoption of technology, undergoes a significant decrease of about 20%. The decrease in labour costs is attributable to the efficiency of crop management resulting from precision agriculture since agricultural operations are performed with efficiency and speed. All this results in efficiency in the management of human resources, which, in this way, can also be reallocated to other company production activities. As regards the quality of durum wheat production, we underline that the qualitative parameters of the grain produced have significantly improved, both from a commercial point of view (the hectolitre weight and protein content values have increased) and phytosanitary (a lower incidence of attacks from part of phytopathogenic agents), which are monitored by the farm thanks to the adoption of a traceability system through the use of a QR code. Finally, considering the environmental aspect, this work provides a clear evidence of the savings in terms of inputs distributed in the field. In this sense, the adoption of precision agriculture guarantees sustainable agriculture from an environmental point of view. These potentials of technologies are increasingly recognized at a political level. Following the declaration for "a smart and sustainable digital future for European agriculture and rural areas" signed by most Member States in April, the European Commission presented and discussed new technologies and digitalization in agriculture highlighting the advantages and opportunities it offers for the sector. Then, the European Commission announced the Green Deal policy for Europe and its From Farm to Fork strategy, oriented to investing in cutting-edge research and innovation and preserving Europe's natural environment". In this deal, digital technologies are presented as "enablers to achieve the sustainability goals." In addition, for the period 2021–2027, the European Commission has proposed a CAP focused on the goals of social, environmental, and economic issues, giving a clear signal that it is necessary to build sustainability driven by digital agriculture. Indeed, the post-2020 CAP proposals take into account the importance of the use of technologies in the sector. This paper is a first step in understanding how technology investments could affect the economic result of a farm. More in-depth analyses are still required, considering that the achievement of desired technology modification and behavioural change requires support from the public, industry, research community, extension services such as training and provision of advice, generation, and dissemination. Farmers need to have continuous access to reliable and relevant knowledge sources to be able to innovate, successfully solve problems, and respond to new opportunities for development. The AKIS Systems (Agricultural Knowledge and Innovation Systems) promoted by the European Union is a prime example that aims to speed up innovation.

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Chapter 5

The role of managers or owners of SMEs in driving the digitalization process in the agri-food sector

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Introduction

The adoption of digital technologies, also referred to as digital transformation, is a challenging process of change that has to deal with strategy more than technology per se (Kane et al., 2015). Due to a unique position that allows them to shape strategy, extant research has demonstrated that top managers influence the choices related to adopting technology (Midavaine et al., 2016; Shah Alam, 2009; Damanpour and Schneider, 2008; Jarvenpaa and Ives, 1991; Rizzoni, 1991). Moreover, top management patronage and behavior are critical for creating a supportive climate as well as providing suitable resources (Low et al., 2011; Walsh 1988;). Extant literature investigating top managers' intention to adopt digital technologies has been focusing on variables such as education, age, gender, etc. (Bantel, and Jackson, 1989; Young, et al., 2001). Yet, these variables may only partially explain differences in adoption behaviors. Since choices within the organization reflect the top management's cognitive elements and values, the way top managers behave towards championing innovations may function as an intermediary amongst the environment and the assimilation of the technology within the organization (Lin et al., 2014). Therefore, understanding the attitudes, motivations, characteristics, values, and subsequent behavior of the manager are central to understand how and why technological innovation is accepted and implemented by some firms and not by others.

Managerial influence on strategic technological change is even more emphasized at the SME level, where the top manager or owner-manager is considered to be an "all-rounder," involved in every organizational process and playing a unique position in the firm's decision-making process (Hambrick and Mason, 1984; Berergon and Raymond, 1992; Geletkanycz and Hambrick, 1997; Winston and Dologite, 2002; Jeyaraj et al., 2006). At the SME level, the adoption of digital technology was studied in terms of factors influencing the firm, either externally, such as competitive pressure and network influence, or internally, such as technological competences and human capital (Nguyen, 2009; Mehrtens et al., 2001; Giotopoulos et al., 2017). A similar approach was applied to SMEs in the agrifood sector, and among the factors considered to influence the firm in the adoption process, there was evidence of top management's support (Premkumar and Roberts, 1999).

More recently, new theoretical approaches were adopted to better analyze how managers promote and sustain a successful digital transformation at the SME level (Warner and Wäger, 2019; Li et al., 2018). According to Teece (2017), the dynamic capabilities can be divided into three categories: sensing, seizing, and transforming. They are used to indicate different activities performed by the manager, such as identifying technological opportunities, mobilizing resources to address specific needs and opportunities, and carrying out continuous renewal.

Based on the work by Lin et al., 2014, and to pursue the research stream presented by Annosi et al, (2019) regarding the role of the manager in the process of adopting digital technologies by agrifood SMEs, we have developed this qualitative study.

Methods

To investigate how the managers of agrifood SMEs actively promote and sustain the successful adoption and usage of digital technology, the Grounded Theory (GT) methodology was applied in this study. According to Charmaz and Belgrave (2007), GT is a systematic inductive methodology to conduct qualitative research aimed toward developing new theories. Since research and theory on the subject of technology diffusion in this sector are still emerging, this study presents a multiple case study approach, selected because of its particular strengths in developing and extending theory (Eisenhardt and Graebner, 2007; Yin 2003). The context of the agrifood sector seems to be attractive for studying the role of the manger in digital technology adoption and usage for several reasons. First of all, SMEs face several obstacles linked to the introduction of technological innovations, such as a lack of human and financial resources, limited organizational capabilities, and lack of a strategic vision (Premkumar, 2003; Kuan and Chau, 2001; Mehrtens et al., 2001;). Secondly, these weaknesses the SMEs typically have are even more emphasized in the agrifood sector, where they struggle not only because of limited resources but also because of the lack of an appropriate digital infrastructure and training. (Pickernell et al., 2004; Baourakis et al., 2002). Based on these premises, data was collected from a sample of 24 agrifood SMEs in the Marche region (Italy) through semi-structured interviews during the period of March-April 2019. All the interviewees covered a managerial position (CEO, owner). We focused on the manager/owner of the enterprises because in SMEs, these people assume a central position and are considered to be the ones who make the final decision related to the internal and external organization of the firm (Durst and Runar Edvardsson, 2012; Bridge et al., 2003). The firms were selected based on their experience in the adoption and usage of digital technologies. The process of sampling concluded when the saturation point was attained, a condition in which a newly added unit of analysis did not provide any additional relevant information. The saturation point was reached after 33 interviews for a total of 24 SMEs. Then, the total sample was divided into two subgroups, creating two different scenarios of adoption and usage. The first group of Low Technology Integration enterprises (LTI) makes use of digital technologies only to a limited extent and solely concerning administration. The second group, on the other hand, comprising High Technology Integration enterprises (HTI), vaunts a greater inclusion of digital technologies, showing increased usage both in the areas of administration and production. Additionally, a cross-case comparison between the two groups was made, focusing on the differences that emerged to increase the robustness and the generalizability of the resulting theory.

Data was analyzed based on the canons and procedures of grounded theory research (Corbin and Strauss, 1990). In particular, it was used as an iterative coding process between the data collected, the literature found, and the grounded categories of concepts that emerged from the analysis. The coding process was repeated three times, advancing from simple and evident patterns to cross-cutting themes and insights from the theory (Gioia et al 2013). Each round of coding was done independently by the two researchers to increase the reliability of the study. What emerged from the comparison of the two groups of firms is a set of specific beliefs, intuitions, behaviors, and practices that are only present in the group of companies that undergo a successful process of digital transformation, the HTI. These findings will be explained in more detail in the following section.

Findings

In the following sections, we describe theoretical themes related to managerial characteristics that emerged from the corresponding grounded model by comparing examples of codes emerging from LTI and HTI firms. To support our arguments, we provide quotes taken from the interview transcripts as explicative examples.

Managerial characteristics

Managerial Beliefs

The strong belief of the HTI managers in technology as a means to innovate and improve their business is the first feature that could explain the difference between the HTI and LTI enterprises. In fact, more so than all the other managerial characteristics, discussed later on in this section, this belief is considered one of the most relevant factors affecting the adoption of technology since it represents the starting point on which decisions, and consequently actions and practices, are based (Tikkanen et al., 2005; Lefebvre et al., 1997). Intuitively, we observed that HTI managers strongly believe in the adoption of new technologies as a means through which the firm adapts to growing competitive pressure and new market requirements (Davis, 1989; Bertrand and Schoar 2003). The dominant managerial belief that emerged from the interviews with HTI managers is that improving enterprise performance strongly depends on technology adoption, as stated by one manager of Company 7:

"Performance improvement passes through technology adoption".

Company 7 is the highest technological integrated enterprise among our sample. Therefore, this belief is the consequence of a considerable application of technologies in the business.

We understood from the interview that this belief is the result of a process of awareness that started in a moment of generational change, when the company was transferred from father to son. The need for Innovation became evident for the young, new owners of Company 7 after they realized that only the integration of new technology in their business could solve the complexities and obligations that had drastically increased since their Father's Day.

On the contrary, even if some managers of LTI enterprises confirmed the importance of technology as a driving factor in their long-term strategy, we observed discrepancies between the belief and the actual behaviors and actions that were not directed towards technological innovation. For instance, the manager of Company 2 decided to adopt a certain kind of digital technology only because it was mandatory: "We adopted software for electronic invoicing [...], partly because it is now mandatory".

Even though he affirmed the relevance of technological innovations in his business, the manager of Company 1 perceived the use of technology as a threat:

"I see technology as an additional interference of a certain kind of industry in the agricultural sector".

Both these two LTI firms are characterized by a more traditional and conservative way of doing business. This type of business management derives from the basic belief that technology does not lead the firm's performance but is only considered as a marginal factor in the business strategy.

Furthermore, we observed that some LTI managers complained about the current technological underdevelopment among the different players of the local agrifood supply chain. It is not uncommon that in the agrifood chain, some farmers are not using any digital technology at all; in some cases, they don't even have a computer to send and receive e-mails. Within the context of digital technology adoption, this awareness stands as a barrier. Here is one example of this situation explained by the manager of Company 22:

" ...[...] let's just say that our farms, which is to say our suppliers, started to use e-mails only last year because they were obliged by the government, which had imposed electronic invoicing. Before last year, I was forced to send them all communications by post. Do you understand where the problem is in our business?"

This self-explanatory quote gives a clear idea about some of the reasons behind a low level of technological integration, but also more generally behind the adoption of digital technology. It doesn't make sense for our entrepreneurs to adopt communication technologies if they cannot use them to communicate with their suppliers. In this case, the suppliers are local dairy farms.

Managerial Cognition

Given the lack of skills and knowledge among owners/managers of agrifood SMEs in the field of digital technologies, it is important to assure a constant flow of knowledge. The process of digital technology adoption also entails an organizational change and therefore, owners/managers are forced to face several complexities. The context in which these enterprises are operating is nowadays characterized by a constant level of change. To be flexible and successfully capable of innovating, promoting a learning culture is fundamental. In a climate where such companies operate, continuous change is the norm. So, the capacity to innovate in response to change is pivotal for the organizational development and might also be achieved through the promotion of a "learning culture" (Gilbert and Cordey-Hayes, 1996). In line with this concept, we observed that some HTI managers understood the importance of the learning culture and created an environment where everyone in the company is willing to learn:

"My employees are curious, they are passionate about technology, they subscribe to industry magazines, they keep me informed, reporting to me things that I didn't even know myself [...]. Sometimes it's me who has to say stop to them; I tell them that I have already done enough, I want to stay like this for a bit... Instead, they bring me to check out new technologies and try them [...]. You need to have knowledge about what you buy" (Manager of Company 8).

The need for a constant flow of knowledge is underlined in this quote. The manager perfectly understood the need for constant knowledge, and in response to this, he was able to create a learning environment where each employee is active in this sense. Within this company, the process of gaining knowledge takes place automatically through both the manager and the employees. It is no coincidence that this firm massively relies on digital technologies for its daily operations. However, in our sample, we also observed a similar cognition in another HTI manager. Here is a quote by the manager of Company 13, who is referring to technology and technology providers:

“... [...] even if someone has outdated knowledge, you always need to ask them (ask technology providers used as a source of knowledge), you need knowledge on a constant base; you at least need to have a look to see what is going on or to refresh your knowledge in order to understand what you have lost because of the frequency of the business’s activity”.

Instead, among the LTI managers interviewed, we did not observe the same effort deployed by the HTI managers to guarantee a constant flow of knowledge. The absence of this cognition is probably a consequence of the lack of importance given to technological innovation. The fact that they don’t understand how important digital technologies are to sustain competitive advantage leads them to not invest time and resources in encouraging a constant flow of knowledge. An emblematic and self-explanatory example of this attitude is provided by the manager of Company 19, who stated the following:

“I don’t stimulate knowledge acquisition, in the sense that I gain knowledge casually. I talk to my colleagues or with other people who tell you if they tried this or that technology. I am not proactive in the process of acquiring this information”.

Managerial behavior

From a behavioral point of view, we observed that the HTI enterprises differ from the LTIs because the former sustains these types of behaviors while the latter doesn't:

Proactive learning behavior in the acquisition of new and relevant knowledge (B1);

Constant attention to emerging challenges and novelties (B2).

The connection with the aforementioned belief is clear. If the core belief of a firm is based on technological innovation, new knowledge about digital technology should be constantly added and the emerging challenges brought on by globalization and technological novelties should constantly be researched. Specifically, in B1, proactive behavior is defined as all the actions undertaken by the manager to acquire knowledge about the best sector-specific technologies available on the market and how to include these technologies within the firm’s business model, anticipating even the early majority of adopters (Lumpkin and Dess 1996). In this regard, the manager of Company 7 said:

“The first factor for success is the curiosity of the owner/entrepreneur because curiosity opens you up to novelties and the use of a network. Network is a facilitator".

Proactive behavior is the consequence of the curiosity of an entrepreneur who is seeking new knowledge (Crant, 2000). The search for new knowledge creates the necessity of being open, considering and listening to multiple external sources of expertise, experiences, and opinions coming from the same sector or other sectors. As far as B2 is concerned, the manager of Company 6 said:

“You are active in the search for information, doing it every day because you always find new stimuli”.

From this quote we understand that “constant attention” means everyday attention, underlining the manager’s vast commitment to seeking out challenges and novelties. Within the boundaries of the business of Company 6, one of the emerging challenges that were mentioned in the interview is the low price of milk that is being paid to farmers. To tackle this challenge, the manager adopted what in B2 is called a "novelty,” that is, the voluntary milking system he adopted on his farm.

On the contrary, the managers of the LTI enterprises did not show the behaviors present in B1 and B2, typical features of HTI enterprises. LTI appeared to be much less proactive in acquiring relevant knowledge and less concerned about emerging challenges and novelties. For instance, the manager of Company 4 said:

“I don't compensate for the lack of knowledge. I try to do what I can. I don’t usually look for knowledge. This is also because if I don't have the right skills, I prefer to take it easy and take my time".

Managerial practices

Usually, the decision to adopt a particular digital technology comes after a relatively careful evaluation of certain criteria. This evaluation is undergone by the managers of both HTI and LTI enterprises, though the groups differ in terms of the quality and quantity of criteria considered. On the one hand, the managers of LTI enterprises have been shown to make relatively poor judgments, mostly based on two factors:

The real need for digital technology;

The cost of the investment.

On the other hand, the mangers of HTI enterprises usually make a much deeper analysis when adopting new technologies, including the criteria stated above plus additional ones. Here are some of the additional criteria that were mentioned during their interviews:

Creation of a business plan, including the SWOT analysis, for investing in technology (Company 6 and 10).

Evaluation of the effort in implementing technology in terms of the time needed to switch from the old technology to the new one (Company 10).

Assessment of the cost and economic return on investment, advantages in the logistics, and optimization of production processes (Company 7).

Evaluation of employee safety and economic return on investment (Company 8).

Evaluation of the cost and economic return on investment, as well as savings in terms of employee deployment (Company 9).

Once the digital technology has been adopted, we observed that HTI managers usually evaluate the performances of the business using formal benchmarking activities. Of course, given the fact that their strategy is mainly based on adopting digital technology, it is not reliable to only count on subjective evaluations of firm performance, such as in the case of LTI managers. The difference between the two groups is shown here through different performance evaluations. High tech managers said:

“We use benchmark indicators that we find available on the market. When we adopt new technology, we refer to our historical data as well" (Company 7).

On the other hand, low-tech managers said:

“I evaluate the performance by eye. It is useless to talk about percentages when the bases are so paltry” (Company 5).

The lack of rigor in practices is also visible between the groups when we observe the frequency with which the strategic choices are checked. The pattern of the interview answers is also similar in this regard, showing a systematic approach in HTI enterprises. The managers of HTI enterprises check their strategic choices constantly:

“We check our strategic choices every day [...]” (Manager of Company 6).

The managers of LTI enterprises check them more sporadically:

“I never check our strategic choices” (Manager of Company 2).

In this regard, it is interesting to notice that the difference between the two groups is not only related to the frequency with which strategic choices are revised but also the presence or absence of a real strategy. It is common in agrifood SMEs to not have a real strategy (Costa and Jongen, 2006) because the business rhythm is dictated by the rate of everyday activities.

The lack of a clear strategy can also be seen in the degree of the vagueness of the answers by some low-tech managers:

“We rethink our strategic choices gradually. Maybe this year you innovate for something and next year for something else” (Manager of Company 3).

Another difference between the two groups of SMEs emerged regarding their exposure to relevant information. The managers of HTI enterprises usually vaunt higher exposure to important information about digital technology. As the manager of Company 6 stated:

"I find ways to collect information through other people or magazines, or through other peers, to evaluate certain factors, which then allows me to make a managerial decision".

In the interview with the manager of Company 2, on the other hand, she had never gone to expositions or events related to digital technology, and that she is only in contact with peers, owners of businesses similar to hers. These peers are also entrepreneurs whose businesses are not based on digital technology, therefore they do not represent relevant sources of information about technology.

Furthermore, we observed that indistinctively among the HTI and LTI groups, feedback from customers is used as an incentive for adopting and implementing digital technology. The feedback is collected, in most cases, orally by the figures who are directly in contact with the end customers. Below is an emblematic quote, in which the manager of Company 15 (LTI) actually decided to adopt a business software based on feedback provided by a specific group of customers, ethical purchasing groups (GASes). These groups’ request is very specific because they buy products as one big collective order. This order is comprised of several small orders for each household that is part of the group. Therefore, the firm has to manage many different packages at once and consequently has to be very flexible.

“... [...] we received a big impetus from the GASes because we were not able to process their orders anymore by only using Excel [...]. Not only did they give encourage us, but they also helped us in the process of adopting the enterprise software because some of them are very skilled in computer science".

Conclusion

In this study, we report how managers of agrifood SMEs enable the successful adoption and usage of digital technologies. With a comparison between the two groups of cases, we emphasize the managerial characteristics that are related to a higher level of integration of digital technology within the firm. Overall, we can say that all the differences between HTI and LTI enterprises can be summarized in the presence or absence of a certain rigor applied to business practices. For HTI enterprises, we observe clarity, a systematic approach, and logics set on adopting digital technology. As for the other managers, those of LTI enterprises, we observe the absence of these practices and a major degree of disorientation towards the process of technological innovation.

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Chapter 6

Network's dynamics for innovation adoption in the agricultural sector: the case of precision agriculture

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Abstract: *Recently, the agri-food sector has had to face several challenges related to the innovation process, the most significant of which seems to be that of its digital transformation. As a consequence, the issue of digital technology adoption is becoming of important scientific interest due to its potential impact on products, services, processes and new business models. In general, the adoption behaviour can be indirectly explained by studying factors that lead a firm to innovate; among these factors the literature emphasizes the function of networks. Although the importance of networks in the innovation process has been widely acknowledged in the literature, a better understanding of their role in the adoption of precision agriculture is still required. To achieve this goal, qualitative research was developed by using 8 case studies recollected among that few Italian farms which can be defined innovative for having already experienced precision agriculture. Results show that only a few farms have the capability to develop and manage innovations internally; success often requires cooperation between individual actors and organization. Finally, the paper provides some practical advice and a set of propositions for those farms that are trying to achieve digital technological innovations.*

Keywords: Precision agriculture; Innovation; Networks; Quality analysis
JEL CODE: Q16, O33. D85, Q55

1. Introduction

As the innovation process is a strategic factor and an important driver of economic growth and productivity, the capacity to innovate is a necessary condition, in particular for those firms seeking to create and maintain a competitive position in the global market (Cho & Pucik, 2005).

Innovation is a very broad concept and has been studied extensively from many points of view (Touzard et al., 2015). The major point of reference for innovation concepts is Schumpeter's 1982 original notion of innovation (1982) which refers to the classical view that is based on a sequence of phases involving the creation of ideas, invention, research and development, application and diffusion. However, in contrast to the classical view, referring to observations in practice, Schumpeter argues that innovation emerges in a complex iterative process where communication, learning and social interaction play important roles. Consequently, innovation is not seen as a mere technical issue but rather "the result of a process made up of many steps and gathering many individuals, organizations and institutions along the way" (Laperche, 2012).

In fact, the innovation process is not solely an internal process. Thus, for the firm, innovation is always the result of interactions and feedback between individuals, organizations and institutions involved in the process (Rosemberg & Landau, 1986). In other words, while acknowledging the role of technology in shaping economic progress, the innovation process would be the result of network dynamics at an institutional and organizational level, which are therefore interesting to explore (Wendschlag, 2009).

This supports the view on networking as a suitable tool for innovation support. Indeed, many studies on innovation accentuate the fact that innovation is a systemic process in which firms interact and collaborate with a variety of networks (Ritter & Research, 2003; Pittaway et al., 2004; Chesbrough, 2012). In addition, the innovation literature has shown how firms capable of creating networks are more innovative than "isolated" ones. Firms participate in different networks to spread the risk and uncertainty involved in the innovation processes, shorten innovation time, reduce costs and access external resources upon which innovations may potentially be built (Canter & Graf, 2011; Li et al. 2018).

However, according to Nieto & Santamaría (2008), critical issues such as the selection of partners and what type of networks favor innovation still require further research. Previous studies have demonstrated that farms do pursue innovation (Knudesen, 2007; Fortuin & Omta, 2009), albeit to a lesser extent compared to firms in other sectors. Consequently, networks become especially important for those farms because, as is known, these are usually restricted from a dimensional point of view. In addition, due to the close interactions and dependencies between farms and the actors in the food supply chain, networks become a baseline requirement for any successful initiatives towards innovation.

Today, among the various innovations which interest the agriculture sector, the precision agriculture technology has emerged as an important phenomenon that has attracted the attention of several scholars and practitioners, principally due to its potential impact on products, services, processes and business models (Kosior, 2018; Bucci et al., 2019).

The main precision agriculture technologies include information gathering tools (such as yield monitors), targeted soil sampling and remote sensing tools, variable rate technology, guidance systems (such as light bars and auto-steer equipment). Precision Agriculture (PA) is conceptualized by a system approach to re-organize the total system of agriculture towards a low-input, high-efficiency, sustainable agriculture (Shibusawa, 1998). This new approach mainly benefits from the emergence and convergence of several digital technologies.

Thus PA, might change farming into digital farming, thus assuring the optimization of the management of resources throughout the farm system and making the value chain more traceable and coordinated at the deepest level. Hence, the adoption of innovative practices as well as the role that networks play in it deserves more attention. On this premise, the present article investigates network dynamics that affect the process of precision agriculture technologies adoption in the agriculture sector.

One of the main characteristics of networks is the coexistence of different kinds of relationships, personal and professional among these. The presence of multiple types of relationships modifies farm dynamics, creating a space where traditional innovation activities take place in an unusual way (Ceci & Iubatti, 2012). In details, the paper will address the following research questions:

- How do different types of relationships favor the adoption of precision agriculture technologies?
- What types of actors favor this process?
- How networks play a role in supporting the digital technological process?

We address these research questions through a qualitative analysis of 8 of the most innovative farms, with a great experience in PA, located in the center of Italy. In particular, we use a qualitative content analysis methodology to examine the data obtained by carrying out semi-structured interviews. Since qualitative methods are largely inductive, they are particularly suitable to approach to develop hypotheses for further research steps, helping in providing context and foundation for quantitative analyses (Pignatti et al., 2015).

In order to accomplish the above-mentioned objectives, we have structured this work into five sections, including the current introduction. In Section 2, we present a framework for reading the agricultural innovation process in light of the current political and social contest. Section 3 presents a literature review on firms' innovation adoption behavior, focusing on the role of networks. In Section 4 we describe the method employed in our research. The main results of our research are outlined in Section 5. The final section includes our conclusions and the implications of the study.

2. The innovation process in the agricultural sector

Defining the innovation process in the agricultural sector is more complicated than for other sectors. Indeed, literature concerning the innovation process and its underpinning drivers in this sector is very fragmented due to a number of additional elements that affect the development of the innovation process (Shikida, Azevedo & Vian, 2010; Souza Filho et al., 2011; Avolio et al., 2014).

That is why, especially in this domain, it is very difficult to generalize the discourse about innovation diffusion and development (Crossan & Apaydin, 2010). We could simply and comfortably define innovations in agriculture as new methods, customs or devices used to perform new tasks. However, given the current social and political context referring, in particular, to the challenge of climate change and the environmental crisis, we support the idea that innovation in this sector can no longer be fully understood as a mere technological issue but rather (and perhaps first of all) as an organizational, institutional, and cultural one. Moreover, to fully capture the essence of innovation across a wide range of issues, the purpose of an innovation - and what it is or should be – can no longer be taken for granted; the same goes for the dynamics according to which innovation has to be first exogenously generated and then passively adopted.

Therefore, let us begin to discuss the theme of innovation in agriculture by breaking the innovation issue down into the following questions: i) What is the purpose (or incentive) from which innovation in agriculture eventually arises? (WHY innovate?) ii) How does innovation unfold? (HOW can we innovate?).

The first question is only apparently straightforward but is actually quite challenging to answer. The core objective of innovation in agriculture has always been that of productivity enhancement and cost-effectiveness at a production process level. A critical issue implicit in the innovation process lies in the fact that, typically, the adoption of a new technology is a slow diffusion process (Griliches, 1957). This dynamic implies that the few early adopters (pioneers) benefit from the innovation effect on productivity and efficiency.

Nevertheless, given the traditionally inelastic agriculture demand curve when, later, the majority of producers adopt it, the new technology determines an increase of the farm output and a more than proportional decrease in market prices. As a result, the farms that are late adopters typically face critical conditions: high production costs due to the innovation adoption and decreasing sales prices. This is Cochrane's (1958) famous "treadmill effect": in the presence of a technical progress, any farmer who does not quickly adopt it is threatened with declining profit. This scenario puts pressure on farm managers to deal with the difficulties arising from these innovation dynamics; early adopters are therefore likely to possess superior managerial skills (Chavas, 2001).

This means that innovation and technical change tend to favor good managers and this "managerial bias" has important implications. For example, one of these implications is that the benefits from technical change can vary greatly across firms within a sector. Moreover, as is known, farmers are generally exposed to a supply chain dominated by monopolies both upstream and downstream of the agricultural firm.

To summarize, from the point of view of the farmers these dynamics result in the risk of generating a loss, rather than a gain, following the innovation and technological change introduced. The risk of income loss associated with the widespread adoption of an innovation is one of the reasons why farmers are often (and in this sense rightly) reluctant to internalize such innovations without being able to count on a clear political guarantee in terms of income support measures to prevent any market collateral (shock) effect.

Consequently, in this context, how can innovation unfold? In spite of the potential market risk connected to the widespread adoption of cost-saving and yield-increasing innovations, we can say that farmers would be willing to innovate to some extent if the policies could effectively support the introduction of an innovation. However, at European level, there are still no specific measures that support the adoption of an innovation in the agricultural sector, but there are generic measures to boost the innovation of this sector. For instance, a number of Common Agricultural Policy (CAP) objectives have been introduced for innovation in agriculture. Within the new Rural Development Policy programming period, the European Innovation Partnerships (EIPs), the Operational Groups (OGs) and different technological clusters became new ways to foster innovation (Finco et al., 2018), giving proof of applying the "Multi-Actor Approach" (MAA) [1].

Developed under Horizon 2020, MAA puts into practice the "interactive innovation model", which allow to foster the development of research into practical applications and the creation of new ideas thanks to interactions between different actors ("cross-fertilisation") and the sharing of knowledge (Ingram et al., 2018; Knierim, et al., 2019). Thus, the set of motivations or incentives that push the innovation process in the agriculture sector is not as straightforward as it seemed at first sight. In order to understand why farmers, innovate, it becomes crucial to identify the key drivers that are able to affect the innovation adoption process.

In particular, as we will discuss later, the presence of an adequate context from which an innovation process may originate can be found in the case in which producers (both

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horizontally and vertically along the supply chain) are systemically connected to each other, thereby forming a collaborative environment that we could define as a network. According to Roger (Rogers, 1971) adoption of a new idea is caused by human interaction through interpersonal networks. If the initial adopter of an innovation discusses it with two members of a given social system, and these two become adopters who pass the innovation along to two peers, and so on, the resulting distribution follows a binomial expansion.

3. The role of networks in the innovation adoption process: a literature review

According to the literature, we can say that innovation adoption could be attributed to different factors. Indeed, the various factors and determinants considered important for firms to innovate have been extensively analyzed by the literature (Mohr, 1969; Majumdar, 1995; Becheikh et al., 2006; Dziallas & Blind, 2019). Most of the literature, through quantitative studies, identify internal and external factors that lead firms to innovate (François et al., 2002; Avermaete et al., 2003; Cirani, & Moraes, 2010; Baregheh et al., 2012; Pérez Castillo et al., 2013; Bolfe et al., 2020; Bucci et al., 2020; Chen, 2020).

Internal factors are linked to the various features of the organizations, such as: business size, sales of the firm, the experience age of the company, number of employees; the firm's turnover; the characteristics of the entrepreneur and R&D activities. On the other hand, external factors are related to the firm's environment. These external factors are linked to the socio-economic, institutional, administrative and physical contexts in which the firm operates. The external factors are: the existence of public funding, the presence of agglomeration economies, networks, relationships, market orientation, policies and external organizations. Among the aforementioned factors, the literature emphasizes that networks play an important role and are a necessary condition for the adoption of innovations (Katz & Shapiro, 1986; Warriner & Moul, 1992; Robertson et al., 1996; Ritter & Gemünden, 2003; Bandiera & Rasul, 2006; Zeng et al., 2010).

In particular, different authors highlight that networks are positively associated with the pre-adoption (Glanz et al., 1992; Rogers, 2003) and adoption (Frambach & Schillewaert, 2002; Berta et al., 2005) of an innovation. In addition, a growing part of the literature has pointed out that the adoption of innovation is a collaborative phenomenon that results from various interactions among different actors (Hagedoorn, 2002; Hamfelt & Lindberg, 2015). In this respect, single firms rarely innovate alone they tend to band together in teams and coalitions based on 'swift trust'. In fact, we can define a network as a set of relationships between the firm and business partners, suppliers, customers, professional and trade associations, technology centers, service providers, clusters, research organizations (such as universities), employees, friends, consultants and many others.

These networks may not only be business relationships, but also involve personal relationships. Thus, networks are formed by heterogeneous groups of actors. This section aims to summarize and review the importance of networks in the adoption of an innovation in firms, focusing on the theoretical and empirical studies that are relevant to support this aspect. According to Corsaro et al., (2012), two elements seem to characterize the importance of networks: the first element is the multiplicity of outcomes or advantages that could derive from collaboration and the second is the variety and diversity of actors involved.

Looking at the first aspect, a body of literature argues that networks enable firms to overcome the limited resources (both financial and human) needed for the innovation process (De Massis et al., 2018). On one side, the availability of funds and budgeting for innovation-related activities all seem to have a positive and significant effect on innovation. Financial autonomy and profitability increase the probability of carrying out investments, doing in-house R&D and generating innovations (Geiger & Cashen, 2002; Beneito, 2003).

On the other side, human resources, enable companies to have a qualified and motivated workforce capable of creating new technologies and absorbing those developed externally (Hoffman et al. 1998). The network therefore provides access to complementary resources which are not easily available internally. Secondly, different studies show that the network is useful for overcoming the internal lack of knowledge and information relating to the firm's decisions with regard to the innovation process (Bullinger et al., 2004; Phelps et al., 2012).

Thus, through networks, knowledge is not only transferred but also created. However, to create new knowledge the diverse sources also need to be integrated within the firms. Another important role that the literature recognizes to the networks is their capacity to enhance the innovation performance and productivity of firms (Lin & Lin, 2016).

Firms use their network relationships to facilitate their international process (Narula, 2004; Ojala 2009) and to speed up finding new business and market opportunities (Ibeh & Kasem, 2011). An increasing number of studies show that networks are important for firms to minimize the risks and uncertainty associated with innovation. Networks are usually important for ensuring co-investment. Such investment enables risk to be spread and usually leads to higher-quality investments and larger levels of investment for individual firms. Specifically, all these lacks that networks can solve, are strongly present in small-medium sized enterprises (SMEs) respect large firms (Edwards et al, 2005).

More in detail, large companies have more resources to innovate and support risky activities than in SMEs and, at the same time, large firms can benefit from economies of scale in R&D, production and marketing (Damanpour, 1992; Tsai, 2001; Stock et al., 2002). Indeed, different studies underlined that SMEs do not have the internal infrastructure to support sufficient interaction, or the knowledge and financial capital necessary for a successful innovation process (Jarillo, 1989; Nooteboom, 1994; Desouza & Awazu, 2006; Van de Vrande et al., 2009; Durst et al., 2013).

In addition, within SMEs, top managers play a unique position in shaping organizational strategies, processes and outcomes affecting the adoption of innovation (Hambrick & Mason, 1984; Geletkanyez & Hambrick, 1997). Therefore, due to the important role of managers in the decision-making process, the managerial networks, which refer to the connections of top managers with external actors, are critical for innovation adoption (Kraft & Bausch, 2018).

Compared to the other industries, the creation of networks is even more complex in small-scale farms in which farmers are not perceived as real entrepreneurs as in non-farm business (De Wolf et al., 2007). Farms may have been owned or managed within the same family for generations. This ownership/management role has militated against farmers from being entrepreneurial (Kahan, 2013). However, the role of the farmer in Europe is changing, as farmers have to develop new skills to be competitive. In a word, they need to become more entrepreneurial (McElwee, 2006). For small-scale farmers to become managers they need to be innovative and forward-looking.

Relating to the second aspect, the literature stressed that different actors involved in the network of a firm provide different types of information and knowledge that can influence the process of innovation adoption (De Faria et al., 2010; Mors, 2010). This is mainly due to the fact that different stakeholders often have contradicting priorities, goals and views.

Thus, researchers tended to investigate the impact of any single actor within a network on innovation adoption by firms. According to Lasagni (2012), firms could invite users or customers to participate in the innovation process directly to quickly obtain new product definitions. At the same time, several studies have documented that universities and other research institutions can be important partners that bring new scientific and technological knowledge into the firm (Bozeman, 2000; Drejer & Jørgensen, 2005).

Finally, it is important to underline that in addition to the positive benefits, networks can also have negative consequences on innovation: the costs of maintaining additional ties, reduced information benefits, or information overload (Ahuja, 2000).

4. Materials and methods

While the process of technology adoption by farmers has been widely studied through quantitative research (Adnan et al., 2019; Michels et al., 2019), over the last two decades there has been an increasing interest in the use of a more qualitative approach. Qualitative content analysis is one of the numerous qualitative approaches used to analyze text data

The goal of content analysis is to provide knowledge and understanding of the phenomenon under study, since it is considered the study of recorded human communications (Babbie, 2001) with a "systematic, objective, quantitative analysis of message characteristics" (Neuendorf, 2002). The flexibility of the methodology makes it particularly appropriate for the Social Science research, given that, according to Bates (1999), content analysis is focused of is the "study of gathering, organizing, storing, retrieving, and dissemination of information".

In comparison to sociology, the use of qualitative research strategies is less developed in agricultural economics, even if the social aspect of agricultural economics can contribute new and useful perspectives to the field of qualitative study (Bitsch, 2000). Content analysis can be both quantitative (focused on counting and measuring) and qualitative (focused on interpreting and understanding). In their work, Hsieh and Shannon, (2005), summarized three distinct approaches for the qualitative content analysis: conventional, directed, or summative (Figure 1). The major differences depend on the coding schemes and the origins of codes.

Conventional content analysis implies a direct approach in which that coding categories are derived directly from the text data. The directed approach starts with a priori with the study of the theory or relevant research findings in order to find the initial codes. Finally, the summative content analysis needs the counting and comparisons of keywords and after that, the interpretation of the context is needed.

For this study we applied the Conventional Content Analysis, generally used with a study design whose aim is to describe an emergent phenomenon, such as the diffusion of technology through a network. This type of design is usually appropriate when an existing theory or research literature on a phenomenon is limited.

In order to finalize the conventional approach, we avoid using preconceived categories (Kondracki & Wellman, 2002), instead of allowing the categories and names for categories to emerge from the data. Based on the Theory of the Diffusion of Innovations by Rogers (1962) the choice of the sample is concentrated on the innovators and early adopters categories among Italian farmers. The process of adoption over time is typically explained as a classical normal distribution of the "bell curve"

The model includes five type of users. The first group of users are the "Innovators": they are Technology Enthusiasts, these innovators usually try technological products even before they are released to market

Then it comes the "Early Adopters", also referred to as Visionaries, since they are the primary users who buy the new product, as soon because it comes out on the market.

Next come the Early Majority: this group is "Pragmatists",before choosing to adopt a particular technology, they wait to see its effects on those who adopt it before them.Then, the Late Majority Group, also known as "Conservatives", since they usually wait to adopt new technology after the majority of other consumers have already done so.

Finally, the Laggard group is composed by "Skeptics" users, since they are the most traditional among consumers, even considered technology-averse. This group is typically made up of older consumers that make the decision to purchase technology once there is an even newer technology making its way through the adoption lifecycle.

According to Moore (1995), the theory also suggests five characteristics of an innovation, which may affect its rate of adoption: I) relative advantage; II) compatibility; III) complexity; IV) trialability and of V) observability.

The adoption of Smart Agriculture among farmers affect on all these aspects. This has led Moore to propose a "chasm" in high-technology adoption between early adopters and the majority, risking a fatal stalling of the adoption process.

Several studies suggest that network activities and collaboration with innovation practitioners are correlated with overcoming the chasm. From this perspective, innovations can be developed within a dynamic and co-evolutionary process, in which the actors of the network are the key to creating and maintaining innovation processes.

According to Knierim et al., (2019), farmers included in a range in innovation processes, have been revealed as strategic partners to dealing with the uncertainties associated with digital technologies. For these reasons our study that is qualitative and exploratory in nature, proposes the use network from the farmer's perspective, as a tool to cross the chasm. Based on these premises, a qualitative content analysis method was applied to highlight how an organized network can support the adoption of new technologies among farmers, by analyzing the good practices related to the digitalization, promoted by the interviewees.

For the design of content analysis we followed the approach designed by Elo & Kyngäs (2008) which proposed three general steps for content analysis: (1) preparation (2) organising, and (3) reporting, and in order to guarantee the trustworthiness in all these three steps, we followed the checklist for researchers, proposed by Elo et al., (2014), attempting to improve the trustworthiness of a content analysis study in each phase. For the design of the content analysis, we followed the approach designed by Elo & Kyngäs (2008) which proposed three general steps for content analysis: (1) preparation step thus selecting the unit analysis of the sample (2) organizing step representing the coding and categorization of the results and finally reporting step (3) useful to build conceptual framework.

In order to guarantee the trustworthiness in all these three steps, we followed the checklist for researchers, proposed by Elo et al., (2014), attempting to improve the trustworthiness of a content analysis study in each phase. Relating to the first step, the sample was not selected randomly. Purposive sampling is the most commonly used method in content analysis. This type of sampling is suitable for qualitative studies where the researcher is interested to collect information from those who have the best knowledge concerning the research topic, which is farms that have experience in precision farming and have a network that fosters innovation. Thus, the farms were selected based on their experience.

The process of sampling concluded when the saturation point was achieved, a condition in which a newly added unit of analysis (a farm) did not provide any additional relevant information. Saturation is used in qualitative research as a criterion for discontinuing data collection and/or analysis. The saturation point was reached 8 interviews. Although the number of interviews may seem low for this research, it is important to point out that the sample size is dictated by theoretical saturation. In addition, the sample size is in line with several qualitative studies on digital innovation applied in different contexts, that use samples which varies from 3 up to 14 participants (Eze et al., 2011; Almeida et al., 2017; Cheong, & Mohammed-Baksh, 2019; Kashada et al., 2020). Table 1 shows the farm's charachteristics of the sample.

Table 1 - Sample

Sample	Region	Farming system	Year of experience in PA	Type of Technology adopted
Farm 1	Marche	Milk	10	Robotic milking system
Farm 2	Marche	Cereals, Fruit and vegetables	20	Tractors with ISOBUS, Rateo variable aplications, prescription maps, drones, detection of soil resistivity, DSS
Farm 3	Emilia Romagna	Cereals	12	Tractors with ISOBUS and Rateo Variable applications
Farm 4	Emilia Romagna	Cereals	15	Tractors with ISOBUS, variable rate fertilizer spreader, machine for weeding and treatment with variable dosage distribution
Farm 5	Emilia Romagna	Cereals, Fruit and vegetables	5	Tractors with ISOBUS, Rateo variable applications, prescription maps, drones, detection of soil resistivity, DSS
Farm 6	Lazio	Milk, cereals, fruits and vegetables, Grape	4	Tractors with ISOBUS, Prescription maps, Near Infrared sensors
Farm 7	Toscana	Grape and Oil	15	Telemetry on company tractors, variable dose machinery, use of prescription maps, detection of soil resistivity, management platforms for monitoring all processes
Farm 8	Toscana	Grape, Fruit and vegetables	15	Tractors with ISOBUS, Rateo variable aplications, prescription maps

Precision agriculture technologies are a sub-grop of digital technologies including the Internet, mobile technologies and devices, data analytics, artificial intelligence, digitally-delivered services and apps that are changing the whole agriculture and the food system. Examples of technologies at different level of the agri-food value chain: farm machinery automation allows fine-tuning of inputs and reduces demand for manual labour; remote satellite data and sensors improve the accuracy and reduce the cost inputs; and traceability technologies and digital logistics services offer the potential to streamline agri-food supply chains, while also providing trusted information for the final consumers consumers (Bucci et al., 2018).

Based on these premises in depth, face to face, interviews were conducted with the managers of farms. In line with the literature, we decide to interview this figure because managers play a unique position in shaping organizational strategies, processes, and outcomes affecting the adoption of innovation. As a consequence, the managerial networks, which refer to the connections of managers with external actors, are crucial for innovation adoption. All interviews were conducted in person, except for 2 of them, which were done on Skype.The interviews typically lasted 60–90 minutes and were tape re-corded and transcribed verbatim. The interviews were approached with a questionnaire related to the use of the networks in the process of technology adoption. Then the utilization of data triangulation determined an all-inclusive knowledge and a clear understanding about participants (Yin, 1989). The interview transcripts were imported into ATLAS.ti., a qualitative data analysis tool that allows organizing and sorting the transcribed interviews into themes, or 'coded'.

The coding process permitted all the relevant data sources related to the use of the network as a means to reach technological innovation within the farm to be examined. The analysis was performed by two researchers to increase the comprehensivity and provide sound interpretation of the data (Burla et al., 2008), and both researchers were trained in conducting in-depth interviews and analyzing qualitative data. The main results are organized firstly in codes, derived from the quotes directly expressed by the respondents. This data was then organized thematically by creating consistent groups of categories. For the third step, we grouped the categories into several themes which allows the researchers to interpret and explain the phenomenon.

5. Results and discussion

Before starting the content analysis, we performed a word cloud used as a graphical representation of the answer of the interviewees (Figure 3).

Figure 1 - Word cloud summarizing the most frequent words among interviewees

In particular, in qualitative research, the word clouds are useful as initial screening tools for qualitative research data (DePaolo & Wilkinson, 2014). By analyzing the resulting word clouds we were able to determine that farmers have more frequently resorted to words such as “Communication”, “Information”, “Network”, “Change” and “Precision"during the interview.

In addition, the innovative characteristics, the pionieristic vision and the experiences in precision farming technologies usage of the selected farm, was confirmed by the interviewees themselves, which considered themselves innovators and early adopters:

- “I have been attracted by everything that is innovative, also in agriculture. My father and my uncle transmitted their passion to me thus allowing to introduce technological innovations into the farm, thus realizing the important contribution that I was making within the farm. Honestly, I can say that on the regional level there is no such innovative reality like ours” (Farm 2);
- “We started in 2016 with basic precision farming technologies. From that moment on, we have never stopped innovating, continuing to invest in the latest technologies. Here in Italy, we think we are ahead with these technologies, but in the United States, for example, these technologies have already been used for 20 years” (Farm 6).

Before describing all the major themes that emerged from the data analysis, we want to present the answers to the three proposed research questions, by using the most representative quotes of participants, to increase the credibility of the study findings (Graneheim & Lundman, 2004).

Q1: How do different types of relationships favor the adoption of precision agriculture technologies?

- "But in agriculture more than in other sectors the human relationship is still very important. This is why it is important to have a direct and constant exchange with consultants, who always keep us updated on the latest news" (Farm 5);
- "Political support is still not enough. We have participated in several founded project calls, but on the one hand, we have been discouraged by the constraints for participation and on the other, by the bureaucracy that slows down the innovation process. To make you understand: once we participated in a project called for the technological change in agriculture, proposing certain technologies within that project. We had the results of the call after two years, and by that point, the technologies we proposed within that project had become outdated" (Farm 7).

Q2: What types of actors favor this process?

- "Being in close contact with technology providers absolutely has advantages. First of all, if something breaks, we are guaranteed quick service. We are also the first to be informed about the latest innovation available on the market, and then, if we are lucky they also let us test it as a pilot site" (Farm2)
- "Technological innovation is often stimulated by University, which is often our partner in funded projects" (Farm 8)
- " It often occurs that, farms that want to start investing in precision agriculture from zero, turn to us asking for some advice on which technologies to buy. We are always open to discussion, especially with those companies that do not believe in the efficiency of precision agriculture" (Farm5)

Q3: How networks play a role in supporting the digital technological process?

- “I like going to fairs and events because it can always happen to meet other farmers that do the same thing you do, but in a better way and therefore you can always learn new things thanks to the positive example from those who are better than you” (Farm 1);
- “For our company, it is essential to have a network of companies with characteristics similar to ours, in order to exchange views and opinions on technology. Since we are still few (with these technological characteristics), it is essential to confront each other” (Farm 4);
- “ We are an agricultural cooperative so we have purchased the necessary equipment that we use for working the land of all the members of the cooperative. Thanks to this change, of course, we have contributed to making farmers aware of this new management possibility (AP management)”(Farm 3).

By using the full set of codes and categories, we developed the data structure in Figure 4, which allowed us to derive the main theoretical theme that explains how the network can be used in the process of precision farming adoption.

In particular, as information about new technologies is a necessary condition for adoption, a good understanding of potential information failures that limit farmers’ adoption of available technologies is considered key. This puts the focus on the transfer and the acquirement of new information through the networks. Since the adoption of new technologies presents learning and adaptational challenges for farmers, the theoretical approach of the papers builds on the role of the network as a learning organization.

Figure 2 - Conceptual framework

The process, involving the capacity of an organization (firm) to learn from others, is also referred to as organizational learning within a network (Knight, 2002: Easterby-Smith et al., 2008). Networks are considered important sources of knowledge for firms (Powell, 1996; Maskell, 2001; Tallman et al., 2004). The diffusion of information and the subsequent adoption of innovation relies heavily on social relationships, particularly in regards to agricultural management.The interactions of a variety of actors, and the subsequent emergent networks of information exchange, are fundamental in the adoption of innovative technologies. In fact, the structure of these networks can influence the advancement or weakening of technological change and, for this reason, is a central attribute to successful innovation systems (Klerkx et al., 2010; Spielman et al., 2011). Based on the above framework, in the following subsections, the main aspects connected to the network dynamics, that determine a successful adoption process of digital technology, will be discussed.

5.1 Type of Ties

Within the network, farmers build two different types of ties: Strong and Weak. Strong ties exist between close-knit members with frequent interactions, such as family member and closer friends. By contrast, weak ties are characterized by distant social relationships and infrequent interactions, which are commonly observed between acquaintances or strangers (Zorzi, 2019).

In this study, strong ties are established with similar individuals, such us innovative farmers, with whom the same issues of interest are shared and with whom a relationship of trust is built over time. However, a network characterized exclusively by the presence of strong ties could show a a structural weakness, since the information between members with a strong tie colud be redundant, considerind the similarities between them (same interests, professions, or geographical location). On the contrary, including weak ties whitin the network could lead to greater contamination between different members, by providing non-redundant information but also create crucial bridges through which information can move rapidly and widely in a network (Zhang et al., 2020).

5.2 Key partners

The study shows how farmers form strong ties with individuals from whom they can derive high quality information about the technology. Farms connect with innovative farmers like them, with a proven expertise in digital technologies. At the same time, farmers have a direct relationship with technology providers, who not only provide assistance for their proprietary technologies, but also constantly update farmers on the newest technology on the market. In addition, farmers can also benefit from the assistance of IT consultants that work in partnership with clients, advising them on how to use information technology in order to meet their business objectives.

Farms also have a close collaboration with the research institutions, such as Universities, to carry out jointly research projects on smart farming technologies (Eastwood et al., 2017). On the contrary, farmers have rare contact with the laggards, since they have no points in common with the latter. These results are in line with the work of Rose et al., (2021) which suggests that a multi-actor approach is necessary for the diffusion of digital technology.

Finally, even if the interviewees recognize the importance of the policies for the innovation, necessary to guarantee investment funds for the purchase of new technologies, farmers are not satisfied with current political support such as the access to the public funds, which is a challenging process.

5.3 Key benefits

Through the network, farmers are able to learn about new technologies, and by comparing themselves with the members of the network they get feedback on the use of technology. This also highlights the importance of the networks as "learning organizations" in relation to the farming context, characterized by a weak organisational framework. In this study, we can define a network as a set of relationships, alliances and other different forms of interaction with external sources of knowledge.

Within the network the actors can share a different types of information about technologies: the interviewees share information about the novelty on the markets, and also about important fairs and events related to technology, in which they participated. During trade fairs there is no physical distance between actors in the network; moreover many actors meet at the same time. This creates specific conditions for the exchange of information and knowledge-building. Farms as visitors attend trade shows to learn about new solutions, suppliers, and products (Gopalakrishna et al. 1995) by interacting with products and prototypes, exhibitor staff and other customers, visitors obtain tacit knowledge about market offerings that would otherwise be difficult to acquire (Borghini et al. 2006).

Sharing experiences and information leads to the acquisition of new knowledge about technology, and as a result new business opportunities can open up. In line with the previous studies (Rothwell & Dogson, 1991; Edwards et al., 2005; Bentivoglio et al., 2016; Blanc et al., 2018), this research confirms that, also within the agri-food chain, farmers consider networks as ways to extend their innovative technological capabilities.

6. Concluding remarks

The changes brought about by globalization and the digital economy are creating pressures on firms. Moreover, the fast development of digital technologies imposes an even faster pace of change at the organizational level. Some firms are more exposed to the necessity of adopting and successfully using the digital technologies, while others are under less pressure. However, in the long run, no competitive firm can avoid the effect of digitalization.

The agri-food supply chain and in particular the first step of farming, strongly characterized by traditional practices and by fragmentation, is still at the initial stage of digitalization. With this study, we aimed to enrich current knowledge on digital transformation in the agricultural sector and the role that networks play in this change. Specifically, we examined the type of networks that the farmer, considered as managers, interacts with and the type of information exchanged.

Our framework, emerging from our analysis and based on the model of the network as a learning organization, contributes to the literature by emphasizing the role of networks, which is necessary to boost and support the adoption of digital technologies and its use in the agri-food chain. Unlike previous research that focused on demographic variables related to the managers, such as age, gender, and education, our research tries to explore and highlight the characteristics of the farmers' network that are increasing their managerial skills. This is crucial for the digital transformation process.

In order for good farm managers to become truly entrepreneurial they will need to develop these characteristics. In this sense, we underline the importance of the core belief of the manager and his/her ability to create networks as a factor that explains and justifies most of the strategic actions supporting the digital transformation process. Our study suggests that managers need to invest in forming the right attitude to digital technologies and collect information and knowledge by any means possible. The network of relationships is the most common and efficient way of pursuing these learning activities. Great attention must be put into the selection of the network members from which to be influenced. In particular, multi-actor innovation networks allow fostering interactions between actors for jointly solving agriculture-related challenges.

Constructing innovation networks generally involves attracting entrepreneurial members that act as champions, fostering linkages and cooperation, stimulating learning and mobilizing adequate resources. From the literature we learn that the digital transformation process is a never-ending and highly dynamic process whose success strongly depends on the digital strategy. In highly dynamic and continuous processes we believe that is important to have fixed and strong networks that act as a support for proactive behavior. For this reason, the sharing of information through specialized networks should be enhanced in order to facilitate the collective learning process.

In this context, we underline that the policy should support the adoption and transfer of digital technologies in agriculture through ad hoc strategies aimed at the creation specialized networks. In particular the Common Agricultural Policy (CAP) through the second Pillar and the structural Funds for innovation could have a crucial role. Several examples are provided for the Italian context, such as the development of the National and Regional Agri-food Technological Cluster, which is an example of a network between companies, research centers, local representatives and relevant stakeholders in the agrifood chain. However, for many farmers these technologies are hard to grasp: this is due to the limited access to training in digital technologies, the poor attainment of digital skilling and the limited access to the opportunities that can be derived from possessing these skills.

As is the case for all research, our study has a few limitations that should be taken into account when considering the reliability of the results obtained, this research provides a starting point that will assist in a further understanding of the technological change phenomenon.

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Chapter 7

Digital Farming under the technology provider's perspective: insights from a Grounded Theory Model

- Title of the publication: Digital Farming under the technology provider's perspective: insights from a Grounded Theory Model
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- To be submitted

Abstract

How can technology providers accelerate the technological change in the Digital Era? Considering the ongoing demand-led digitization in the Agri-Food supply chain, we investigate this research question by conducting qualitative research to understand the leading practices technology providers utilize to facilitate the adoption and diffusion of digital technologies among farmers. Using in-depth interviews and archival data from 30 CEOs from technology companies, we propose a theoretical framework to explore which strategies are crucial to effectively leverage the digital transformation from the supply to the demand side of technology. The paper provides evidence regarding the existence of specific barriers limiting access to achieve digital transformation among the Agri-Food supply chain actors.

Keywords: Digital Transformation, Technology Providers; Buyer-Supplier; Grounded Theory

Introduction

In the Digital era, managing buyer-supplier relationships has become crucial to boost technology diffusion on the market. This occurs because the adopters generally perceive these technologies, such as Cloud Computing, the Internet of Things (IoT), Artificial Intelligence (AI), Robotics, and Big Data, as disruptive since their introduction significantly alters the way companies or entire industries operate (Christensen 2003). Digital technologies have disrupted the traditional transactional relationship between buyer and supplier (Gupta and George,2015), changed how buyers and suppliers behave, interact, and co-create value by establishing an interexchange of data, information, and knowledge. (Di Gregorio et al., 2019; Mims, 2019; Lamberton and Stephen 2016).

Over the last decades, management studies on interfirm cooperation and strategic alliances have widely demonstrated how strong relationships among firms positively affect the creation, transfer, and absorption of new knowledge (Rai, 2016; Dhanaraj and Parkhe, 2006; Madhok and Tallman 1998; Parkhe,1993; Teece, 1992). Technology diffusion encourages, in the same way, information flows, quick distribution of experience, and formal and informal cooperation and sharing (Silverberg, 1991). Alliances between companies may be a feasible strategy to overcome barriers in the process since partners may support each other in managing common problems, such as awareness of and compliance with new technological solutions. As Rogers (1962) wrote, all members cooperate to the extent of seeking to solve a common problem to reach a mutual goal, given a common objective. Also, partners may provide access to resources and capabilities that are not available in-house. (Higgins, P. G. and Yarahmadi, 2014). Cooperation is essential because it reduces the risk and complexity involved in developing new products and processes by spreading it among several partners with agreed complementary aims. Closely related to Lundvall's (1998) idea of "learning by interacting", cooperation implies the development and acquisition of new capabilities, as each agreement involves a shared commitment of resources and knowledge (Penrose 1959; Miotti and Sachwald, 2003).

In this context, buyer-supplier relationships have been the focus of considerable research, highlighting how trust, commitment, and long-term orientation are essential to maintaining long term buyer-supplier relationships (Trautmann et al., 2009, Griffith et al., 2006; Johnston et al., 2004; Monczka et al., 1998). An effective buyer-supplier relationship has been defined by Sridharan (2002) as two or more chain members working together to boost a competitive advantage through sharing information making joint decisions, and sharing benefits that result from greater profitability of satisfying customer needs than acting alone.

However, while the buyer's perspective in buyer-supplier relationships receives much attention, prior studies have shown differences between buyers and suppliers. Arkader (2001) has found that buyers' perspectives are different from suppliers' regarding both the facilitators and the barriers of buyer-supplier relationships. For instance, buyers identify “problems due to environmental factors (especially, adverse logistics and tax systems)” as important barriers to cooperative relationships, while suppliers identify “organizational barriers (mainly, the existence of functional resistance and the loss of power by buyers in the purchasing departments)”

Supply-side agents, such as consultants and technology solution providers, cover an important role in innovation diffusion, acting as mediators between technology and adopting client firms (Attewell, 1992; Ettlie & Reza, 1992; Von Hippel, 1988) since they may help clients overcome adoption challenges with technological, implementation, and training know-how (Levina & Ross, 2003; Ko, Kirsch, & King, 2005). For this reason, technology providers need to work closely with customers and view the latter as a critical component of the supply chain (W.C. Swink and Narasimhan, 2007). To properly manage these relationships, buyers and suppliers must maximize trust and cooperation, minimize opportunism and risk, and collaborate on setting and accomplishing goals (Doney & Cannon, 1997; Zaheer, McEvily, & Perrone, 1998). As a result, the provider should be considered a trusted partner.

Despite the strategic role of technology providers, as suppliers, in the innovation process, the mechanisms about how suppliers search for buyers in the markets and get hold of long-term relationships with them to remain un-researched (Obal et Lancioni, 2013; Suosa and Rocha, 2019), mainly when clients hail from different industrial background and have scant technology knowledge and experience (Weilget and Sarker,2009).

This research aims to fill this gap by developing a better understanding of these mechanisms and the conditions under which the technology providers could cooperate, thus efficiently and effectively increasing the diffusion of technology among the buyers, since there is a need for” ponder more holistically the roles played by the company that offers the digital technology” (Liang Li et al., 2018).

Given these premises, this paper addresses how suppliers try to improve long-term relationships with their buyers by studying which types of mechanisms are expected to facilitate more rapid diffusion of technology.

We address this research gap through qualitative research by interviewing a sample of 30 technology providers who respond to open questions dealing with their perception of the key factors enhancing the building and maintenance of buyer-supplier long-term relationships in the context of the Agrifood Sector.

The remainder of the paper is paper organized as follows: Section 2 presents the theoretical background and the hypotheses development. Section 3 indicates the methodology and Section 4 provides the results. Sections 5 and 6 discuss the conclusions and limitations of the study, respectively.

Theoretical Background

Since the emerging digital technologies are creating new opportunities on the market, firms, especially SMEs, have to face the problem of balancing the risk of rushing into the new market with high technology investment costs, potential losses from cannibalizing existing business, and the uncertainty occurring in the emerging market (Jin and Li, 2012). The digital market is characterized by uncertainty which affects the way buyers and suppliers interact. While from the supplier perspective, market uncertainty represents the uncertainty of changes in demand, price, and competition; from the buyer perspective, firms who are deciding to adopt digital technology for a digital content market have to make complex decisions loaded with high uncertainty related to the new technology, the intellectual property, the new business model issues. They have to consider the characteristics mentioned above of technological investment, market differentiation, and uncertain profitability before adopting the latest technologies.

To overcome these challenges, inter-organizational long-term collaboration is one strategy that can strengthen relationships between buyer and supplier, enhance trust and allow firms to survive in a highly competitive environment (Pfeffer, 1972). Buyer and supplier long-term collaboration focuses on mutual benefits to achieving future goals in the long run. According to Ganesan (1994), long-term collaborative relationships maximize profits over many transactions through relational exchanges. A large and diverse literature exists on interfirm relationships. In particular, the importance of buyer-seller relationships has been studied extensively: the business practitioners and academic researchers focused attention on the mechanisms that build long-term relationships.

Trust has a significant effect on the success of long-term relationships (Dirks and Ferrin 2001) and it refers to "the confidence in the face of risk" that the organization has toward the partner firm (Fink et al., 2010). Previous literature has shown that long-term, inter-organizational relationships are built on mutual trust (Jeffries and Reed, 2000; Morgan and Hunt, 1994;). Interorganizational trust is defined as the belief and confidence placed upon a supplier organization by the buyer organization members (Zaheer et al., 1998). It leads to positive outcomes such as competitive advantage, improved performance, perceived risk reduction and satisfaction (Pavlou, 2002; Zaheer et al., 1998;) and efficient transactions by reducing transaction costs (Bradach & Eccles, 1989). It also reduces opportunism, and it promotes cooperation (Morgan & Hunt, 1994). According to Venkatesh et al. (2011), trust has also been found to create positive attitudes that subsequently led to an increased likelihood of innovation adoption. Empirical work on inter-organizational trust in the context of small firms has focused on small and medium-sized enterprises (SMEs), trust in service providers (Coulter and Coulter 2002), trust in bank-small strong relationships (Saparito et al., 2004), and the role of trust as the primary determinant of success in manufacturing networks of SMEs (Sherer 2003). While these studies contribute to the growing body of research trust in the context of SMEs, empirical research on the role that trust plays in enabling markets for technology is limited (Jensen, 2015).

Commitment has a significant role in structuring business relationships. It refers to the motivation to stay with a supplier or to an enduring desire to maintain a valued relationship. Kumar et al. (1994), distinguished two different types of commitment: affective and calculative commitment. Affective commitment, based on a general positive feeling towards the exchange partner, expresses how customers like to maintain their relationship with their supplier.

Calculative commitment refers to a firm's motivation to continue the relationship because it cannot easily replace its current partner and because it cannot obtain the same resources and outcomes outside. Several aspects of commitment have been examined in the study of organizational relationships. Information sharing, defined by Anderson and Narus (1990) as the formal and informal sharing of meaningful and timely information between firms, allows companies to proactively provide valuable information to the partner that may affect the partner's operations (Heide and Miner, 1992). This kind of proactivity helps to align expectations and avoid conflict and resolve disputes between partners (Morgan and Hunt, 1994). Anderson and Narus (1990) argued that previous communication is an antecedent of trust and the relative trust-commitment theory of relationship marketing also supports this proposition. Communication not only attenuates the risks involved in making decisions within business relationships (Heide &Miner, 1992), but also impacts positively by creating an impression that the partners are mutually supportive. It has been acknowledged that communication encourages commitment and loyalty through fostering participative decision-making (Anderson et al., 1987). Biggeman (2012) recognized three aspects of communication behavior essential to the successful buyer-supplier relationship in market performance: the willingness of parties involved to disseminate meaningful information, communication quality, the extent of information sharing between partners, and participation in planning and goal setting.

In addition to trust, commitment, and communication, long-term relationship satisfaction has also been recognized as an antecedent of cooperation. Cooperation refers to "situations in which parties work together to achieve mutual goals" (Morgan and Hunt, 1994). This concept implies that actors involved in a relationship combine their efforts to build a successful relationship. Cooperation is a dominant sentiment that facilitates organizational relationships: an excellent cooperative relationship enhances partners' capability and promotes partners' efficiency in exploiting Interorganizational resources. Skinner et al. (1992) acknowledged that goal compatibility, role clarity, domain consensus, and norms of evaluation and exchange all impact cooperative relationships, among many others. A meta-analytical study of Palmatier et al. (2006) indicates that frequency and quality of communication among exchange partners add to higher levels of trust, commitment, and relationship satisfaction in buyer-seller relationships, further contributing to cooperation among exchange partners (Palmatier et al., 2006).

As firms become more dependent on outside partners to meet sophisticated customer needs in the digital economy, managing inter-organizational relationships effectively becomes essential to gain a competitive advantage. Consequently, inter-organizational cooperation receives considerable research attention. Most empirical investigations of inter-organizational association within channel dyads have investigated the phenomenon mainly from the buyer's perspective. (Kim and Umanath, 2005; Bensaou, 1997;)

However, we believe that investigating the inter-organizational cooperation from the supplier side's perspective could be more interesting, especially because their role is especially relevant for customer-interfacing innovations, such as digital technologies. In this context, technology suppliers could help their clients overcome adoption challenges with technological, implementation, and training know-how (Levina and Ross, 2003; Ko et al., 2005). Despite the incipient literature on how digital technology changed the way companies cooperate and communicate, there is little evidence of how technology suppliers interact with their clients in the era of Digital Transformation. Technology is changing faster than what organizations can cope with. It is critical not just to adopt new technology but also to ensure its successful implementation in its business model.

For this reason, technology suppliers are moving beyond the vendor-customer relationship to play the role of a strategic partner in helping organizations to adopt, integrate and understand the benefits of digital technologies. However, most of the previous research has centered on large firms as clients. Some studies suggest that large firms' information system theories and practices may not be suitable for small ones (Farhoomand and Hrycyk, 1985; Premkumar, 2003). The existent literature has traditionally examined the implementation of digital technologies in large firms, and specific insights into entrepreneurial SMEs are relatively scarce (Jin & Hurd, 2018; Mohd Salleh et al., 2017). According to Premkumar (2003), SMEs are different from large firms in several ways: in SMEs, decision-making is centralized in a reduced number of persons and there is little long-term planning, and there is a greater dependence on external expertise and services for information systems Besides, SMEs face unique challenges in implementing digital technologies because they may lack the necessary resources, skills, and commitment; As Obal (2017) wrote, in a high risk and uncertainty conditions, such as the adoption of new digital technology, SMEs often have to rely on technological suppliers. Despite the differences mentioned above between small and large firms, research on how technology suppliers interact with SMEs as clients and build trusted relationships, is very limited, and a better understanding of these issues is necessary (Giotopoulos et al., 2017; Nasco, Toledo and Mykytyn, 2008). In the light of these considerations, we feel a need to deepen our understanding of the micro-mechanism by which technology suppliers build trust as a potential explanatory factor for the cooperation and the long-term relations relationship maintenance with the buyers.

Methods

To answer the research question set out at the beginning of this paper, a qualitative case study was build, following the inductive theory-building approach (Eisenhardt, 1989; Yin, 2003). Since the buyer-supplier interactions in the digital era have not yet been widely explored in the literature, the inductive case study approach could help us generate valuable insights.
This paper analyzes data from 30 technology suppliers interacting with SMEs from the Agrifood sector. The food sector was chosen as a theoretically relevant context for examining power in relationships (Chad et al., 2010; Pullman et al., 2009). Besides, since the agri-food sector is considered one of the lowest digitalized sectors in Europe, we want to analyze how technology suppliers approach and interact with their clients that generally have scant knowledge and, more in general, are unfamiliar with digital technologies. Case studies were chosen according to the following criteria:

1. The technology produced by the supplier had to be related to the Agrifood sector: digital platforms, Decision Support System (DSS), drones, sensors, smart tractors, were the most common technologies investigates;
2. Technology suppliers had to be directly in contact with the final user (farmers or Agrifood operators) to understand the main constraints related to the adoption and the usage of technology;
3. In the case of Agritechs, the technology startup of the Agrifood sector, those selected had to have their final product already on sale in the market.

Data collection

To collect data, an interview protocol was built to focus the respondents' attention on the relationship with their clients. This protocol was split into three sections: (1) characteristics of the technological offer; (2) relations with partners and Institutions; (3) buyer-supplier relations. This protocol formed the basis of the semi-structured interviews, conducted either in-person and by phone. For an inductive theory building study, the semi-structured interview is suitable since it allows the researcher to ask specific questions about the phenomenon of theoretical interest. It also enables the interviewees to express themselves freely, revealing more profound insights about the theory (Gioia et al., 2013). Starting from March 2019 until July 2019, 30 interviews of Italian companies were interviewed. The case analysis triangulates the qualitative data from the interviews with the additional data from several sources: company reports, online public documents, and online videos to establish a connection between concepts in different literature streams and sustain a competitive advantage in quality.

Data analysis

Once the data collection was completed, all the interviews were transcribed and analyzed with the qualitative software MAXQDA. Data analysis was conducted according to the three-phased coding procedure developed by Goia et al., (2013). This three-phased coding process starts with the identification of the 1st-order categories. (Figure 1)

Results

Following Gioia et al. (2013), Figure 2 shows data structure that emerged from a three-stage coding process. The sentences in the boxes on the left side of the figure represent the first-order concepts, both for technology providers and end-users, obtained through open coding, an explanatory process that uses codes basing on respondent's statements. Then the authors identify the second-order categories by grouping in the middle of the model the convergent categories at a higher level of abstraction. After that, a grounded theoretical model was built (Figure 1) by identifying three analytical dimensions that emerged from the analysis: 1) Trust Building between Buyer and Supplier of technology 2) Mechanisms adopted by providers to boost technology acceptance and usage; 3) Typical customer of the tech-supplier

Each of these themes is then presented and discussed under the technology providers 'perspectives.

Horizontal solutions			Vertical solutions	
I Order	**II Order**	**Theoretical Themes**	**II Order**	**I Order**
I came from the engineering world and started studying agronomy again before I could talk to a farmer and understand his needs. Today people believe that I am an agronomist, but in reality, I am an engineer	A supplier needs to acquire the basic knowledge	**Trust Building**	Direct experience in the field of agriculture	*We have always worked in the agri-food sector*
You know, I had to study a lot before I was sure to deal with the farmers. Because if they understand that you don't see what you're talking about, they don't trust	Trust passes through the perceived experience			
It works like this that you have to put yourself on the same level as the farmer if you want to hope to have a dialogue with him	Mirror technique: tech supplier at the same level as the farmer		High market reputation	*You don't need to advertise us a lot because we are already well known on the market*
We use an agronomist as a link between the farmer and us. Here we	Use of a mediator, e.g.: agronomist			

are, all engineers, and nobody understands agriculture				
To incentivize the use of the platform, we provide the solution for free, for example, as happens in research projects, and when a particular company adopts the platform, we use that company as a case study and as an example for other farms	Use of case study	**Technology acceptance and usage**	Vicarious learning	*We often organize open days in which we send our most loyal customers to test our products*
Theoretically, our solution has no limits. Then you have to see what the farmer wants. Because sometimes, they ask us for things that seem easy to them to develop, but in reality, it is not	Flexible technology		Standard technology	The technology offered may include additional services, but the basic one remains (example of the tractor)
Today the customer does not look so much at the product you sell, but also at the services you offer along with that product	Servitiation		Servitiation	*You must always be available for the customer, 24 hours a day*
We do not currently invest many of our resources in dissemination and dissemination activities,	Poor dissemination activities		Social media	*We are very active from this point of view, and we often participate in*

which is shameful. But we can't do everything				*fairs, where we have the opportunity to get to know farmers directly*
We have recently started investing in the agrifood sector, having perceived its potential	Agrifood as a promising sector		They operate only in the agri-food sector	*We have always worked in the agri-food sector*
We don't want to go looking for a single customer if he has to pay us an annual fee of 300 euros. Using the cooperative as a single customer allows you to halve resources and take a larger share of the market	Agricultural cooperatives as client	**Typical customer**	Farmers as client	*Being little known on the market, we must address the individual farmer, visiting individual companies to make our product known*
We serve both farmers and other supplier companies directly	B2B and B2C		B2C	*Our client is mainly the farmer, and the focus is on him*

Figure 1: Theoretical framework

Trust Building

To build trust in the end-user, the technology providers implement different strategies. Horizontal solution suppliers are those providers who are less familiar with the agrifood sector. Therefore, they need to acquire knowledge and experience in the sector before speaking with the final customer. This process is not immediate since the technology providers take months or even years before reaching a certain familiarity in the sector and consequently credibility on the part of the farmers. Technology providers can also use agronomist consultants who help them interact with farmers to help them perceive their needs. On the other hand, technology providers find barriers when they interface with a sector characterized by a low digitization rate. Therefore, they need to interface with intermediaries, able to understand the needs of the companies in the Agri-Food Sector, and be able to provide adequate technological solutions:

"I come from the world of engineering and I had to start studying agronomy again before talking to farmers and understand their needs. Today people believe that I am an agronomist but in reality, I am an engineer."

The technology providers of vertical solutions, on the other hand, already have experience in the agri-food sector and a particular reputation. They are not looking for customers, but farmers through a bottom up process who turn to them to purchase new technology. The farmers are less hesitant towards them because these companies are often leaders in the sector.

Technology acceptance and usage

Horizontal solution providers produce technologies that are flexible and that are well suited to each operational context. To encourage the use of these diagnostics, they often provide free demos to their end customers. The relationship with the end customer must be improved because the suppliers of horizontal solutions usually do not yet dedicate many resources to dissemination actions. While on the other hand, the vendors of vertical solutions are highly specialized and often theirs is a standard technology, which is tested during the Open Day, in which the technology providers are in close contact with the end-users. To strengthen this closeness, these technology providers use social media extensively, such as youtube or Instagram, in which they disclose videos on the use of the technology itself.

Typical Customer

For suppliers of horizontal solutions, agrifood is an entirely new and up-and-coming market. They tend to prefer big players on the market or large agricultural cooperatives as final customers, active in both the B2B and B2C trade. The suppliers of vertical solutions operate exclusively in the agrifood sector and prefer farmers and contractors as final customers through a B2C relationship. Besides, from an analysis of political facilities, it emerges that technology providers do not take full advantage of digital transformation policy opportunities. This is because there is still no clear political strategy that allows the technological change in the Agri-Food sector. It seems that sometimes, companies operating in the Agri-Food sector are forced to innovate, even when they don't need to introduce any other type of additional technology. This is the case, for example, of the electronic invoice. The Institutions, in this case, represented by the European Union, acting locally through the Italian Government, create the need to adopt new technology. The electronic-invoicing system became mandatory in Italy on the 1st of January 2019 for all sectors' businesses (Directive 2014/55/UE). Consequently, all the companies that were not using this system, that in our study are defined as those who lack a clear commitment towards technology, were obliged to adopt new digital technologies, such as software for e-invoicing.

Conclusion

The proliferation of digital technologies will play a significant role in agriculture. Digital transformation can unlock the potential for smallholder farmers to increase their incomes. It is an opportunity for farmers to be visible, be empowered, and engage directly with their customers.

This paper is a first step in understanding how technological providers' role could impact different stakeholders of the Agri-Food supply chain. Synergies between buyers and suppliers are vital; key players must work together.

Therefore, to increase smallholder farmers' income, an integrated approach of increasing productivity, links to markets, and access to inputs have to be adopted. Achievement of desired technology modification and behavioral change requires support from the public, industry, research community, extension services. Several supporting programs are available, starting from Common Agriculture Policy, to Industry 4.0: they both play a prominent role in digital adoption and diffusion of technologies. Finally, the Digital Innovation Hubs (DIHs) could reinforce the EU's competitiveness in digital technologies. DIHs are ecosystems that consist of SMEs, large industries, startups, researchers, accelerators, and investors that support companies to become more competitive. DIHs act as a one-stop-shop, serving companies within their local region and beyond to digitalize their business. The concept of a Digital Innovation Hub is innovative. It brings different actors together to develop a coherent and coordinated set of services through a one-stop-shop to support companies—

especially small companies or enterprises from low-tech sectors—that have difficulties with their digitization.

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Chapter 8

Implementing the Sustainable Development Goals with a digital platform: experiences from the vitivinicultural sector

- Title of the publication: Implementing the Sustainable Development Goals with a digital platform: experiences from the vitivinicultural sector
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Abstract: *Emerging technologies, such as Digital Platforms, Internet of Things, remote sensing and Big Data, are going to significantly influence the achievement of the 17 Sustainable Development Goals (SDGs) targets, pursued by all United Nations Member States starting from 2015. As the whole agricultural sector is transforming in a more knowledge-intensive system, precision agriculture could play a significant role to achieve the SDGs, by reducing environmental impacts of agriculture and farming practices, increasing the profitability of the farm and thus improving the quality of life for farmers Based on these premises, the aim of this article is to present VITIS, a digital platform, for the management of vineyard water and nitrogen stress, developed by the Operational Group SMART VITIS and tested in 4 pilots located in Marche Region. All the functions and modules of the platform were built by following a Design Thinking approach. This approach started from the analysis of the needs of the winegrowers, the end-user of the solution. While a focus group, made of agri-experts was conducted to receive feedback from the test phase of the*

platform. This study illustrates how this approach can be a useful tool to develop targeted digital solutions for farmers with low digital skills.
Keywords: Digital Platform; vineyards; Design Thinking Approach; Focus Group, Sustainable Development Goal

I. INTRODUCTION

The 2030 Agenda for Sustainable Development is a plan of action, signed in 2015 by all countries of the United Nations, with the aim to eradicate poverty in all its forms. The Agenda includes the 17 Sustainable Development Goals (SDGs) seek to address issues relating to hunger, poverty alleviation, democratic governance and peace building, climate change and disaster risk, and economic inequality [1]. Considering the fact that the global population is growing at a fast rate and natural resources are finite, Precision Agriculture and digital technologies could help farmers to maximise yields, improve the efficiency and sustainability of agriculture, thus contributing to the implementation of the United Nations [2-3]. In fact, the adoption of Precision Agriculture Technologies could directly affect the following SDGs:

- **Goal 2: Zero hunger** which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture;
- **Goal 13: Climate Action** which aims to take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy;
- **Goal 15**: Life on land which aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

The 2030 Agenda for Sustainable Development leaves just ten more years to provide effective solutions to these issues. Therefore, all actors involved must simultaneously step up their efforts to develop new Agricultural Knowledge and Innovative Solutions (AKIS). Nowadays, technologies, such as Digital platform, based on the collection of Big Data from several sources, producing useful information to farmers, can contribute to the achievement of a sustainable farm management. In fact, digital platforms for data management are revolutionizing the way to manage agriculture [4-5]. Some of the platforms and software are multi-purpose focusing on whole-farm management in the fields, for precision agriculture applications and inventories. Some others are dedicated to specific applications, such as for forecasting specific diseases or pests, for irrigation [6-7].

Almost all the platform on the markets have the capability to collect information from different data sources:

- External data sources (i.e. weather station data networks, historical satellite data archive, water supply managers' networks);
- Data acquired in real time from distributed smart sensors (drones, smart electronic leaf, …) through intelligent networks (battery-powered smart networks wireless);
- Precision farming tools and agricultural smart vehicles.

The fact that large amounts of data are collected from a variety of sources makes the gathering of all these data sets together in one place very important for any farmers wanting to improve the whole farm's sustainability. Available Platforms are focused on agricultural tasks but most of them do not have a strong real-time module to manage IoT devices and information. For high-income crops such as grapevine, it is important to monitor all the environmental parameters which allow obtaining high-quality productions. High-quality grape production requires the adoption of innovative systems that assist the optimization of wine quality and yield [8-9]. For this reason, Precision viticulture has established itself as a specialized field of smart agriculture aiming at maximizing the oenological potential of wine grape yield. [10-11]. In addition, in order to compete in international markets, it becomes of utmost importance to achieve higher quality standards in the vineyard. This has led to a radical renewal of viticulture and a review of agricultural techniques, with the aim of maximizing quality and sustainability through the reduction and more efficient use of production inputs such as energy, fertilizers and chemicals, and minimizing input costs while ensuring the preservation of the environment. [12-13].

Wine has become a global high-value commodity such us strategic productions for European Union (EU). Related to the grape production, the EU represented around 45 % of the world's total area under vines, with 3.2 million hectares cultivated in 2015 and 2,4 Million of holders. In 2019 the production raised up to 25.763 thousand tonnes. In 2019, Italy, Spain and France and Greece are the largest EU producers of wine and table grape, accounting for more than 80 % of production [14] (Figure 1).

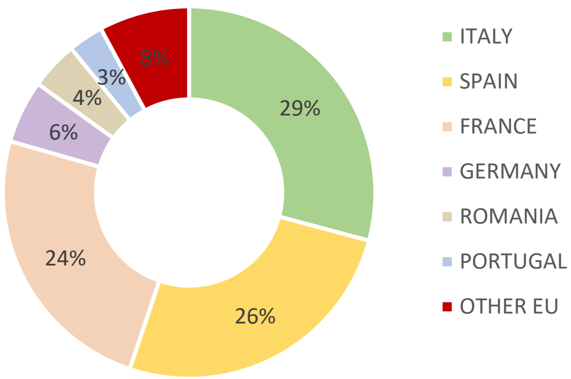

Figure 1: European wine grape production in 2019

In Italy the 5 top producers of grape are Puglia, Veneto, Emilia Romagna, Sicilia and Abruzzo Region [15] (Figure 2).

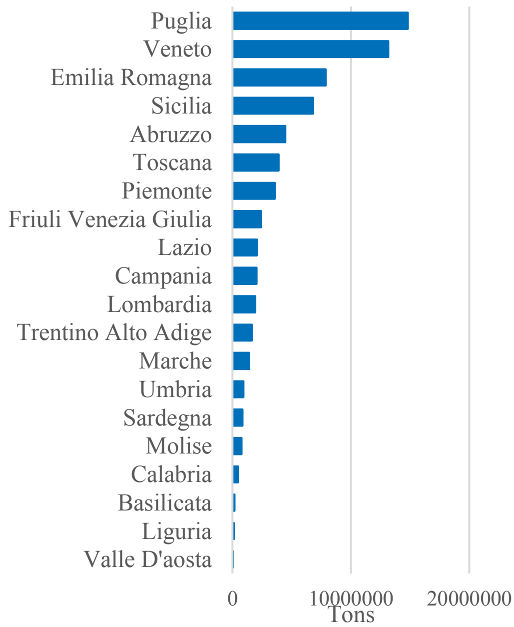

Figure 2: Wine grape production by Italian Region in 2019

Despite its limited grape production (930 tons in 2019), Marche Region is found to have the potential for high quality standards wine considering the availability of several terroirs suitable for the wine grape cultivation. For this reason, the Region, with its local varieties, produces wines labelled with Controlled Designation of Origin (DOC) and Denomination of Controlled and Guaranteed Origin (DOCG) schemes. While the DOC label recognizes the quality and typicality of wines produced in limited small- and medium-sized areas, DOCG, follow the highest production standards to obtain an excellent quality product. At present, Marche has 18 (DOC) wines and 5 (DOCG) wines [16] (Table1).

Table 1: Grape Varieties and Wine Denomination in Marche Region

	Marche Region
Varieties	Biancame, Lacrima, Maceratino, Malvasia, Montepulciano, Montonico Bianco, Passerina, Pecorino, Sangiovese, Tai Rosso, Trebbiano, Verdicchio, Vernaccia Nera
DOCG wines	Castelli di Jesi Verdicchio Riserva, Conero, Offida, Verdicchio di Matelica Riserva, Vernaccia di Serrapetrona
DOC wines	Bianchello del Metauro, Colli Pesaresi, Colli Pesaresi- Sottozona Focara, Colli Pesaresi- Sottozona Roncaglia, Colli Pesaresi- Sottozona Parco Naturale Monte San Bartolo, Pergola, Lacrima di Morro d’Alba, Rosso Conero, San Ginesio, Esino, Verdicchio dei Castelli di Jesi, Colli Maceratesi, Serrapetrona, Verdicchio di Matelica, I Terreni di San Severino, Rosso Piceno, Falerio, Terre di Offida

The need to maintain high quality standards of wine production could justify the adoption of site-specific management practices to simultaneously increase both quality and yield. Digital platform and the related Decision Support Systems (DSS) are already available on the market to support the growers in making their decisions. However, the use of these platforms is still very low. [17-21] Therefore, it is crucial to develop an easy to use system and convince farmers to adopt them. The aim of the article is to highlight how the use of the Design Thinking approach is a useful flexible tool for developing a digital platform that can both satisfy the needs of the end user and provide feedback from other stakeholders. The rest of the paper is structured as follows. Section 2 provides an overview of the main characteristics of the VITIS platform. Material and Methods are explained in Section 3. Section 4 shows the main results of the analysis and conclusions are drawn in Section 5.

II. THE DIGITAL PLATFORM SYSTEM

Digital platforms are characterized by specific architectures that define them. Each product distinguishes by a specific architecture that outlines modalities through which its parts and functions are composed. The main structure of the VITIS platform developed by Gruppo Filippetti, consists of the integration of the platform environment with specific data management and modeling components for agriculture, as well as with sensor data input systems (Figure 3). The platform is a set of application modules and infrastructural technologies conceived and developed to provide advanced cloud services in the field of smart technologies and the Internet of Things. The data measured by the sensors distributed on a large scale are by their very nature highly variable and can quickly and for each individual use case constitute significant volumes that cannot be managed with common database engines. IoT Smart Platform uses Big-Data technologies and a robust and performing architecture for data collection, persistence and recovery. The innovative character of the platform is that it can be used to collect data in the field and subsequently it is possible to use that same data to train an Artificial Intelligence or Machine Learning model. These data streams can be generated by field sensors (temperature, pressure, soil temperature, soil humidity, moisture, etc.), the robot itself, and other sources like i.e. satellite photographic data ad 3D mapping. VITIS platform allows the integration of all these sources data, gathered daily and seasonally, to generate new aggregated information to implement advance analysis and prescription activities on the field.

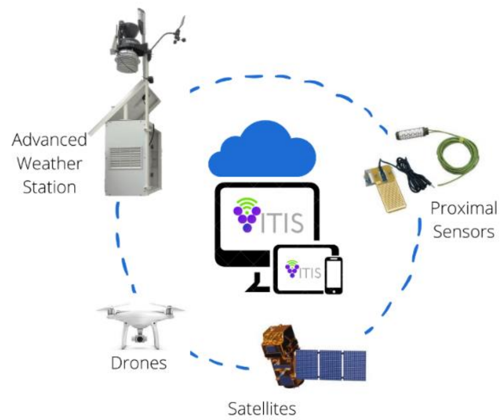

Figure 3: Vitis platform structure

The sustainable wine production involves the precise use of water and N inputs in the vineyard. Improved knowledge on grapevine ecophysiology, the use of sensors for soil and canopy monitoring, plant phenotyping and improved crop management can help save water and N inputs [22-23]. To achieve these goals, the VITIS platform developed specific algorithms for the management of vineyard water and nitrogen stress.

III. MATHERIALS AND METHODS

The modular nature of the platform implies that its development can be achieved through a Design Thinking approach, a systematic method to create solutions in the form of products or services based on the needs of the end-users. Several authors [24- 27] agree that this approach is common in organizations of all sizes across all industry sectors, including technology companies. For this reason, we found it useful to apply this approach in the development of a platform for the management of the vineyard, considering that agricultural operators usually have low digital skills and therefore it is not easy to immediately implement ready-to-use solutions. The design thinking process uses five fluid steps that result in a solution built around the needs of "users" and "stakeholders." The "user(s)" (farmer) experiences the problem and the stakeholders (technology company, consultants, contractors, university) are those who have experience around the perceived problem. The process begins with an open-minded assessment and continues through five steps until the appropriate solution is produced, often in a nonlinear pattern. The goal of this process is to identify an optimal solution informed by feedback obtained through discussions with, or observations of, users and stakeholders in the context of the perceived problem.

As reported in Figure 4, the Design Thinking Process follows 5 different steps:

1. **Empathise**: Innovation always starts with a in-depth diagnosis of the needs and expectations of users and potential users of the product, and understanding the technical conditions and market conditions of the product. The empathize step is primarily done through interviews and observing the actions of the users in the context of the problem. Stakeholders will be looking to answer questions such as "Who is the user?" and "What is it important for the users?"

2. **Define**: This steps provides the definition of the issue and the needs of the user. Stakeholders now will be seeking to answer this question :"What is the audience's point of view and what are the needs of the end user?
3. **Ideate**: Ideating is the brainstorming period to generate a wide range of potential solutions. The more ideas, the more likely the optimal solutions will be identified. Creative solutions should evolve from the defined problem statements. Solutions should speak to the different aspects of the problem investigated.
4. **Prototype**: This stage involves creating or building a rough representation of one or more ideas to show to the end user.
5. **Test:** In the last stage, the prototype should be presented as a solution to the original user in order to obtain its opinion on the generated product. In this way, users can test its functioning. The scope of this step is to check the functioning of the designed solution in a real environment in which the product will be used.

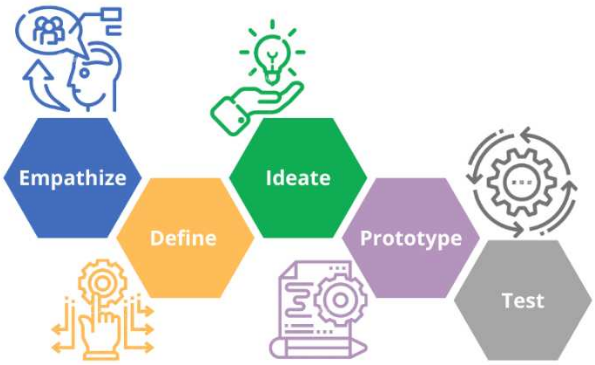

Figure 4: Design Thinking process

Then, the iterative process would continue with reworking and adjusting the product as the design team receives feedback from end users. Finally, in our analysis, the main results from the Design Thinking approach process are synthetized in a SWOT analysis which stands for Strengths, Weaknesses, Opportunities, and Threats, a strategic planning technique used to assess these aspects related to business competition or project planning. [28- 29].

IV. RESULTS

The first step implies to gain a deep understanding of the customer or end user for which the product is designed for. In our study, 4 winegrowers were selected for testing the platform and 4 pilot sites with different characteristics (cultivated variety, plot extension) were chosen. To know the characteristics of the company and the characteristics that the platform should have had, a survey was built. The survey had 4 sections. The first section explores the characteristics of the pilots. The second section queried respondents on their current wine yard management practices. In the third section, a series of questions asked landowners about their knowledge, understanding and current use of precision farming technologies. In the last section winegrowers were asked to indicate what functionalities were desired in the platform. Table 2 synthetize the main characteristic of the pilots.

Table 2: Characteristics of the pilots

	Variety	Hectars	Management
Farm 1	Verdicchio	3,27	No emergency irrigation and manual harvesting
Farm 2	Verdicchio	1,37	No emergency irrigation and manual harvesting
Farm 3	Montepulciano	4,41	Emergency irrigation and mechanized harvesting
Farm 4	Montepulciano	2,39	Emergency irrigation and both manual and mechanized harvesting

However, in the absence of feedback from the winegrowers as the platform is still being tested, we decided to conduct the test of the platform with a team of Agriexperts in order to know their feedback on the platform. Considering that agricultural knowledge from experienced experts is needed for the purpose of validating the feasibility of generated strategies and correcting the mistakes in provided decision supports, we found useful to consider the team of agri expert as the users of the platform, and test the platform with them [30]. In order to accomplish the test, a focus group of 5 agriexperts was performed and a SWOT analysis synthetized the main results emerged.

STRENGTHS: The VITIS platform provides real-time data on the quantity of nitrogen present in the soil and the level of humidity thanks to the humidity probes present in the pilot sites.

WEAKNESSES: According to agriexperts, some functions of the platform are still not very intuitive and for this reason one is needed more user-friendly interface.

OPPORTUNITIES: Insert in the platform the possibility to customize the level of information request (from general to more specific); possibility of automatically processing weekly bulletins that summarize the main information order to facilitate winegrowers to reading and understand the data. According to [31] for farmers is usefull to visualize data in formats of map, table, list, line chart, pie chart, and flowchart, so that they can easily understand data collected from sensors.

THREATS: Consider the possibility of a scarce usage of the platform by winegrowers. To solve this problem, the agriexperts recommended organizing training meetings and drawing up guidelines for the use of the platform.

These results provide an in-depth presentation of the feedback from agriexperts related to the VITIS platform. The team of agriexperts provides useful recommendations to implement the phase of platform adoption among the end-users.

V. CONCLUSION

In order to enhance the sustainable impact of digital technologies on food and agriculture production, it is necessary to achieve a broad social consensus. This paper has presented the Design Thinking approach as a helpful tool for technological companies developing digital solutions. Results showed how this process could have a positive impact on the user's acceptance by carrying out a user-centred designed process, based on the continuous and active involvement of the user representatives with the entire development of the platform. The decision to test the solution first on agriexperts helped the technology provider to build a specific solution in order to minimize the resistance of farmers to digital platforms. The platform will offer to farmers a sustainable smart farming open data network. This allows the winegrowers to provide an added value to their productions in the form of better decision making or more efficient input management. This, of course, remains a work in progress for our research team, in the sense that among our future goals is the extension of the current platform.

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Discussion and Conclusion

Due to the improper use of environmental resources, the transition to a sustainable development model is now mandatory in light of the concerns that have emerged in recent years. Factors such as soil erosion and degradation, loss of biodiversity, climate change, urbanization, population growth, and food increasingly demand have propelled the industry to seek more innovative approaches for protecting and improving crop yield. These aspects are crucial for the application of Precision Agriculture Technologies to guarantee sustainable agricultural production. It has been estimated that digital technologies in a farm could reduce costs and enhance effectiveness of the farm management up to 70%, compared to the conventional one. (Lowenberg-DeBoer et al., 2019) In particular:

- ❖ Reduction in input cost (from 10 to 75%) (L. Pedersen et al., 2006; Shockley & Dillon, 2018));
- ❖ Yield increase (from 7 to 20%); (S. M. Pedersen et al., 2017);
- ❖ Labour cost savings (up to 30%) and reduced labour time (up to 50%) (McCorkle et al., 2016; S. M. Pedersen et al., 2008; Pérez-Ruiz et al., 2014);

Major benefit of Precision Agriculture are related to: lower costs in farming; better quality of yield produced and reduced damage to the soil; increase precision and quality in the process; extend operation time; provide a quantitative decision base; improve interoperability and coordination; reduce the farmer's workload and optimise process times and costs; using Big Data methods to provide the farmer with access to broader data analysis, including comparative analysis; allow better land and equipment utilisation; maintain ecological standards.

In this work, the sustainability of the sustainability was evaluated in terms of economic performance, environmental and social aspects. In addition, the acceptance of end-user wasbe tested with a qualitative approach. The assessment of sustainability was useful to provide farmers with an evaluation in short- and long-term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make agriculture sustainable.

In particular, our results provide some insight into how Precision Agriculture is adopting and perceived among Italian farmers.

First of all, the concept of precision agriculture has changed over time, and it co-evolved with the technology itself. Starting from 1990, during which Precision Agriculture was perceived just only as an in-field technology, then technology included all the farm process with Smart Farming's development in the 2000s. Nowadays, the use of "Digital Agriculture" refers to the evolution in agriculture and agricultural engineering from Precision Agriculture and includes more sophisticated technologies such as robots to enable the automation of sustainable processes in agriculture.

Then state of the art in research of Precision Agriculture in Italy is presented, which shows how Precision Agriculture is becoming a trending topic in academic research (Pallottino et al. 2018) as well as the most promising areas of expansion for precision agriculture in Italy may be in the most profitable sectors, such as wine and olive oil, in addition to the cereal sector one.

However, despite this growing digital trend, one of the main difficulties of this study was related to the lack of an official statistic on the diffusion of precision agriculture in Italy because there is currently no official census of precision farmers in Italy. To overcome this limit, starting from the significant factors that influence technologies adoption in agriculture, found in the previous literature, we estimated the technological innovation of farm, starting from data related to computerization of farms in the ISTAT database (2010), assuming that a computerized farm is more inclined to use precision agriculture technologies. According to literature, since computer technology is an integral part of precision agriculture, computer use is a predictor for the adoption of PATs. To identify the determinants of the computerization of farms, a multiple linear regression method was applied. Results indicated that Internet access and the use of a web page are the basic requirements that lead to farms' computerization. Although Standard Production is a significant variable ($p>0.01$), the value of its coefficient is very low, highlighting that a variation of 1 of the computerization would bring about almost zero variation in standard production. On the other hand, the farm size (Size) does not seem to influence computerization. But the most interesting results concern the characteristics of the farm owner. Age and educational level have been shown to be significant explanatory factors. In particular, old age has a negative relationship with the adoption of computerization. There is a significant difference (p>0.01) in adult (Age 2) and old (Age 3) farmers 'propensity to computerization: the respective coefficient indicates that adult farmers had slightly more familiarity with technologies than old farmers. Similarly, farmers' level of education significantly affects (p>0.01) the computerization of farms: farmers with a degree or diploma (Education Lv 2) are more likely to computerize compared to the others, with a lower Educational level (Education Lv1). Once we identified the key characteristics of innovative farmers in Italy, we looked for two case studies to carry out economic analyses relating to the sustainability of investments in precision agriculture.

The first case study presented contributes to research to identify crucial points of reference for cost-effectiveness and efficiency in PA-derived production inputs. The case study shows how a large farm can effectively exploit the returns to scale associated with adopting PATs packages, generating income as a consequence. Indeed, PA requires a significant investment of capital, time, and learning. Thus, costs associated with PATs may prevent smaller farms from being able to invest in these technologies. From the second case study, in addition to the economic benefits, important results emerged from an environmental point of view (reduction of inputs) and a social point of view (reduction of the labor force) In fact, we found out that the significant benefit for this farm is not focused on saving inputs (nitrogen) but rather on keeping the labor input (-20%), which allows the manager to optimize the management of human resources that can be dedicated to other management activities rather than strictly operational in the field. In addition, the introduction of technology allows to improve the quality parameters of production, both from a commercial point of view (increase in protein content values) and for the phytosanitary aspect (lower incidence of attacks by phytopathogens agents), thus guaranteeing better production traceability associated with the use of a digital QR code system.

Based on these results, the research went deeply to understand the characteristics of the Farm managers who efficiently conduct these digital farms. The originality of the work is to apply this qualitative approach in agricultural economic studies in which quantitative methodologies are traditionally used to explain these phenomena. Research into 'farmers as entrepreneurs' has not provoked a good deal of investigation in the entrepreneurship literature as evidenced by a major literature review of this subject. This approach offers a managerial vision of the agricultural sector, in which farmers are not considered real entrepreneurs as in non-farm business. From the analysis, it emerges how the agripreneurs understood Precision Agriculture as an accessory to beautify the agriculture machine and a tool to increase profitability and be competitive on the market. Adopting the new technologies in agriculture is not a threat, but an opportunity to revitalize the sector and create new and more sustainable value. Then has also been investigated the role of these agripreneurs inside the network as a requirement to adopt digital technologies. Results show that only a few farms have the capability to develop and manage innovations internally; success often requires cooperation between individual actors and organizations. Since the adoption of new technologies presents learning and adaptation challenges for farmers, the papers' theoretical approach builds on the role of the network as a learning organization. The process involving an organization's capacity (firm) to learn from others is also referred to as organizational learning within a network. The interactions of various actors and the subsequent emergent networks of information exchange are fundamental in the adoption of innovative technologies. In fact, these networks' structure can influence the advancement or weakening of technological change and, for this reason, is a central attribute to successful innovation systems.

The effective use of technology is related to the technology provider's ancillary support, a key factor in the technology adoption process and a key player in the innovative farmers' network. As Obal (2017) wrote, in high risk and uncertainty conditions, such as the adoption of new digital technology, SMEs often have to rely on technological suppliers In fact, cooperation between farmer and technology providers is essential because it reduces the risk and complexity involved in the development of new technology. Closely related to Lundvall’s (1998) idea of “learning by interacting”, cooperation implies developing and acquiring new capabilities, as each agreement involves a shared commitment of resources and knowledge. Our results, based on qualitative research, which involved 30 Italian technology providers, showed how commitment, communication, and cooperation (jointly research projects) could enhance the farmer's trust in Precision Agriculture Technology.

Finally, a practical approach of the collaboration between buyer and supplier in a Regional Project is analyzed. This project is related to VITIS development, a digital platform for the management of vineyard water and nitrogen stress, and tested in 4 pilots located in Marche Region. All the functions and modules of the platform were built by following a Design Thinking Approach. This study illustrates how this approach can help develop targeted digital solutions for farmers with low digital skills. by carrying out a user-centred designed process, based on the continuous and active involvement of user representatives along the entire project. Focusing on engaging all the stakeholders along the value chain to expose results, benefits and return of investment, the resistance of farmers to technologies will be soon minimized.

Based on the main results obtained from the research, this research contributes to the existing literature in three ways. First, it has examined precision agriculture technology management in an attempt to improve farm sustainability. Then, the work explored the innovation adoption from the farmers' managerial point of view, that it has to be considered an agripreneur, responsible for the technological decision of the farm and which is involved in a network in which collaborates with technology providers. The tools adopted in this work have proved to be suitable for assessing sustainability concerning the agricultural and rural contexts in which they have been applied, confirming their intrinsic validity and ease of interpreting the results. However, it emerged the need to integrate the analytical aspects with those of policies and regulations. Considering future societal and environmental needs, the main challenge for the EU is to encourage sustainable agricultural production through new policies aimed at innovation. A condition that can occur thanks to the application of digital technologies. In Europe innovation is a hot topic and for this reason it has been placed at the heart of the EU's policies. In the interest of monitor the innovativeness of Members State, EU created a set of indices based on economic, demographic and social performance. According to the Digital Economy and Society Index (DESI) 2020, which monitors Europe's overall digital performance and tracks the progress of EU countries in digital competitiveness, Finland, Sweden, Denmark, and the Netherlands scored the highest ratings in DESI 2020 and are among the global leaders in digitalization, while Italy remains a moderate innovator. However, several national policies aimed at digital innovation have been proposed during these years. In December 2019, the Italian Ministry presented the "Italy 2025" strategy, a five-year plan that places digitization and innovation at the center of "a process of structural and radical transformation. Regarding the digitization of businesses, the government has renewed the National Plan "Industry 4.0" and launched the "Transition 4.0" plan, with greater attention to innovation, green investments, and SMEs' participation. While the other sectors can draw on this funding, the Agrifood sector seems to be cut off from these innovation policies, which are decidedly more oriented towards Industry. However, at the European level, we are witnessing a political revolution. Following the declaration for "*a smart and sustainable digital future for European agriculture and rural areas*" signed by most Member States in April, the European Commission presented and discussed new technologies and digitalization in agriculture, highlighting the advantages and opportunities it offers for the sector.

Then, the European Commission announced the Green Deal policy for Europe and its strategy From Farm to Fork, oriented to invest in cutting-edge research and innovation, to preserving Europe's natural environment". In this deal, digital technologies are presented as "*enablers to achieve the sustainability goals*." In addition, for the period 2021–2027, the European Commission has proposed a Common Agricultural Policy (CAP) focused on social, environmental, and economic issues, giving a clear signal that it is necessary to build sustainability driven by digital agriculture. The post-2020 CAP proposals consider the importance of the use of technologies in the sector. An example is provided by the help of the Farm Sustainability Tool for Nutrients (FaST) by income support beneficiaries. This tool will facilitate the sustainable use of fertilizers for all farmers in the EU while boosting the Agrifood sector's digitization.

To conclude, innovation and digital technologies offer win-win solutions for farmers and food operators. This means combining benefits for the environment and climate while increasing efficiency and competitiveness. However, the uptake of digital technologies remains far below expectations. This gap will be addressed with specific policy measures to ensure that everyone, including the small and medium-sized farmers, can access technology and benefit from it.