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Studies on the adoption of digitalization and high technology for precision agriculture.

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Abstract

The study investigates which are the effective approaches for the introduction in the use of new technologies in sustainable precision agriculture and what the necessary networks are for effective technology adoption. At the European level, some studies and research are starting to be carried out to analyze these factors and the actors in the field. The limit of these studies is given by the fact that during the technological revolutions, chaotic situations are determined that do not allow a systematic analysis that a scientific approach requires. It is a fact that new strategies and new approaches are needed for innovations to be introduced with new methodologies not only at research level or on large farms but at small companies level. European countries are responding differently both in terms of speed and actions in terms of introducing innovations. However, the urgency to ensure that to maintain quality and quantity and security we must move from technology is real and cannot be postponed, compared to the forecasts for the development of the planet in environmental and economic and social terms. The innovation of agriculture is not only technological with an eye to the use of technologies but is realized in its sustainability only if it is also economic and social. Therefore innovations cannot be introduced only from a technical point of view but they also influence the economic dynamics of resource and profit management, the planning of corporate planning - with the need to introduce new first-approach tools such as the business model canvases or more structured like lean farming- and social, from the point of view of the typology, quality and quantity not only of the workers that serve to ensure that a system linked to the analogical becomes digital but also from the new role that begin to have the a community of producers and consumers and training and consultancy that is going to change but has not yet fully realized the evolutionary process necessary in the production-consumption model nowadays known.

Riassunto

Lo studio indaga quali siano gli approcci proficui per l'introduzione nell'uso delle nuove tecnologie in agricoltura di precisione sostenibile e quali siano le reti necessarie perché l'adozione della tecnologia sia effettiva. A livello Europeo iniziano ad esistere alcuni studi e ricerche rivolte all'analisi di questi fattori e degli attori in campo. Il limite di questi studi è dato dal fatto che durante le rivoluzioni tecnologiche, si determinino situazioni caotiche che non permettono un'analisi sistematica che un approccio scientifico richiede. È un dato di fatto che si rendano necessarie nuove strategie e nuovi approcci perché le innovazioni siano introdotte con metodologie nuove non solo a livello di ricerca o su aziende agricole di grandi dimensioni ma a livello di aziende di piccole dimensioni. I paesi europei stanno rispondendo in modo diverso sia in termini di velocità che di azioni in termini di introduzione delle innovazioni. Ma l'urgenza di far sì che per mantenere qualità e quantità e sicurezza si debba passare dalla tecnologia è reale e non rinviabile, rispetto alle previsioni di sviluppo del pianeta in termini ambientali, economici e sociali. L'innovazione dell'agricoltura non è solo tecnologica ma si realizza nella sua sostenibilità solo se è anche economica e sociale. Le innovazioni dunque non si possono introdurre solo dal punto di vista tecnico ma vanno ad influire anche sulle dinamiche economiche di gestione delle risorse e dei profitti, dell'impostazione della pianificazione aziendale – con la necessità di introdurre nuovi strumenti di primo approccio come il business model canvas o più strutturati - come il lean farming - e sociali, dal punto di vista della tipologia, qualità e quantità non solo dei lavoratori che servono a far sì che un sistema legato all'analogico diventi digitale ma anche dal nuovo ruolo che iniziano ad avere le comunità di produttori e consumatori e della formazione e consulenza che va a modificarsi ma che non ha ancora pienamente realizzato il processo evolutivo necessario nel modello di produzione-consumo che conosciamo.

Aknowledgements - Ringraziamenti

Non avrei mai pensato di trovarmi a fare un dottorato e di concluderlo. E con questa premessa non posso che provare, con queste poche righe, a ringraziare diverse persone che mi hanno seguito, incoraggiato, fatto capire altre ragioni oltre alla mia, e alla fine che mi hanno fatto crescere, dentro e fuori l'Università e che sono certa non smetteranno di essere uno stimolo per la mia mente. Non voglio però solo ringraziarle, gli dedico anche questo lavoro, che sarà forse un piccolissimo frammento di conoscenza ma che per me ha sicuramente un significato che va oltre al testo scritto. Qui citerò solo alcuni che per me hanno rappresentato il bene degli ultimi anni. Ho avuto un insegnamento anche da chi ha rappresentato il male, ma i nomi li tengo per me e pochi intimi.

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Studies on the adoption of digitalization and high technology for precision agriculture.

Summary

Studies on the adoption of digitalization and high technology for precision agriculture.

1. Introduction

Talking about the adoption of digitalization and high technology is not an easy issue today, and after three years of deepening, it is clear how much necessary and urgent it is. Since this study started, the main thought was that agriculture was considered as ever, even if the surrounding was changing, and talking about the digital revolution was considered "too much" and who talked about the need for a new approach faced with a sort of disregard (in the agricultural environment) or "chaos"(outside the agricultural environment). However, little by little disruption became apparent in both environments, and at every level, a new awareness arose. This awareness brought to make a trial on several approaches that can be considered to talk about innovations in agriculture, but the only one feasible for the time we are living in is an "ecosystemic" approach.

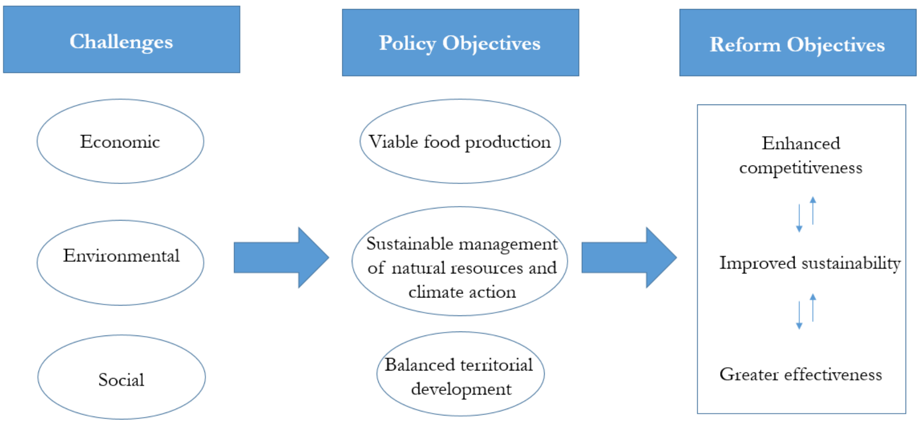
Therefore, this is a first attempt to assess a methodology to understand how innovation, digitalization, and high technology could be introduced in a proper way inside the agricultural system. "Ecosystemic" in "agriculture 4.0" (which is only a fancy name that brought the sense of the whole system we are writing about) refers to all the actors that bring or take something from the agri-environment and underline a brand new approach that try to give a role to farmers and at the same time to research, in terms of opportunity to bring innovation into the system. Not only. Farmers are considered both at the center of this ecosystem and the production chain together with their products in terms of needs and profitability.

As it is, the reality is a little bit different, and it is a long run to a different system of production, at least until now, but several interesting projects born outside the "agri-box" around Europe and the rest of the world. Recapitulating, new technologies, new actor systems, new production processes, old habits, old actors (the average age in agriculture is high) need new approaches, new policies, new professionals and new training. It cannot be defined as a new market, but it seems to be. According to this, a European study from Science and Technology Options Assessment (STOA) Panel analyses, starting from the current situation, the future of farming in Europe (Schrijver, Poppe, & Daheim, 2016).

It analyses several aspects, and it is useful to resume the main ones about the overall aims of Common Agricultural Policy (CAP), the demographic situation and, the market for precision farming.

CAP has three main objectives divided over three themes: economic, environmental, and territorial. Key objectives formulated in the CAP are viable food production, sustainable resource management of natural resources and climate action, and balanced terrestrial development. The overall objectives of the reform are to enhance competitiveness, improve sustainability, and get greater effectiveness (Chart 1).

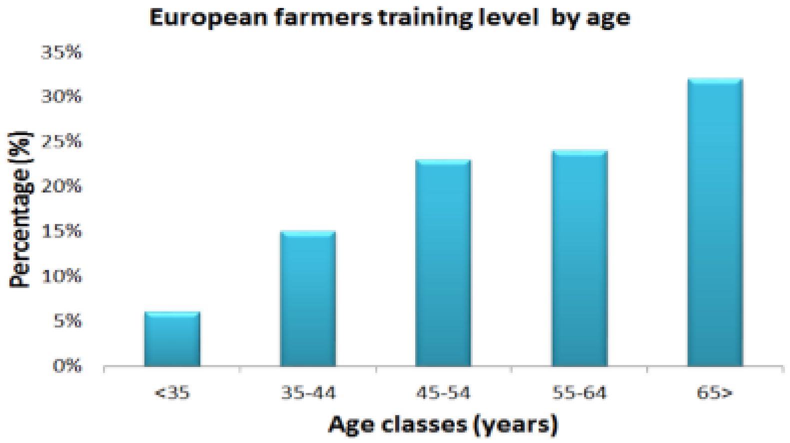
Chart 1. A schematic flow of challenges, policies and reform objectives



According to this study, and the Eurostat data, EU farmers and farm managers have a high age profile compared to other sectors of the economy. Only six percent of farmers are less than 35, while thirty-one percent of farmers are older than 65 years *(Table 1)*.

Although the overall number of farmers is declining, the proportion of the different age groups remains relatively constant. In terms of technology adoption, this is one of the worst scenarios.

Table 1. EU farmers/Farm Manager by age groups (adapted from STOA, 2016)



The study assesses in the paragraph on "The market for precision farming" that there are no exact definitions for precision agriculture (PA), and the recent arrival of the phenomena makes statistics lacking behind. According to this, thanks to a consultancy, it was estimated that the global market for precision agriculture amounts to 2.3 billion euro at the end of 2014 and is expected to grow every year with a mean of 12 percent through 2020. If we think about the agricultural sector, maybe it decades that do not have this kind of development in terms of the market's investments. Resuming all this information can be understood that even if the market and policies go on a part, the rural sector risk to remain stuck because of the emerging of too many barriers. The study will overview the central aspects and some first approaches to bring agriculture to a different awareness of its crucial role. It is necessary to underline how the topic treated in this work is evolving in terms of innovations, policies, fundings, investments, and attention from the agricultural actors, so the aim is to present state of the art, mainly in Europe, to contribute to order in a chaotic and chaos market, also because data on the use and effect of precision farming technology in the EU is so far scarce and site-specific.

In addition to this, from the adoption point of view, the approaches around Europe are different and are rarely devoted to small and medium enterprises, which are a lot in each country. This study tries to enlight opportunities for adoption for this target, which is cut off from the first adoption of innovative technologies but is also a target that contributes to maintaining our traditional products, our landscape but also contributes to soil quality and all agricultural extension services. It is quite essential to underline that until now, all the studies focus on the rate of adoption by farmers on the technologies in agriculture. It is crucial, and there will be space to analyze also that data, but, if the agricultural sector and research mainly, continue to focus only on what happened without describing possible new paths to adoption, it would not be essential if the adoption is fast or slower, because it is not going to be created a new environment to approach the emerging needs related to climate change and production.

2. Objectives

This study tries a first approach to adoption through the study of the environment that permits innovation to be applied in agriculture, enhancing different approaches in technological research, business, and social environment. This work is presented as a general introduction to the research work started three years ago and want to start to help to put an order in the growing sector of digitalization in agriculture which is not only precision agriculture technologies, but is a new approach inside a birthing paradigm. The study is composed following the investigation process as shown in the following page (*figure 1.)* . Howerver, data and results are a different matter from the usual expected.

This is because the argument investigated start rising interest not only in the scientific and technological research but also at policy level, social and entrepreneurial one. The general aim is to underline the importance of an ecosystemic view and the necessity of more researchers and people interested in digitalization to take part to rethink the known. Therefore, the scientific work started systemically trying to put order, and pick significant research studies, practical case studies and setting order in the several PA technologies and sources available. This, taking into account a "higher" level (policies) and the "lower" level (field application and PA adoption). Those aspects need a point of contact and through this work, some ways were clarified as the use of digital platforms or collaborative spaces, the introduction of new business model for PA farms or new training courses, with different arguments from the past. Above this, the analysis was carried out investigating strength, weaknesses, opportunities or threats given by the adoption of PA. In this framework, this research tried to sum some results, and to suggest possible paths for a future methodology for the agricultural actors to adopt PA.

It is a significant changing of point of view with a scientific approach; if agriculture is one of the primary sectors that enable us to live, who work in this sector should start to think that separate compartments and strong sectionalisation have been useful and will continue to be only in some cases, but facing a new paradigm also new way to explore and test technologies are needed. Today, innovation is considered not only an innovative product; innovation happens when people start using that product in a profitable way; otherwise, we can not talk about innovation.

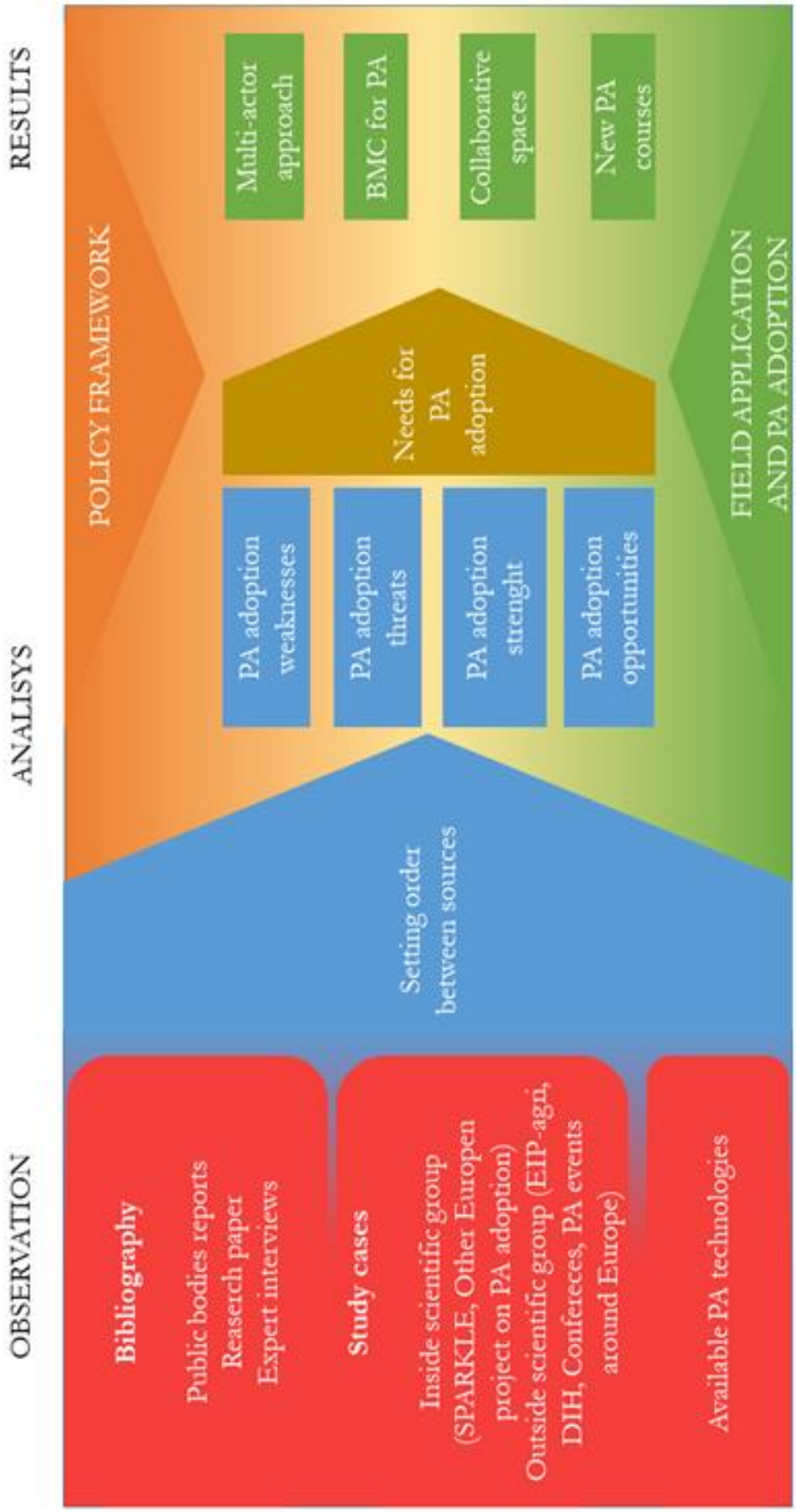


Figure 1. Criteria followed in this work to understand PA adoption path.

3. The digital paradigm shift in agriculture

Technology is running very fast in the last years, but the digitalization of agriculture, even if nowadays is a kind of hype, came from the end of the past century. If it should be found a starting point, we can state that everything started with the so-called "Green Revolution" and continued with the introduction, firstly of electronics devices for communications on tractors as the ISOBUS (standard ISO 11783) and with the introduction of Global Positioning System (GPS) technologies. Thanks to this system (ISOBUS), with a single display, all compatible ISOBUS tools connected to it are driven from the tractor cab.

From this milestone, a series of applications has been expanded year by year with integrations and mergers with GPS systems and increasingly precise sensors that today allow for total automation and traceability of every intervention that is done in the field (Kverneland, 2019). Despite this, it is perceived by farmers that GPS and precision systems are valid opportunities only for medium and large companies or not profitable as much as it could be. However, this would be like saying that the satellite navigator is only useful on large cars. In reality, ISOBUS is a technology that offers innumerable advantages also to small farms, as well as, of course, other larger ones. Indeed, improve and standardize the quality of cultivated products upwards, increase the efficiency of the production process, with higher yields per hectare and a decisive rationalization of costs, help to reduce the environmental impact of fertilizers and pesticides thanks to a targeted use of these products that all target, eliminating waste, reduce the fatigue of the agricultural operator thanks to the automation of operations and increase his safety at work and trace the entire production path and document it with end-of-campaign reports that can be delivered to buyers (food processing industries, transformers, and others)

Introducing the paradigm shift could be a concept that can be applied to all sectors because it is not only a sectorial manner; it is mainly a general changing, but in this case, we apply it to agriculture. As the definition asserts, the *paradigm shift* is "*a time when the usual and accepted way of doing or thinking about something changes completely*"(Cambridge dictionary, 2019). It is not a new concept in agriculture; there are other trials made to explain paradigm shifts between different agricultural systems(Wynen, E., 1996). The study of Wyen focuses on organic farming VS conventional farming. In 1996, when the paper was written, Precision Agriculture was emerging for the first time in some congresses around the world. Precision agriculture can be considered not only a "system" because, in general, but only physical units are also mentioned in the word "system."

Nevertheless, agriculture has a specific, less measurable dimension: the approach to agriculture. It comes close to what is considered a paradigm by Kuhn (1970). It's easy to understand why we need to talk about a new precision farming paradigm In his seminal work on paradigms ' The Structure of Scientific Revolution ' first published in 1962 (Kuhn et al., 1970) define paradigms (or ' normal science') as "...research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundations for its further practice"(Wynen, 1996). Scientists research inside the existing paradigm. They use to define and test hypotheses and interpret data in this "world view." As revealed in textbooks, lectures, and laboratory exercises, a paradigm and its rules limit the nature of acceptable solutions and the steps they are to be Obtained through. Although Kuhn's discussion on paradigm shifts is related to science, an analogy could be made with the agricultural sector.

Subsequent theories on paradigm shifts and development are advanced, and the concept well explained by Kuhn takes into account the Heideggerian referral "science does not think.". The more significant part of the chaos described by researchers is due to the lack of rules to order and categorize all the innovations happening. Kuhn believes there is no' proof' that shows that the beginning of a new paradigm is a new theory. A current phase of a paradigm shift, however, goes as follows: crises are beginning to interrupt' normal science.' These crises are attributed to events that the theory on which day science is based can not explain. "Normal science" is designed so that most scientists reject a new paradigm (that is, a new 'science' with its hypotheses, laws, and assumptions). That is, phenomena are considered to be another piece of the' puzzle' within the current framework that has not been resolved yet but will be resolved in time. The standard implementation of existing theories is never seen as disproving anomalies. Thus, "ad hoc" changes were made to "normal science" to deal with them.

Meanwhile, a new hypothesis is being established that can only answer some of the questions that have been asked at the start. Many scientists are taking a step towards the new theory, which requires adapting to the concepts on which their work is focused. New questions are being asked, answers are being found in different ways than before, appearing specialized publications and communities. Claims are made in the academic institutions' curriculum for a special place. Never is a discussion between the two competing paradigms entirely satisfactory, since theories are incommensurable, and each camp's proponents base their arguments on different assumptions and priorities. With time, textbooks are written, new ideas are popularized, more scientists are taking the step, and the new paradigm is gradually becoming "normal science," shifting away from the old paradigm. Darwin's evolution by natural selection is an example of a paradigm shift in biology. It acknowledged, indeed, its inspiration was derived from a species' ability to change over time. The previous paradigm maintained an invariant organism, remaining unchanged from its creation day. Individual variation was mere' system noise' and not worthy of serious study. Variation within and between species within the Darwinian model has become fundamental to scientific research and has been responsible for the emergence of new fields such as genetics, and ultimately biotechnology. Although Darwin at first faced many skeptics, his theories have indeed been accepted for many years, though not universally.

Similarly, some theories have been around for a while, and natural death (for example, alchemy) has died. In other words, paradigms are not 'true' or 'false'; their survival depends on their heuristic value. Whether a new theory would lead to a new paradigm can not be proven that displaces the dominant form, this study tries to get a different point of view for possible discussions on precision agriculture and its role as a new paradigm.

3.1. Rethink the known: social and open innovation to build a new paradigm in agriculture

In the digital paradigm, as it is, social innovation and open innovation play a significant role. Sustainability cross through precision agriculture and digital innovation is a puzzle piece in the digital shift paradigm. Social innovation definition is "we define social innovations as new ideas (products, services, and models) that simultaneously meet social needs and create new social relationships or collaborations. In other words, they are innovations that are both good for society and enhance society's capacity to act" (Murray, Caulier-Grice, & Mulgan, 2010). Social innovation is the living component needed to realize a change. As explained in the appendix paper, " Proposal for spaces of agrotechnology co-generation in marginal areas," by allowing individuals to share and create value and goods, technological co-generation creates advancement by social entrepreneurship in societies that make them more resilient and ready to change. Digital technologies, like mobile phones or web platforms, are considered tools that enable people to realize social innovation taking off intermediate steps between actors. On the other side, open innovation can be seen as an organizational method to carry on research in a different way in companies or academics. Thus, it represents a new organizational paradigm that enhances cognitive and organizational mechanisms combining them with the network and social networks (Costa, 2014). The definition of open innovation coined by Chesbrough is «a paradigm that states that companies take and must resort to external ideas, as well as internal ones, and enter into internal and external paths to the markets if they want to progress in their technological skills » (Chesbrough, 2014). It is important to underline how social innovation and open innovation came from the same root that keeps together the aspect related to the concept of innovation sharing the same generative process.

3.2. From the "*spade to the satellite.*"

If today we can talk about open innovation that contributes to advance in technologies and researches or social innovation that contribute to enhancing rural communities' resilience, on the other hand, it is central to focus on how it was possible to shift from the "spade to the satellite." through centuries, thanks to industrial revolutions. The technological development of agriculture in Europe is at a turning point, and today's agriculture is challenged with ICT technologies, which means higher efficiency and minor impacts. Technological development will bring and is bringing effects on management, business models, distribution chains, markets, and policies.

In the following tables, taken from the appendix paper "Approaching the Fourth Agricultural Revolution: Analysis of Needs for the Profitable Introduction of Smart Farming in Rural Areas." the fundamental steps of innovation in agriculture can be focused together with the increasing working capacity.

Table 2. - Comparison between industrial revolutions and agricultural revolutions (Lombardo et al., 2017)

Technological revolution	Popular name for the period	Big-bang initiating the industrial revolution	Year	Big-bang initiating the agricultural revolution	Year	Agricultural revolution
First	The Industrial revolution	Arkwright's mill opens in Cromford	1771	First theory on reversing plough*	1774	First
Second	Age of steam and railways	Test of the Rocket steam engine for the Liverpool–Manchester railway	1829	First gasoline tractor engine**	1890	Second
Third	Age of steel, electricity and heavy engineering	The Carnegie Bessemer steel plant opens in Pittsburgh, PA	1875	-	-	-
Fourth	Age of Oil, the Automobile and Mass Production	First Model-T comes out of the Ford plant in Detroit, MI	1908	Fordson tractor based on T model**	1915	Third
Fifth	Age of Information and Telecommunications	The Intel microprocessor is announced in Santa Clara, CA	1971	ICT and digital systems in agriculture management***	1997	Fourth

*AA.VV, (2008)

**Zoli, M., Vieri, M.(1998)

*** Ist European conference on precision agriculture. (1997)

In the previous table is reported the technology or the machinery corresponding to a turning point of technological revolution (on the left side industrial revolutions, on the right side agricultural revolutions). In the same work, another contribution also deserves to be reported because it gave the immediate idea of what precision agriculture means in terms of working capacity. This is not the only aspect to be investigated, but it is clear why this approach should be adopted. In table 3 also emerges another aspect that will be discussed, that is that increasing working capacity means less workforce needed in the field. The workforce could be an emerging problem if agriculture continues to use a labor-intensive approach; on the other hand, precision agriculture could coexist with this approach even if the workforce needed would change. It would not be necessary to get more unskilled workers but became urgent to train workers for precision agriculture technologies needs.

Table 3. Work needed for a furrow slice of 8 dm2 for different yard typologies representing diverse technologies revolutions. (Lombardo et al., 2017)

Yard				Working capacity $m^3 h^{-1}$
Man + Shovel	Volume/h	$m^3 h^{-1}$	2,5	
	Yard efficiency		0,85	2
Horse + Plough	Forward speed	$m h^{-1}$	3600	
	Yard efficiency		0,8	230
Tractor + Single Plough	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	336
Tractor + five ploughshare	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	1680
Tractor + five ploughshare + Automatic Drive	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,9	2160

3.3. What is precision agriculture today

Researchers have been trying to define precision agriculture since the '90, and it will continue to do it. In parallel with this in the last years, several studies started to be made on the adoption of precision agriculture. All the definitions and the studies try to take all the aspects (sustainability, profitability, ethical issues) into consideration together at the same time, but not very often, it happens. *Effectiveness, efficiency,* and *impact* are aspects that need to be investigated to understand better the new paradigm of precision agriculture, but before it is important to order what is known.

In general, Precision Agriculture Technologies (PAT) can be grouped in three different categories; 1. Guidance technologies, 2.Recording technologies, and 3.Reacting technologies. In the following table, a synthesis to clarify PAT is made.

Table 4. Precision agriculture technologies overview

PA Category	**PA Technology crossing through**	**Description**	**PA technology**
Guidance technologies	Global Navigation Satellite System(GNSS)	Hardware and software that guide tractors and machinery within a field. These include all types of automatic tractor steering and guidance and self-propelled farm machineries, such as driver assistance, MG, and traffic controlled farming.	Controlled traffic farming Machine guidance Driver assistance
Recording technologies		Sensors can be mounted on rolling, airborne or satellite platforms or ground-based stations. These collect spatial information that includes information on soil mapping, mapping of soil moisture, canopy mapping and yield mapping.	Soil mapping Canopy sensing Soil Moisture mapping

Reacting technologies		Hardware and software capable of varying the position of agricultural inputs in the area treated. These include technologies for the application of nutrients, plant protection agents, irrigation, seeding, and precision weeding and not less important, variable-rate irrigation and variable-rate application technologies.	Variable Rate(VR) irrigation Variable Rate Technologies Variable rate weeding

adapted from (Soto, Barnes, Balafoutis, Beck, & Vangeyte, 2019)

In the table above are reported the main PA categories and technologies briefly. What the table does not tell is that each category is linked within the category or between different categories as the following scheme:

Controlled traffic farming ←→ Driver assistance

→ VR weeding

Machine guidance → Canopy sensing

→ VR weeding

→ VR technologies →VR Nutrients

→ VR Seedings

→VR Pesticides

Soil mapping ←→Soil moisture sensing

←→Variable rate irrigation

Soil moisture sensing←→Variable rate irrigation

Canopy sensing←→ Variable rate weeding

←→ Variable rate Nutrients

←→Variable rate Seedings

In this path, it is interesting to cite a brand new article, "Setting the Record Straight on Precision Agriculture Adoption". The article state and proof that there is a perception that precision agriculture (PA) adoption is slow. This research analyses public data on the use of PA in crop production at the farm level throughout the world. It analyses PA adoption estimates from completed surveys using random sampling techniques, as well as adoption estimates using other survey approaches, to record PA using existing data adoption trends at the national or regional level. The analysis shows that guidance from GlobalNavigation Satellite Systems (GNSS) and associated automated technologies such as sprayer boom control and planter row or section shutoffs have been implemented as quickly as any major agricultural technology in history. Authors state that the main reason for the belief that adoption of PA is slow is that PA is often correlated with variable rate technology (VRT)—just one of many PA technologies, one of the first to be embraced by many farmers, but now only reaches 20% of farms. This adoption rate indicates that farmers like the VRT technology, but are not persuaded of its importance. Estimates of VRT adoption for farmers ' niche groups can surpass 50%. The most significant gap in the adoption of PA is in the developing world for medium and small farms, not using motorized mechanization (Lowenberg-DeBoer & Erickson, 2019).

Europe is in a different situation from developing countries where there is a lack of digitalization and technology, and the gap is more significant than in other places; indeed, developing countries work mainly on the adoption of enabling technologies like mobile phones or the use of online platforms. The real problem they are facing, and what can be shared with a different proportion with Europe is the lack of digital infrastructures (Tsan et al., 2019). In Europe, data tell us that 86% of farm holdings size under 20 ha (Schrijver, Poppe, &

Daheim, 2016) this affect the policy orientation for agriculture and technologies related. The "technology adoption" should be treated not only from a data or market-oriented point of view. However, it is a step by step process, and until now, the considerable work made is around collecting data, discuss them, or collect study cases. After the collecting phase, study cases could be considered under another point of view, focusing on effectiveness, efficiency, impact, and sustainability (in terms of profitability, environment, ethics) like from a public body point of view. Some studies underline the need for an ecosystemic perspective to estimate the adoption rate by farmers(Pathak et al., 2019).

This could help to measure the whole system turning around precision agriculture. *Effectiveness* is the relationship between the results obtained and the objectives set; *efficiency*, is the relationship between the costs, resources used and the results obtained; *impact* reveals the positive and negative effects of the actions implemented, then it can be evaluated the sustainability of the action (in terms of profitability, environment, ethics). The changing paradigm in agriculture means a different approach in other aspects like technology adoption, farm management, business models, and, as already written, competencies.

3.4. Why we need precision agriculture: a climate and sustainable perspective

We are (the whole humanity, Ed.) on a turning point regarding our future, and agriculture is under a focus lens because its pros and cons on GHG emissions; on the one hand, it can contribute to reducing emissions if technologies and flexible approaches will be adopted; on the other hand, it is the cause of one-third of global GHG emissions.

Agricultural soils account for approximately 37% of overall EU agricultural emissions, mainly due to the application of artificial N fertilizers and animal manure to soil (EEA, 2017).

Active management of farmlands by effective agronomic methods and technology offers a powerful forward-looking approach for climate change mitigation. The UN Framework Convention on Climate Change (UNFCCC, 2008) stressed the importance of implementing and disseminating management strategies and solutions to minimize agricultural GHG emissions. UNFCCC also reports that the agricultural sector could make a significant contribution to global efforts to reduce atmospheric GHG levels for its considerable mitigation potential

In the following table, a general overview from FAOSTAT Data on the amount CO_2 equivalent emissions per continent (table 5) where it can be seen how in perspective other continents contribute negatively than Europe and the top 10 emitters in the world in the last 27 years. Also, in this case, the incidence of Europe is not relevant. (table 6)

Table 5. Emission (CO_2 equivalent), Agriculture per continent. Foresight 2030-2050 (FAOSTAT, 2019)

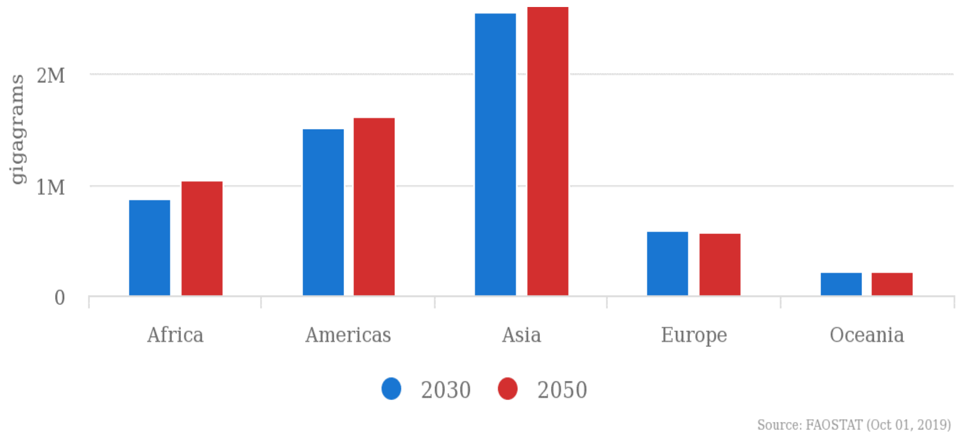
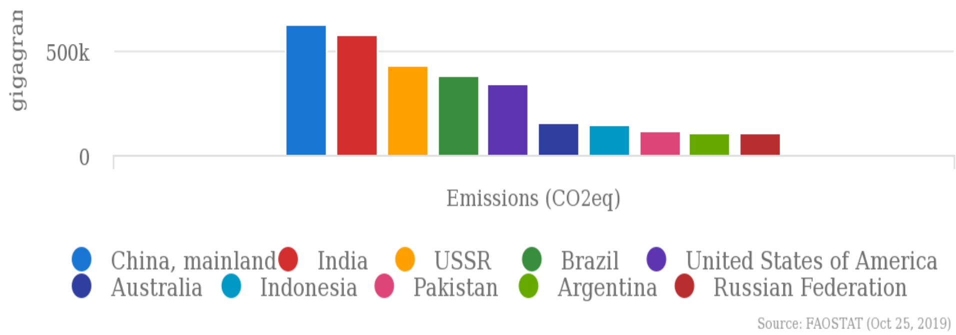


Table 6. Top 10 emitters (CO_2 equivalent) Agriculture total average 1990-2017 (FAOSTAT, 2019)



The scientific literature on the agronomic, socio-economic, and environmental impacts of PAT in the EU is highly dispersed and has gaping holes in empirical evidence, less complete and accurate, and therefore does not cover the whole or most relevant parts of EU agriculture (Soto et al., 2019).

Farmers have the potential to reduce agricultural activities ' GHG emissions and preserve or boost productivity.

Focusing on technologies, JRC, after a review work classification, listed the PAT categories that contribute far more to the reduction of GHG emissions.

Table 7. List of PAT Type and related ranking

Ranking of PATs	**PAT type GHG**	**GHG reduction potential**
1	Variable-rate nitrogen application (VRNT)	5
2	Variable-rate irrigation (VRI)	3
3	Controlled traffic farming (CTF)	2
4	Machine guidance (MG)	2
5	Variable-rate pesticide application (VRPA)	2
6	Variable-rate planting/seeding (VRP/VRS)	1
7	Precision physical weeding (PPW)	1

The scale of importance of GHG reduction potential (Likert-type scale identified by the authors): 5, very high potential; 4, high potential; 3, moderate potential; 2, slight potential; 1, low potential. (Adapted from Soto et al., 2019).

The willingness to adopt precision agriculture for climate adaptation reasons is not an issue that birth from farmers' points of view and also through scientific surveys and reviews. This appears very clear. Data until now tell us that only the higher ranking of adoption in some EU countries is average 20%, and for this reason, the more substantial part of reviews and works conclude that adoption is slow. The climate perspective for the whole vision is important, but as we are going to see forward also economic barriers and scarcity of targeted policies can contribute to this situation.

3.5. Who needs precision agriculture: barriers to adoption

If the average awareness of PAT is considered high within farmers is not the same about adoption (Soto et al., 2019). This is mainly due to several barriers to different aspects, as confirmed in several works as the project "Regions4Food Interreg project" or the paper in the annex (Lombardo et al., submitted). In those cases, the lack of digital culture in the sector and low technological adoption speed, the lack of evidence on the return on technology investments, and the lack of integrated solutions between technologies are considered the main barriers to adoption for farmers. From a more general point of view, the high initial cost of investment and prolonged periods of payback the uncertainty over the significant positive economic effects of PAT and thus insecurity over the likelihood of restoring this intervention poses a significant barrier to adoption, primarily for those farmers with lower incomes that are less able to manage the technology. By contradistinction, adopters provide a positive perception of the technology's ability to speed and minimize workloads or extend working hours throughout crucial moments (e.g., during harvesting period working nights). A different perspective seems to exist in that non-adopters concentrate on financial barriers while adopters underline the indirect benefits of these technologies. Farm size is another significant obstacle to PAT adoption. The role of socioeconomic factors tends to be less evident in determining PAT adoption.

In very few studies and one review, the focus on the drives was on political, sociological, environmental, and entrepreneurial dimensions identified the plan to adopt new technologies in agriculture. The following scheme makes more definite the possible interpretation of the factors affecting attitude to adopt ex-ante and ex-post drivers of adoption.

Table 8.List of ex-post & ex-ante factors

	Ex-Post Adoption	**Ex-Ante Attitude to use**
Socio-demographic factors	Age Computer confidence Information Education	Age Previous experience Education Confidence Perceived ease of use Social Factors
Competitive and contingent factors	Geography Size Soil quality	Trialability/Observability Size Facilitating factors Perceived ease of use
Financial resources	Income Ownership and tenure Full-time farmer	Cost Perceived benefit Perceived usefulness

Indeed, the typical PA adopter is portrayed as an educated farmer, owner of a more massive farm with rich soil quality, to apply more productive farming practices to face increasing market pressures. The adopter perceives PA's productivity benefits and wants to hire consultants because he already has trust in the use of the software. Integrating ex-post and ex-ante strategies provides a symmetrical system of factors affecting the implementation of PA, the existence of related structures suggest that this can be a realistic way of understanding the adoption mindset. Two classes of farmers are addressing the initial situation in terms of disposition towards PA technologies. First, farmers who have a positive attitude using PA technologies seem to be the real potential market for PA. Secondly, non-adopters reflect the non-market share of farmers today. Non-adopters do not have enough skills and capabilities to manage PA techniques or lack of financial assets to over-purchase them. They have specific interpretations of these innovations ' utility and ease of use.

Nonetheless, these innovations are viewed as an advancement that allows farm productivity more efficient and effective. In turn, their perceived utility and ease of use are determined by various factors: a low-cost system is considered useful, irrespective of whether it is a low-performance machine, as it retains its ease of use. Farmers enjoy on-site demos, free tests, support services relevant to the use of new technologies, as they foster the idea that it is easy to use technology. The essential functionality of the new technology is essential to prevent incompatibility between PA devices and difficulty in using and handling different technological devices concurrently (Pierpaoli, Carli, Pignatti, & Canavari, 2013).

A study from Ireland proposes an agricultural innovation index to measure the level of adoption (Läpple, Renwick, & Thorne, 2015), and even if the method changes, the conclusion is more less the same as the other approaches.

3.6. When is precision agriculture profitable?

Technology is revolutionary when it creates a new environment where the product or service works worse than the mainstream product, but becomes useful to people who have initially been non-adopters of the mainstream product due to a lack of expertise and resources to use the old technologies. Through encouraging non-adopters to do the same job-saving time, power, and cash, the lesser performing new technology could be useful. Therefore, if the growth, production and distribution system becomes creative, and innovation becomes revolutionary, aligning with the new market values. Finally, a disruptive technology is usually targeted at low-profit markets, explaining as to why low-cost organizations can take advantage of this low-profit market. Big companies generally have hierarchical management, higher R&D costs, strong-quality products, and elevated stakeholder profits; at the same time place their products to their current customers in order to avoid market uncertainty(Pierpaoli et al., 2013).

There is actually no legislative opportunity in the EU or any country to implement PAT. However, taking information from the JRC report, in general, farmers adopting PAT are influenced by various institutions, events, and individuals, providing them with information and acting as points of information. These information points made farmers conscious of the PAT they adopted and its existence and usefulness.

Peer-to-peer training emerged as the essential element which inspired both variable-rate technologies (VRT) and machine guidance (MG) solutions to be embraced by farmers. Even valuable items are visiting-tours to trade fairs, scientists, and industry dealers, which affected farmers using PAT. Researchers' role has a more significant impact on users of VRT than on users of MG, possibly because VRT is less advanced than MG technologies, and observational experiments were carried out with VRT. Likewise, industrial dealers had a more significant impact on MG than VRT's acceptance, possibly because MG systems can be mounted with minimal effort (e.g., when a tractor is renovated).

Numerous incentives could improve EU farmers ' adoption of PAT. Monetary incentives, financial as well as the prospect of improved economic results through the introduction of these innovations are the factors that further promote the implementation of PAT. Non-monetary incentives, however, also seemed to interest the farmers being surveyed. Providing support to boost the machinery's efficiency by direct engineering assistance, education, and technical support could enable 58-70 percent of farmers surveyed to implement. The only motivation that attracted fewer than 50% of respondents was staff training Farmers may find training non-permanent operators to be less safe, as these operators might switch to other farming businesses (Soto et al., 2019).

3.7. Where precision agriculture can be profitably applied

If enabling steps are not to be taken to expand the use of PA technology for farms under 100 ha (97% of EU farms), it could become harder and harder for these farms to cope with farms in the United States, Canada, and New Zealand or even with bigger EU farms, that all invest heavily in PA technologies. This, should be necessary in order to reduce the negative impact of the dimension factor, funding from the EU's CAP after 2020 to promote the broader diffusion of PA technology will be necessary. Smaller EU farmers could, therefore, not only sacrifice their profitability. We may be struggling to meet greening targets and priorities for EU environmental policy. Significant barriers are on the path of spreading PAT around Europe and mainly in the Mediterranean area for small farms. For example, Usually, farms under 50 ha do not have adequate access to PA technologies, and it could be an opportunity if they should be eligible for a specific subsidy to invest in essential PA technologies or a voucher to use contract services or to buy smartphones, laptops, machines, or electrical devices(Fresco & Ferrari, 2018). This argument is strictly linked with the guaranteed access to broadband but also to the presence (quantity) and the distance (proximity) from the farm's to PA services, PA retailer, educational system focused on PA (Universities departments, Agricultural School), research centre and public territorial offices for knowledge transfer and innovation in agriculture (Lombardo, S. et al., 2018).

The issue of available connectivity and the presence of a service's network is resolving together with the diffusion of PAT. In some cases, where farmers can be defined as early-adopters for that territory, they should take more than 100 km to find a new sensor or a spare part for the digital components (oral testimony, Az. Agr. Donato farm, Alberese (GR) Italy, December 2018).

In conclusion PA is profitably applied where the services are widespread capillary or where the dimension of the farm is vast, and the availability of resources is different, but PA is also profitably applied if the connectivity is assured and the cyber-physical systems. Such structures can be integrated, interdependent, cooperative, independent, and in different applications, they can provide computation and interaction, monitoring/control of physical components/processes. In other words, considering the exchange with the physical world (including human users), these systems play a key role in data capture, typically in-tenuate as (autonomous) systems intelligent sensor networks with specific sensing and actuating capabilities. The cyber and physical world can not be considered as two separate entities, but after the integration of sensors/actuators in so-called cyber systems, they are closely correlated with each other. By enabling real-time control from conventional embedded systems, cyber systems became responsive to the physical world, leading to the concept of the cyber-physical system (Fresco & Ferrari, 2018).

A barrier to adoption is also posed by the variety of emerging digital technologies and a lack of standardization. Making a choice which technologies to use is difficult, and in these decisions, there is a shortage of advisory services to help farmers. In order to support the implementation of digital technologies, education and support programs must be strengthened. (Trendov, Varas, & Zeng, 2019)

Materials & Methods

4. The digital Ecosystem in agriculture

The UN Sustainable Development Goal of a' world with zero hunger' by 2030 would need more efficient, effective, sustainable, sustainable, open, and robust food systems (FAO, 2017). The solution may include digital innovations and technologies. The so-called' Fourth Industrial Revolution' (Industry 4.0) is seeing the exponential development of several industries by' disruptive' digital technologies like the Internet of Things, Artificial Intelligence, Blockchain, and Immerse Reality. It is anticipated that the next period of growth in mobile connections would come mainly from rural communities. In the ' digitalization ' of agriculture and the food value chain, however, there are challenges to tackle.

There is the risk of incurring the ' Digital divide ' between economies and sectors and those capable of adopting new technologies (OECD, nd).

Indeed, low technical infrastructure, high technology prices, low levels of e-literacy and digital education, low regulatory framework, and restricted access to services in emerging economies and rural areas indicate that these regions risk being left behind in the phase of digitalization.

Each aspect of the agrifood chain would transform with digitalization. Resource management can become highly optimized, individualized, clever and anticipatory throughout the process. The advantages of digitalizing the agrifood sector are compelling, but it will require significant improvements in agricultural processes, local economies, populations, and the management of natural resources. This will be a task, and a comprehensive and integrated strategy is required in order to obtain the full potential benefits.

In this path, for example, at a higher level than the European one, FAO is committed to helping governments and partners bridge these multidisciplinary digital divisions to ensure that the emerging digital society benefits everyone.

Several conditions are required to shape virtual agricultural transition in different contexts. Availability, accessibility, availability, ICT in education and help policies and programs (e-government) for online initiatives can be seen as essential conditions; the use of internet, mobile phones, and social media, digital technologies and funding for agri-business and technology culture (talent growth, sprint projects like hackathons, incubators) can be seen as essential conditions.

Therefore, there are three main enablers: the use of the internet, mobile and social networks by farmers and agricultural extension officers, technological expertise among the rural population, and a culture that encourages digital agri-preneurship and entrepreneurship. Establishing a' digital agriculture ecosystem' requires farmers and agri-preneurs to build an inspiring environment for development. Financing and collaboration on digital farming projects are already increasing, and start-ups are beginning to attract international investors and media attention. In this cycle, young people have a unique role to play. They often have the benefit of digital literacy and the ability to find innovative solutions. Through incorporating technological subjects into educational programs, we can also develop a better understanding of the applications of digital tools and creation skills. In the end, one of the driving powers stronger than the others, behind digitalization, are government policies and structures and methods applied.

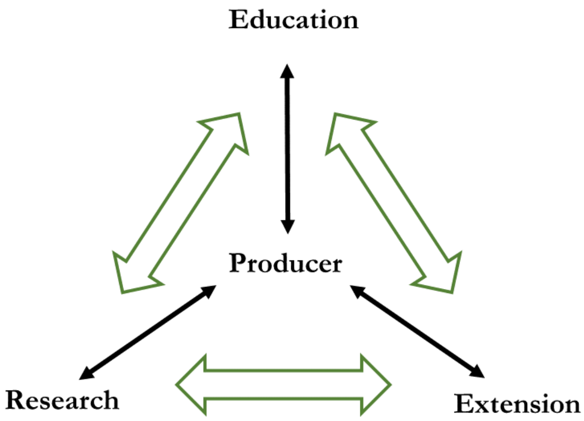
4.1. Multi-Actor approach

A system of knowledge in agriculture that aims to stimulate the creation of a real supply chain is needed to increase the professional skills of agricultural entrepreneurs and economic operators through the adoption of information and training processes more suited to the needs. Furthermore, in working system abilities and potential of users able to stimulate the adoption of innovations in the company are important as the promotion of processes aimed at creating a network of knowledge, stimulating interactive learning, and starting real bargaining processes among stakeholders.

It is crucial to enhance the creation of meeting places and opportunities for operators to make scientific knowledge (innovation databases, observatories, laboratory networks, innovation fairs) really usable and facilitating the circulation of information (adoption of innovative means of communication) and facilitate the beginning of participatory decision-making processes; Promote (effective) processes of dialogue, cooperation, and experimentation of innovations between farms and research centers, favoring stakeholder involvement (innovation laboratories); Promote the start-up of "innovative companies" (innovation incubators for agricultural enterprises) and, above all, connect and make the various consultancy, training, and knowledge transfer activities identified with the CAP measures interact. The shift for a digital transformation can be put into practice if the approaching model is no more linear but multi-actor, reticular. (Demiryurek, 2014)

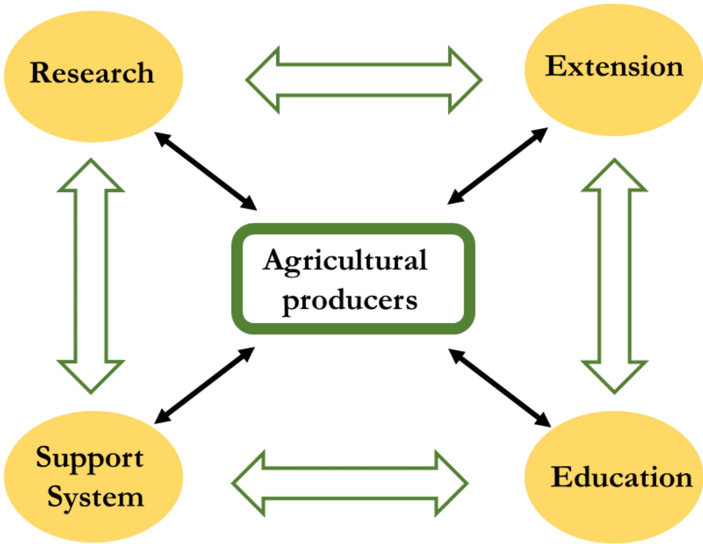
To understand the genesis of this model, should be essential to refer to the Agricultural Knowledge and Information System for Rural Development (AKI/RD) that highlights the three necessary components of AKIS/RD and the central purpose of the system - to serve farmers, that here are defined generally as producers(Rivera, Qamar, & Mwandemere, 2005). AKIS is a useful concept for defining an innovation process, with a focus on the organizations involved, their connections and relationships, the organizational framework with its benefits, and the frameworks of the budget (Poppe, 2014).

Figure 2.- Agricultural Knowledge and Information System for Rural Development (Rivera et al., 2005)



Focusing on innovation, also in this field, he triple helix approach involves the co-generation of innovation through the cooperation of the three main actors operating in a specific context where innovation is produced and which are: Universities/research centers, companies and government public bodies that determine the policies. All this cannot, therefore, be connected to the multi-actor approach, which involves more than three main actors like the scheme proposed by Rivera that is an " evolution" of the previous figure.

Figure 3.- reticular AKIS/RD model (Rivera et al., 2005)



The above system is an implementation of the triple helix and takes into account all the possible stakeholders present in the agricultural system. An improved model for approaching the fourth agricultural revolution, tested and continuing testing in Europe is for the SmartAgriHub projects is the "lean multi-actor approach". Multi-actor governance is a first step towards achieving synergies between agricultural modernization and sustainable rural development.

From several projects, reports (Eip-Agri, 2019) and researches emerged that there are at least six conditions needed to support the shift to multi-stakeholder governance in rural areas. (Koopmans, Rogge, Mettepenningen, Knickel, & Šūmane, 2018)

1. Informal networks are a key component of functional governance structures.
2. It is necessary to professionalize bottom-up programs, appropriate processes of collaboration, effective communication, and the credibility of decision-making bodies.
3. Polycentered decision making is a way of managing control and adapting to unexpected disruptions and adjustments.
4. Multiple policy levels need to integrate the lessons learned from the bottom-up initiatives

5. The Agency[I] is essential in creating new methods for governance
6. Trust and accountability were key factors in the effectiveness of coordination and collaboration across different levels of government and industries.

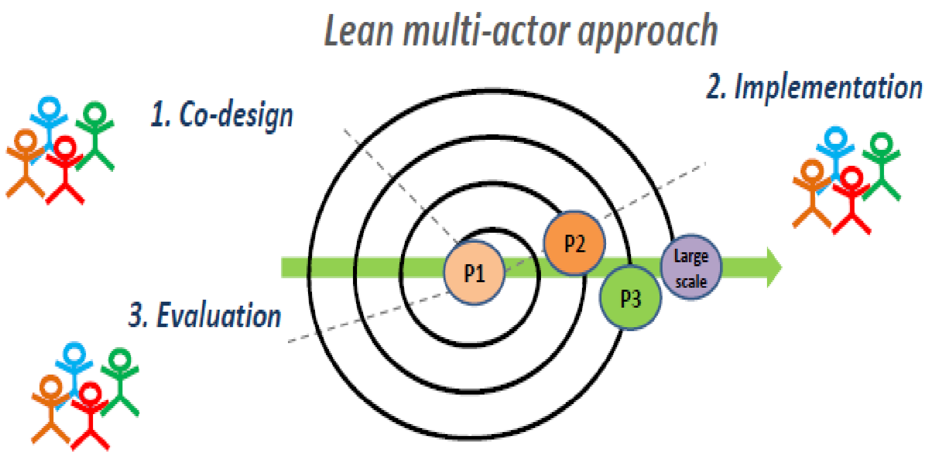
In the following figure, an example of the three main fundamental steps of a lean multi-actor approach that provides several actors activating in 1. Co-design process, 2. Implementation phase with adjustment on the product or service and 3.the final evaluation to upscale the product or the service co-designed. All those steps progress with a lean approach whose principles, referring to toyotism[II], are the following: Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardise), Shitsuke (Sustain). (for further details see annex I)

The multi-actor approach is the most comprehensive approach to follow the European paradigm shift in agriculture crossing several projects or structures like the Erasmus+, Horizon 2020, Eip-AGRI, Internet of Food and Farms 2020 and, SmartAgriHubs.

Figure 4. – Lean Multi-actor approach (Wolfert, 2017)

[I] Civic agency addresses public problems while also taking up long-term goals of transforming technocratic cultures and generating a new civic politics. Harry C., Boyte, 2007 (https://www.opendemocracy.net/en/building_civic_agency_the_public_work_approach/

[II] "A business model pioneered by Japanese auto manufacturer Toyota in the 1960s, prefiguring flexible accumulation. It includes just-in-time production, giving greater autonomy to work teams, constant monitoring and improvement of processes, and constant quality control, all of which are designed to reduce waste or unnecessary effort". (Rogers, Castree, & Kitchin, 2013)



4.2. Tools to enhance digital transformation

Small producers could make tremendous benefits by coordinating and working together to define their concerns and increase their demands. Farmers ' organizations owned and controlled by farmers themselves can inspire farmers and promote the provision of services that meet their needs and meet the required quality standards (Rivera, Qamar, & Mwandemere, 2005).

Together with the new technological mechanisms (smart economy, digital innovation) and development (sharing economy), the creative and innovative ability of the workforce turns the quality of skill into "competence to act": this transition creates a new educational and social agreement (social learning), in which the training and education framework forms the basis for creating individual talented potential. (Costa, 2016)

From the research point of view, also a change of perspective is needed. The "participatory" or "cooperative" research has as its fundamental distinctive trait that of being configured as research not on the subjects that take part in the research, but as research with and for such subjects. The practical approach to research tends to exclude the participants from each decision-making phase, where researchers place themselves in the context of self-directed subjects while the participants assign an outward-directed role. In participatory research, on the other hand, all are subjects that act directly in the construction of the research process. The research begins with a phase of reflection on the experience where a problematic element has been identified that makes it necessary to activate an investigation process; on the basis of this first reflective investigation we focus on the type of research that we intend to conduct, we organize the process, and then during the implementation of the research we can find spaces for reflection that allow us to take stock of the situation and possibly decide on interventions of modification of the cognitive implant. (Mortari, 2018).

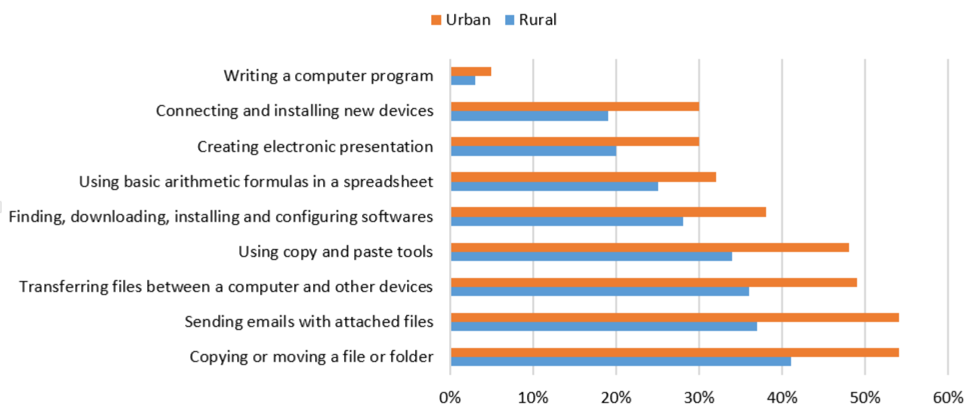
In this framework, precision agriculture adoption, digitalization, and innovation should find the right tools to be boosted in the agriculture sector. In the following paragraph, there is an attempt to overview, without claiming to be exhaustive, as the sector is rapidly evolving, some main tools to change approach firstly in business, within actors, and in the learning process taking examples from real use cases.

4.2.1.The Business Model Canvas for precision agriculture

Probably the first aspect to be taken into consideration is that digital entrepreneurship implies the development of existing businesses by newer digital technologies and the creation of new, creative companies distinguished by the use of digital technologies to enhance business operations, the invention of new (digital) business models and the interaction with consumers and investors across new digital channels (European Commission, 2013). The technological revolution would change the structure of the labor market and the nature of the work in the agri-food field.

It will redefine the position of farmers and Agri-preneurs and shift the skills needed in the agri-food industry. It can also change the way people work because, due to differences in technological abilities and software usage, it is likely to affect female and male staff similarly. In general, rural areas are lagging in the process of gaining digital skills(figure) A framework of digital skills training for farmers needs to be developed so that they can learn to identify and incorporate best practices and technology for their farm sector.

Table 9. - Average proportion of the population in rural and urban areas with a specific digital skill, 2017 (adapted from, International Telecommunication Union, 2018)



Independently from the digital skill acquired farmers and the other actors of the agricultural value chain should start approaching to Business model Canvas in order to understand better how profitable could be introducing new technologies in the management of the farm at several levels from the technological and in field operations to the production process until the marketing aspects. The Business Model Canvas (BMC), developed by Osterwalder, Pigneur & others is a streamlined start-up-based corporate management and business model that helps all new and existing companies to creatively reflect their organization and concentrate on both organizational and strategic management and marketing strategies.

It allows the businessman to describe, design, and innovate his / her business model and share it with management and partners. BMC represents a plan for a company's successful operation, identifying revenue sources, target client base, products, and financing details. In essence, it tells us how a business' key drivers fit together. The BMC spread rapidly and is widely used as it provides a way to create a reasonably clear business model using just one sheet of paper. Moreover, what is unique about it is that it can be used to characterize any enterprise from the world's largest organization to a startup with only one worker. The prototype consists of nine steps required by the Business Model Canvas to construct a business model.

BMC has some advantages

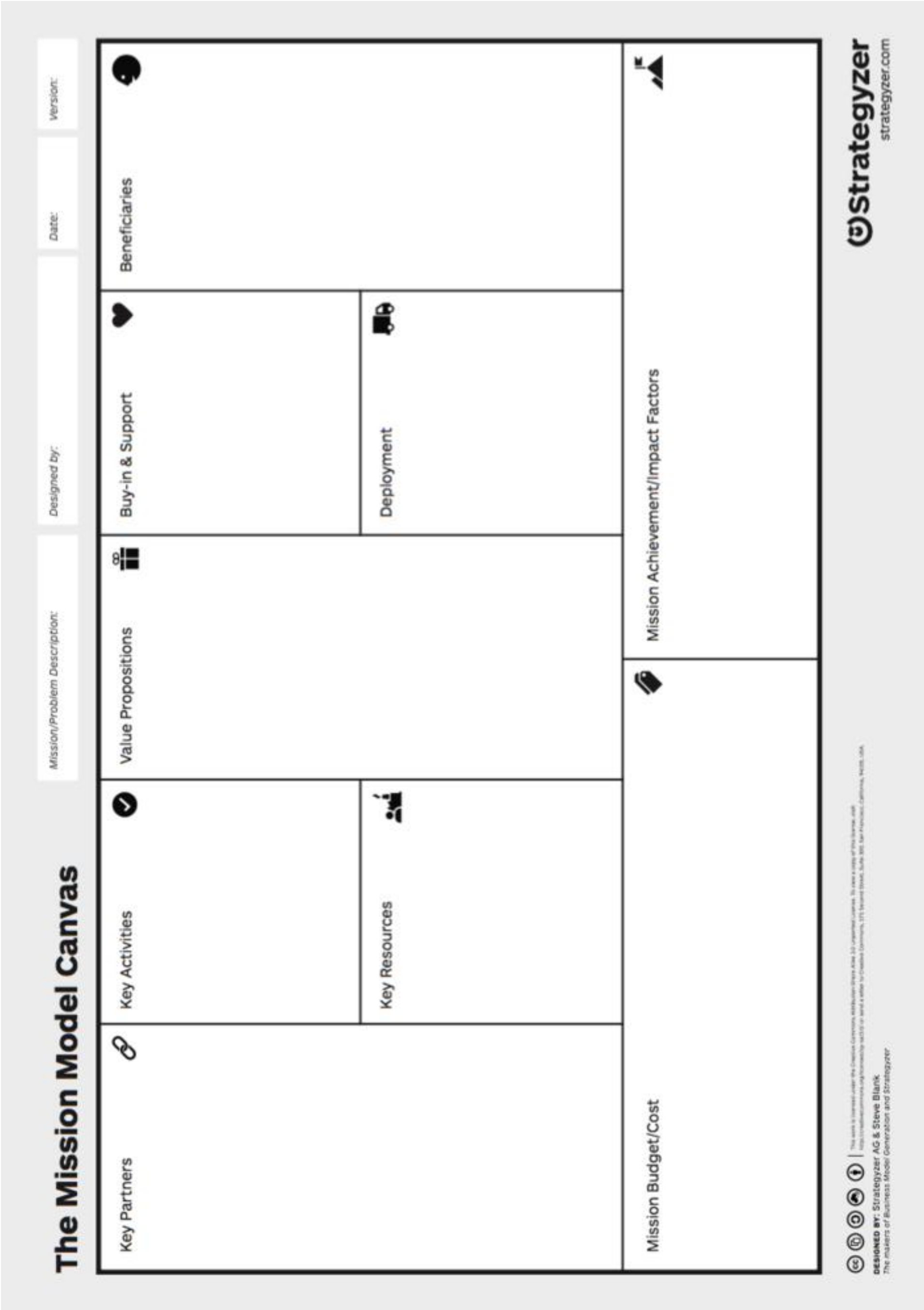
- Simple to understand: Because the canvas is very clear on a single page.
- Focused: excludes all unnecessary data found in a traditional business model.

- Flexible models and different ideas are sketched.
- Customer Focused: the canvas forces first of all to consider the value the business is providing to the customers, and only then what it takes to deliver that value
- Shows Connections: the graphical nature of the canvas on a single page shows how the various parts of the model interrelate.
- Easy to communicate: it is so easy to understand the picture. It is easy to share and clarify.

In the following page, an example of a BMC is reported. It is essential to underline the importance of looking at *Left/Right Split elements* on the left-hand side of the canvas, which represent costs to the business, whereas elements on the right-hand side generate revenue for the business.

However, it is also important to remember that the BMC comes to life when it is filled.

Figure 5. - Business Model Canvas (free download https://www.strategyzer.com)



The experimentation made during the Erasmus Plus KA2 SPARKLE (Sustainable Precision Agriculture: Research and Knowledge for Learning how to be an agri-Entrepreneur) lead by the University of Florence is one of the first attempt at a European level to introduce BMC in PA (SPARKLE project, 2019).

The report underlined how BMC could be improved in the sense of understanding the impacts of PA through a matrix to submit to farmers approaching the BMC. This tool resulted in being useful to enlight barriers drivers, benefits, or impacts of PA in the farming business. Also, other big projects at European level try to use the business model framework as a starting point, in the case of Internet od Food and Farm 2020 in which a specific working package is devoted to exploring BM from different farming experiences. Learning from others allows things simpler to see and analyze. Since business models are unique to each business, however, there is an endless number of business models. In the past, many business model taxonomies were created to see the patterns in these models. Usually, these classification systems attempt to give a systematic description of business models that organizations utilize(Savelkouls, 2017). The trials made confirm the policy framework and the suggestions made by Eip-Agri during its focus groups (Eip-Agri, 2016)

4.2.2.Digitization and digitalization for rural areas

Digitization consists of changing from analogic to digital, and it is a central problem affecting developing countries but also small-scale farms in Europe, although things are getting better thanks to national policies enhancing digitization of services.

Digitalization is the use of digital technologies to change a business model and provide new revenue, and value-producing opportunities (Gartner Glossary, web)using" disruptive" digital technologies like the Internet of Things, Artificial Intelligence, Blockchain, and Immerse Reality. All those technologies could be applied in different situations and can be very useful to improve business but also learning paths. Even if is there are legal, ethical and social issues open for the data use concerning mainly data ownership, access to data, management of data should be taken into consideration (Kritikos et al., 2017) also to help to overcome barriers in adoption also because those technologies are going to be more widespread from now to the future without forgetting that often farmers are scared to share data without receiving anything in return. An interesting overview of costs has been made in the JRC report, where is visible the cost per technology, and below is reported the table.

Table 10. - List of PATs and PATs services indicative costs(Soto et al., 2019)

PAT type	Description	Source	Price range for PAT (€)
Machine Guidance			
Guidance systems (GPS)	Guidance systems refer to the systems that are used for the tractor guidance. Lightbar guidance is an entry-level guidance system that indicates to the tractor driver how to steer the tractor for following the most effective route during field operations. Mechanical steering is a system that aids in steering the tractor. Autopilot is a system that can fully control the steering system of the tractor without having any help from the tractor driver. There are different levels of accuracy according to the GPS equipment used such as WAAS (30cm), Radio Beacon (10cm), RTK (3cm).	Groover (2009)[III]	Lightbar Guidance System – 30cm Accuracy **1735 €**
			Lightbar Guidance System – 10cm Accuracy **4500 €**
			Mechanical Steering Systems - 10cm Accuracy **5800€**
			AutoPilot Systems – 3cm Accuracy **36640 €**
		Price (2011)[IV]	Lightbar **1830 €**
			WAAS (Wide Area Augmentation System) **5500 €**
			Omnistar **7330 €,**
			Radio Beacon **11910 €,**
			RTK (Real Time Kinematik) **19240 €**

III https://pubs.ext.vt.edu/448/448-076/448-076_pdf.pdf
IV http://www.bookstore.ksre.ksu.edu/pubs/MF2942.pdf

VRA Seeding			
VRA seed drill (with GPS)	VRA seed drills are seed drills that can apply seeds in different densities. They use a field computer that computes the seed doses that must be applied by site-specific needs (through sensor or map based prescription maps), by a GPS unit that understands the tractor position on the field, by a microcontroller that receives information from the field computer and adjusts the seed doses accordingly and sometimes by sensor(s) that instantly measure the organic matter for applying seeds.	Farm Industry News (2007)[V]	**16490-93420 €**
VRA seed drill kit	VRA seed drill kit is a group of components that are implemented in a conventional seed drill for enabling it in precision agriculture. The key components of the system are microcontrollers for controlling the seed doses, a field computer that sends data to the microcontroller based on prescription maps, and a GPS unit for the tractor.	Farm Industry News (2013)[VI]	**12500-25500 €**
VRA Fertilization			
VRA spreaders (with GPS)	VRA spreaders can apply fertilizers in different doses to the site-specific needs. These systems are consisted by field computer that computes the doses that must be applied by site-specific needs (through sensor or map-based prescription maps), by a GPS unit that understands the tractor position on the field, by a microcontroller that receives information from the field computer and adjusts the fertilizer doses accordingly and sometimes by sensor(s) that instantly measures the crop needs for fertilizers.	Cochran et al. (2004)[VII]	**16030-35720 €**
VRA spreader kit	VRA spreader kit is a group of components that are implemented in a conventional spreader for enabling it in precision agriculture. The key components of the system are microcontrollers for controlling the fertilizer doses, a field computer that sends data to the microcontroller based on prescription maps, and a GPS unit for the tractor.	The Daugherty Companies (2015)[VIII]	**4580-9160 €**

[V] http://farmindustrynews.com/high-performing-grain-drills

[VI] http://farmindustrynews.com/planters/electric-variable-rate-planting-entrepreneur

[VII] http://ageconsearch.umn.edu/bitstream/34678/1/sp04co01.pdf

[VIII] http://www.ag-electronics.com/2015_inside_pages.pdf

VRA Spraying			
VRA sprayer	VRA sprayers can apply different doses of spraying products. VRA sprayers can be boom sprayers or orchard sprayers according to the crop type. These systems are consisted by field computer that computes the doses that must be applied by site-specific needs (through sensor or map-based prescription maps), by a GPS unit that understands the tractor position on the field, by a microcontroller that receives information from the field computer and adjusts the fertilizer doses accordingly and sometimes by sensor(s) that instantly measures the crop needs for spraying doses.	Farmers Classified[IX]	**30000-100000 €**
		Silvan[X]	**53100 €**
		Gerhards and Sökefeld (2003) (The cost includes together the VRA sprayer, the weed detection system, and the direct injection system)	**107000 €**
VRA sprayer kit	VRA sprayer kit is a group of components that are implemented in a conventional sprayer for enabling it in precision agriculture. The key components of the system are microcontrollers for controlling the spraying doses, a field computer that sends data to the microcontroller based on prescription maps, and a GPS unit for the tractor.	TeeJet[XI]	**9160-27470 €**
		Downey et al. (2011)[XII]	**13740 €**
VRA Irrigation			
VRA Irrigation Equipment Adoption	VRA irrigation equipment is the equipment that is needed for applying variable rate irrigation. This equipment consists of sensors that detect crop water needs such as weather stations, soil moisture sensors, and actuators for applying accurate water doses such as solenoid valves.	HydroSense[XIII]	**<40 €/ha**
		Kim et al. (2008)[XIV]	**915 €**

[IX] http://classified.fwi.co.uk/browse/sprayers-and-spreaders

[X] http://www.silvannz.co.nz/documents/catalogues/20121115112122_9.pdf

[XI] http://www.teejet.com/media/463685/98-15014-r2%20eu-electronic%20teejet%20price%20book_final%20hi-res%202014-2015.pdf

[XII] http://californiaagriculture.ucanr.org/landingpage.cfm?article=ca.v065n02p85&fulltext=yes

[XIII] http://www.hydrosense.org/eDocuments/annexes/Annex%207.2.13%20Minimum%20dataset_April14-2.docx

[XIV] http://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=53900&content=PDF

PATs Services			
On the Go Soil Sensing	On the go soil sensing is a mapping service that collects soil samples for measuring soil parameters according to precision agriculture methods. Also, non-destructive methods for estimating these parameters can be used. This service aims to produce prescription maps for variable rate fertilization and variable rate seeding in order to achieve the highest economic profit by managing in-field variability.	Hurst et al. (2015)[XV]	**6.5 €/ha**
EO Crop Scouting and Services	Earth Observation-based crop scouting services offer added value services to farmers by exploiting satellite data. These data are used for assessing crop status, providing yield estimation, delineating management zones and as a result, producing prescription maps for variable rate applications (seeding, fertilization, spraying).	Space-tec (2012)[XVI]	**6-10 €/ha**
UAV Crop Scouting and Services	UAV based crop scouting services offer added value services to farmers by exploiting high-resolution data collected from drones. These data are used for assessing crop status, providing yield estimation, delineating management zones, and as a result, producing prescription maps for variable rate applications (seeding, fertilization, spraying).	Wilkes (2015)[16][XVII]	**10-25 €/ha**

Therefore, also in light of these data, although not exhaustive of all the existing realities, but indicative, the adoption of the PAT represents a more significant challenge for small farmers, while it will be easier to implement them as large farmers and agri-food companies. It is still a long way to get toolkits for small-scale farms, even if there is some attempt but is still firmed at the hobby gardening level (https://create.arduino.cc/projecthub/biswa11/garduinhttps://create.arduino.cc/projecthub/biswa11/garduino-bba809o-bba809.).

XV http://www.massey.ac.nz/~flrc/workshops/15/Manuscripts/Paper_Hurst_2015.pdf

XVI http://www.copernicus.eu/sites/default/files/library/GMES_GIO_LOT3_Sector_Summary_Agriculture_final.pdf

XVII 29 http://www.cornucopia.org/2015/02/uavs-awaiting-take-off-us-agriculture/

It is important to remember that small farms across Europe face many similar challenges as geographical remoteness, aging population, scales of production, access to markets, and there are broader impacts on the resilience of employment and contribution to local economies. (Eip-Agri, 2019)

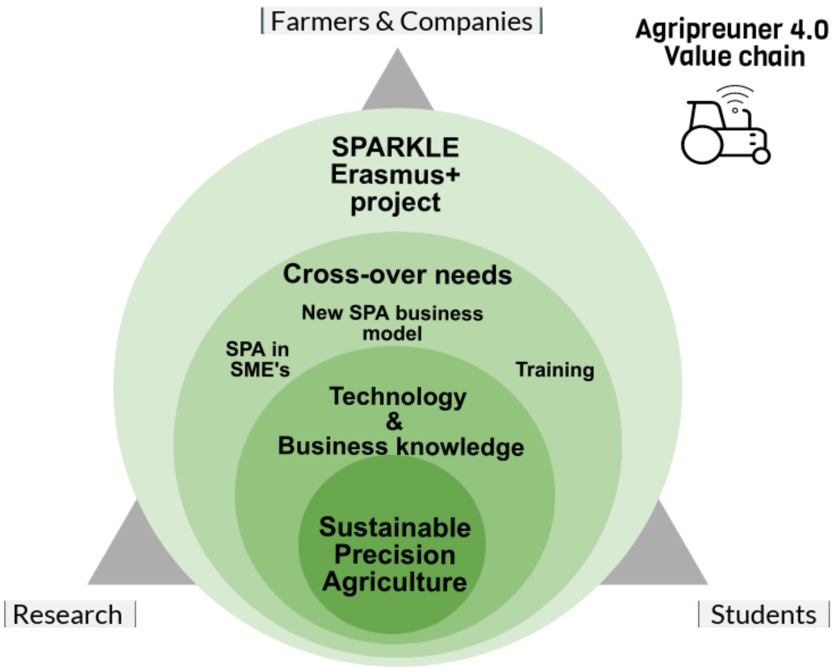
4.3. Sharing knowledge for farmers and students

Digitalization creates the opportunity for digital expertise and people who know how to use digital devices, identify inputs, and build programs and applications. This requires not only rudimentary literacy and numeracy but also the ability to handle data and communicate. Education must be improved rapidly in populations where such skills are lacking; ICT is developing at an incredibly rapid pace, and learning rates must be maintained (UNDP, 2015). From another point of view within academics, a new awareness is raising about those digital domains. Indeed, usually, researchers (especially the younger ones) do not have difficulties to use new technologies and PAT are there to testify it. What is lacking and what several European projects and policies are trying to bridge is the participatory approach (see § 3.1) and the collaborative approach that is lacking between farmers and other actors and within actors. So, if researchers invent things that are not sufficiently picked up and often do not address issues of concern to farmers. At the moment, there is still a significant knowledge gap between research institutions/industries and daily users (advisors and farmers), and this technology gap needs to be bridged by growing end-user skills. In this path, several projects are flourishing at the European level, also in the more "knowledge" based calls like the Erasmus program. There will be more in-depth presented the project SPARKLE but there are also Rural4Learning (http://www.rural4learning.it) the project promoted by the Italian Ministry of Agricultural, Food, and Forestry Policies as part of the 2014-20 Rural Network program, which aims to transfer experience, knowledge and good practices on rural development to students of Agricultural Institutes and Universities of Italy.

All those projects are ongoing, but the first results are encouraging, and it can be said that it is probably one of the paths to follow to improve knowledge on PAT technologies. In particular, the SPARKLE project has several aims that arise from a need analysis started in 2016 about the huge gap among academics, students and farmers on PAT and knowledge transfer in digital agriculture. One of the main objectives is to realize (in January 2019 is going to start) is a pilot course, the first moodle in Europe among 4 Universities which enroll farmers in the creation of the pilot, tailoring the course on their needs and for farmers.

Resuming, the main objectives are: create a Comprehensive Ecosystem, involving the whole agricultural ecosystem, designing the future of the sector and providing the required skills, mobilizing digital knowledge through academics, students and farmers. Fostering the introduction of the new paradigm in Agriculture: Sustainable precision agriculture and finally, supporting the digitalization and High Tech Farming, providing new competencies as agro-electronics and agro-informatics.

Fig. 6. – Conceptual framework of the project (SPARKLE, 2018)



The project takes place over the three years 2018-2020, and the preparation of the pilot test has involved an enormous amount of work in terms of collaboration between academics, researchers and farmers, involved in the project (11 partners including four universities, three farms and four innovative companies). This has meant that a community of practice has been created in which the partnership has realized both the great potential and the limits of collaboration. Thus this brought, for the definition of the contents of the course, to a vast and participatory work whose product declined in all topics that will be addressed is shown in the following table.

Table 11. – General overview of the SPARKLE course

AREA	LESSON N°	LESSON TITLE	TOPIC N°
AREA 1 - SPA OVERVIEW	1	Introduction to SPA	1
			2
			3
			4
			5
			6
	2	Variables and systems	7
			8
		Use cases/case study	9
		Use cases/case study	10
AREA 2 -TECHNOLOGIES	3	Positioning Systems	11
			12
	4	Proximal Sensing	13
			14
			15
			16
	5	Remote sensing	17
			18
	6	Variable Rate Technology	19
			20
			21
			22
	7	Robotics	23
			24
			25
	8	Data Analisys	26
			27
			28
	9	Communications	29
			30
			31
AREA 3 - SOCIAL AND ECONOMIC ASPECTS	10	Policy and Managment	32
			33
			34
			35
			36
			37
			38
			39
			40
			41
			42
AREA 4 - ENTREPRENEURSHIP IN FARMING	11	Entrepreunership in SPA	43
			44
			45
			46
			47
			48
			49
			50
	12	Toolkit for Agripreuners 4.0	51
			52
			53
			54
			55

In the following year to obtain and maximize the results of the course, a MOOC course will be held on the FEDERICA platform http://www.federica.unina.it/). This will be the first step to try to open to the broader public a course on Sustainable Precision agriculture, divided (hopefully) into four different MOOCs that recalls the four units in which the Moodle is divided.

"If you have an apple and I have an apple, and we exchange apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas."

G.B. Shaw

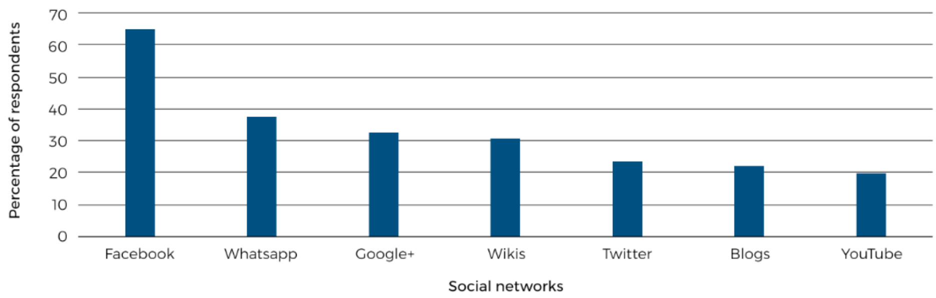
4.4. Collaborative spaces "online."

Internet access is an essential component to unlock innovation and digital possibilities. Online spaces can be used for several purposes inside the agricultural value chain, from the marketing of the product to the delivery. Online spaces allow users to disintermediate steps between actor, for growing knowledge, exchange practices, keep on date about weather conditions. The primary examples are social networks, but there are also emerging platforms that work on the opportunity for farmers to be closer to consumers with a sharing economy approach. This approach recalls the rural social innovation manifesto (see annex II, Giordano, A., Arvidsson, A.,2015)

Going deeper into detail, some examples can be brought to attention. The web is a vast place, and researchers or digital farmers can use it to link each other and share knowledge. One example could be "sabantoag" company (https://sabantoag.com) and its Chief Technical Officer, Mr. Kyler Laird. Sabanto is a Farming-as-a-Service company performing row-crop operations using advanced autonomous equipment. Mr. Kyler Laird has a Github space where shares its repository on robotics with everyone (https://github.com/kylerlaird?tab=repositories). This is only an example, there could be millions of example like this more or less popular, but is to highlight how close could be a solution for a researcher stuck on an issue or a farmer getting a problem in terms of software or data analysis; usually, the web has the answer, this permit to save time and to advance research and work for farmers. Until the 2000s, those kinds of things were informatics domain; today, everything can be fixed with web resources.

Another project that disintermediates passages between producers and consumers is the e-commerce platform. An interesting project, widespread mainly in France, is "the hive that says yes"(https://laruchequiditoui.fr/fr) that applies the same business model of a sharing economy platform (like Blablacar) but works only if there is a real community that participates in the decision process, with reviews and shopping. In this work, social networks, web forums, WhatsApp chat, or Telegram channels are taken into account because they are informal methods for sharing information and knowledge, but it seems a sterile work report something so ephemeral even if very functional for farmers. In the following table, there is a synthesis of the average usage of more popular social networks among 62 countries.

Table 12. – social media preferences among agricultural stakeholders (Trendov et al., 2019)



4.5. Collaborative spaces "offline."

Collaboration "offline" formally starts with the beginning of the co-working in 2005 when Brad Neuberg uses the term to describe a physical space shared by independent and dynamic workers. Neuberg founded the first coworking space, The Hat Factory, in a loft in San Francisco. A few years before, in 2001 at MIT in Boston, Prof. Neil Gershenfeld gets a loan to open the Center for Bits and Atoms. The first Fab-Lab(fabrication laboratory) is born. These two events will become the methodological pivot on which today the Digital innovation Hubs (DIH) are built and all the existing multi-actor and collaborative spaces, maker spaces or other collaborative initiatives work. Coming back to the main idea of Prof. Neil Gershenfeld to put together Bits and Atoms, it should be said that making a comparison with the rural world the road ahead is long, but some trial has been made (see annex II). In the following paragraphs, DIH is going to be discussed as a model to follow, but what is important to underline about collaborative spaces is that it could be a real opportunity for small farmers to develop a digital skill while transmitting their skills in agriculture. Not only digital skills can be improved but also the business ones.

5. European agricultural policies to enhance digital transformation in agriculture

Using digital technology would provide the need for policy and legislation on the information to be produced. Lack of standardization in data format and ownership could create disparities, especially in a circumstance where large international firms pursue digital agriculture for agribusiness while smallholders and local agri-preneurs simultaneously use technologies to address societal challenges in rural and agricultural areas. It is not enough merely to incorporate technology that produces results. EU countries' experience suggests that enhanced telecommunications sector liberalization supports widespread connectivity. Efficient spectrum management can also benefit mobile network operators by reducing the cost of deployment that will bring greater access to ICT services to end-users. Trying to integrate the agri-food market as a core focus of existing national online policies aimed at changing more significant business and society.

The primary conditions and enablers for digital transformation will need to be provided by the social, economic, and political systems. The "Law of Disruption" (Downes, 2009)notes that technology is rapidly evolving, but economic and social structures are gradually changing and are having trouble keeping up. The design and management of digital public programs require a high level of administrative capability that exceeds the capacities of some countries. Addressing the digital divide should be made a policy goal, and policymakers must send both farmers and future private sector stakeholders and start-ups the socio-economic case for digitalizing smallholder farming. There is a growing interest in data-enabled farming and related services, as well as much new technology business and start-ups entrants. The use of machine learning and Artificial Intelligence will be powered by extensive data collection, and new models will need to be created to make the data usable. Digital agricultural transformation strategies combine IT infrastructure with social, organizational, and policy changes in Europe. (Trendov et al., 2019)

To the practical level of regulations, there are numerous EU regulatory instruments capable of defining and enhancing the use of precision agriculture technology (STOA, 2016). For example, Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on the European Agricultural Fund for Rural Development (EAFRD) supporting rural development provides incentives for agri-environmental-climate commitments, motivating farmers to adopt environmentally friendly farming techniques. This strategy also encourages development in physical assets to modernize and improve agriculture, which could help PAT growth. The regulation provides programs to provide better agronomic practices and comprehensive pest management, related to the agricultural holding's economic and environmental performance; it could help users of PAT. Besides, the latest legislative proposal for a Common Agricultural Policy (CAP) emphasizes the need to contribute to mitigating and adapting climate change by increasing the level of ambition of environmental and climate action. Although details of implementation are not specified, the proposal reflects actions aimed at promoting and encouraging farmers to implement climate and environmental-friendly agricultural practices (Soto et al., 2019). On the other hand, despite the wide meshes of the regulation happen for example that at local level, this year, Emilia Romagna region, in Italy, is the first region in Europe by number of Operational Groups (over 10% of those set up throughout the EU) aims at supporting actions to tackle climate change and the likely greater conditionality of the new programming (PianetaPSR, 2019).

An open issue on legal aspects, that should be better regulated and discussed is the lack of transparency and clarity on issues such as data ownership, portability, privacy, confidence, and accountability in the commercial relationships governing smart farming contribute to the farmers ' unwillingness to participate in the widespread exchange of their farm data which encourages smart farming. Digital technology and Big Data systems are ' socio-technical ' and are the product of people, economic, organizational, and social and legal ties. The concerns of farmers about data licenses have a direct impact on their willingness to share agri-cultural data and thus suggest the potential impact of smart farming and digital technology on agriculture. Farmers currently feel they take too much risk and vulnerability and do not benefit from the rewards that smart farming brings. Unless smart farming is to understand its promise, it is not possible to neglect the broader legal and regulatory issues. While sharing data, it is essential to ensure that information license terms and conditions are comprehensible and transparent. Pay attention to those aspects which control who has access to the data, which benefits the advantages of data sharing and privacy concerns. Building knowledge, educating, and raising awareness among agricultural stakeholder communities about issues arising from more generally collecting, controlling, sharing, and using agricultural data, is a key part of the strategy to ensure better data management practices. Until the legal dimensions of Smart Farming's socio-technical big data discussion are discussed, farmers will continue to have "mixed feelings" about how they are made to interact with smart farming technologies and their suppliers (Wiseman, Sanderson, Zhang, & Jakku, 2019).

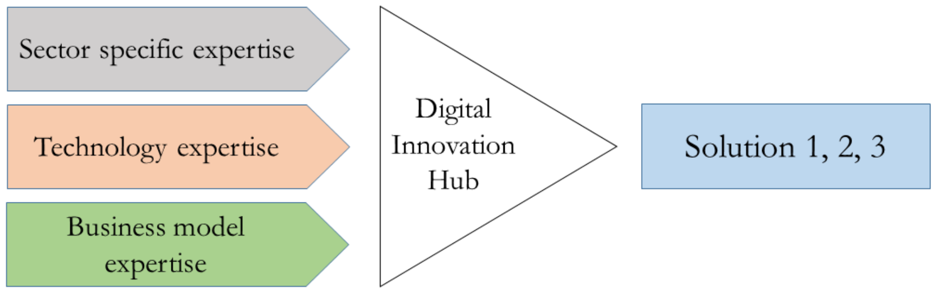
5.1. Digital innovation hubs in rural areas

In some cases, on a global scale, governments have initiated efforts to establish nationally integrated and multisectoral networks to combat food insecurity and safety. Such incipient regional program networks involve non-profit and non-profit organisations, both public and private, as well as global programs directed at food security objectives. In order to foster opportunities to address challenges, many governments have formed alliances with other sectors of society, including multisectoral extension and information services providers.

According to DG CONNECT, the concept "Digital Innovation Hub" (DIH) applies to an ecosystem in which any company may access the new information, experience, and software to evaluate or experiment with virtual technologies related to its goods, processes, or business models. The Hub can also provide links to stakeholders, promote access to fund digital market development, and help connect users and technology innovation providers across the value chain. Any or more "competence centers" are the cornerstone of a DIH. They have advanced technical knowledge and services (laboratories, equipment, manufacturing pilot lines, and others). Within the hubs, they cooperate with the necessary partners in the innovation chain to support businesses in their digital transformation, including investors, business development, and legal experts, and others. (ENRD, 2017a)

Rural DIH are practical tools to address the double digital divide in rural areas: they will help improve both slow and superfast internet access in rural areas and expand the technological capabilities and abilities of both rural enterprises and the broader rural community. Nonetheless, their practical implementation faces specific challenges, like measuring and assessing appropriate financial and human resources for the creation of the network, involving the local community and attracting companies (so that digital hubs may not become empty buildings with decent broadband connections), and providing the necessary facilities to meet local needs. Most DIH can not be grouped into a specific category but do a mix of these(ENRD, 2017b)

Fig.7. – The digital innovation hub model (adapted ENRD, 2017a)



DIH focus on several critical priorities like

- Providing training to build technical capabilities and ensure that new technologies and resources are accessible to the rural population. Small and micro businesses are created and supported.
- Build and protect jobs and start-ups.
- Develop company potential and expertise through endorsing networks and platforms, market incubators, or mentoring, for instance.
- Encourage and foster diversification of the farm.
- Identify and develop new markets for new products or services and existing ones.
- Encourage entrepreneurship through small-scale pilot initiatives to explore new ideas for rural business(ENRD, 2017a)

To have a Rural DIH that work some essential conditions should be satisfied:

As a proper connection to broadband is expected, it is essential to have the correct structure, and the location's attractiveness and great area & excellent local amenities (education, safety, and others.) are essential and advantageous. Those elements risk creating elitist choices even because the DIH has a start-up cost and also a maintenance cost (the average is hundreds thousand euros) in terms of people, services, and structures.

Table 13. – The digital innovation hub scheme per category and services(ENRD, 2017b)

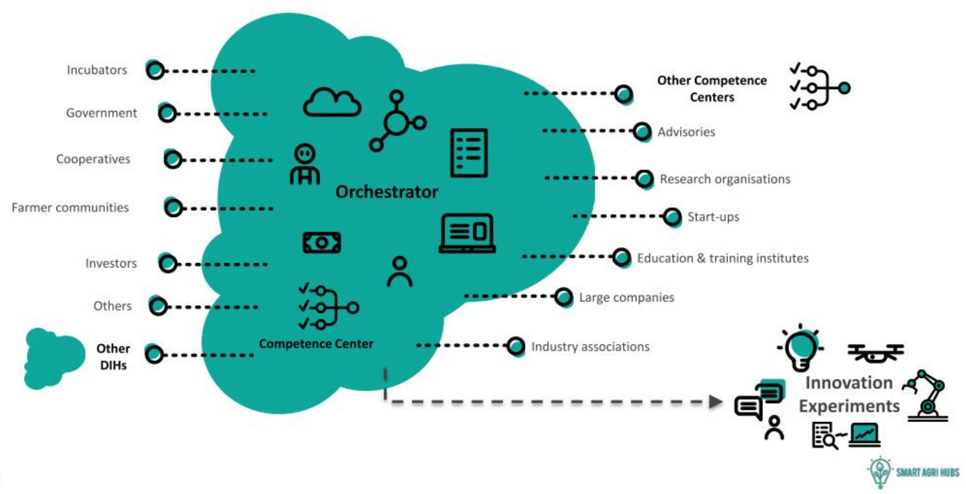
	FOCUS ON BUSINESSES	FOCUS ON COMMUNITY BASIC
PROVIDES SPACE	Office and co-working space, meeting rooms, training space, video conferencing facilities	Essential services (crèche, library, and others.)
PROVIDES SERVICES	Networking & peer-to-peer activities, training, mentoring and business advisory, e-commerce	Improving digital literacy, training classes

There is an interesting project involving several countries, companies and research centers in Europe called SmartAgriHubs

The overall objective of SmartAgriHubs is: to integrate and support the EU-wide network of rural DIHs to facilitate digital transformation for sustainable development in agriculture and food production(Wolfert, 2019)

The central concept takes inspiration from rural DIH but is a way to boot and boost the DIH approach. It is like a DIH "System of Systems". In the following figure, there is a functional scheme of how it works.

Fig.8. – SmartAgriHub general scheme(Wolfert, 2019)



Discussion & Results

6. Investigation ongoing

As explained in the introduction, boosting digitalization in rural areas, improve the diffusion of PAT are bullet point of the next CAP policies and is an issue of the next generation of farmers, and future workers of the agricultural sector. This chapter cannot be exhaustive because mainly the digitalization of agriculture is a very open issue, and it is going to be at least for the near future. Europe works very hard in the direction of enhancing digitalization. There are hundreds of study cases from companies or research around Europe talking about PAT, DIH, and innovation in agriculture. Focusing on the effects of DIH and its role in the enhancing PATs it is important to underline that improving broadband connection in some situations is a direct result of the introduction of the DIH, attracting new companies and creating new jobs and improving digital skills and capacity of rural businesses, attract new residents and visitors, including business and youth families, generate new revenue for the area, and improve basic services. The capability of improving the wider rural community's digital literacy taking coding courses and virtual technology lessons for adults but also organizing children's "coder dojo" (https://help.coderdojo.com/hc/en-us) party.

All those actions are useful to strengthen and improve partnerships with the local community while improving the picture, identification, and strategic vision in rural areas (ENRD, 2017b). For those reasons, experiences and results demonstrate that a DIH should be settled up by both local public stakeholders and private stakeholders who can play an important role. An important lesson is that behind these initiatives, often represented in a board, steering group or association; there are always experienced and committed organizations. Early involvement of the Community is crucial to the success of rural digital hubs in order to ensure that hubs are not only empty buildings with connectivity and facilities but also at the heart of rural community involvement.

The experiences around Europe tells that Rural digital innovation hubs are not 'one-size-fits-all' tools. Moreover, they are not a medicine that closes the divide between city and country magically. Rural digital hubs are platforms for a new strategy of rural areas improving the reputation of rural areas as ideal locations for digitalization and innovation has been described as one of the digital hubs ' main challenges.

"One of the main challenges was to transform the expectations of the local youth, and convince them that they have services and support that can allow them to build a future in the local area." Corinne Ibarra, CoCotte Numerique (ENRD, 2017b)

In terms of design and production, DIHs in agriculture are still at an early stage. The most frequently mentioned principle for DIH in agriculture is collaboration (and networking) between different actors, both at horizontal (innovative) and vertical (agri-food) levels.

DIHs need to be farmer-centric (in terms of easy solutions, rural IT network knowledge, market heterogeneity issues, confidence enhancement, and others) and not just technology-centric. (Eip-Agri, 2017).

Conclusions

The work made cannot be considered exhaustive, but it is a first attempt to define an emerging issue. At the beginning of this work, talking about collaborative spaces for agriculture or the need to use different tools to introduce innovation in agriculture was "as rare as hen's teeth". After three years and some visionary experience tailored for small scale farms in the Mediterranean area (Rural Hub), the starting process of several projects (SPARKLE, SmartAgriHubs, Rural4Learning, and many others) a path is described, and it is in continuous evolution. Trying to make a bridge between sectors, between competencies, and start from the particular going to the big picture requires many efforts from different actors. Many citations made are mainly from EU bodies report or international bodies like FAO. It is just a matter of time, and even the universities will reach the pace and the balance between sectorial knowledge and broader visions without relegating the topic of the adoption of technologies to social fields but opening the engineering sector as happened for Industry 4.0. Someway, collaboration is the turning point and should be considered between actors, within actors. This because as already written innovation technologies are not a new product, today means new services, something that is useful for farmers (in the specific case). All this is important, but it is necessary to remember that the framework is sustainability and the development goals given by the United Nations

Analyzing the functions these technologies perform in both lowering GHG pollution and rising farm profitability can direct legislators to determine the importance of including precision farming as part of future agricultural and climate policy resources (Soto et al., 2019).

While sharing data, it is essential to ensure that the terms and conditions of the information license are comprehensible and transparent. Pay attention to those factors that govern who has access to data, gaining from the advantages of data sharing and privacy concerns. Creating information, informing and raising awareness among farm stakeholder groups regarding issues arising from gathering, monitoring, exchanging and using agricultural data more broadly is a vital part of the strategy to ensure better data management practices (Wiseman et al., 2019). First, the absence of systematic official data on the topic is a significant challenge in recognizing digital agricultural transition. Much of the data–e.g., on e-literacy levels–is available only at the country level, with no distinction between urban and rural areas. In the meantime, network data is focused solely on penetration and does not provide detail on service quality and availability. There is also a lack of information on government support and regulatory frameworks for digital transformation; this has been identified by proxies, including the provision of government e-services and regulations on connectivity and technological disparities in the adoption of digital agriculture technologies among countries, as well as between global companies and those at a local regional and international level. The latest thing to bear in mind is the impact of digital agricultural technologies on efficiencies compared to significant agribusiness players; small-scale farmers face a drawback. It causes disparities between large and small-scale farmers, with resulting inequalities between developed and developing countries. Also, transformative technological advances or technology are not tailored for the scale of smallholder farmers. (Trendov et al., 2019)

Annexes

Attached some articles regarding the research conducted during the preparation of the thesis. Some of the topics presented in the previous chapters are exposed in more detail.

I. Lombardo, S., Sarri, D., Corvo, L., & Vieri, M. (2017). **Approaching to the fourth agricultural revolution: Analysis of needs for the profitable introduction of smart farming in rural areas**. *CEUR Workshop Proceedings*, *2030*, 521–532. http://ceur-ws.org/Vol-2030/HAICTA_2017_paper65.pdf

II. Lombardo, S., Sarri, D., Vieri, M., & Baracco, G. (2018). **Proposal for spaces of agrotechnology co-generation in marginal areas**. Atti Della Societa Toscana Di Scienze Naturali, Memorie Serie B, 125. https://doi.org/10.2424/ASTSN.M.2018.3 http://www.stsn.it/AttiB2018Supp/3-Lombardo_COLORE.pdf

III. Lombardo, S., Marco Vieri, M., Martínez-Guanter, J., Sarri, D., Pérez-Ruiz, M. (2019). **Boosting precision agriculture pass through a co-creation process?** Precision Agriculture for Sustainability , special issue of Agronomy, 2019, Submitted

Approaching to the Fourth Agricultural Revolution: Analysis of Needs for the Profitable Introduction of Smart Farming in Rural Areas

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Abstract. Innovation in rural areas depends upon several factors. One of the most important of those is the technology transfer and how it takes place. Referring to the "long waves" theory on the technological revolutions, since the first agricultural revolution to the one we are experiencing today, some indicators, held together, can establish the relevance of innovations for each revolution. This approach, based on a comparison between agricultural systems, starts from a SWOT analysis to make a matrix table created and inspired to the smart specialization strategies on high technology farming of European Commission on research and innovation on the Agrofood sector. The aim of this work was to build a conceptual framework to understand if the frenzy period of precision agriculture could be a chance mostly in terms of sustainability. This paper highlights on a first approach to delineate some guidelines in order to provide feasible technological transferring for every kind of agriculture system.

Keywords: agricultural revolution, rural social innovation, precision farming, technology transfer, smart farming

1 Introduction

Nowadays it is possible to make an evaluation of what and how innovation and technologies in rural areas spread through industrializes centuries. There are different economic theories that explain the dissemination of innovation through industrial revolution, but it is difficult to find specific comparisons in the agricultural field.

Organize ideas and innovation and comparing different technologies for the same kind of agronomic activity, is an essential requirement to understand in this age and even in the future, where and how precision agriculture could help the agriculture systems. To deal with this challenge, on the one hand it is necessary to refer to conceptual framework known as the "Long wave" theory of Kondratiev (neo–Schumpeterian theory), which stated that radical technological revolutions influence innovation and markets above social and economic changes. On the other hand, we need to take into account the "Transition theory", that try to explain technological

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revolution emphasizing the spreading of niches. On these frameworks, it can be resume that the two conceptual frameworks have similar targets and adopt evolutionary economics with social change as a process of co-evolution of societal sub-systems but with different historical coverage. Lastly, it is also important to bear in mind that the Transition theory consider the sustainability, as opposed in the neo-Schumpeterian theory, therefore it could be important for future evaluations. In order to evaluate agricultural systems in their complexity, can be helpful the SWOT analysis that allows to evaluate ex-ante or ex-post systems or policy programs as Common Agricultural Policy (CAP) as well as to focalize points of strength or weakness and to underline opportunity or threats. This methodology is necessary to defining differences between agricultural systems, characterized by different innovations, and those which are now developing with the new approach named "precision agriculture". In the larger part of agro industrial farms the high tech farming (HTF) is becoming a reality. The question to be resolved, therefore, is the following: is it possible to assert the same for other farming system? Farmers will have initial economical efforts, but for some agricultural operations, there are immediate effects for environmental and economic sustainability. There are severalexamples of technologytransferring to farmers in Europe inside Mediterraneanregionsasproject "Mare, Ruralità e Terra: potenziare l'unitarietà strategica" MARS + (Tirrò et al, 2013), "Vivaismo sostenibile" VIS (Recchia et al, 2013), "Valorizzazione della filiera vitivinicola attraverso la tracciabilità elettronica e le applicazioni della viticoltura di precisione." TRA.PRE.VIT (Sarri et al, 2015) and "innovazioni per il miglioramento della viticoltura Toscana" IMVITO (Vieri et al, 2013). These projects documented that there are in addition initial barriers as in the learning in using the software or to understand the usefulness of collecting field data to deal with precision agriculture. Additionally, it must also be taken into account that precision agriculture solutions is becoming commercially achievable and is estimated that from 2014 to 2020 the precision agriculture market will grow every year by 12%, more less 50% in 4 years (EC, 2016a). Finally, it is important to measure the differences between old system and new one to let farmers choose consciously what type of system adopt in order of economic, social and environmental efforts and sustainability.

2 Materials and Methods

2.1 Technological Revolution Models

A first approach to delineate some guidelines in order to provide feasible technological transferring to the different kind of agriculture systems requires an initial reference to the theories that have been point out about technological revolutions. Kondratiev wave theory describes technology revolutions and how innovation irrupts through economy and markets. The also called "long wave" theory, revised and discussed by many economist has many contact points with the "Transition" theory that mainly analyses processes of radical change in society connected with big changes in socio-technical system. Kondratiev theory (neo-Schumpeterian theory) is not usually associated with sustainability instead, “Transition” theory is it and is limited in its debate of how to influence social and economic opportunity. Within this theory, “the advantages of the new technology are so great that policy and institution accompany the development of the new industry” (Köhler, 2012). There are several modern economist which have been tried to describe long waves as Freeman and Louçã (Freeman and Louçã, 2001) that have summarized in six phases the life cycle of a techno-economic paradigm i.e. 1, the laboratory/invention phase, 2 decisive demonstration(s) of radical technical improvement and commercial feasibility, 3 Explosive, turbulent growth, characterized by heavy investment and many business start-ups and failures., The phase 4 refers to continued high growth, as the new technology system becomes the defining characteristic of economy, with impacts on most, if not all sectors of the economy. The ‘regulatory regime’ is therefore reconfigured to support the new technologies and industries’ products. Then the 5 step "Slowdown" as the technology is challenged by new technologies, finally the 6 stage "Maturity" leading to a (smaller) continuing role of the technology in the economy or slow disappearance. Therefore, the innovation trajectories in long waves theory for technological revolutions defined by Perez (Perez, 2010) are based on the diffusion of the technological revolution and time and can be identified in four phases defined by a first irruption phase followed by a frenzy period then by a synergy period and finally a maturity period (figure 1).

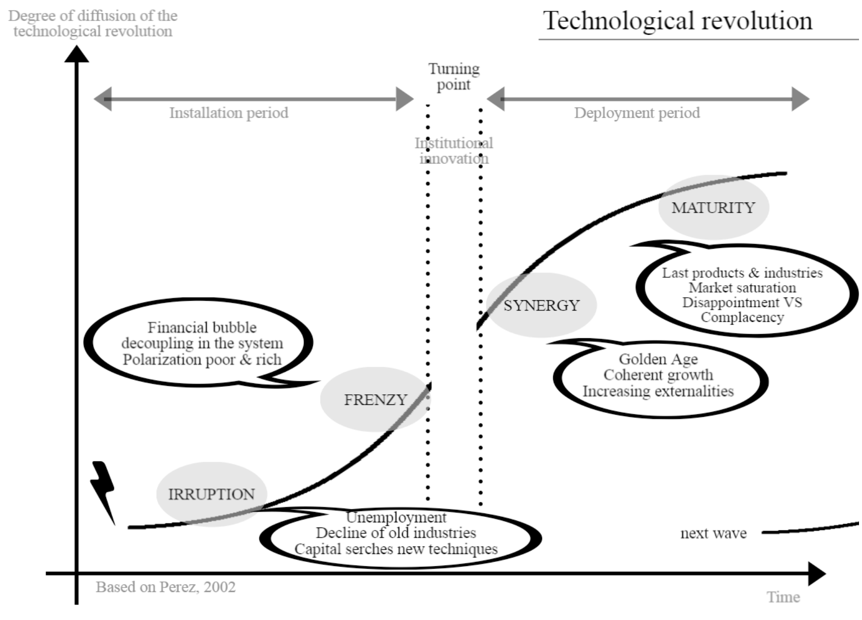

Fig. 1. Graphic of technological revolution, based on Perez (2002).

Generally, the discussion on technological revolution is on industrial field, but it can be borrowed also on agricultural revolutions that usually deduce from industrial ground.

Lastly, if the larger part of economist agree with the "Schumpeter-Freeman-Perez" paradigm that identify five waves for agricultural sector, innovations that bring new waves can be compared with industrial revolution waves as showed in the table 1.

Table 1. Comparison between industrial revolutions and agricultural revolutions.

Technological revolution	Popular name for the period	Big-bang initiating the industrial revolution	Year	Big-bang initiating the agricultural revolution	Year	Agricultural revolution
First	The Industrial revolution	Arkwright's mill opens in Cromford	1771	First theory on reversing plough*	1774	First
Second	Age of steam and railways	Test of the Rocket steam engine for the Liverpool–Manchester railway	1829	First gasoline tractor engine**	1890	Second
Third	Age of steel, electricity and heavy engineering	The Carnegie Bessemer steel plant opens in Pittsburgh, PA	1875	-	-	-
Fourth	Age of Oil, the Automobile and Mass Production	First Model-T comes out of the Ford plant in Detroit, MI	1908	*Fordson*tractor based on T model**	1915	Third
Fifth	Age of Information and Telecommunications	The Intel microprocessor is announced in Santa Clara, CA	1971	ICT and digital systems in agriculture management***	1997	Fourth

*AA.VV, (2008).
**Zoli, M., Vieri, M. (1998).
*** IstEuropean conference on precision agriculture (1997).

Technological revolutions in the industrial sector and also in the agriculture sector occurred along the same years. Nevertheless, it must be noticed that for the main tool of the green revolution i.e. the tractor, and specifically for the T tractor have elapsed only few years, while it is just a fact to find the first microprocessor on tractor have spent many years. Consequently, the first approach with CAN-bus was made only in 1988 (Biondi, 1999).

2.2 SWOT Analysis Method

In order to evaluate each agricultural revolution that generated different agricultural systems, a SWOT analysis was carried out to assess ex-ante or ex-post the systems with the objective to focalize points of strength or weakness from internal and to underlines opportunity or threats from external (Table 2).

Table 2. SWOT matrix model

	Helpful (to achieving the objective)	Harmful (to achieving the objective)
Internal origin	Strengths	Weaknesses
External origin	Opportunities	Threats

2.3 A Matrix to Compare Technological Revolutions in Agriculture

A matrix that compares agrarian revolution with a system based on the precision agriculture method was made with the target to make order in this frenzy period and in order to compare it with other known systems. This system, inspired to the smart specialization strategies on high technology farming of European Commission on research and innovation on the Agrofood sector, splits different mechanized/not-mechanized field operations divided in technology oriented (eyes, touch, arms, mind) and in service oriented (memory, experience, identity) (table 3). Under each operation are shown the unit used (Vieri, 2016).

These operations were defined for the precision farming (but they can be explained also for the others technological revolution) as follow:

- EYES & TOUCH to monitor the single element on wide area (sensors and digital layer) and recognise the effects in each element treated (on board, proximal and remote sensors)
- ARMS to do huge and precise tasks (automation, robot)
- MIND to be aware of what, where and when to act in each single productive step (Modelling and Decision Support Systems)
- MEMORY to be aware on what has been done (telemetrics, traceability, data store)
- EXPERIENCE (Data Management & Prescriptions)

- IDENTITY of agricultural resources and sustainable use at Local & Regional level (territorial complexity, TRL of tools & services, Know-how, CoPs).

Table 3. Comparison between agricultural revolutions in terms of field operations technology oriented

Agricultural revolution	Operation			
	EYES ha/year/man	TOUCH ha/year/man	ARMS h/ha/man	MIND surface
First	2-3	2-3	From 800 to 80	subsistence farm
Second	scheduled andprescribed application		From 80 to 10	levelling out methods and practices
Third	200-300	200-300	From 10 to 2	farm
Fourth	300-500 (multiparameter)	300-500 (multiparameter)	From 2 to ~ 1	global level

Table 4. Comparison between agricultural revolutions in terms of field operations service oriented

Agricultural revolution	Operation		
	MEMORY data	EXPERIENCE farmer	IDENTITY farmer
First	oral	oral/personal experience	family
Second	levelling out methods and practices		
Third	oral/written/data	local level/farms	farms
Fourth	big data	global level	local level

In the tables 3 and 4, clearly show how technology have influenced since the first to the fourth agricultural revolution the different operations. Moreover, it is possible to highlight as in the green revolution, (the second agricultural revolution) farmers did not carry on decisions on many operations.

3 Discussion & Results

In the first agrarian revolution thanks to innovations in the design and efficiency of ploughs, human strength increased even though there were less people employed in farming because of industrial revolution and wars. In the second agrarian revolution mechanization played a key role allowing everyone, more profits and production. Thanks to this, although the increasing number of people, the born of agroindustry resolved the hunger problem, with mechanization and chemicals. On the other hand, the system loses its complexity in terms of territorial knowledge and peculiarity. In the third agrarian revolution, times of innovation reduced in bias of more complexity of systems and technologies used. Knowing this, a first approach, committing the neo-Schumpeterian theory of technological revolutions and applying the SWOT analysis to the fourth agricultural revolution can be discussed and resumed as follows: (Table 5).

Table 5. SWOT Analysis on the fourth agricultural revolution

	Helpful (to achieving the objective)	Harmful (to achieving the objective)
Internal origin	Strengths • knowledge – based agriculture • augmented capacity • multidisciplinary	Weaknesses • speculative business model • digital divide of rural communities • limited access to data and innovation
External origin	Opportunities • innovative value chain • circular economy • social cohesion • empowerment of rural communities • antifragility	Threats • business as usual value chain • inequality • exploitation of rural communities • fragility

The table above summarize the state of the art of what is the fourth agricultural revolution.

Thebiggest difference between the fourth agricultural revolution and the others is that the former happens during the era of the digital revolution. This opens to the opportunity of changing radically the value distribution and allows the re-thinking of the local products (and local producers) as the core of a new value system based on the triple bottom line approach (people, planet, profit). This paradigm has been defined "rural social innovation", and is aimed at investigating the pathways for a Mediterranean social innovation initiative (Giordano, A. and Arvidsson, A., 2015). Referring to the SWOT analysis, this means that threats can become opportunities for medium and small agricultural companies and this represents a challenge for the territories in which these companies play a significant role for the social and economic development of the communities.

Trying to realize it, we should also consider that there are different actors turning in this system, discovering who exactly they are and how they act.

The main actors of this system are:

- government (local or central), as the actor in charge for the policies
- farmers, as the actor in charge for the supply
- people, as the actor in charge for the final consumption demand

In this scenario, policies should take in consideration the real need of rural communities, taking care of the important role played by them for maintenance of landscape, water regulation, traditions, food quality and finally, of all the dimensions that can generate positive social and environmental impacts.

The last European Policies (CAP) and the Declaration of Cork 2.0 claim this path well signed (EC, 2016b).

Table 6. Perspective of possible evolution of technological shifting in agricultural contest

	Empowerment of rural communities		
Speculative as usual business model	Traditional technology transfer	CSA Digital innovation hub	Innovative value chain
	Top- Down policies	Marketing of local products	
	Exploitation of rural communities		

Furthermore, the SWOT analysis risks realizing a static vision of the reality. In fact, it is not possible to effect on strengths and weaknesses but it is possible to have a deeper vision of the SWOT analysis working on and convert treats in opportunities. In this case, referring to the table 5 there are two key variables, the value chain (strength-weaknesses related) and the level of empowerment-exploitation of rural communities and we intend to show how guidelines can influence the evolution of the new agricultural paradigm, in terms of technological shifting, and their related effects. This dynamic framework can develop (if the factors on the axis go to the upside and the right) in a Community Supported Agriculture system (CSA), a digital innovation hub, or other online and offline networks that fulfil the rural social innovation approach, which include a digital approach (Lombardo, 2017 in press).

Every action took by actors, in other directions, cannot realize completely the innovations needed in rural areas for farmers. In fact, turning threats in opportunities means that the access to technology allows little and medium companies to use environmental peculiarities (i.e. biodiversity or landscape) as levers for marketing. For this reasons instead, those peculiarities can be the lever of a new value distribution.

3.1 A First Approach to Comparison Between Precision Agriculture and Other Agricultural Revolutions

Whilst it has been considered the policies and a different innovation approach in rurality, on the other side arises the necessity to compare operational data in order to understand that filling the gap of technologies innovation in agriculture is a real need. As an evaluation example of agricultural working stages, the ploughing was considered. The reference unit analysed was the working capacity expressed as $m^3\ h^{-1}$ ploughed considering a soil furrow slice with a 0,2 m deep and 0,4 m width, for a total surface of 8 dm^2 worked by a man with a shovel. The time required was set to 800 hours per hectare as documented by CosimoRidolfi (Faucci, 2008) and further a yard efficiency of 0,85 was set. In view of these parameters, it follows that the amount of soil to plow was 2000 m^3 per hectare and that a man with a shovel was able to work around 2,5 m^3 per hour. This reference unit yard was compared with the horse with plough, to the tractor coupled with single plow, a tractor with a five ploughshare plows and finally with a tractor equipped with a five ploughshare plows and automatic drive. The yard working capacity was calculated multiplying the forward speed by the soil furrow slice surface. Then the resulting value was multiplied by the yard efficiency.

Table 7. Work needed for a furrow slice of 8 dm^2 for different yard typologies representing diverse technologies revolutions.

Yard				Working capacity $m^3 h^{-1}$
Man + Shovel	Volume/h	$m^3 h^{-1}$	2,5	
	Yard efficiency		0,85	2
Horse + Plough	Forward speed	$m h^{-1}$	3600	
	Yard efficiency		0,8	230
Tractor + Single Plough	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	336
Tractor + five ploughshare	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,7	1680
Tractor + five ploughshare + Automatic Drive	Forward speed	$m h^{-1}$	6000	
	Yard efficiency		0,9	2160

The results showed, referring to the unit $m^3 h^{-1}$and taking as reference unit the man work, the huge differences between the productivity of a tractor (like that one of the 2ndth and 3th agricultural revolution and the more used kind of tractor), compared to the productivity of a tractor with automatic drive. The difference encountered between the productivity of the tractor with ploughshare 336 $m^3 h^{-1}$ and the tractor with five ploughshare 1680 $m^3 h^{-1}$ is attributable to the increasing number of ploughshares and not to the technology used. It is important to underline, the relevant difference if the technology used changing. In fact, a tractor with five ploughshare has a productivity of 1680 $m^3 h^{-1}$, but a tractor with five ploughshare and automatic drive has a productivity of 2.160 $m^3 h^{-1}$ that is 1,3 times more.

4 Conclusions

Approaching to the fourth agricultural revolution and trying to understand emerging needs, in both operational and policies it could be a chance to introduce profitable innovations in agriculture to have a sustainable managing of the natural resource. The highlight on one field operation, comparing through different kind of technology used, is the first step to underline the necessity of a technology introduction also for small and medium agricultural enterprises. In this contest, it is important to remember the feasibility of a technology and the cost to effort for every kind of company. The challenge for the policy makers in the framework of a technological revolution, such as precision farming, is boosting knowledge and technological transfer also for those farmers who can't have all the capital needed.

For this reasons, it is desirable to design and implement an economic and social ecosystem able in supporting this kind of policy. Only in this way, it will possible to shift from a extractive business as usual value, to a community supported agriculture system (CSA), where the value generation and redistribution is coherent with the effective value contribution given by the actors involved in the process.In conclusion, these kind of policies allow us to consider a new SWOT analysis that faces the challenge of the rural social innovation approach.

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Roberto BARBUTI, Stefano CHESSA, Roberto FRESCO, Paolo MILAZZO

PREFACE

The technological innovation in biology and agriculture often leveraging on innovation in computer science and engineering, pushed forward the process of integration among these disciplines. In particular, information technology (IT) provides common methodologies and tools for the automatic acquisition and analysis of the data that concern the management and optimization of the natural and territorial resources.

In agriculture, applications of IT enable the integration of interventions concerning its sustainability and productivity, by offering methods and tools to monitor, control, analyse and optimize the production while keeping it respectful of the environment. Similarly, the best practices for bio sustainability, for the management of bio-diversity and for the bioremediation of the environment (including soil, water etc…) are also progressively adopting IT, which enable more focused (and thus more effective) applications.

In this context, the conference "Technologies and innovation for sustainable management of Agriculture, Environment and Biodiversity" (TI4AAB), was held in July 2016 at the Natural History Museum of the University of Pisa located in the Calci Charterhouse (Calci, province of Pisa) in order to encourage the sharing of emerging knowledge about the above topics.

In fact, the conference was dedicated to fostering innovative cross-disciplinary research and applications and to stimulating the exchange of strategies and experiences, among academic and company experts from different disciplines (agriculture, biology, computer science and engineering and environmental decision making), in order to encourage a common, interdisciplinary discussion about the adoption and perspectives of IT in modern agriculture, environmental management, biodiversity and bio-sustainability in general.

The conference was held under the auspices of the municipality of Calci, the University of Pisa and of the "Ordine dei Dottori Agronomi e Dottori Forestali". It was also attended and supported by some leading national and worlwide industries, like CAEN RFID, OSRAM, STMicroelectronics, EBV Elektronik, Qprel Srl, AEDIT Srl, EMipiace Srl, and Zefiro Ricerca & Innovazione Srl, and by the Italian National Forestry Authority.

This volume constitutes a selection of the contributions presented at the conference and cover the aspects of innovation in agriculture, biology, and applied information technology. In particular, concerning innovation in agriculture, the paper by Nin et al. studies new soilless cultivation systems for wild strawberry growing in the Tuscan Appennine mountains. The paper by Prisa describes experimental research concerning the use of zeolites in combination with effective microorganisms, in order to improve the quality of olive trees. Finally, the paper by Lombardo et al. describes collaborative approaches to innovation in agriculture (co-generation of technology).

Concerning innovation in biology, the paper by Baldacci et al. describes the results of the preliminary phases of the AIS-LIFE project, which aims at developing aerobiological information systems in order to improve pollen-related allergic respiratory disease management. Still concerning the AIS-LIFE project, the paper by Natali et al. aims to describe the strategy used in AIS-LIFE project, to evaluate daily pollen concentration in the atmosphere produced by many allergic plant species. The use of data and GIS system are shown as an approach to assess allergy risk maps.

Concerning innovation in computer science applied to agriculture and biology, two contributions focus on modeling approaches, and two contributions provide a survey of information technology applied to agriculture and biology. Specifically, the paper by Bodei et al. describes the application of the IOT-LYSA formal modelling framework to a possible scenario of grape cultivation, in order to assess water consumption, and the paper by Barbuti et al. proposes a mathematical model of artificial reefs, in order to study the dynamics of algal coverage and of populations of fish in some Italian artificial reefs. Finally, the paper by Fresco et. al. explores the current challenges and IT solutions in order to realize a digital agriculture framework, intended as an evolution from Precision Farming to connected knowledge-based farm production systems, and the paper by Pucci et al. provides a survey on biologging methodologies for the collection of knowledge about animals' behaviour, making a review of some related common data analysis techniques.

All papers have been carefully reviewed by experts in the specific fields. Here is the list of the reviewers, that we thank for the collaboration.

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PROPOSAL FOR SPACES OF AGROTECHNOLOGY CO-GENERATION IN MARGINAL AREAS

Abstract: S. Lombardo, D. Sarri, M. Vieri & G. Baracco, *Proposal for spaces of agrotechnology co-generation in marginal areas.*

In the European agriculture sector the basic training levels is very low, despite the dedicated funding. The challenge of the new industrial revolution in agriculture toward precision farming is an opportunity to promote this new paradigm among all stakeholders of the agricultural sector. The new paradigm could start changing the top-down approach by abandoning the technology transfer used to date. To this end, it shall be introduced open innovation to research in order to enable social innovation in rural communities for a bottom-up approach. The ultimate goal is the agro technical co-generation of products and services that can take place in collaborative spaces such as Fablab.

Keywords: Rural Fablab, rural training, Co-generation agrotechnology spaces, social innovation, open innovation, Digital Innovation Hub.

Riassunto: S. Lombardo, D. Sarri, M. Vieri & G. Baracco, *Proposta di spazi di co-generazione agrotecnologica in aree marginali.*

Nel settore agricolo europeo, il livello di formazione di base è molto basso, nonostante i finanziamenti dedicati. La sfida della nuova rivoluzione industriale in agricoltura rappresentata dall'agricoltura di precisione è un'opportunità per promuovere questo nuovo paradigma tra tutti portatori di interesse nel settore agricolo. Il nuovo paradigma può innescare un cambiamento nell'attuale approccio top-down, consentendo il superamento delle tecnologie utilizzate al momento. A tal fine, si introdurrà il concetto di "*open innovation*" alla ricerca in modo da rendere possibile l'innovazione sociale nelle comunità rurali favorendo un approccio bottom-up. L'obiettivo finale è la co-generazione agro-tecnologica di prodotti e servizi che possa aver luogo in spazi collaborativi come i Fablab.

Parole Chiave: Fablab rurali, formazione rurale, Spazi agrotecnologici di co-generation, innovazione sociale, open innovation, Digital Innovation Hub.

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INTRODUCTION

The main social, economic and technological transformations that human history experienced have been determined by innovation factors in three fields: energy, communications, logistics (Rifkin, 2014).

Now, we are at the beginning of the IV industrial revolution dominated by computerization with the possibility to share, more or less immediately, and to create information, goods and services through sharing and collaboration. This change affects all productive sectors, including the agricultural one that is, however, in some respects back to others, in terms of access to information and knowledge. Data resulting from a study promoted by the European Commission's Science and Technology Options Assessment (STOA) on the future of agriculture in Europe have shown that 91% of farmers have a basic education and only a 6% are specialized. On the other hand, the 80% of people over 65 (representing one third of the current farmers) have not received none (EC, 2016). Figure 1 shows an average of training level across Europe: among the Mediterranean countries, Italy obtains, even if only slightly, the best result.

The histogram (Fig. 1) highlights that the basic training level is still very low in all the age bands (not more than 35%) and the younger classes (below 35 years and from 35 to 44 years) suffering of considerable basic training gap. This shows the gap between agriculture and the ability of accessing innovation, and consequently this leads to considering the endogenous and exogenous reasons associated with it. In Italy, the first agrarian revolution finds fulfillment in the foundation of the Agriculture school promoted by Cosimo Ridolfi (Centro studi sulla civiltà Toscana, 2008) that constitutes the birth of modern agriculture. The second revolution started after the industrial revolution and the Second World War, and it is known as the "green revolution" of the XX century. Nowadays, in view of a new paradigm (industry 4.0), in agriculture the condition for the third fundamental evolution/revolution of modern agricul-

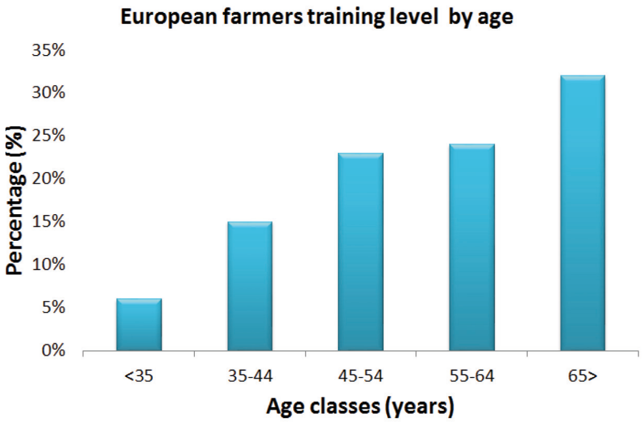

Fig. 1 - Results of European farmers training by age.

ture is being created. It focuses on the computerization (e.g. Internet of Things, IoT) with the objective to increase efficiency, preserving the land (cross-compliance) and sustainability in all its aspects as well as people. In this framework, education in innovation is a useful step to allow farmers to enter quickly and effectively in the transformation underway. In that way, moving from the bottom up approach, toward horizontal and participatory improved methods, can enhance the resilience (intrinsic in rural communities) facilitating the transition to environmental sustainability and social economic models now necessary and urgent (Vieri *et al.*, 2016). About the transfer of innovation, two significant examples of "best practices" at the Italian and European levels related to technology and research results transfer and achieved through the social component of the involved people, were the MATEO (http://www.olivicoltoritoscani.it/pagine/progetti/mateo) and Mars Plus (http://www.marteplus.eu) projects. The MATEO project (Criteria for introducing mechanical harvesting of olives oil: Results of a five-year project in Central Italy), pertaining to the technical and economic business models in Tuscany olive growing, helped to identify the criteria for effectively introducing mechanization (Vieri *et al.*, 2010). The study, in addition to the different levels of mechanization applicable according to well-defined criteria, underlined that the entrepreneurial and managerial skills of the farmer affect the capacity for innovation and improvement of production. This statement is very important because the olive growing is, after cereal crops growing, one of the main agricultural activities in Europe. On the other hand, also the maintenance of the tradition in the harvest should not be seen as backwardness but, instead, as an opportunity for the territory to maintain a knowledge that can be useful for the mechanization, from the standpoint of replication and the improvement of a sustainable and suitable process for that area and community. Another case of European project aimed at increasing the competitiveness of the olive and wine-growing sectors in mountain zones, the so-called "heroic agriculture" was the MARS+ project. The project, starting from an analysis of the evident challenges in the territories of Liguria, Tuscany, Sardinia regions as well as Corsica Island, has set out a framework to transfer technological innovation in order to facilitate the process of mechanization and more generally to increase the enterprise' innovation level in these fragile areas (Tirrò *et al.*, 2013). (The cross-border project between France and Italy MARS+. Sub-project - Innovative technologies for the mechanization of the areas hard to reach). These last two examples showed that combining data on education in agriculture is necessary, also in view of computerization and of the rising of new technologies, to experiment new methods of technology transfer. This is linked with the progress being made in other sectors, where fruitful results are being achieved with working methods that predict and predispose to the creation of development situations and collective, open and horizontal research. This work aims to propose the use of collaborative approach through social innovation methods to achieve the goal of technological co-generation in agriculture (and not technology transfer with top-down method).

FROM TECHNOLOGY *TRANSFER* *TO CO-GENERATION OF TECHNOLOGY*: OPEN INNOVATION IN AGRICULTURE

Technology transfer, in a context in which there is a lack of training and low rate of innovation, and depending on social and cultural factors is still a necessary goal for the competitiveness of the agricultural sector, and especially for small and medium-sized agricultural enterprises (SMEs) often present in limited and marginal territories.

The area of research and development as we know is changing and more and more often is contaminated by the open innovation paradigm.

In this regard, Chesbrough said, "The Open Innovation is a paradigm which states that companies can and should use external ideas as well as internal ones, and access to internal and external paths to market if you want to advance in their technology skills." (Chesbrough, 2003) Figure 2 shows graphically the current closed innovation paradigm and the open paradigm. The old paradigm has certain inputs and outputs, derived by the contribution of technical knowledge and internal development of company products. In the new paradigm, the boundaries between company, territory and community become porous and there is not a defined control of all outputs with the possibility of forming new markets and technological spin-offs. The definition given is important, but not easy to implement if the reality that you take under consideration is the agricultural one. One of the levers to assist in this process is the triggering of a fruitful approach among multiple actors, through spaces dedicated to collaboration and exchange.

The technology transfer model based exclusively on research and development within universities, research centers and companies today is combined if the needing is agriculture oriented to short chains, territory and communities. For these reasons, it is more appropriate to start talking about co-generation of technology in agriculture, which provides a common-based peer production (CBPP) (Benkler, 2006) rather than technology transfer, which provides a top-down approach.

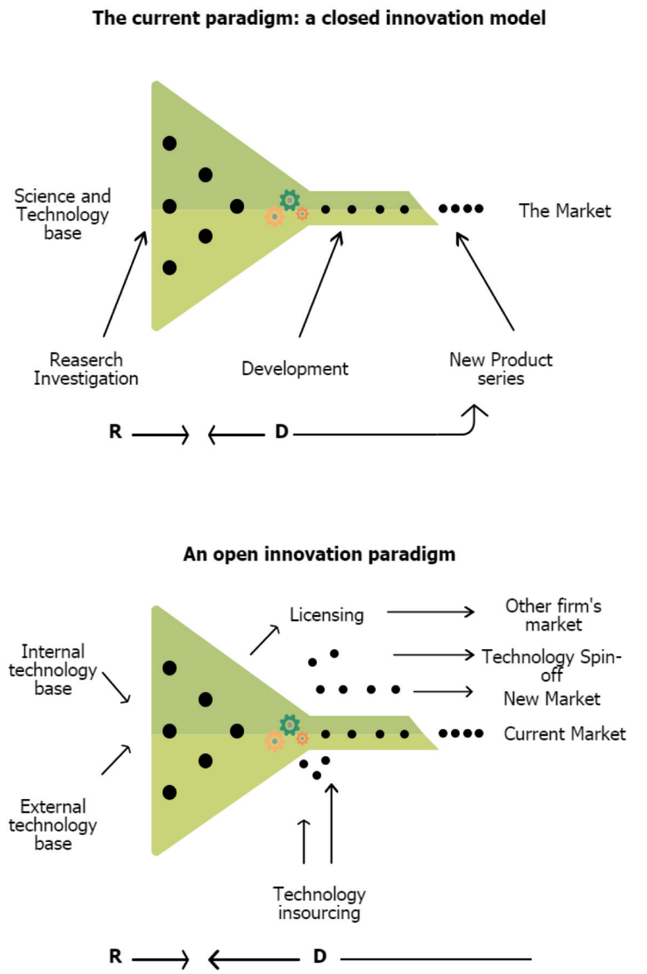

Fig. 2 - Graphical illustration of Closed innovation model vs Open innovation model.

SOCIAL INNOVATION

Starting with one of the possible definitions, we define social innovations as "new ideas (products, services and models) to meet social needs (more effectively than the existing alternatives) and at the same time, create new relationships and collaborations. In other words, useful innovations for society and that increase the possibilities for action" (Murray *et al.*, 2010). Innovation as we have known it is no longer just a matter of new products or services, but often focuses on people. Just think of the social platforms or applications and tools that disintermediate processes (smartphones, for example). Technological co-generation in enabling individuals oriented to sharing and creating value and products generates progress of social innovation in communities making them more resilient and ready to change. There arises the objective of which tool to use to ensure the co-generation of technology in the marginal areas.

CO-GENERATION OF TECHNOLOGY: THE COLLABORATIVE SPACES

Ensuring technological co-generation through appropriate tools can mean resorting to the creation or discovery of physical space to share as, for instance, a collaborative space. The collaborative space is a physical and/or virtual place where there are groups of people finding forms, methods and ways of working, and exchange knowledge involving a high level of cooperation, responsibility and partnership between actors different from each other (researchers, artisans, professionals, businesses, etc.). The goal is to promote the exchange of ideas, co-designing services, places and products, in other words the basics of the open innovation paradigm (Montanari, Mizzau, 2016). In the agricultural sector, a collaborative space can be a useful tool to make up the shortage and fragmentation of skills and abilities, working at the level of co-generation of technology and peer-to-peer education and value creation. The approach used in the collaborative space is at par, of learning by doing, opening the possibility of exchange and comparison among the different actors living and working in the same area: researchers, makers, farmers and all other shareholders (not just stakeholders). Rural communities to support themselves, to be resilient and vibrant, in addition to adopting or perpetrating sustainable models must be permeable to knowledge and innovation. In this process, a crucial role is played by places of meeting and exchange for a community, such as collaborative space, whose main example in urban areas is coworking. In the same way, collaborative spaces in urban areas have been working as a catalyst to make it sustainable and competitive people, skills and activities that are likely to remain excluded from the classic working circuit (due to the crisis and…). It can be thought of borrow this mode - in appropriate forms, and meeting the needs of rural areas - by responding to the practicality of the needs related to the rural world, indicating a different route to outright collaborative spaces. It thus introduces the concept of "third place", which is a neutral ground where the heterogeneity of the actors can come out of traditional working dynamics to approach a new way of sharing, planning and realization of ideas, tools and actions. With this regard, we may need to use different tools from one computer, and we may need to take practical actions "in the field" using specific tools (think of the need for improvement or modification of tools aimed at of sustainable precision agriculture). The interest of this work falls on the so-called rural collaborative spaces and specifically on the role of Fablabs that, thanks to the computerization and philosophy, can be understood as a key tool for the application of Open Innovation paradigm. Fablabs are also community centers where different expertise and skills meet and experience made available for social innovation projects designed to meet the needs of the territory (Manzo, Ramella, 2015).

FABLAB – GARAGE 4.0

Fablab (fabrication laboratory) (Fablab, 2012; Fablab, 2016; Menichelli, 2014) were designed by Neil Gershenfeld, a US physics and information technology professor at the Massachusetts Institute of Technology at the "Center for Bits and Atoms" in 2005. They are a collaborative space for bits and atoms (organic matter) aimed at encouraging experiments with both digital technologies and physical objects, the use of open source software and open and big data processing, the development of solutions for Smart City and Smart Farming. They are spaces where it is possible to learn to use digital technologies in relation with physical reality. Fablab is therefore defined as part of a network, a community, a set of tools, knowledge, processes, but also a service, a business, not a franchise, but mostly it is a concept still under development. There are four rules that distinguish and define a Fablab:

- access to the laboratory should be public;
- the laboratories must sign and show the Fab Charter (http://fab.cba.mit.edu/about/charter/);
- the laboratory must have a set of tools and shared processes;
- laboratories must be active and participate in the global network.

At the moment there are about 663 Fablabs around the world, and Italy with its 63 laboratories (and the number is growing), ranks third in the world by number after the US and France. Of each laboratory activities range in all productive sectors. As for the primary sector, the rural fab lab is a reality less common but still present in the world (actually the first Fablab "ante litteram" was born in India in 2002 with the help of MIT with the goal of developing cheap technology in the rural community of the village of Pabal) (Walter-Herrmann, Büching, 2013). Economic, social and environmental sustainability is the main characteristic of these spaces. Collaborative reality that characterizes those makes them suitable to enterprise creation as well as technological and social innovation thus encouraging new relationships and new partnerships. Social innovation in rural areas is a useful approach to bring the focus back to the products, implies the co-generation of ideas and projects from the bottom, use of technology and new organizational forms that they take as a model the network logic of horizontality. Porter value chain model (product> logistics> branding> finance) is revisited and corrected moving from "chain" linear toward a "system" where the center is the product, whose value increases according those generated by wider communities through storytelling mechanisms and disintermediation. Fablab or rural collaborative spaces are based on real needs: the primary sector is characterized long-standing problems of size and fragmentation of ownership, data management, a lack of innovative capacity, etc. These rural collaborative spaces can therefore be useful to rural producers (farmers, businesses, neorural, "agrigiani"), university educational institutions, technical schools, institutions, community (citizens). All stakeholders in the primary sector can make Fablabs bearing in mind that the bottom co-generation processes are by definition invested in and this requires the presence of key figures such as community manager and/or influencer of rural communities that can be identified among researchers, professionals, farmers, citizens, institutions. Every can contribute with experience, expertise and capabilities, providing even physical meeting spaces. At the macroscopic level, the implementation of a rural Fablab can be anywhere, even if it is preferable to intervene in marginal areas and in peri-urban areas.

Concerning economic aspects, Fablab can be compared to private companies and their efforts to acquiring instruments and tools but the main difference is the knowledge level. Accordingly, the Fablab can be also economically compared, for instance, to a public library where is possible to access freely to the wide and high levelled knowledge. In Italy, usually, establishing a Fablab has the same bureaucracy of non profit associations in terms of rules, costs and constrains. As mentioned previously, the costs affordable for starting a Fablab ranging from € 1.000 for a micro Fablab to up € 100.000 for a big Fablab. The difference is mainly due to the tools' investments, while there are variable costs for spaces' acquisition and management.

The Fablab can be seen as the Renaissance workshops or garages that have given rise to the phenomenon of start-ups in Silicon Valley to pursue the objective of generating new products and services, models of learning peer to peer, learning by doing and opportunities for growth and cohesion of local communities like the KICs Knowledge Innovation Communities.

RURAL COLLABORATIVE SPACES, PHYSICAL AND VIRTUAL: EXAMPLES

Rural collaborative spaces revolve around the concept of social innovation and make it one of the pillars along with technology and sustainability. At the global level, the Open Source Ecology project (Opensourceecology, 2016) (OSE) is an example of that. The OSE mission is to create a global collaborative platform that optimizes economic development, production and logistics, through the open source collaboration to accelerate innovation like never before. Specifically, the project is aimed to develop and dissemination of the opportunity to create modular agricultural machinery and adaptable compared to all agronomic situations, made for self-construction. OSE is a virtual platform to access, to share and find information as for example, a default set for the realization of 50 different full-scale industrial machines (Global village construction set), like a LEGO set, achievable at much lower cost compared to market costs in order "to build a small, sustainable civilization with modern comforts". The web site specifies all construction costs, plans and the share of software for electronic components is driven primarily by Arduino. Everything is tested physically in a real farm located in Missouri where the reference community of OSE meets and collaborates in the project, also via conference call. The idea, even not easy to achieve because the regulatory reasons tied to the machine's testing (at least in Europe), enters into a well-known mechanism of commerce and embraces a new technology paradigm fully, disintermediating the availability of means and triggering a social innovation process that potentially can be global. In Vallaura, Barcelona, the "self-sufficient lab" is another example of rural collaborative spaces where a green lab, an energy lab and a food lab coexist with University of Barcelona and makers. This "self-sufficient lab", has a passive structure, used as a place of training and transfer of knowledge to all stakeholders in the rural area around Barcelona (Valldaura, 2016). Other goals of the project are the preservation of the territory, an informed use of natural resources and the promotion of the Nature Park in which resides the complex, allowing, at the same time, the research and development of new water-saving systems or energy use. In Italy, Rural Hub (Ruralhub, 2016) was the first rural collaborative space that involves a network of researchers, activists, scholars and managers. Rural Hub pursuit new models of economic development to meet the social needs and market emerging from the world of new rural enterprises. Born as a collective research for the promotion of the connection between new innovative companies, investors and associations created to satisfy the lack of a business incubator capable of triggering entrepreneurial renewal, technological and sustainable in the food industry. Rural Hub was founded as the first hackerspace that allows the connection, the exchange and sharing between people, ideas, technology and social innovation projects applied to the rural world but also for sharing a living place (co-living) and working (co-working). The main peculiarity of the platforms is the fact of being a tool for enabling shareholders on the platform (physical or virtual) thus determining environmentally sustainable processes economically and socially. The start of these activities is not always an initiative of university or research centers, but as OSE shows us, can be an initiative that starts from the society, by the necessity to respond to a need, bringing back to the community the awareness of actions and of tools that are used in the territory.

FUTURE DEVELOPMENTS

The proposal to develop technological platforms of co-generation in rural areas, and thus supporting innovation in agriculture, is just one of the possible ways to help rural communities, often resilient, to enter in the IV industrial revolution. Other necessary items can be found through other training methods but mostly the key to introduce technological innovation in rural areas can no longer be delegated to agricultural informants or intermediate bodies. This because they are no longer able to intercept the needs of territories and farmers so effective for most of them, as could be a long time. In this, the disintermediation process is a fundamental part of the ongoing paradigm shift. The community platforms, online and offline, which focus on needs, can be an alternative development.

In addition, the collaborative spaces, as mentioned earlier, are trading platforms both physical and virtual. Ultimately, in order to assess whether a country collaborative space, a maker Fablab or space is an appropriate tool to transfer and generate innovation, you have to take into account various aspects, including:

- the land on which we act must be uniform for the needs and sufficiently large;
- the needs should be real and perceived by the community of reference;
- the technology introduced is selected by local actors (is needless to introduce techniques or items that are unfit for land and people) with CBPP approach;
- people who live and work the land are key players in the innovation process;
- a key role is played by the presence of active social innovators within communities (not all innovators know what they are);
- the approach "Open" and collaborative shall be applied by all the players involved or get involved in the process;
- the involvement of institutional players (public or private) has a key role in the sustainability of the starting-up phase of Fablab and of all cogeneration spaces.

Where these conditions occur, you can effectively build rural collaborative spaces. The sustainability of these spaces is another matter that should be thorough but surely, creating social and environmental value, it must be ensured. One of the possible ways, in the case of physical spaces, is the creation of collaborative spaces intended as territorial Hub, where you are delivering services that go beyond agriculture, thus expressing the multifunctional potential of rural areas.

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Article

Boosting the adoption of precision agriculture through a co-creation process?

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Abstract: There is a consensus among the scientific community that technologies can help stimulate innovation for sustainable agri-food systems and the production of better and safer food while preserving natural resources and biodiversity. However, the agricultural sector must design innovative models to adopt technologies in a natural, efficient and sustainable manner. Technologies and new adoption models could accelerate the creation of advanced decision-making tools that allow to the sector to make smarter data-driven decisions. Innovation cannot only help the industry make the right moves but also aid the human factor. Farmers do not usually trust exogenous consultants but trust their agronomists and suppliers. For this reason, we do not define a new figure in this paper but a pool of experts to whom we designate as “agriculture-technology designer team”. The “AG Tech designer team” is a new model of practice that reinvents how producer cooperatives can use data and technology. The objective of the team is to help farmers embrace precision farming technology to achieve greater efficiency, greater productivity and higher production performance. The innovation lies in the cooperative approach to product development. In this work, a quantitative analysis of Andalusian cooperatives of production managers or technicians was carried out with the help of PESTEL analysis to understand in the proposed “AG tech designer team” is feasible before adopting is as a possible solution for the market..

Keywords: Adoption process, innovation, sustainability of precision agriculture, PESTEL analysis

1. Introduction

A new wave of digital technologies is enabling farm operators to manage crops and orchards with a much higher degree of precision than was feasible in the past, and when combined with the power of high-powered CPUs and big data analytics, such technologies are driving the development of sophisticated decision-support tools that allow businesses to make better data-driven decisions [1]. Under these circumstances, the role of the farmer has changed, and awareness of this role is still evolving worldwide. Recent scientific advances are making it possible for policymakers to understand more clearly the vital role of agriculture in the future of society [2]. The awareness of the need for sustainable processes to achieve food security and food quality for the increasing global population is also rising. Indeed, according to forecasts, in 2050, 9.1 billion people will populate the Earth. According to the “World Population Prospects”, half of the increase, from 2010 to 2050, will mainly due to countries such as India, Pakistan, Nigeria, Ethiopia, the United States, the Congo Democratic Republic (DRC), Tanzania, China, and Bangladesh. On the other hand, countries that are already “developed” will have to face a reduction in chemical inputs in agriculture, and all nations worldwide will have to deal with water consumption and security, climate change and increasing population. Life under this general framework may be facilitated if everyone plays their role in making efforts to achieve the Sustainable Development Goals of the United Nations for 2030. Thus, dropping down to the local scale could be done by applying sustainable precision agriculture (SPA) (or climate-smart agriculture – CSA), which could be a small but important step towards achieving larger goals. Consequently, it is crucial to ensure that precision agriculture (PA) spreads and is used by farmers, from the most significant to the smallest. There are several barriers to overcome, such as the indifference to innovations within the entire agricultural sector. There should be a shift to PA as the new normal in the sector, from the research being taught in new university courses to new kinds of services provided by a consultant. Nevertheless, very few studies have explored multiple components of the dynamical adoption process, and most have concentrated explicitly on assessing the effect of a single aspect. These studies have concluded that the adoption of PA innovations omits many of the technology diffusion determinants explored in other market environments and that the scope and multidimensional nature of the adoption process are very underrepresented [3]. The new CAP in Europe will try to fix some gaps, but the path to balance seems to be very far. Compared to the current industrial sector, the agricultural sector has missed some chances to overcome these barriers. In the following work, we try to understand one possible way to help the agricultural sector: placing at the service of farms (in this case, a union of cooperatives) knowledge and practices regarding technologies, policies, and laws from an agronomic perspective. On the one hand, there are several ongoing projects in Europe to transfer knowledge and make farming communities stronger that are at the cutting edge of digitalization. Nevertheless, on the other hand, there is also a significant amount of confusion and disorder surrounding technologies in agriculture, posing the real risk of losing the opportunity to make the sector shift through the digital revolution with equity for all farmers. In this scenario, the following work tries to investigate the situation in Spain and Italy and to provide a possible way to find one of the many feasible solutions to achieve a good technology transfer result. Not only can technology help the sector make the right shift, but the human factor is also crucial. For this reason, we try to define a kind of proposal that goes beyond the innovation broker to disseminate innovation in agriculture, analysing the limits of such figures and underlining the importance of a collaborative and multi-actor to transfer technology to agriculture. Farmers usually do not trust exogenous consultancy, but they trust their agronomists and their providers.

For this reason, in this paper, we define not a new figure but a pool of experts whom we designate an "agriculture-technology designer team" (AG Tech designer team). An AG Tech designer team (for example, a local reference farmer, researcher/professor, regulatory official, and technicians) is an innovative work structure that reinvents how that farmer cooperatives can use information and analytics. Among its objectives is embracing the complexity of digital agriculture, addressing multiple dimensions simultaneously to help cooperative farmers to innovate faster. This team will provide the necessary tools to reduce the gap between consumers and producers to orient them concerning opportunities and innovation, minimizing the risk of failure in adopting and accelerating the implementation of new technologies.

Aim of the AG Tech designer team:

- To make framers adopt precision agriculture technologies (PATs) to achieve greater sustainability, more profitability, and more quality in production.
- To design the best services/products for each cooperative case to meet real needs.

Compared to classic consultants, the AG Tech designer team plays a different role. Indeed, first, it is a group; second, this group is composed of at least one agronomist, one agroforestry technician, an expert in PA and a technician chosen by the cooperative who that can focus on the specific needs of the cooperative. The novelty is in the collaborative approach to designing the service. Consequently, the technology will achieve the aim defined at the beginning and will meet the need expressed.

The learning-by-doing and collaborative approach in designing the service is chosen to overcome the difficulties that usually occur when a consultancy service or a tech provider tries to help cooperatives farmers cooperatives decide on which strategy fits best (see Figure 1)

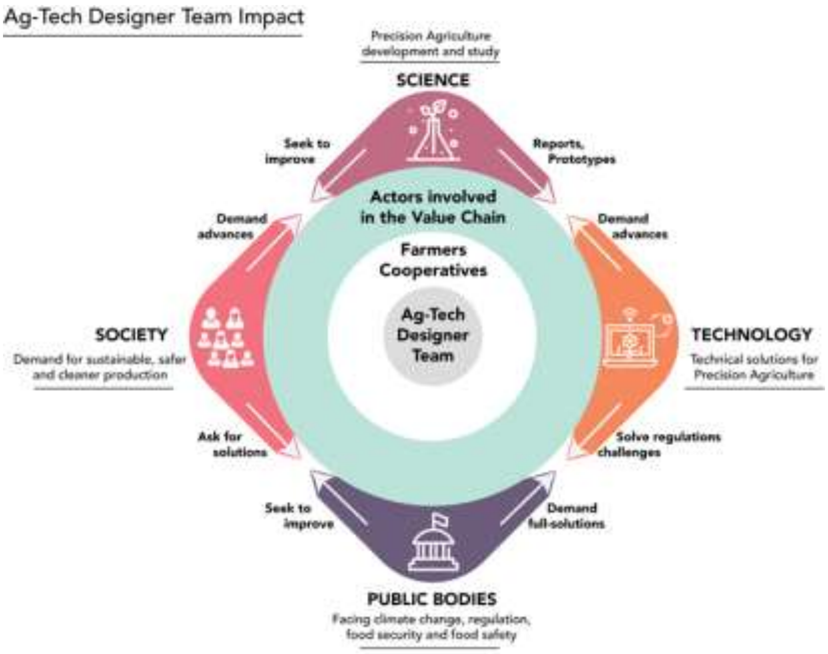


Figure 1. Conceptual framework of the impacts generated from the creation of an AG Tech designer team

2. Materials and Methods

Survey

This qualitative-quantitative survey was carried out to try to investigate an approach to PA for farmers in Italy and Spain. A survey was administered and translated into two different languages, Italian and Spanish, to better accommodate the farmers better and make its completion more accessible. The method chosen represents the best way to approach this kind of issue for the first time. Once the results are qualitatively validated by academic experts, the survey can proceed to a strict quantitative analysis that considers hundreds of cases. "Qualitative research ... consists of a dynamic process that ties together problems, theories, and methods...consequently the research process is not a well-defined sequence of procedures that follow the clear design, but a complex interaction between the conceptual and the empirical world, where deduction and intuition are realized at the same time [4].

Nevertheless, premises are needed: the Spanish agricultural system is broadly different from the Italian system in terms of farm dimensions and organization. In Spain, there are producer cooperatives, but in Italy, such arrangements are uncommon. This kind of difference also had a consequence for the survey, which was sent to a large number of producer cooperatives in both Italy and Spain. We did not receive any answer from the Italian organizations. However, some of the Spanish cooperatives completed the survey very quickly and enthusiastically.

In total, 51 questionnaires were received; 39 were partially completed, and 12 were fully completed. The survey was created with LimeSurvey and sent via e-mail to reach everyone quickly. To discuss the results, we will consider only the fully completed questionnaires. The survey consisted of 24 questions divided into four sections: 1. general information, 2. the reference framework, 3. the technologies framework, and 4. farm management information systems (FMIS) for farmers. Below, in Table 1, the questions and the sections to which they belong are reported.

Table 1. Questions submitted with the survey and the related properties.

Question Number	Section	Question	Kind of answer
Q1	General Information	Cooperative name	Free response
Q2	General Information	Name and surname	Free response
Q3	General Information	Working position	Dichotomous choice
Q4	General Information	E-mail	Free response
Q5	General Information	Age	Classes
Q6	Reference framework	Before this, did you know what PA is?	Dichotomous choice
Q7	Reference framework	According to your awareness and those definitions, what share of farmers in your cooperative use/adopt PATs?	Classes and comments
Q8	Reference framework	In your opinion, are there any barriers to PAT adoption in your cooperative?	Dichotomous choice
Q9	Reference framework	Which of these barriers for you are most important?	Multiple choices
Q10	Reference framework	Which of these needs should be met the fastest?	Multiple choices
Q11	Technologies framework	Did you receive training for using PATs?	Dichotomous choice
Q12	Technologies framework	Which information initiatives were implemented by your organization to promote PAT utilization within the farming community in your cooperative?	List of several choices
Q13	Technologies framework	How many training initiatives were implemented by your organization to promote PAT utilization within the farming community in your cooperative?	Classes
Q14	Technologies framework	Who helped you understand how to use the technology adopted?	List of several choices and comments
Q15	Technologies framework	What kind of PAT was most encouraged through information/training/advisory activities?	Multiple choices
Q16	Technologies framework	Would you adopt these new technologies or PA practices if they demonstrated you a clear return on investment?	Dichotomous choice
Q17	Technologies framework	Why did you choose to use PA?	Multiple choices

Q18	Technologies framework	Since when you use Precision agriculture?	Multiple choices
Q19	FMIS for farmers	To what extent are farm Management Information Systems used by farmers in your cooperative?	Multiple choices
Q20	FMIS for farmers	Are you interested in being trained in PA?	Dichotomous choice
Q21	FMIS for farmers	Would you like to have a farmer as a trainer instead of a researcher or technician/consultant? Or both?	Dichotomous choice
Q22	FMIS for farmers	In the case of trained farmer + technicians which characteristics should the farmer have? Are you willing to choose this task?	Multiple choices
Q23	FMIS for farmers	Talking about the exchange of best practices, which tool do you prefer?	Multiple choices
Q24	FMIS for farmers	If the cooperative offered a new service based on precision farming techniques, through experts and technicians from the cooperative, would you be willing to use it?	Dichotomous choice

3. Results & Discussion

Data analysis

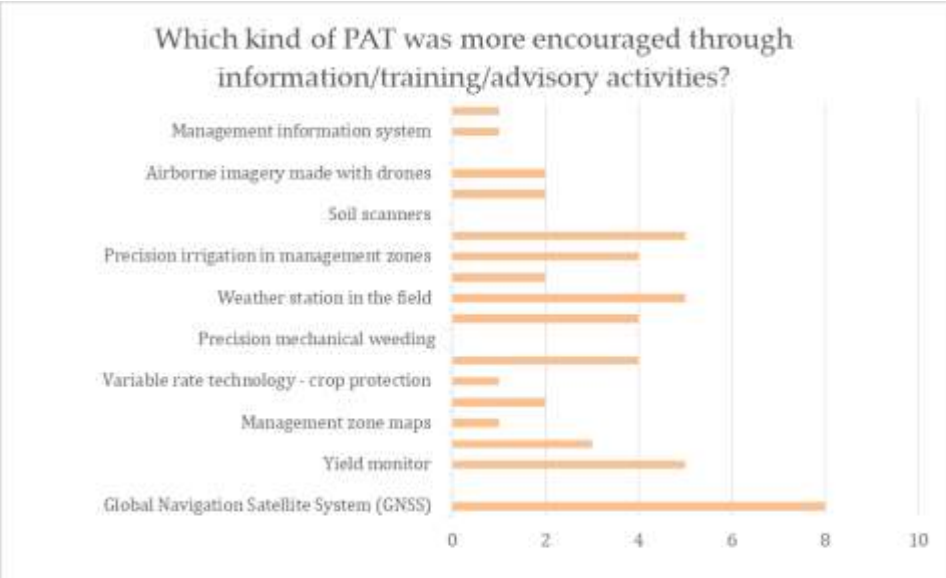
This work takes into account that only 12 people out of more than 50 who were contacted completed the survey: ten belonging to producers' cooperatives, one from a provider, and one from a union. As noted above, the qualitative results of the study can be used, considering what we can evaluate as the multiplier effect related to one survey. Indeed, for each survey, completed by a technician or a responsible individual, there is a direct link to several farmers (one thousand in total) and companies that rely on the cooperatives' decisions about the services provided. Thus, for each survey, we can know the qualitative orientation of hundreds of people.

Regarding the rough data, the first section of the questionnaire was devoted to “general information”. From this section, we captured the information described above. The majority of respondents are technicians. Regarding the age of the respondents, the most represented class is 36-45, followed by 46-55. Concerning the survey conducted on farmers in other contexts, these designated classes are younger than those in other surveys, which is mainly due to the different positions. The average age of farmers in Europe is considered a barrier to the adoption of PA, and the introduction of digitalization is higher [5]. All respondents answered Q6 (Before this, did you know what PA is?) in the affirmative. In the second section, we introduced concepts related to the “reference framework”, and the first question of this section was Q8 (In your opinion, are there any barriers to PAT adoption in your cooperative?): only one respondent did not agree about the existence of obstacles. The following question (Q9) focused on which barriers are the most critical, and from the list, the answers with the highest scores among the 11 possible responses are 1. lack of digital culture in the sector and technology adoption speed; 2. lack of evidence on the return on technology investments; and 3. lack of integrated solutions. The 11 possible answers were inspired by the common framework of a Regions4Foodnterreg project [6].

The evidence from Q10 told us that information and communication technology (ICT) specialization in the agricultural sector and the need for a “translator” are the issues that are most crucially in need of a solution, for example, "progress in data governance and an increase in public data that allows the development of digital models", "more awareness-raising actions, the dissemination of success stories and training", "improving digital infrastructure" and "defining a clear framework that allows collaborations with the private sector". Interestingly, very had received training to use PA (Q11), and cooperatives mainly organized conferences on PAT to promote the adoption of technologies (Q12). In general, training initiatives are to spread PAT adoption are not well known, but in a few cases, cooperatives organize from 2 to 5 initiatives per year (Q13). According to the respondents, some understood how to use technology on their own, while others understood with the help of a provider or a researcher. In this regard, the comments that the respondents wrote are useful; some respondents stated that "I did not receive any help from the cooperative, and no one cares about improving the adoption of PAT. What I learned, I learned on my own and outside the workplace" and "I took information from sectorial journals or focus meetings with specialized companies" (Q14).

The table below provides a quick overview of the technological priorities perceived by users during information, training, or advisory activities (Q15) (Table 2).

Table 2. Kinds of PAT that were most encouraged through information, training, or advisory activities.



The results confirm that global navigation satellite systems (GNSSs), weather stations, yield monitoring, and soil moisture sensors are the leading technologies introduced in the main events. All respondents answered Q16 in the affirmative: in the case of new technology adoption, a clear return on investment would be shown. The survey indicated that PA would be adopted only if cooperative members would save money and increase productivity and quality, and there was less attention to environmental, sustainability, and safety issues (Q17). Thus, these results fall under the scope of another study (one more extensive than the current study), but this survey confirms that there is a gap between research findings and farmers. In the cited Joint Research Centre (JRC) study, indeed, it is proven that, for example, with variable rate technologies (VRTs), there is a clear saving in terms of products, or the same outcome is achieved with autosteering guidance and fuel-saving; however, farmers do not trust and decide not to adopt such technologies. In the last question (Q18) of the "technologies framework" section, the respondents were asked when PATs were adopted. The range of time indicated in the survey was considered from the first conference in PA in 1997 to 2019. No one adopted PA before 2004, and the most significant share adopted PATs starting in 2015. The last section of the survey was devoted to "FMIS for the farmer". This section is quite essential for the aim of the study because it provides the most interesting answers regarding the proposal of the "AG Tech designer team".

The first question (Q19) addresses the extent to which farmers in the cooperatives use FMIS. The main results are for "the nutrient management plan (both mineral fertilizer and manure)", "the soil management plan (e.g., to directly improve soil conditions and fertility)", and "input (fertilizers, plant protection products, and others) record keeping". All study respondents are interested in being trained in PA (Q20). However, regarding the preferences for the kind of trainer, "Would you like to have a farmer as a trainer instead of a researcher or technician or consultant? Or both?" (Q21), the answers are not straightforward: (in order of preference) first, a trained farmer and a technician; then, a farmer alone; and, lastly, a technician. The following question is on the characteristics of the top preference (the farmer and the technician together) (Q22), and the first choice among the several given is "experience in your field (independently of age)", followed only by "reliability". Question 23 concerns the exchange of best practices and tools preferred by cooperatives to share knowledge and experiences. Demos with technicians and/or farmers is the first choice (made by all of the respondents), followed by the contacting university or agricultural school and, at the same level, unions and cooperatives themselves. Social media, YouTube tutorials, and provider training are important only to an extent. The last question of the survey concludes with the question about the proposal for a new service, as mentioned above. Regarding the idea of using a new kind of service such as the "AG Tech designer team", all of the survey respondents answered in the affirmative.

Data and strategy validation

To better summarize the data and attempt to describe a path to be followed in this work, a strategic planning process was adopted as an exercise in strategy and the evaluation of the best paths to follow, i.e., so-called PESTEL analysis (PESTEL analysis allows a better understanding of the subject and the internal and external factors involved. PESTEL is an acronym for Political, Economic, Social, Technological, Environmental and Legal factors.) [7]. In this case, the PESTEL analysis was used to validate the proposed model for on the creation of the "AG tech designer team" and to provide insights on the results of the qualitative survey at a macro level.

Table 3. Development of PESTEL analysis.

Political	• Common Agricultural Policy CAP 2020-2027 • Regional policies declining CAP and enhancing a multi-actoral approach
Economic	• Willing to pay of producers' cooperatives • More profit and quality products • Costs at the starting point to acquire technologies and services
Social	• Acceptance of innovations in agriculture for small and medium farms
Technological	• Availability of innovations for small and medium farms • Feasibility of innovation for small and medium farms
Environmental	• Environmentally friendly products, fewer pesticides, right amount, right time, right place (PA definition) • Contribution to reduce GHG emissions
Legal	• Safer and ethical products (workforces could be better managed with PA technologies and should be more specialized)

4. Conclusions

In conclusion, a survey was conducted to evaluate the feasibility of the introduction of an "AG tech designer team" for producer cooperatives to enable small and medium farms to implement innovative technologies and practices within their farms. The complexities and multidimensional nature of the adoption process are poorly represented in the literature [3]. Validation of the model via PESTEL analysis before a concrete application in reality can provide an understanding of the boundaries that the proposal moves.

There are some volunteer projects that can help farmers in enabling technologies. For example, the free web platform for precision crop management as "NewFarm Agriconsult" (https://oad.agrimeteo.eu) is a collaborative network of experts whose objective is to provide farmers and their advisers with tools to optimize their agronomic decisions. In the "AG Tech designer team" proposal, a step further is made by trying to meet the farmers' needs via a collaborative approach.

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