UNIVERSITÀ
DI SIENA
1240

DEPARTMENT OF BUSINESS AND LAW
SCHOOL OF ECONOMICS AND MANAGEMENT

Msc. in International Accounting and Management

INNOVATION AND SUSTAINABILITY IN AGRI-FOOD SECTOR: THE SIENA FOOD LAB CASE

Supervisor
Prof. Angelo Riccaboni

Co-Supervisor
Prof. Cristina Santini

Candidate
Giovanni Marcocci

Academic Year 2020/2021

Abstract

The purpose of this thesis is to analyze the relationships that exist between innovation, sustainability and performance in the agri-food sector. In particular, it focuses on the effects of the application of Smart Farming and Precision Agriculture on the performance and competitiveness of farms. To do this, we first carried out an analysis of the literature on these relationships, trying to understand the key aspects and how to measure impacts through the use of Key Performance Indicators. Then we analyzed the Siena Food Lab project, identified as a case study to observe in the field what has been seen in the literature. The project, which aims to promote technology transfer to farms in the province of Siena, was analyzed in its initial phase, so it was possible to observe the structure and the current degree of technological adoption of the farms in the sample. What emerges is the need of farms for resources and adequate knowledge to be able to implement innovative solutions and achieve better performance in terms of profitability and impact on society and environment. In this, the support from institutions and organizations that promote projects such as the Siena Food Lab will be essential.

Innovation and Sustainability in agri-food sector: The Siena Food Lab case

Introduction

Today the agri-food sector is experiencing significant changes that will lead the companies to a crossroads: either to react in a resilient way and survive or slowly go towards the abyss and disappear. There are many challenges that the sector and its players must face. Today, nearly a billion people do not have proper access to food, and considering that by 2050 world will reach ten billion people, this number will grow further. Furthermore, the sector is one of the major causes of greenhouse gas production and the consumption of natural resources such as soil and water. There is a clear need for the sector to reverse this course to ensure a prosperous future in environmental and social terms. This problem affects all economic sectors and is on the agendas of the most important international organizations and the main fora of relations between states (i.e., Food System Summit 2021; G7 and G20; Agenda 2030, Green Deal, Farm to Fork, etc..).

These have identified a solution in implementing a sustainable transition that involves all economic sectors around the world. For some time, sustainability has found space in companies' realities, especially the more structured ones, without finding a consensus on the operationalization methods and often used as a marketing tool in greenwashing practices. Concerning the agri-food sector, it is necessary for companies to innovate following sustainability principles, thus adopting new processes and new technologies that go by the name of sustainable innovations. The most significant difficulty in implementing sustainability strategies is the poor perception of the effects it can have on the environment, society and economic return. The upstream part of the agri-food sector, those linked to agriculture, is characterized by small companies looking for immediate returns to continue their business, looking only short term.

The literature identifies Smart Farming and, in particular, Precision Agriculture as two tools capable of bringing farms towards an innovative production process that can look at both environmental and social problems and greater profitability of the firms at the same time.

Hence, the thesis aims to analyse the characteristics and effects of innovation and sustainability in the agri-food sector and, in particular, the use of Precision Agriculture.

Furthermore, through the Siena Food Lab project, used as a case study, we investigate the technological degree and the orientation to technology that allows the implementation of sustainable practices, such as Precision Agriculture, in the agricultural context of the province of Siena, also examining the determining factors.

We have outlined the importance of educating to Smart Farming, and the role that University - Business collaborations can have in fostering technological adoption among small companies. Given the complexity of the topic - since most small companies do not have adequate knowledge and resources for accessing Smart Farming - the Siena Food Lab represents a living lab for evaluating the solutions that can foster innovation adoption.

The thesis is structured as follows: the first chapter will provide a descriptive analysis of the agri-food sector, identifying its problems and future challenges and observing how the players in the sector have received innovation and sustainability. Then it will examine the concepts of Smart Farming and Precision Agriculture, giving an overview of their diffusion. The second chapter will study the relationships identified in the literature between innovation, sustainability and corporate performance, providing the basis for measuring sustainable performance through Key Performance Indicators. It will end with the analysis of the effects on the performance of the application of Smart Farming. Finally, the third chapter will focus on the Siena Food Lab case, illustrating the characteristics and methods of the project, whose primary purpose is to promote the adoption of Precision Agriculture in Siena's territory. By analysing data collected through a survey, a picture of the farms in the province of Siena will be provided on the current degree of technological adoption underlying the implementation of Precision Agriculture practices and on the future orientation on these issues.

Chapter 1. Agri-food Sector

1.1 An overview: the business, dynamics and trends

Agri-food is one of the largest, most important and complex worldwide industry. It supplies the countries with fundamental and primary goods: food. Agriculture and livestock have always been essential sources for mankind. Throughout thousands of years, agri-food activities have represented the basis of the development of civilization and without them, it would not have been possible to have progresses. Like other economic sectors, this one has experienced significant changes over time, due to the development of modern techniques and the need to respond to a constantly growing food demand. In particular, with the economic boom that began at the end of WWII and which had led to an increase in population, wealth and urbanization, food and agricultural production increased dramatically, introducing substantial technological and cultural changes in production practices. This period, known as the Green Revolution, has fostered a significant increase in the production of the main species of food, due to the use of new hybrid varieties created with artificial selection techniques and new type of production processes[1]. Since the 1950s, global yields have constantly increased and, as a consequence, there was a decrease in the share of world population exposed to the risk of undernutrition. This modernization process, strengthened by the ongoing globalization that has characterized the last few decades, has reshaped the sector in which the role of industry and food distribution has increased its relevance at the expense of the agricultural sector.

Today, the features of the agri-food sector reflect the various changes that have mainly occurred in Western economies. The first phase of this evolution is represented by a local range of food production and consumption, with direct linkages to the agricultural production capacity of a territory. Then, there was a phase of modernization and industrialization in which the processing and distribution have assumed a central role. The final phase, ends with the current structure characterized by the globalization of

[1] Often the beginning of the Green Revolution is attributed to the American scientist Norman Borlaug who, in Mexico in the 1940s, developed new and more resistant wheat varieties. Due to the success achieved its technologies spread worldwide in the following decades.

consumption, low-cost orientation, and the extreme industrialization of agricultural practices. Although it is the sector that first affected human life, nowadays its structure is perfectly comparable to that of the sectors developed in the modern era, such as manufacturing, and probably even more articulated and complex.

According to FAO (2018)[2] "*Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded*." Therefore, the agri-food system, can be defined as the complete set of activities, people, institutions, infrastructures and processes involved in the production and consumption of food. The word *system* emphasizes the interconnections, globally and locally, of the multiple sectors that are part of the broader sphere of agri-food. Therefore, the agri-food system, as shown in figure 1, is characterized by the whole range of players and their activities that create value thanks to close interconnections.

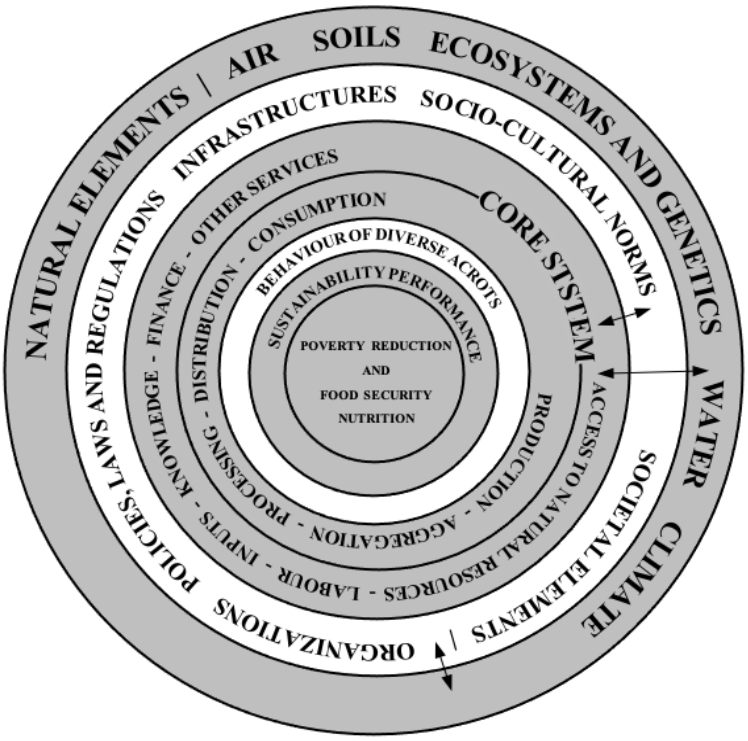

Figure 1. Food System Wheel. Source: own elaboration from Sustainable food systems: concept and framework. FAO 2018

It starts from the centre with the main goals which include poverty reduction, food

[2] FAO. 2018. Sustainable food systems: concept and framework. Brief. FAO, Rome, Italy.

security and nutrition. Then, there is a subdivision into three brackets: the first embeds the core system and includes the set of activities strictly linked to the production and delivery of the product to the final consumer. It includes inputs, processing and distribution processes, knowledge and funding factors. The other two concern the surrounding environment that influences and, in turn, is influenced by the activities and processes of the core system. One embraces the social sphere, including the policies, laws, organizations and infrastructures that represent, somehow, the widespread public opinion on this issue. It captures the institutional and organisational pattern including the public and private sector. The other includes the entire set of natural elements such as soil, air, water and the general ecosystem that are involved in food processes.

Hence, it is possible to say that it is a dynamic and complex system that involves human and environmental processes with high levels of interconnections that influences each other, and are linked with agri-food activities. The boundaries of the food systems are established at different levels (global or local) and for different contexts (rural or urban). It is essential to understand the food system's dynamics in order to solve present and future challenges, given its relevance in recent years.

The agri-food system can be divided into many subsystems: agricultural systems (one for each crop or animal species), input supply, processing, product distribution and waste management systems. These systems, then, interact with other external systems such as energy and commercial ones. Therefore, a change in one of the external systems could provoke changes in the structure of the food system, and vice versa.

Each subsystem has its internal supply chains and actors that contribute to the outcome, its use and disposal. According to Saccomandi (1991) "*The agri-food supply chain means the set of economic, administrative and political agents who, directly or indirectly, delimit the path that an agricultural product must follow to get from the initial stage of production to the final stage of use, as well as the complex of interactions of the activities of all the agents that determine this path*."

Taking into consideration the core system of agri-food we can say that every type of activity, from farming and harvesting to aquaculture, has its supply chain that involves certain actors. Trying to give a general picture of how the various supply chains are structured, it is possible to divide the supply chain into three large macro areas.

The first is the production area in which the ultimate goal is to procure and process primary products to make consumer products. This area includes the activities who are dedicated to agricultural production, the capture or breeding of animals, forestry and aquaculture. It also includes all the players in the food industry or those who are involved in producing and processing food, drinks and consumer goods using raw materials.

Here we find the presence of many SMEs with a few large companies dominating the market, especially on the raw material transformation side.

The second is the distribution area that involves all the players who purchase the products and deal with the distribution and marketing to the final consumer. It includes retailers, wholesalers and large-scale distribution as well as Ho.Re.Ca. that transform products to deliver complete ready-to-eat meals to consumers.

To the latter belong the final consumers, which create the demand for a specific food product and consume it. Consumers are partly responsible for products disposal.

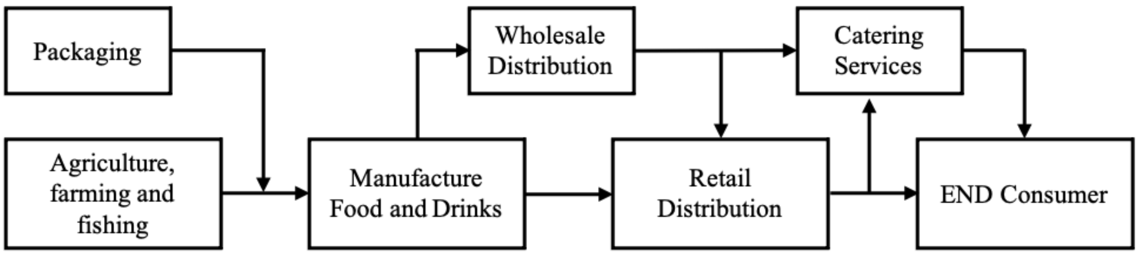

Figure 2. Food supply chain in the agri-food sector. Source: Morales-Polo and Cledera-Castro, 2019.

The above-mentioned areas characterise the general food supply chain and the actors that directly influence them.

In addition to these players, however, others have a lower degree of involvement, and, for this reason, they can be defined as external or secondary actors. Some examples are companies that produce manure, fertilizers and additives, and those that supply water and electricity or the machinery used in the production and processing of food.

In conclusion, the supply chain is a vertical segment of the agri-food system that collects a chain of agents, companies operating in related sectors, and operations that are dissociable, separable and linked together by technical, commercial and financial ties.

1.1.1 World Facts and Figures

Considering the agriculture, forestry, fishing and food and beverage sectors, it is possible to identify an articulated and complex agri-food chain that generates a worldwide value of production close to 5,700 billion dollars (WIOD Release 2016). 65% of this value derives from food and beverage, 30% agriculture and the remaining 5% from forestry and fishing.

More than a third of world agri-food production (35.2%) comes from Asia, that accounts for the 40% of agricultural world production and 50% of fishing. Huge Chinese and Indian players impose themselves on others also for demographic issues. Taking food and beverages into consideration, the European Union and NAFTA have an overall impact on production by over 80%.

Going into details, worldwide China (20.1%)[3] has the predominance, followed by the United States (11.5%) and India (6.7%) with Germany (3.2%), the first European country, in sixth place. Regarding the single sub-sectors, China (21.9%) still dominates agriculture and fishing, while for food and beverages it is the European Union (20.4%) which exceeds China (18.9%) and the United States (15%).

Focusing on the European Union, the leading nations are Germany, Italy, France and Spain in both the agricultural and processing sectors. All of them, are characterized by a solid production base linked to strongly localized supply chains.

In 2019 France maintains its leadership as the main European agricultural producer with a value of around 73 billion euros[4], followed at a distance by Germany, with 55 billion and Italy with almost 52 billion, while Germany dominates the food and beverage food.

Focussing on the origin of the inputs, Italy employs mainly domestic inputs (80%), thanks to a highly diversified production base and solid local supply relationships. German supply chain is much more fragmented, where a non-negligible share of intermediate inputs comes from Eastern European countries.

---

[3] The percentage is obtained with the Global Value Chain Income (GVC) indicator which adds up the contributions to the national agri-food chain (the added value generated that flows into the national agri-food chain) and those to the agri-food chains of other countries (added value generated that flows into the agri-food chains of other countries), in relation with world agri-food production.
[4] CREA. Annuario dell'Agricoltura Italiana 2019

Therefore, there is a significant integration of the supply chains within the eurozone. This phenomenon arises because of the creation of a free trade area and the adoption of the single currency. Each member country specializes in production with the higher comparative advantage, making use of the internal expertise of the country itself, and outsourcing others productions and activities. This has led to considerable fragmentation of the subsectors of the supply chains, especially in the food and beverage sector.

1.1.2 Italian Agri-food sector

Regarding Italy, the agri-food sector, that has a cultural and brand relevance and that is synonymous of 'Good Food', significantly contributes to the country's economy.

In 2017, taking into account the entire productive structure of the agri-food sector and the transport of goods, there are more than two million companies, with an annual turnover of 577 billion euros and employment of nearly four million people[5]. The business represents 36.8% of Italian companies, 18.4% of turnover and 22.7% of workers.

The largest share is the primary sector which has more than one and a half million farms, employing more than eight hundred thousand people and a turnover of 38 billion euros. Observing the average annual turnover of farms, equal to about 25.000 euros[6], we can see how the structure of the sector is characterized by a great fragmentation of Italian farms with the persistence of micro-farms that have a pivotal role for the development of high-quality products and local development but are marginal according to the total amount of production.

Within the sector, as shown in Appendix 1.1, there is a marked difference among different supply chains. About 70% of the companies in the agri-food sector is represented by farm businesses, and their turnover accounts for 6.6% of the total. The food, beverage and tobacco industry, together with the wholesale trade, have the highest percentages of

[5] As already pointed out, the data of the agri-food chain are overestimated due to the inclusion of the goods transport sector (which does not only concern agri-food products) and large-scale distribution (which also sells non-food items). However, the transport of goods represents only 0.9% of companies in the agri-food chain, 1.7% of turnover, 2% of employment and 1.9% of value-added.

[6] Cirianni, A., Fanfani, R., & Gismondi, R. (2021). Istat working papers.

turnover, respectively 34.7% and 24.4% with just 3% of the total number of companies. This analysis highlights that the primary agri-food sector is ‘crowded’ and low-paid compared to downstream activities. This peculiarity represents a critical point in the sector, as it creates such competitiveness as to minimize profit margins, making only large companies emerge and succeed.

In 2020, strongly influenced by the coronavirus pandemic, despite a marked reduction in national production (-3.2% in production volume and -6% in added value), the Italian agri-food system remains one of the main cornerstones of the national economy. It produced a value of over 522 billion euros in all its components (agriculture, agro-industry, services related to food), equal to 15% of the Italian GDP.

Taking into consideration the primary sector, its added value on the entire Italian economy is confirmed at 2.2%, as in 2019, and rises from 4.1% to 4.3% including the agri-food industry. The significant decline in employment in both the primary sector and the agri-food industry should be highlighted, respectively -2.3% and -6.7% compared to 2019[7].

1.1.3 Problems and Challenges

After the Green Revolution, the agri-food sector shows its criticalities since production systems that are no longer sustainable.

Global population in 2019 accounted for 7.7 billion people and the 54% was established in urban areas; FAO estimates mankind to reach almost 10 billion by 2050. As a consequence, the demand for food will become higher than the 60%[8]. The situation becomes even more urgent considering that today, despite producing more food than the actual needs of the population, almost 800 million people are undernourished. It is clear how the problem of food security must be taken into consideration.

Furthermore, intensive agriculture causes of ecological degradation; dependence on non-renewable and unsustainable energy sources and the resulting processes and dynamics have become increasingly unbalanced and unfair. The structure of this sector is

[7] Istat, Andamento dell’economia Agricola. Anno 2020
[8] FAO. 2018. The future of food and agriculture: Alternative pathways to 2050. Rome. 224 pp.

characterised by a limited number of transformation and trade large companies, which hold a large part of the power and influences political policies and market trends, and by many small production companies with no bargaining power, with low profits and under the pressure of large companies (Swinnen et al., 2021).

The agri-food system stands at the centre of present and future challenges for a more sustainable world (Calicioglu et al., 2019). Many world institutions and organizations, such as FAO[9], IFAD[10] and WHO[11], are committed to respond to sustainable world challenges. In 2015, the member nations of the United Nations delivered the 2030 Agenda for Sustainable Development, a program divided into 17 Sustainable Development Goals whose fundamental principles are the end of poverty, hunger and malnutrition, sustainable development in agriculture, fisheries and forestry, and a response to climate change.

In particular, FAO[12] identifies 5 major challenges that will involve the sector in the coming decades:

- Provide food and other products sufficient to be able to meet the growing and changing global needs;
- Eradicate hunger and food insecurity;
- Preserve and improve the productivity and sustainable use of available natural resources;
- Adapt to climate change;
- Contribute to the mitigation of climate change.

a) Food Demand

In the upcoming decades, the demand for food will increase and change. This will happen because, as mentioned before, the world population will significantly increase, especially in developing areas, such as Africa and South Asia, and because of the demographical structure evolution and its spatial location. Population is shifting towards urban areas, and it is estimated that, in 2050, over two-thirds of the population will be urban. The move from rural to urban areas produces changes in living, working and consumption

[9] Food and Agriculture Organization of United Nations
[10] International Fund for Agricultural Development
[11] World Health Organization
[12] FAO. 2018. The future of food and agriculture: Alternative pathways to 2050. Rome. 224 pp.

conditions, consequently affecting the demand and quality of food products. Furthermore, the demand for food is affected by an expansion of the global economy and yearly income per capita. In China, for example, thirty years ago the annual per capita income was under 1000 dollars, while today, with the consolidation of the country's economic power, it has reached 8000 dollars; such a change has a decisive impact on the needs of the population, including the demand for food.

A modern population more globalized, urbanized and technological in addition to a greater quantity of food, has been directed towards a change in consumer preferences. Today diets are based on resource-intensive and unsustainable foods from ultra-processed foods, fast food, foods and drinks that are high in sugar, salt and fat. In addition to an enormous consumption of resources and energy, these diets are a source of problems such as for overweight and obesity that characterize a large percentage of the world population.

Therefore, the agri-food sector has to respond to the growing and different food demand by trying to reverse the pathway towards healthier and more sustainable diets.

b) Food Security

"*Leave no one behind*" is the central promise of Agenda 2030 that underlines the commitment to tackle the discrimination and inequalities that threaten the people's rights. The agri-food sector does not lack problems related to inequalities, although there is enough food for everyone, not everyone has the opportunity to obtain enough food. This causes inequality between those who have access to abundant food and those who suffer from hunger. Inequalities can be observed both between countries, and within the same country. A determining factor is the difference in per capita income, indeed in human history, wealth has always represented a source of enormous inequalities. Another factor is the access to natural resources such as land, water, oil and minerals; this not only generates inequalities but also conflicts which in turn generate food insecurity and malnutrition.

To solve the problem of food insecurity it is necessary to focus primarily on how to increase the employment rate and income. Decent incomes allow families and individuals to have access to food. Considering that most of the poor people are concentrated in rural areas where the main activity is agriculture, a phenomenon is created whereby low agricultural incomes cause the population to move to the cities. In this way, on the one hand, the contribution of agriculture to GDP decreases, which will see fewer and fewer actors on the other, the unemployment rate in urban areas increases, creating situations of conflict and outmigration. For this reason, the agri-food system must promote a transformation to increase the well-being of people who live in rural areas in search of value for primary production compared to downstream activities.

c) Natural Resources

Globally, agricultural production has tripled since the Green Revolution and this is due to both the efficiency of production techniques and the resource expansion in the use of land, water and natural resources. About 50% of the planet's habitable surface and 70% of freshwater extracted[13] are used for agricultural practices at the expense of the natural environment. Much of the forests are disappearing, the aquifers are under severe stress or polluted by pesticides and herbicides and biodiversity, in general, has suffered great losses. In recent years, the strong trend in biofuel production has further aggravated the situation. Furthermore, it is estimated that about one-third of agricultural land is moderately or highly degraded[14] which has a very negative impact on the well-being of those living in these areas. These limitations lead to having to focus on an increase in crop yields and this can only be possible with substantial investments in research and development of new production practices.

As far as fishing is concerned, the growing demand for fish products has led to the exploitation of more than 90% of sea fishing, and, if this trend is not reversed, it will lead to a very serious shortage of fish products. Farming, on the other hand, is one of the major causes of deforestation, as it increasingly needs space to meet the demand for land-based animal products.

Investments in the agri-food sector can make it possible to overcome the limiting nature of natural resources to respond to the growing demand for food and reduce food losses. The characteristics of these investments will be fundamental to achieving higher levels of performance and higher degrees of sustainability.

13 FAO. 2018. The future of food and agriculture: Alternative pathways to 2050. Rome. 224 pp.

[14] FAO. 2018. The future of food and agriculture: Alternative pathways to 2050. Rome. 224 pp.

d) Climate Change

Today the issue of climate change is a hot issue on the tables of the major political decision-makers. IPCC[15] estimates that the temperature has increased by almost 1 degree compared to pre-industrial levels and that it will reach 1.5 degrees between 2030 and 2050. In December 2015, at COP21[16], the Paris Agreement on climate change was signed which commits the signatory governments to keep the temperature within the maximum of 1.5 degrees through a path of decarbonization.

The effects of the increase in temperatures are in progress: the rise of the seas caused by the melting of the Arctic ice, the increase in extreme weather events even in atypical areas and times of the year, drought and desertification. They are responsible for enormous and irreversible damage to ecosystems and biodiversity around the world.

Serious repercussions of the increase in temperature will be on natural resources. First of all, regarding the conditions and future constraints of agricultural production putting the crops and production capacities of the species at risk. Then, through changes in sea temperature, sea currents and the salinity and oxygen level of the waters, there will be strong repercussions on global fishing, causing the extinction of fish species. Finally, water scarcity and expanding desertification will negatively affect animal health, creating problems for livestock farmers.

Not to mention the problems that exceeding the 1.5 degrees would cause on civilization: cities and islands completely submerged by water, atmospheric events such as cyclones and floods increasingly frequent and devastating and dozens of animal and plant species would go extinct.

Most of the global warming is caused by the anthropogenic greenhouse effect, that is that generated by all human activities that produce GHG emissions.

The agri-food sector is not only one of the most affected by but is also one of the main responsible: "*Food systems are responsible for a third of global anthropogenic GHG emissions*" (Crippa et al., 2021). This is mainly due to agricultural practices using

[15] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. World Meteorological Organization, Geneva, Switzerland, 32 pp.

[16] Conference of the Parties of United Nations Framework Convention on Climate Change.

nitrogen-based fertilizers and pesticides, fermentation during the digestive processes of ruminants, manure management, forest clearing to expand arable land and pasture. Furthermore, modern food systems tend towards intensive production and longer supply chain generating large amounts of GHG emissions.

Given these premises, the scope for action that the agri-food system has to do in reducing global emissions is clear. Through more sustainable and less impactful practices, it will have to be able to respond to the growing demand for food by limiting its GHG emissions.

It will also have to take into account and adapt to the ecosystem and environmental changes that are already in progress, and that will characterize and influence the future of our planet.

This is an overview of the current European and Italian context of the agri-food system that leaves large spaces for analysis and which is part of a broader framework of sustainability to be achieved in all economic and productive sectors to ensure that future generations live in a healthier and fairer world.

The most important institutions and organizations, as well as states, are directing their efforts towards the implementation of sustainable medium-long term strategies. First of all, the UN with the 'Agenda 2030 for Sustainable Development Goals' focused on environmental, economic and social sustainability. These topics were taken up by the European development program called the 'Green Deal' with which the European Union promotes initiatives and investments with the general goal of achieving carbon neutrality by 2050, flanked by objectives of economic growth and social balance.

The agri-food sector with its characteristics and since the symmetry between the quality of nutrition, its diffusion, still seriously unbalanced in the world, and its sustainability is essential for the future of humanity, has great room for improvement. The European Green Deal has implemented the *Farm to Fork* and *Biodiversit*y strategies to accelerate the transition to a sustainable food system and protection of nature against the degradation of ecosystems. To do this, investments in research and development, innovation and sustainable practices will be required by both the largest companies that will have to be an example and by the millions of micro-enterprises that characterize the sector.

1.2 Innovation

Innovation means "*the act of introducing a new device, method, or application to commercial or practical objectives*" (Schilling and Shankar, 2019). Therefore, it is the introduction of something new into the world, this can be a device (a new phone or a new machine), a method (a new system of assembling a machine or a new business process), a new material (a new type of glue or new envelope). Although, this new element must be applicable for commercial or practical purposes; so, it must be useful to the business both to be used internally or to be sold externally.

Innovations have many different sources. They can be created by individuals, by the university, by government research centres (science parks and incubators), by non-profit organizations and as a primary source from firms. Often, they derive from networks and exchanges of knowledge between the previous sources. They can derive from research or human creativity or from a demand pull, driven by the so-called 'absorptive capacity' or the ability to recognize and assimilate the value of new external information to use it for commercial purposes.

According to Schumpeter[17], innovations can be classified into different types based on their nature:

- Product or Service: a new product or service having an economic value that is introduced into the market;
- Process: a new way of producing the existing factors of production to make an existing product or service, like a change in the way the firm carries out its activities;
- Market: such as the geographic extent of the market itself;
- Intermediate inputs: such as the choice of new production factors to be included in the process;
- In the organization: to be understood both in the configuration of the company and in its relations with stakeholders.

In addition to the classification based on the nature of innovation, it is possible to identify two distinct types of innovation based on intensity: incremental and radical. The former

[17] Ziemnowicz, C. (1942). Joseph A. Schumpeter and Innovation. *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*, 1171–1176.

are slightly different innovations from existing solutions, so they make minor changes and adjustments to known practices. The latter is completely new and different from the prior solutions; something completely new is created.

They can also be distinguished on the destination of the innovation in architectural or modular innovations. In the first case, there is a change in the configuration of the entire system and in the way in which its components interact. In the latter, a component is changed without changing the system configuration. An example is needed to explain this last distinction. Let's consider a bicycle, in the past they had the pedals directly attached to the front wheel, changing the way the components interact, now the system is used with the chain and pedals in the middle of the bike, this is an architectural innovation. On the other hand, taking the same bicycle if the pedals, the seat or the handlebar are changed, there is a change in the components but not in the way they interact with each other, this is a modular innovation. Finally, it is necessary to distinguish between competence enhancing innovation, that is an innovation that is based on an existing technology using the company's skills and deepening its capabilities, and competence destroying when an innovation destroys skills by replacing technology and making them obsolete.

These definitions of innovation are applicable and concern all economic sectors including the agri-food sector, which we will observe in detail.

1.2.1 Innovation in Agri-food

Today the theme of innovation, especially in the agri-food sector, plays a central role and it is constantly evolving. It covers a broad spectrum of activities and involves all the levels of the business, from field production to distribution and transformation. Innovation is the final output of a supply chain with different actors, rules and approaches characterized by the specificity of the sector and its evolutionary processes. We have gone from a linear supply chain where innovation was generated with a top-down approach to a systemic supply chain characterized by the interaction between different subjects and the use of numerous skills and disciplines (Capitanio et al., 2010)

The fundamental objective is to encourage the adoption of innovative solutions by the widest audience of farmers and not just by individual entrepreneurs. Especially in the agricultural sector, it is very difficult to convince a large number of farmers. In fact, the beginning of the innovative process was very slow, with few pioneers who managed to overcome suspicions and distrust of new technologies to be applied to agriculture. This is due to various factors, primarily the economic ones where the cost of resources and the price of products make profit margins very low and zero investment opportunities. To solve these problems, support plans have been provided by public bodies and global organizations such as the European Commission, FAO and the World Bank, which recognize agriculture as an engine of economic growth.

In the transformation sector, especially in the food and beverage industry, the innovative process is slightly more developed, although research and development activities are minimal compared to other economic sectors. The search for cost competitiveness, the changing food demand and the identification of new needs are factors that push this sector to take advantage of scientific and technological advances by including them in its business processes. And to do this, investments are needed allowing the internalisation of innovative processes (Finco et al., 2018)

In both cases, the presence and collaboration with research bodies and the creation of a correct relationship between research and business that allows outlining adequate innovative patterns are fundamental. It is difficult to innovate alone in agri-food, but the role of the network, like regional clusters, is fundamental. In this way, networks are created consisting of different actors such as universities, institutions, governments and companies that interact with each other exchanging knowledge and applying the results within their realities. This approach to innovation was dubbed the Triple Helix Model by Etzkowitz and Leydesdorff (1995). They show that in a knowledge-based society, the boundaries between the private and public sectors, research and technology, academia and industry, are disappearing. The model theorizes how each of the three sectors, represented as helices, in addition to developing individually and independently based on its mission, develops overlapping with the others. In this way, an interactive circular system is created where the three helices contaminate each other and exchange goods, services and functions with each other. In particular, the fundamental role of universities is highlighted, which is positioned on the same level as the other two sectors.

Thus, the third mission emerges, adding it to teaching and research, the two main objectives. The third mission is the direct application and enhancement of knowledge for the social, economic and cultural development of society.

Today it seems that investments in the sector have taken off, to underline the fact that the sector is in the path of improvement and innovation, nearly 30 billion dollars were invested in the agri-food sector in 2020.[18] These investments concerned all levels of the supply chain, from the increase in production efficiency to the impact on the environment (Kuhne et al., 2010). In addition to the adoption of new practices and new technologies, a large part of the investments is aimed at the digitization of the sector. Obviously, in this process, the digitization and development of new technologies or the application of existing technologies to the agri-food sphere play a fundamental role.

It is possible to divide the innovations into the various sectors of the agri-food system. Starting from the downstream activities, thanks to the adoption of new practices that use automation and robotization systems, Precision Agriculture techniques (Agriculture 4.0), use of the Internet of Things (IoT), new ways of doing agriculture such as vertical agriculture and aquaponics it was possible to increase and improve production. Particular attention should be paid to 'novel food' which includes indoor and vertical farms, insect breeding as a protein alternative for feeds and human nutrition, aquaculture and new types of ingredients. They make it possible to reduce the impact on the environment and strongly reduce GHG emissions that distinguish traditional techniques by using fewer natural resources and soil and ensuring high levels of production and nutrition.

Considering the food processing actors, who deal with the transformation and packaging of products, there are innovations regarding the efficiency of the activities, the quality and sustainability of the final and processed products. In particular, the focus is on eliminating food loss and promoting circular economies. The agri-food sector is characterized by large food loss that involves all the players in the value chain. Food processors have a key role in reducing it, they can be promoters of activities aimed at redesigning production, packaging and storage methods to favour the correct use of all production factors. Restaurants themselves also have leeway in promoting new solutions to reduce waste and develop zero-waste restaurants. It is essential the adoption of circular economy approach, in which a waste of a process can prove to be an input for a new one, allowing the reuse of waste and efficiency in production costs (Jurgilevich et al., 2016).

[18] AgFunder, 2021 Farm Tech Investment Report.

In this field, many innovations have been implemented such as animal manure reuse systems, both as fertilizer for fields and as a source of biogas production. This enables the lowering of the emission related to animals breeding; emissions are particularly high in intensive farming. Furthermore, many investments aim to develop new food products with a more sustainable production in terms of emissions, land use and from the nutritional aspects. Cultured meat produced in the laboratory, with soy or tofu, and insects used as ingredients are examples of alternatives to conventional foods that retain high nutritional properties but have fewer production costs and environmental impact. Furthermore, research and investments have concentrated on superfoods to improve human health and food safety. Superfoods are foods with great beneficial and nutritional capacities for health: supplements, functional foods and nutraceuticals[19]. Although it should be emphasized that not all scientists agree on their real functions, observing that the nutritional contents do not differ too much from common foods.

Finally, looking at the downstream activities of the agri-food system, there are many innovations linked to retailers and distributors. Thanks to digitalization, in particular the Internet of Things, logistics technologies have been implemented and can provide real-time data on availability, orders and shipments, allowing for precise and waste-free management. The above-described scenario also guarantees perfect traceability of the product by checking the path for producer to the final consumer and helping consumers to gain information about the product and its origin. For example, in case of food-safety outbreaks, it is possible to have a timely product recall. A very interesting issue is the application of blockchain technology in the agri-food chain. Blockchain enables players to verify and interact with the information of a given product, from the place and cultivation methods to the covered distance for its final delivery. As a consequence, products are monitored in real-time along the entire supply chain.

A fundamental role in the implementation of innovations is played by final consumers, policy-makers and researchers. In particular, consumers, with their changing choices, influence and create new opportunities for producers. Current eating habits oriented towards healthy and sustainable diets represent a real driver of innovation, pushing manufacturing companies to direct their efforts towards climate-friendly and zero-waste

[19] Nutraceuticals are products that contain active compounds extracted from the plants that perform a beneficial action when taken in concentrated doses. They have documented biological and metabolic effects, are taken orally in formulations similar to drugs, and provide very few calories.

activities, aiming at responding to consumer demand.[20] In the second half of the 1900s, scientific evidence emerged of the connection between food choices and the consequences for human health. This has led to the crisis of the production-oriented model, based on the industrialization of production, single crops and the use of two pesticides and fertilizers, as it is held to be partly responsible for people's health.[21]

As previously mentioned, the creation of networks in which companies, public and private organizations, universities and research centres interact and exchange knowledge is fundamental for the development and introduction of new technologies. In this context, the important role of policy-makers and researchers emerges (Aleffi et al., 2020). Policy-makers plays the regulating role and, given the recognised importance of innovative capacity, promote and check that the entire agri-food supply chain performs in the best possible way. They can influence firms' innovative choices through incentives and investments, to enhance innovation where mostly needed. Researchers disseminate knowledge along the supply chain through their studies and promote the implementation of innovative solutions emerging from multiple research fields (Wilson, 2012). Literature[22,23] confirms that there is an exchange of benefits among the actors. Universities and researchers, can provide knowledge and information for promoting the adoption of innovation and they can gain feedback about the research they are carrying from the exchange with producers.

From the above-described scenario, it emerges that innovation is pivotal for ensuring solidity and continuity to the agri-food sector, offering numerous opportunities to all the actors involved and many areas for improvement.

---

[20] EIT Food: The top 5 trends for the agrifood industry in 2021.
[21] Barilla Center for Food & Nutrition, "The cultural dimension of food", 2009.
[22] Galan-Muros, V., & Davey, T. (2019). The UBC ecosystem: putting together a comprehensive framework for university-business cooperation. *The Journal of Technology Transfer*, 44(4), 1311-1346.
[23] Ivascu, L., Cirjaliu, B., & Draghici, A. (2016). Business model for the university-industry collaboration in open innovation. *Procedia Economics and Finance*, 39, 674-678.

1.3 Sustainability

The concept of sustainable development is a modern concept, formalized for the first time by the World Commission on Environment and Development (WCED) with the report ‘Our common future’, known as the Brundtland report, in 1987. It is defined as "*development that allows the present generation to satisfy their own needs without compromising the possibility of future generations to satisfy their own*.” However, the concept of sustainability is very complex and has not found a common approach over time.

It has often been used with meanings for marketing and advertising purposes and superficially associated with nature, neglecting its dimensions in their full scope. This has created conflicting debate and opinions on the methods to be followed to integrate it in the company, creating confusion and lack of clarity, especially among the less experienced. Indeed, the solutions proposed by sustainability can be better or worse and not true or false as the problem changes over time and the stakeholders involved may present different ideas and values on the causes and related solutions. “*For example, with respect to sustainability of ecosystems, environmental ethicists may focus on the intrinsic value of nature; applied economists may focus on the instrumental value of nature; and non-academics may bring tacit knowledge garnered from practical experiences and personal values associated with nature and resource use*” (Batie, 2008).

Given that, it is necessary to provide some basis on what sustainability is. The three fundamental pillars on which sustainability is based are time, biophysical limits and relationships (Pulselli, 2011). Time is a key element for sustainability since human activities must be seen as a continuous becoming, to understand which are virtuous actions and which are not for the continuation of the human species. Nature has the intrinsic characteristic of being able to survive over time, in fact over the billions of years it has continued its evolution by diversifying, exploiting the safest energy source: solar energy, and getting rid of the waste produced. This has failed the human that exploits more than what is available to them, does not know how to dispose of its waste and that, if it does not take into consideration the biophysical limits, in a very short time it will exceed the critical thresholds that will trigger unpredictable and uncontrollable processes. Finally, relationships are those processes whereby different systems exchange information and influence each other. It is necessary to take into account all the reciprocal interrelationships, to consider the potential effects that an action has both on the system itself and on the systems with which it is in contact. Economy, society and the environment are the three systems to be considered to implement processes aimed at achieving sustainability. Guaranteeing the availability and quality of natural resources (*Environmental sustainability*), the quality of life, safety and services for citizens (*Social sustainability*) and economic efficiency (*Economic sustainability*) cannot be separated from each other but they must be goals that go hand in hand (Elkington, 1997).

Furthermore, the interaction between innovation and sustainability is fundamental to achieving sustainable paths. Taking into consideration the triple helix model, discussed in the previous paragraph, the different actors must adopt new types of interaction between them. In a way, we moved from the traditional model towards a Quadruple Helix Model, which is stated by Van Winden and Carvalho (2015): "*it opens up questions about the nature of the demand and can also transfer innovation from having a narrow technological orientation towards a more social focus.*" Therefore, the fourth helix represents the citizen and the community, which in the previous model were ignored, but which in reality need to be included in the innovative processes. These innovative processes must not be considered only as technological progress, as has often been done in the past, but above all as a range of actions and mechanisms that simultaneously bring improvements to the environment, society and the economy.

Still being an unclear and not fully regulated topic, a distinction must be made in decision-making levels. The first is the national or global policies, where objectives and indicators are decided, the sectors to be encouraged or punished and how to direct consumption. The examples are the 17 SDGs of the 2030 Agenda. The second level is the companies, which, to be more virtuous, try to go beyond the norms by volunteering to improve their sustainability. This commitment is communicated through the sustainability reports, it is certified and reported to obtain relational, reputational and economic advantages. Finally, the third is the individual consumers who can improve their consumption choices and their lifestyles. The responsible consumer is a powerful actor who, from below, is capable of influencing good practices through voluntary behaviour and can be subject to more or less imposed rules that influence its consumption decisions.

Now, if we think of the agri-food system described above, it is easy to understand how sustainability represents a fundamental element to be integrated and applied in all the supply chains and actors that characterize it.

1.3.1 Sustainability in Agri-food

Global agri-food systems have reached high levels of unsustainability and the problems expressed in paragraph 1 are the manifestation of this. The need for change is evident. The crisis caused by Covid-19 also further underlines the need for more resilient and robust food systems to achieve environmental safety and guarantee a better world for future generations.

Since sustainability is not a topic that affects only individual phases of the agri-food system, it is appropriate to define a Sustainable Food Value Chain (SFVC). FAO (2014) defines it as: "*the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources*. "

In particular, it must meet economic, social and environmental sustainability: it must be profitable in all phases, it must have a positive impact on the society in which it operates, and it must have no impact or have a positive impact on the environment.

The promotion of sustainability in the agri-food system is driven by endogenous factors, such as the commitment of individual companies, and by exogenous factors such as consumer demand, increasingly focused on the issue of sustainability, and national and international regulations such as the Green Deal European[24]. In particular, within the Green Deal, an important part is reserved for the Farm to Fork strategy designed to push a significant transformation in the European agri-food system. It is a ten-year plan that proposes measures and objectives along the entire food chain, from production to consumption. At the base is the goal of making food systems more sustainable and each

---

[24] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.
Last access on: 19/11/21

member state will have to adopt national regulations that help achieve this goal, also enjoying support measures during its implementation. It contains the main objectives of the sustainability of the agri-food sector:

- Guarantee sustainable food production;
- Ensure food security;
- Promote a sustainable food chain, from processing to sale including ancillary services;
- Promote the consumption of sustainable foods and the transition to healthy eating habits;
- Reduce food waste;
- Fighting food fraud along the supply chain.

Within companies, sustainability is becoming a fundamental value of the corporate culture at all levels of the organization. In particular, the key issues are the reduction of waste from a circular economy perspective, the conscious use of resources, the design of sustainable packaging systems and in general the creation of a sustainable supply chain through the dissemination of good practices. This is to achieve food and nutritional security, social inclusion and equity and an agri-food system that respects biodiversity (Faggini et al., 2021).

First of all, the process of integrate sustainability must be based on a change in company management and consumer choice habits, both aimed at a sustainable perspective. Companies no longer have to have the classic orientation exclusively to economic and financial business results, but it is necessary to introduce a corporate culture that promotes activities aimed at environmental sustainability and corporate social responsibility (Vitale et al., 2019). Consumers must be guided by conscious choices on the impacts and consumption that the products purchased have on the environment and communities, changing their habits with small daily gestures, for example by changing the composition of their shopping cart by preferring the goods that have low impact.

As previously stated, the combination of innovation and sustainability is relevant in this area. In fact, to achieve the previous objectives, investments in research and innovation, improving consulting services, optimizing data management and processing and knowledge sharing are necessary. For example, digitization applied to purely productive phases is the demonstration of how it is possible to apply technologies, primarily developed for other purposes, to these activities.

1.4 Precision Agriculture and Smart Farming

Since the last decades of the 1900s, the development of digital technologies has been a continuous and exponential process that has found ways of application in any economic and social system.

Information and Communication Technologies (ICT) have impressively evolved over the last decade, and new solutions have created space for technology in agriculture under Smart Farming (Walter et al., 2017). Smart Farming includes a broad range of solutions grouped in Farm Management Information Systems, Precision Agriculture and Agricultural Automation and Robotics. Differences among the three categories sometimes are imperceptible.

Scholars define Smart Farming as a *cyber-physical system* (Wolfert et al., 2017) that combines high tech devices and the physical dimension of farming. In the described scenario, humans make a difference (Lioutas et al., 2019): they effectively analyse collected information and include emerging insights in the decision-making process.

Given the different characteristics of the sectors, not all have been able to incorporate and apply them in the same way. Some were more avant-garde, adapting them to their needs by exploiting them promptly, while for others the adoption process was slower. The latter is the case of the agri-food sector, which for years, especially in the upstream part of the supply chain, was characterized by a low propensity to introduce innovations and technologies. Recently the primary sector is facing a profound revolution linked to the innovation process and the introduction of new technologies that are changing the way agriculture is done. Among these is Precision Agriculture which is assuming an increasingly central role also in the thrust it receives from governments and international organizations. Precision Agriculture is defined by the International Society for Precision Agriculture (ISPA) as: "*a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production.*"[25]

[25] https://www.ispag.org/about/definition. Last access on: 12/12/21

It is based on the idea of doing the right thing, in the right place and at the right time, which generally goes by the name of site-specific management (SSM). Therefore, it allows targeted interventions to reduce the use of natural resources and at the same time increase production efficiency. It uses data processing and automation technologies with sensor systems, autonomous driving, smart vehicles and drones. It also uses monitoring systems that take advantage of big data, IoT and cloud for better integration of the supply chain (Bongiovanni and Lowenberg-DeBoer, 2004).

First of all, data are collected through weather columns, soil analysis, satellite images, crop history and all the information in the possession of the farmer. These data are then analysed and processed using suitable software that interprets their meaning and provides information to improve performance both in terms of productivity and sustainability. This assumes the function of a decision support system (DSS) assisting the farmer in the choices to be made, the quantities and places of application of fertilizers and pesticides, the quantity of water to be allocated to a part of a field rather than to another, the moment in which to do the phytosanitary treatments or in which to collect. All supported by the data collected but not binding, as the final decision rests with farmers (Zamora-Izquierdo et al., 2019).

Furthermore, the data can be combined with the use of other technologies such as tractors with semi-automatic or satellite-assistant driving, and variable rate application systems that guarantee a greater precision in processing, allowing a targeted distribution of inputs, which in agriculture translates into better use of resources and less waste.

Precision Agriculture helps to improve the quality of air, water and soil, thanks to a calibrated use of inputs and necessary resources, it also favours a slowdown in soil degradation due to the excessive and incorrect use of fertilizers and pesticides. It guarantees continuous monitoring of the crops that allows them to verify in real-time their vegetative state and to act promptly in case of problems, and above all, forecasting systems allows them to act in advance on possible problems related to the development of crops (Shafi et al., 2019). Therefore, it represents a fundamental tool for overcoming the problems of responding to the growing demand for food as it increases productivity and therefore profitability, and those related to the impact with the environment thanks to less impacting activities (United Nation Development Programme, 2021). Appendix 1.2 shows the environmental gains expected from the main Precision Agriculture processes and techniques.

The introduction of these new technologies must be integrated with traditional techniques. This process is much faster and easier for large companies that aim to increase production efficiency and can support the necessary investments, which is not always possible for smaller companies. To involve all the players of agriculture, regardless of the size and structure, it is, necessary to gradually introduce increasingly advanced systems. In other words, to properly function, innovation must be inclusive. The agricultural entrepreneur must be supported by professionals who propose solutions that are proportionate to the entity in which operates and the value of the benefit that is obtained (Sørensen et al., 2020).

In this context, analysis is essential to understand and create the appropriate solutions and once again research enters the field, which must be shared between the company, research centres and institutions. It is essential to create a smart specialization strategy that promotes an innovative process in the sector that moves in a single direction. This type of strategy makes it possible to enhance and improve the performance of companies taking into account their characteristics and their competitive advantages, it seeks to match the strength of research and the needs of the company, through a constantly evolving process. This happens with the creation of a network of strategic alliances, partnerships, licenses and investments that allows an enormous exchange and of knowledge and skills capable of strengthening the present and future competitive advantages and opportunities. Many technologies have found application in the agricultural sector despite being technologies developed in other contexts, and this is above all thanks to the exchange of knowledge and intelligent research (Santini et al., 2016). Example of ICT applied to agricultural sector are provided in Figure 3.

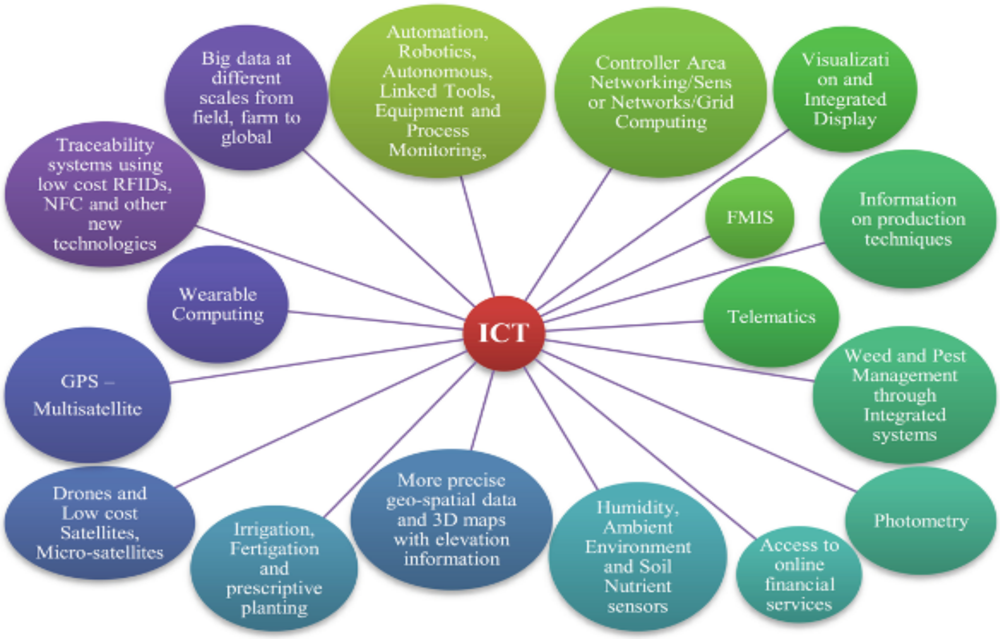

Figure 3. ICT Innovations and Smart Farming from Sørensen et al. (2020).

1.4.1 State of Art

Globally, Precision Agriculture has taken off, about 80% of new agricultural equipment placed on the market has at least one component of Precision Agriculture. In the US, where it first found its application, the introduction of new technologies has been exponential and today very well established. Autonomous driving systems are now standard in American agricultural machinery flanked by the implementation of innovative practices, such as the variable distribution of fertilizers, which is reaching very high percentages. The United Kingdom and Australia are following the US in the introduction of Precision Agriculture, having ascertained its beneficial and economic effects and driving the demand for Precision Agriculture services. In general, the world trend is growing sharply and the market value of Precision Agriculture will reach 13 billion dollars by 2026.[26]

Despite the resulting benefits in Italy, the implementation of Precision Agriculture is still proceeding slowly. It was 2017 when the guidelines of the MIPAAF stated that by 2021 we would go from 1% of the agricultural area cultivated with the use of Precision Farming

[26] https://www.statista.com/statistics/721921/forecasted-market-value-of-precision-farming-worldwide/ Last access on: 20/12/21

equipment and technologies to 10%.[27] Today, Italy is still far from this percentage, settling at about 4%, this is mainly due to the characteristics of the Italian farm. The fragmentation and the small-medium size of the companies do not allow to support the investments necessary for the purchase of new machines and technology, the average of Italian companies is 11 hectares against 17 of the EU average. The high age and low education of those who work in agriculture make the adoption of new technologies an insurmountable gap. The perception that tradition is transformed into quality makes it suspicious of adopting new practices.

However, something seems to be moving and despite the health emergency that has slowed down the sector, this has reached a value of 540 million euros in 2020 with a growth of 20% compared to 2019. 60% of farms use at least one digital solution and 38% employ two, but only 4% of the agricultural area is cultivated through Precision or 4.0 Farming tools or with innovative practices, which underlines the fact that the market has yet to express much of its potential. In particular, the innovative solutions on which the most investments are made are those for monitoring and controlling agricultural vehicles and machinery, with agricultural machinery manufacturers leading the way in terms of turnover. A smaller slice of the market is reserved for crop monitoring, decision support systems and land mapping.[28]

It is in this context that the policies and incentives for the adoption of services and technologies related to Precision Agriculture, such as the CAP and the tax credit for Agriculture 4.0, are inserted. Aids of this kind are and will be fundamental for the drive to adopt these practices, especially to support smaller companies that would otherwise disappear within a few years.

[27] Ministero delle Politiche Agricole Alimentari e Forestali LINEE GUIDA PER LO SVILUPPO DELL'AGRICOLTURA DI PRECISIONE IN ITALIA, Settembre 2017.
[28] Osservatorio Smart Agrifood 2021 della School of Management del Politecnico di Milano

1.4.2 Problems of Precision Agriculture diffusion

The application of innovative methods in agri-food companies has always had difficulties in establishing itself. This is due to the fragmentation of the supply chains, the small size of the economic units, the difficulties of agri-food companies in accessing the innovation system, and the insufficient diffusion of the entrepreneurial culture.

These problems are present not only in rural areas or in developing countries where farms are family-run and often poor, food insecure and with limited access to the market and services, but also in more developed countries such as Italy (Sørensen et al., 2020). Considering that according to FAO about 90% of the millions of farms are considered small, this represents a not negligible problem.

Small farmers are characterized by low profitability due to agricultural yields, limits on access to production factors, markets and financing. Furthermore, due to increasingly frequent climate change, they are particularly affected by shocks due to extreme weather events that expose them to even more serious risks.

These aspects related to the high costs for the adoption of technological and sustainable solutions such as those described in the previous paragraphs are two causes of the low diffusion of Precision Farming practices in small and medium-sized enterprises.

The other main causes are linked to cultural and infrastructural elements. In many cases the average age of farmers is very high, for example in Italy 60% of farmers are over 55 and only 5% are under 35. The level of education of farmers is low on average and represents a stumbling block to overcome. In Italy, over 60% of 40-55 years old farmers do not reach a qualification higher than the lower secondary school diploma and in >55 years old class almost 60% of the farmers have only the elementary school diploma or no title[29]. These characteristics create a very difficult barrier to the introduction of innovative practices and processes by anchoring themselves in the peculiarities of tradition and distrust of novelty, especially those of a digital nature that require a greater degree of adaptation and understanding. Furthermore, everything is aggravated by infrastructural problems due to the location often in rural and remote areas which makes it impossible to adopt technologies that require stable and fast internet connections or mobile signal

[29] http://censimentoagricoltura.istat.it/ Last access on: 22/12/21

coverage (Bacco et al., 2019). Furthermore, another challenge to overcome concerns cultural tradition. Agricultural practices are often strictly linked to the tradition of the place where they are made, making it very difficult to integrate new ones. In addition, Smart Farming is often associated with intensive production techniques that go in contrast with the concept of quality products linked to local tradition, representing a threat (Dang et al., 2020).

To overcome these challenges, intersectoral collaboration is required that involves institutions, companies, universities and governments, developing solutions suitable for each local context and trying to break down all the cultural, social and political barriers that hinder the correct implementation of Precision Agriculture (Kernecker et al., 2020).

Chapter 2. The relationships between innovation, sustainability and performance.

2.1 The system of relationships

The relationships between innovation, sustainability and performance are the basis of company dynamics; knowing the causes and effects is a fundamental point implementing new strategies.

As already mentioned in chapter one and confirmed by the literature "*innovation is a key element of corporate competitiveness in the 21st century, and has therefore attracted special attention of management researchers and practitioners.*" (De Mello et al., 2008)

Innovation and technological change have always been the main drivers of business growth and a cornerstone of competitiveness. Innovating allows companies to thrive over the long term and to explore new opportunities and new markets. Through innovation, it is possible to continuously put on the market products and services that can constantly satisfy the new and old needs of consumers, and this affects the profits, the reputation and the value of the company itself. Nowadays, the shorter product life cycles, and we know that the degree of innovation technology that is incorporated by the product can shorten the product life cycle, and the higher levels of competition have made the capacity to innovate a more fundamental element for the companies' performance and competitive advantages which allows them to respond quickly to changes and challenges.

Performance results also depend on company's structural characteristics such as the size, culture, age and environment in which it operates. The desired results are not always obtained and not all types of companies find the same levels of effectiveness and efficiency in the implementation of innovations. The risk of failing to adopt innovations exists and is great, which is why companies, especially small ones, are wary of it. Simpson et al. (2006) emphasize that "*innovation is a risky and expensive activity that has both positive outcomes in company performance and negative ones such as greater exposure to market risks, higher costs, employee dissatisfaction and unjustified changes*."

Therefore, it is necessary that investments in innovations, whether they are new products, new processes or new forms of organization, are studied and best adapted to the company's characteristics as it is generally accepted in the literature that all companies should do it regardless of their size or sector, to compete and survive in the market. It is clear that, for example, a large and structured company has more resources to invest in innovations and is more able to cope with related risks than a smaller one. If companies do not want to run into dangers, this must be considered in the innovation process, pondering the decisions to be made.

While the effects of innovations on performance have been under study for a long time and the results enjoy a large amount of evidence, those of sustainability are more limited and still under study, leaving room for debate.

Until few years ago it was a common belief that the term 'sustainability' was referred to environmental issues and that attention to the environment was only a legislative obligation, an ethical and moral concept that had nothing to do with the business model and the market. Today we are becoming aware that sustainability and performance are related aspects of the success of a company (Alshehhi et al., 2018). Companies that have always been characterized by the goal of maintaining steady economic and financial balances, in today's context are implementing a process of internalising sustainability. They are focusing on recognizing their social and environmental responsibility by going beyond the economic one, moving from a concept of a short-term culture oriented towards immediate profit to a vision of continuous long-term development. This is driven both by the adaptation to increasingly stringent regulatory constraints and, above all, by the attention that the topic has taken in the eyes of consumers and investors at a global level as well as by the greater sensitivity for the quality of products and the reduction of production costs.

The debate on the effects that sustainability has on corporate performance is still open and finds conflicting opinions since the measurement of these is very difficult. Thanks also to the numerous researches that are being carried out today on this argument, a common line is emerging towards a positive relationship between sustainability and performance (Szekely and Strebel, 2012). In recent years the side of those who consider the relationship to be positive has established itself more concretely than that of the negative ones, which relies on relatively past arguments.

Starting with the criticism, it is highlighted that sustainability involves additional costs that place the company at a disadvantage compared to others that make different choices. Furthermore, the benefits of the sustainable approach are often not visible in the short term and do not have a direct and clear impact on the company's profitability. Taken in this way, these aspects represent a real danger, especially for less structured companies, which need shorter response times to their investments to survive.

On the other hand, however, Mikolajek-Gocejna (2016) states that "*the additional costs are potentially compensated for by a range of direct and indirect benefits which show a positive correlation between social responsibility and financial performance.*" In particular, a better company reputation concerning the responsibility towards employees, consumers, the community and the environment can lead to higher levels of economic performance, which translate into greater corporate value.

According to Cantele and Zardini (2018), the competitive advantage is the key element to observing and measuring the impact on economic performance and it is influenced by direct and indirect effects. The application of sustainability strategies, in addition to directly influencing the competitiveness of the company, for example by lowering production costs thanks to the more correct use of inputs and the efficiency of production processes, influences elements such as the reputation, the satisfaction of customers and the organizational commitment. These in turn affect the competitive advantage which will then affect economic and financial performance. Furthermore, the study affirms that sustainability has strategic importance in the development and prosperity of small and medium-sized enterprises, especially as regards the social and economic components of sustainability.

Finally, to have success and positive results in performance from the implementation of sustainable strategies, it is not enough to have general objectives. It is necessary to analyse in detail the context within which the company operates, considering the entire production chain and the characteristics of its products, identifying a few priority and well-quantified objectives. In this context, the concept of social and environmental responsibility must be inserted, similar to the concept of the shared value of Porter and Kramer (2011) which corresponds "*to the set of policies and operational practices that strengthen the competitiveness of a company while improving economic conditions and social issues of the communities in which it operates*."

We have seen how innovation and sustainability individually represent two key elements for the success and competitiveness of the company, now it is necessary to deal with the two topics jointly.

Sustainability is becoming the reference point and the backbone of current innovation paths. Within the company, the concept of sustainability is intrinsically connected with that of technological and digital transformation and is involving all areas of the company, from governance to operational activities.

The innovative process represented one of the main sources of negative impacts on society and the environment due to the enormous use of natural resources and the very high levels of pollution associated with production processes. If we think about the industrial revolutions and the frenetic and reckless implementation of technological and industrial innovations that characterized them, it is easy to understand how in the past sustainability and innovation were considered opposite concepts.

Today, however, innovation and sustainability are part of a virtuous circle and support each other (Nidumolu et al., 2013) (Kuzma et al., 2020). Innovative processes progressively encompass the three dimensions of sustainable development: environmental, social and economic. This relationship has become so close and fundamental that it is possible to talk about sustainable innovation. A new concept of economic development emerges and it relies on the creation of private and social wealth to eliminate negative impacts on environmental and social systems.

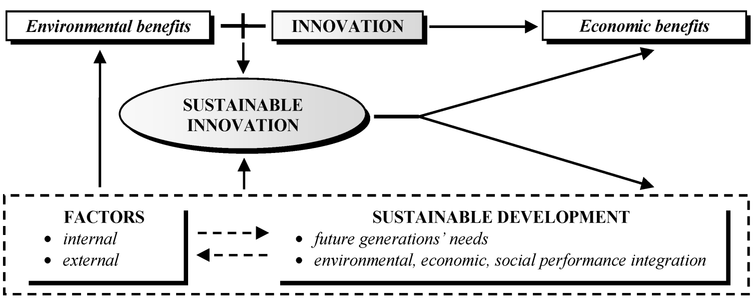

Figure 4. Sustainable Innovation. Source: Pichlak and Szromek, 2021

If on the one hand, all investments and innovative processes must be considered through sustainability objectives, on the other hand, it is not possible to achieve adequate levels of sustainability in business processes without resorting to the introduction of innovations. As stated in a study by the Boston Consulting Group (2016): "*the intersection between corporate value and environmental and social benefits does not happen by chance; it requires a rigorous approach to innovation and a set of organizational design choices.*"

The challenge is no longer trying to improve economic potential but being the main actors in environmental and social changes, internal and external to the company, and, above all, being able to monitor the effects that such changes have on the context.

Therefore, the innovation-sustainability relationship pushes companies to redesign and change their business model to include innovation and sustainability at the same time creating the concept of a sustainable business model. It places stakeholders at the centre of attention through a rethinking of the corporate value proposition, of new products or the redesign of existing ones, of investments in research and development and of promotion and research of sustainable processes along the supply chain in which the company operates, intending to ensure long-term success.

What has been said about the relationships between innovation, sustainability and business performance is true for any economic sector and any business reality, even in the case of the agri-food sector. In this sector, these relationships must be taken into consideration by all the economic actors that are part of it, primarily by the agricultural entrepreneurs at the downstream activities of the production chain. Literature suggests a broad consensus on the critical role of innovation that makes agriculture not only more competitive but also more sustainable and able to respond to the challenges of agricultural development such as climate change and food security (El Bilali, 2018). These relationships are more difficult than in other systems and often the real problem is to perceive the return on investment, the usefulness of the implementation of new technologies and the benefits of sustainable development strategies in agriculture.

Measuring the performance of an activity and monitoring its progress, especially in the agricultural sector, are two very difficult and widely debated processes, but it is the only way that can demonstrate the real impacts of introducing sustainable innovations in the company.

2.2 An overview of methodologies of measuring innovation, sustainability and performances

"*If you can't measure it, you can't manage it*"[30], this sentence summarizes the importance of measuring company performance or individual investments made. Companies need to monitor the effectiveness and efficiency of the strategies implemented also in terms of sustainability and innovation to observe their economic return and alignment with the growing global focus on sustainable development goals. Many companies, especially in the agri-food system, overlook the fact that the measurement and evaluation of their activities are key elements of the performance cycle that allow them to have a detailed idea of their structure and to define clear future objectives affordable for the firm.

Many approaches have been developed for measuring corporate performance and structure such as the Balanced Scorecard by Kaplan and Norton[31] and Keegan's[32] Performance Measurement Matrix.

Taking into consideration the lower part of the agri-food sector, the literature identifies two main models for measuring performance: one based on benchmarking and the other on the identification of key performance indicators (KPIs) (Jones et al., 2021). Taking into consideration the approach based on benchmarking, it is based on an assessment of company performance by comparing them with those of another company that deals with similar activities. In particular, it is defined as the process used to identify, learn and best adapt the practices of other farmers to help improve farm performance (Kahan, 2013). This methodology shows how higher levels of performance can be achieved by selecting the best-performing companies to compare them with own performance and understanding in what and to what extent they differ from the values achieved by the top companies operating in the sector. It is a system based on the identification and knowledge

[30] Peter Drucker

[31] Balanced Scorecard is a management tool that supports the successful implementation of corporate strategies, through the alignment and management of all corporate activities according to their strategic relevance. It translates the company's vision and strategy into strategic objectives, performance indicators, targets and measures with respect to four perspectives: finance, customers, internal business processes and learning and growth.

[32] Performance Measurement Matrix is one of the older management tools for performance measurement. It measures through the use of a four-dimension matrix that integrates different classes of business performance. In particular it considers: cost and non-cost, internal and external business performance. In this way the matrix measures the whole multidimensional environment (internal and external) and focus on cost drivers that are the basis of performance measurement. Given that it is possible to have a holistic view of the overall performance of the company.

of good practices and their strengths and weaknesses. It can be done at any time and any stage of the production and decision-making process. In addition to being done externally by comparing the performance of other companies, it can also be done internally. In this way, an evaluation and analysis of past results are carried out to understand how to improve them and avoid making previously mistakes. An informal first approach can help the farmer to improve performance, for example by wondering why another farmer gets better results and observing him or exchanging information to understand what is wrong and how to improve. Certainly, to be more efficient, a structured approach, characterised by a more formal and analytical point of view, is needed. Starting with a study of one's own company and areas for improvement and which, through a process of identification and analysis of similar companies and their performance, leads to the definition and planning of changes in their businesses based on what has been tested in better-performing.

Benchmarking is an approach that bases the comparison of performance on the analysis of profitability and technological and economic efficiency, therefore on the relationship inputs-outputs and costs-revenues. It is a continuous process made up of various steps in which the farmers can constantly monitor their performance and improve them by following the most virtuous and profitable examples (Kahan, 2013). The main steps are:

- The identification of the problems to be analysed, to identify the physical and financial performance indicators and define the best performers to be taken as a benchmark.
- The collection of information and data that form the basis for comparison between the company and the benchmark companies.
- The comparison and subsequent analysis of the differences allows identifying the strengths and weaknesses, as well as the causes of the problems.
- The evaluation of possible intervention plans to intend to improve performance and the subsequent monitoring that verifies the effects.

Through monitoring, it is then possible to restart the process from identifying problems, creating a cyclical mechanism that aims to continuously improve the performance of companies.

The possibility of measuring and comparing performance allows having a complete and clear picture of the positioning of the company about similar players. This process stimulates models of continuous improvement and positive competition by encouraging the introduction of sustainable innovations and practices in companies. Thanks to benchmarking, companies can identify the essential activities of their processes on which to focus their efforts and investments. Furthermore, with the possible dialogue and exchange of knowledge that takes place between companies, the flourishing of new ideas and business models that can lead to the success of the company's future strategies is encouraged. In short, it is an excellent approach that allows companies to identify the elements on which act to achieve success. On the other hand, for benchmarking to be effective there must be enough information and these need to be well interpreted by those who carry out the analysis. Furthermore, the ability to accurately collect similar data to be compared is a key element in the success of the approach but it turns out to be a difficult and costly process in terms of time and money. It also takes into consideration the company as a whole and analyses it through aggregate measures that do not take into account the single process or single production phase but proceed to a block analysis. (Jones et al., 2021).

The other approach is based on the Key Performance Indicators (KPIs) through which it is measured how the company or the individual parts that compose it are operating (business units, projects or individual employees). KPIs are variables that allow company managers to monitor at what point the strategies implemented are targeting the strategic objectives previously set and, for this reason, in addition to the monitoring function, they are also key elements in the decision-making process. Gallopìn (2005) defines an indicator as an operational representation of an attribute (quality, characteristic, property) of a system. It provides concise information that is quickly understood by those who have to interpret and use it. The indicator is linked to the metrics, which can be numerous for each indicator. They express the quantitative or qualitative value of the indicator.

Therefore, KPI are fundamental tools for understanding and explaining company performance and for identifying weaknesses and potential areas for improvement. It is possible to identify a very large number of KPIs that vary in relation to the sector, the company characteristics and the objectives that the company has set itself. For this reason, to be useful and effective, managers, or whoever has the task of choosing those on which to act, must be able to recognize the right ones for the company and its success. First of all, given the large number of KPIs, it is necessary to be in line with company's strategy and therefore that the strategy is very clear and outlined. Then, to understand which are the fundamental points to touch, the focus must go on the questions that need an answer to give context to the indicators, for example, if you want to increase the number of customers of a company it will be necessary to ask 'how to increase them? Is it concretely possible? What will be the impact on profitability?' Furthermore, how the resulting data are chosen, measured and interpreted is fundamental, if not done correctly they can lead to undesired results. The main limitation of the approach is that it is dependent on the type of variables that are selected and considered relevant (Kahan, 2013). In addition, the high number of indicators and variables that have spread in the agricultural sector, especially since the 1960s with the intensification of industrial agricultural production, has created a situation of uncertainty regarding the usefulness of these measurements due to excess of them without studying the reasons behind them. In a nutshell, measuring too much and randomly does not guarantee a benefit for the farmer but rather, considering the costs in terms of time and resources, it discourages them from collecting data and information.

A good KPI must be simple and easy to measure so that anyone involved can figure out how to improve it; relevant to a particular business factor; aligned with the rest of the KPIs and the corporate strategy to create supportive and not weakening effects; actionable to stimulate its achievement and not create unattainable and difficult to achieve goals causing demotivation, and finally it must be measurable and based on a solid objective capable of creating qualitative and quantitative measures. Only by following these characteristics, it is possible to obtain an indicator that can provide evidence on progress towards a specific target by keeping track and comparing the changes in performance over time. In this way the double reporting and predictive function[33] would be realized which underlines, even more, the fundamental usefulness that measurement through KPI covers. According to Lundin (2003) "*relevant functions of indicators are:*

- to assess conditions and trends (sometimes in relation to goals and targets);

- to provide information for spatial comparisons;

- to provide early warning information;

- to anticipate future conditions and trends."

The two approaches can also be seen in a complementary way, in fact, at the end of the

[33] Leading and Lagging indicators. The first provides information on possible future results while the second assesses the present company conditions.

benchmark process the company that has compared its performance with that of the top-performer sets itself objectives to be achieved which it will divide, measure and monitor through the use of quantitative and qualitative indicators. Conversely, a company that measures itself through a set of KPIs will identify objectives to be achieved within a certain time, also taking into account the performance obtained by their respective competitors or similar companies.

Going back to what was said in the previous paragraph regarding the innovation-sustainability-performance relationship, it is clear that the two approaches described here as performance measures are suitable for measuring the degrees of innovation and corporate sustainability. It is possible both to compare one's state of implementation of innovative and sustainable solutions and practices (benchmarking), and to measure the degree of adoption, present and future effects of these practices through the use of specific indicators.

2.3 Key Performance Indicators for analysing sustainable performances

2.3.1 Sustainable KPIs

Parallel to the inclusion of the concept of sustainability within corporate boundaries, the need to measure and evaluate this topic has developed. How sustainable is the company? How does the company manage resources? How sustainable are the products/services? What contribution does the company make to the community and stakeholders?

These are just a few examples of questions that business managers seek answers to.

The above listed questions emerge because companies on one side must manage market pressures for sustainable production, and on the other the company itself is committed to improve its overall sustainability.

The measurement and evaluation of all dimensions of sustainability – environmental, social and economic - become pivotal. Referring to SDGs of the Agenda 2030, the need for companies to know how to measure their sustainability performance is even more evident: companies must understand how to manage and monitoring their path in achieving the goals set by the United Nations. Furthermore, the demand from individuals and investors regarding the need for corporate information that goes beyond the financial aspect is growing stronger.

Although it has become a necessity, the question of measurement is a difficult and much-debated topic that currently does not find a single and standardized path. In addition to identifying the appropriate sustainability indicators, it is necessary to choose the appropriate data for measurement and proceed with an adequate assessment (Kassahun and van der Vorst, 2014).

The creation of sustainable value is only partially reflected in economic transactions, making the measure of the effects untrue. Although economic measures are by far the simplest to measure when it comes to sustainability, they are no longer enough. They do not take into account the less evident impacts that a sustainable strategy, project or practice has outside of financial performance, effectively excluding the social and environmental part. Measuring, managing and communicating sustainability become fundamental activities in the pursuit of an environmental strategy. The most difficult challenge is being able to measure and quantify elements "*which may be outside the direct control of the company, that are difficult to characterise and often are based on judgments rather than on hard data.*" (Keeble et al., 2003).

A company should be able to analyse all the elements that make up its strategy and business model and the impacts that these have on sustainability-related aspects such as human rights, climate change and environmental conservation. The impacting elements are consequently influenced by the type of business, the physical location of the company and all the players who are part of the supply chain.

So, the creation of sets of KPIs that measure and monitor the results and impacts of business processes on the dimensions of sustainability is fundamental.

After identifying the sustainable aspects relevant to the corporate strategy, it is important to define the improvement objectives in the short and long term. These must be the starting point on which to measure the degree of progress through the indicators. It is clear that measurement is important in the continuous improvement process linked to sustainability, but it is less clear which measurements are to be detected and monitored. The measurement has the objective of generating relevant information for the definition of future actions but, in the case of sustainability, the amount of information is enormous and chaotic and is difficult to break down into small information units, manageable and immediately understandable (Warhurst, 2001).

Therefore, KPIs are an important tool as "*Sustainability indicators simplify, quantify, analyse information that would otherwise be complex and complicated, making it a manageable and significant quantity*" (Singh et al., 2009). They are simplified, concise and communicable information that fulfil the measurement, management and communication requirements imposed by the strategy for pursuing sustainability.

A fundamental difference between traditional and sustainable indicators is while the former measure the impact independently (e.g., air quality), the others reflect and incorporate the connections created in the three dimensions, searching for causes and effects (e.g., generation of pollutants both in the production phase and by the end-user).

In addition to the company level, the adoption of sustainability indicators is useful for the inclusion of issues such as the environment, innovation and society in the definition of policies and public communication. Many international organizations have already developed their own sets of indicators for measuring and reporting sustainability. For example, the indicator models of the Global Reporting Initiative (GRI), the Global Compact and the World Business Council for Sustainable Development (WBCSD) are already widely used, and provide criteria for assessing sustainability according to all the facets of a company. An example of WBCSD indicators is provided in Appendix 2.1. In defining the SDGs, the United Nations figured out indicators associated with each target, for a total of 247 indicators.

These sets of indicators that have found more or fewer applications around the world are attempts to harmonise the measurement of sustainability, which however remains far from adopting a common methodology. This is precisely due to the type of data that must be measured which depend on the characteristics of the company, the objectives it has set itself and the context in which it operates. In fact, due to the lack of common rules and regulations and the huge number of existing indicators used for different contexts, uses and purposes, an effect of subjectivity is created that makes each reality measure what is most convenient. Sustainability has often been used as a fraudulent communication strategy to try to improve a company's public opinion without the implementation of concrete activities (Greenwashing[34]). In addition, metrics and indicators within each of the three dimensions of sustainability have already been created and used but a system that guarantees transdisciplinarity has not yet been defined. We have not arrived at a system of indicators and metrics that integrate those already existing in the various dimensions and create new metrics that facilitate systemic and complete multidisciplinary communication and thinking (Tanzil and Beloff, 2006).

Then we observe the measurement of sustainability according to the Triple Bottom Line criterion, dividing the KPIs by the three different dimensions linked to it.

2.3.2 Environmental KPIs

The environmental part is the fundamental part of sustainability. It concerns the protection of biodiversity and the environment; it considers the use of natural resources, the reduction of non-renewable resources and natural degradation. Attention to this dimension was initially guided by the regulations imposed at national and international level, but only recently companies have been showing a more concrete and rational commitment. With the stipulation of the SDGs, the objectives that should guide environmental strategies and which must be measured through the use of KPIs were defined. Furthermore, the ISO certifications, in particular ISO 14000, have contributed in a fundamental way to the development of systems for measuring environmental performance. The most relevant issues are the reduction of CO2 and greenhouse gas emissions, waste treatment, air quality and biodiversity degradation. Hristov and Chirico (2019) identifie the environmental KPIs that have the greatest impact on the creation of value in the following strategic issues: gas emissions, renewable resources, consumption of resources and waste. These issues allow to monitor and act to ensure a future based on safe, accessible and low climate impact energy. Environmental performance has a significant impact on corporate performance as a reduction in environmental impacts

[34] Communication strategy aimed at supporting and enhancing the environmental strategy of the company through casual use of references to the environment in institutional and product communication, not supported by real and credible results in terms of improving the production processes adopted or the products manufactured.

translates into optimization in the use of raw materials, energy and water, prevention of sanctions and maintenance of reputation (Delai and Takahashi, 2011). The environmental dimension is mainly measured by the impacts that activity, process, production phase has on the environment, "*but within corporate sustainability strategies the focus has to be laid on the effects causing these impacts, e.g., the higher the maturity levels are the more it has to be concentrated on causes rather than on effects*" (Baumgartner and Ebner, 2010).

2.3.3 Social KPIs

It is essential to include the social part in the value creation process through the use of indicators and objectives. Baumgartner and Ebner (2010) define social dimension as "*the consciousness of responsibility for its own actions as well as an authentic and credible commitment (mostly long term) in all business activities and more aiming to stay successfully in the market for a long time. Social sustainability is aimed to positively influence all present and future relationships with stakeholders. Furthermore, the fulfilment of their needs is focused on for assuring stakeholder's loyalty for the company*"

It takes into account the well-being of citizens, the community in which the company operates and the working environment. In particular, there is much evidence in the literature of the importance of using social indicators. Hristov and Chirico (2019) expose the importance of social indicators associated with the management of social resources and human rights, the quality and safety of the workplace, the time dedicated to initiatives and the attention paid to the community. However, it must be emphasized that measuring and evaluating social factors is very difficult due to the intrinsic characteristics of the data. They have more qualitative and less measurable characteristics, especially through standardized systems; think about the social contribution, the sensitization and the involvement of the community and the time dedicated to volunteering. If for environmental aspects there are already consolidated functions and databases for social aspects, the knowledge still presents many gaps. Only recently, thanks to the relevance given by the indicators developed by the GRI, companies have better understood what and how to monitor and evaluate this aspect of sustainability. GRI defines the social dimension of sustainability as the impacts on the social system in which a company operates and on all its stakeholders. These indicators are divided into several topics concerning corporate practices that have both internal and external impacts. Management systems are analysed and measured, such as the organizational structure, the management of social policies, the codes and ethical standards both internally and for the selection of suppliers, workers' rights, discrimination and gender diversity, anti-corruption and controversial activities.

2.3.4 Economic KPI

The economic dimension assesses short- and long-term value generation by a company and its relationship with shareholders. It is related with the long-term sustainability of an organization (Delai and Takahashi, 2011).

The economic aspects, which have always been at the centre of companies' attention, boast already well established and used economic indicators (Revenues, ROI, EBITDA, Cash Flow, etc.). Economic KPIs represent the typical decision-making tool of any company since they allow the measurement of performance concerning purely economic targets and the value generated. In general, most of the traditional indicators and economic information are reported on the company balance sheet. Today it is no longer enough to focus on indicators that show only financial results, they do not reflect sustainable performance and future growth (Rezaee, Z. and Rezaee, H., 2014). Indeed, in recent years, with the spread of the idea that economic growth and development[35] are detached concepts, reference is increasingly made to economic indicators that also take into account the other aspects of sustainability. Economic sustainability must be understood as a capacity for continuous development and must include social and environmental aspects to ensure long-term success. It is, therefore, necessary to establish a relationship between economic performance and social and environmental impact, trying to attribute a monetary value to direct and indirect impacts (Rodrigues et al., 2016).

[35] Development implies lasting growth over time, capable of generating income and employment and supporting the community, enhancing its uniqueness and efficiently managing resources.

For example, by measuring the benefits and revenues deriving from the application of sustainable practices, evaluating the return on investments made on these issues and, more generally, trying to combine profit, as a fundamental element of the company core, with aspects that could seem distant, but which in reality can represent a fundamental driver for the company's long-term successes.

Table 1. Sustainability KPI. Source: own elaboration from Hristov and Chirico (2019)

ENVIRONMENTAL	- Emission of ozone-depleting substance rate - Emission of greenhouse gases rate - % Of emission other environmentally affecting gases - Carbon footprint - Sulphur dioxides - Nitrogen oxides	- % Of waste generated per thousand product units - Dangerous waste generated rate - % Of hazardous material over total waste - % Of reusable/recycled material - % Of waste recycled off/on site - Waste reduction rate - % Of waste reused off/on site - % Of pollution indicators	- Energy intensity (energy used per thousand product units) - Electricity consumption (total consumption per thousand products) - Gas consumption rate - Soil use rate - Water use rate	- Renewable energy rate - Reusable/recycled material rate - Renewable energy rate - Renewable electric source rate - Sustainable water use rate
goals	***To reduce gas emissions***	***To improve the use of renewable***	***To reduce natural resources consumption***	***To reduce waste and to improve the efforts to address "green-ness"***
SOCIAL	- Employee satisfaction rate - Employee turnover rate - Number of trainings hours per employee - Rate of employees that are shareholders - Support employee rate (physical activity, health care and medicine)	- Employment rate - Internal relation rate - Health and safety rate - Training rate - Diversity rate - Opportunity rate - Employee satisfaction rate	- Equality rate (male to female rate) - Child labour rate - Forced labour rate - Number of disciplinary actions - Social security rate	- Charity donations rate (community rate) - Number of social initiatives at national and local level - Expenses for social initiatives - % Of participants in social initiatives - Consumer, supplier and employees' safety rate
goals	***Employees' acceptance of organizational change***	***To guarantee the quality of environmental and work condition***	***To guarantee the respect of the human rights***	***To participate at the social initiative and to maintain a high level of responsibility***
ECONOMIC	- Cost of ownership linked to energy, cost consumption, environmental tax - Growth of gross margin - Total of costs and investments relating to environmental protection - Environmental costs savings - Amount of environmental penalties	- % Of additional revenue - % Of additional price premium brand differentiation - % Of income from recycling/close loop programs - Sustainable innovation rate	- Investments in technology rate - Environmental technology levels - % Of new environmentally sound product development - Response to environmental product requests rate - Response to environmental programs rate - Amount of environmentally safe alternatives	- % Of production sites with environmental certification (ISO 9001, ISO 14001, ISO 5001, UNE 166002 and OHSAS 18001) - Environmental information accuracy rate - Environmental information availability rate - Supplier rejection rate
goals	***To increase return of investments***	***To increase the revenues associated to sustainability dimensions***	***To enhance technology process***	***To guarantee quality of the process***

2.3.5 KPIs and Agri-food

For years, the literature[36] has tried to understand what are the reasons why farm results differ and what are the factors that determine their success.

Size, production methodology, mechanization and innovation have an impact on farming results.

The relationship between KPIs and agriculture is at the centre of a vivid debate: for years the KPI proposed approach was better aligned to the principles of modern industry management, rather than agribusiness. However, changes occurring in the farming industry have improved companies' sensitiveness to market dynamics and trend. The growing pressure of production costs, the growing global competitiveness, the present and future challenges of the sector, have fostered the attention for efficacy in cost management and strategies that could improve profits and performances. This is possible only by combining productivity and impacts on the environment and society and reversing the course of what literature calls the 'productivist'[37] model (Jia, 2021).

Given the scenario, KPI approach got a diffusion among companies, although smaller companies might have cultural difficulties in introducing such a type of evaluation and monitoring process. Indeed, this has not yet been homogeneously received by the sector, indeed the virtuous examples that have assimilated these 'modern' management characteristics are few and limited to large cases. Primarily due to the lack of a common standard that defines how to measure and evaluate the performances and the sustainability of the companies that identify these companies (van der Vorst et al., 2013). From this derives the enormous breadth of indicators that can be used by farms that do not help them. Companies must be able to choose the most significant indicators. Given the characteristics of the sector, this is not always possible, both because there is a lack of managerial bases to identify the most suitable indicators, and because of the costs in terms of time and money. For this reason, only the major players in the sector can afford to study and identify indicators that correctly evaluate their performance and help them in decision-making processes. Often as stated by Santiago-Brown et al. (2015) "*indicators*

[36] Fox, G., P.A. Bergen & E. Dickson 1993. Why are some farms more successful than others? In: Hallam, A.: Size, Structure, and the Changing Face of American Agriculture. *Westview Press*. Colorado.

[37] System failure for intensifying input use and promoting excessive dependence on trade

used to assess sustainability are often selected to validate the scope determined by the proponents of the assessment, and biased selection can compromise assessment validity and reduce comparability and challenge the notion of accountability. Consequently, because the scope of the sustainability concept defines sustainability assessments, assessment methods are often not directly comparable."

It is therefore clear the importance of correctly using KPIs to measure the status of individual companies, the impacts that their decisions and practices have in economic, environmental and social terms and quantifying them in economic terms. Measuring performance is essential in the decision-making process to align activities with the individual objectives defined by the company. Indicators, metrics and models are necessary to abandon unsustainable practices deriving from the production, processing and consumption of agri-food products (Santiago-Brown et al., 2015).

Furthermore, the literature highlights how the characteristics of the sector lead to the need to create a supply chain that allows food products to arrive from farm to fork as efficiently as possible under the three dimensions of sustainability. To do this "*a lot of effort has to be put in the development of a shared language, shared objectives, shared KPIs, etc. A well-defined set of chain performance indicators will help establish benchmarks and assess changes over time; but only when all stages in the supply chain aim to realize the same jointly defined objectives*" (Van Der Vorst, 2005).

In particular, it is necessary to promote and implement this new type of business management in the lower part of the sector. The tools and the knowledge are often lacking for farmers to implement such management. For small businesses, it is no longer possible to rely on a simple cost-revenue analysis.

Through active monitoring with KPIs, it is possible to understand if there is something wrong with one's agricultural management and to change it. The more factors are analysed and monitored, the more the possibilities for intervention are numerous and effective. In addition, time is fundamental in agriculture and through the KPIs it is possible to efficiently schedule the activities to be carried out, to understand when is the most appropriate time to carry them out and where to direct the use of resources so that they give the most profitable results. Having clear the reality of the factors that influence the results and performance of the company allows making more informed choices based on evidence and concrete data. This limits the use of approximate thoughts and judgments that are not based on evidence.

Furthermore, the indicators are the basis of the policies and guidelines proposed by governments, organizations and sustainability programs. They are used to create benchmarks for companies, to obtain certifications and to establish development goals at a local, regional or national level.

2.4 Smart Farming and Performances

Having to feed ten billion people over the next 40 years meets the definition of a wicked problem. Agri-food is led to obtaining short-term revenues causing significant impacts on society and the environment (Connolly A.J. and Connolly K., 2012). According to Lyons (2012): "*We in agriculture must think differently from how we have in the past, by adopting new technology at a faster pace and communicating in a way we never have before. We must find the balance for sustainable food production and protection of resources while satisfying consumer demands*."

Smart Farming goes in this precise direction, combining the need to provide food access to people and preserve the planet.

Smart Farming is becoming leverage for agricultural development: in particular Smart Farming has been, in the past, crucial for improving productivity in intensive agricultural systems (Hammond et al., 2017).

Through Smart Farming, data guides the business management activities allowing to act with awareness of the context and the situation and above all allowing changes in real-time. The data collected is used to understand past actions and plan future ones, following a timely and accurate decision-making process.

Research and policymakers identify Smart Farming as a solution to the problems of traditional agriculture. It has positive influences both from a societal point of view, for example by allowing the provenance and transparent traceability of food, and towards the environment, taking into account animal welfare and the environmental impacts of agricultural practices (Busse et al., 2015) (Wolfert et al., 2017).

Eastwood et al. (2016) state that Smart Farming will allow for more data-based and less practice-based management of agricultural practices, thus redefining traditional practices. All agricultural development trajectories, from intensive to organic, will have to consider and integrate Smart Farming practices to face the future challenges of the sector. Smart farming can play a significant role in improving firms' overall sustainability (Knierim et al., 2019)

It guarantees greater productive and qualitative efficiency, reduction of company costs, optimization of inputs and minimization of environmental impacts, creation of job opportunities for specialized personnel. In this way it improves the economic performance of the company by reducing costs; advanced management and timely intervention skills thanks to constant monitoring through forecasting models. It also reduces the environmental impact by making the use of raw materials, such as water and soil, pesticides and fertilizers more efficient. It, therefore, allows preserving the soil, the aquifers and biodiversity while maintaining high productivity levels.

Given that the primary sector is one of the economic sectors that most contributes to greenhouse gas emissions, Balafoutis et al. (2017) examine the impact on productivity and performance deriving from the current trend of reducing emissions to stop climate change. In particular, it takes into consideration Precision Farming practices by observing how these have the ability to reduce GHG emissions on the one hand and positively impact productivity on the other. Precision agriculture makes it possible to reduce GHG emissions through the reduction and efficient use of pesticides and natural resources, the reduction of operations in the field using machinery (reduction of the necessary fuel) and the conservation of the soil, used also as a carbon reserve. It also improves profitability and business performance thanks to a reduction in costs associated with a greater or equal yield of crops. Responding to the challenge of food safety and security.

Dang et al. (2020) notes how in rural contexts, where the adoption of technologies is much more difficult, small farmers who manage to incorporate Smart Farming practices enjoy benefits; bringing out social and economic benefits also for the entire population.

There is a widespread perception of the importance of Smart Farming and Precision Agriculture in the management and activities of farms. However, there is no lack of criticism of the implementation of Smart Farming. This is above all due to the cultural change that will ensue along with the agricultural sector. Company management will be remodelled according to a more structured and controlled concept, creating conflict with the traditionalist characteristics typical of the agricultural sector (Eastwood et al., 2019). It is, therefore, necessary to develop solutions that have the right compromise between technology and tradition. Combining it with a gradual integration of technology, especially in more rural contexts, allows the farmer to develop the new and different skills necessary to use Smart Farming. The study by Knierim et al. (2019) show how farmers view the use of Smart Farming positively but encounter barriers in implementation. While Balafoutis et al. (2017) note that many farmers do not have a clear idea about the benefits generated by Precision Agriculture.

The lack of skills and the difficulty in understanding the positive outcomes of Smart Farming in business performance are the barriers to be overcome to ensure homogeneous adoption and future success for all types of farms. In this context, the support of institutions and organizations that structure incentive programs and suitable advice is essential, which encourage the adoption of technologies by small farmers, who make up the majority of farms in the agricultural sector (De Schutter, 2011).

In general, a system based on the evaluation of the use of resources, production and related costs is used to measure performance in agriculture. Therefore, use a simple cost-benefit approach for evaluating the effectiveness of your strategy.

It is appropriate to go back to the use of KPIs when evaluating the effectiveness of Smart Farming or Precision Agriculture practices adopted by a firm. The development of a system of indicators to assess the impact of Smart Farming in the sector is a particularly complex issue.

It is often difficult to obtain the information necessary to obtain efficient indicators, especially in small companies. There is no historical data or alternative data that allow a correct analysis. In these situations, it is very difficult to value the social dimension of sustainability; the creation and quantification of social value for stakeholders are complex and does not require the application of standardized procedures. In this way, it is not possible to compare the results with other companies and concerning specific objectives. Furthermore, in contexts where yield ceilings are imposed, the measurement of performance cannot be linked to quantities of productivity (for example the specifications drawn up by producer consortia).

Having said this, therefore, in the definition of KPIs in the agricultural sector it is necessary to have a flexible approach that takes into account the production characteristics of the supply chain and the individual company. In this case, it is necessary to study the context, the market and the causes that influence the changes. Furthermore, it is necessary to structure the KPIs to ensure correct interpretation and correct use by the agricultural entrepreneur. It is, therefore, necessary to carry out a personalization of the KPIs based on the company characteristics and its actors. Finally, the characteristics of each supply chain in the sector must be taken into consideration.

Chapter 3. Siena Food Lab case

3.1 Project Framework

The Siena Food Lab project was born in the Tuscan context, in particular, the province of Siena to foster a dialogue on adoption of innovation in agri-food sector, in particular Precision Agriculture, between the various stakeholders who work in it.

The agri-food sector, characterised by quality productions, has always represented an important heritage for Tuscany which is one of the Italian regions with the highest number of DOP, IGP and STG certified products (68 DOP, 21 IGP and 3 STG[38]).

In the agri-food sector, Tuscany ranks fifth in terms of economic impact on the national territory of quality products (IG[39]) with a value of 1.1 billion euros. In particular, the province of Siena is in first place in Tuscany for the wine sector (508 million euros) and in second place for the food sector (33 million euros[40]).

These data underline how the traditional rural environment is a strong point of the Siena's territory, perceived as a place characterized by natural and cultural resources that over time has further increased the level of reputation of the products, the impact of the agri-food and agrotourism sector of the province.

Taking into consideration the number of farms in Tuscany, as can be seen in Appendix 3.1, about 43,000 agri-food companies are employing just over 91,000 workers. In the province of Siena, there are 5,756 agri-food companies (about 20% of total companies of province of Siena) and 15,206 employees (13% of total employees). Most of the companies and employees are concentrated in the agricultural cultivation part, highlighting how the province is concentrated on the primary activities of the sector. In particular, the supply chains that most characterize the province of Siena are the cereals, grapes and olives productions. Examining the quantities produced, it is observed that

[38] Rapporto Ismea - Qualivita sulle produzioni agroalimentari e vitivinicole italiane dop, igp e stg, 2021
[39] IG means "*identificazione geografica*" and denotes products that have a specific link with the production place. The "IG" denomination allows consumers to have confidence and to distinguish quality products. At the same time, it helps manufacturers to better market their products.
[40] Rapporto Ismea - Qualivita sulle produzioni agroalimentari e vitivinicole italiane dop, igp e stg, 2021

Siena covers a significant share, especially in the production of grapes, for the production of wine: almost 25% of regional production and about 2% of national production. The same incidence is also found at the level of hectares of surface used which represent almost 3% of the total national area devoted to wine grapes[41]. Concerning cereals, the most significant productions in the province of Siena are those of durum and common wheat; and the total quantity of cereals produced is 28% of regional production. For a complete overview of cereal production, see Appendix 3.3. Finally, as regards the olive oil companies, it is noted that these are numerically significantly smaller and characterized by fragmented productions and poor market orientation, but that they represent a significant part of regional production (about 18%).[42]

In summary, it emerges that the province of Siena is characterized by a broad agricultural vocation, involving about 13% of workers at the provincial level in activities related to the agri-food sphere, and which stands out for the quality of its production. Although most of the farms are concentrated in the production of cereals (40%), the grape sector is the one that involves the highest number of employees. Finally, we have to underline the number of employees per company, which also defines its size: 60% of companies have only one employee and 29% have between 2 and 5 employees. Over half of the agri-food companies that present data on the value of production produce less than 250,000 euros per year. Therefore, it emerges that the size of the farms in the province of Siena is on average small. Furthermore, there is a complete lack of data on the level of technology and innovation of agri-food companies, as well as on their level of sustainability, especially in the provincial context.

Based on this socio-economic framework, the Siena Food Lab project focuses on the use of new approaches capable to promote the transfer of innovation to the agri-food system of SMEs in the area according to the "*quadruple helix*" model through interaction between the world of research, organizations and institutions, companies and local communities for the co-creation of value and sustainable development from an economic, social and environmental point of view. This is also in consideration of what emerged in the previous Chapters regarding the role of Precision Agriculture in the greening of agriculture and the

[41] See Appendix 3.2

[42] Data presented in this paragraph are extracted from documents developed, in 2021, together with the Monte Dei Paschi Foundation based on ISTAT Reports and thanks to access to the StockView service of the Business Register of the Chamber of Commerce, Industry, Crafts and Agriculture.

conservation of resources as well as in the competitiveness of the farms.

The Siena Food Lab is a technology transfer project in the agri-food sector that was born in 2020 thanks to the collaboration between the Santa Chiara Lab research centre of the University of Siena and the Monte dei Paschi di Siena Foundation which financed it. It takes place over two years with the main objective of stimulating the adoption of technological innovations to address the traditional challenges of the agri-food sector increasingly linked to social and environmental sustainability issues as well as post-Covid ones. In this way, it wants to limit the barriers in the application of innovations in the agri-food sector such as resistance to change, the lack of training and information, the poor exchange of knowledge between companies and the wrong perception of the effectiveness of innovation. Siena Food Lab also aims to spread an entrepreneurial culture oriented towards technological, organizational and social innovation that is in line with the new needs of markets and consumers.

To do this, it is essential to understand how companies perceive these issues, promoting a debate that helps to understand how the introduction of innovative solutions within the company can help its performance by improving its social and sustainable orientation. It is essential to expand the opportunities of small companies of the province of Siena by improving the adoption of technologies available on the market and increasing their awareness of the SDGs and sustainable objectives. Given the characteristics of the local companies linked to the particular attention to quality production, it is necessary to integrate the innovations with the traditional factors of quality, typicality, origin, and connection with the territory. Therefore, to combine the agronomic knowledge inherent in agricultural production systems with modern technological and social skills that develop new business models to support supply chains and agri-food systems.

The project also tries to create multi-stakeholder cooperation, first between the companies themselves and then with the institutions and research that gives relevance and visibility to good practices and innovations.

Finally, the project aims to create involvement of the new generations through the activation of training internships that stimulate collaboration with the actors of the agri-food chain and the acquisition of training and professional experiences.

To achieve the objectives set, the project is divided into three different types of activities:

1) Technology transfer: Precision Agriculture and Agriculture 4.0 services are provided through two technical partners to farms in the province of Siena. In particular, 60 companies operating in the wine, cereal and olive oil sector were selected as the three sectors represent a significant share of agricultural production in the province of Siena and are strategic for local development. During the second year, the number of companies will be expanded. Thanks to the project's technical partners, companies will be able to map fields, collect and share data and information, use forecast models, prescription maps and vegetation indices, also through the installation of agro-meteorological stations.
2) Siena Food Lab Academy: a series of meetings are organized to increase the skills of students, entrepreneurs, agronomists, agricultural experts, agro-technicians and other professionals in the sector to integrate their knowledge with innovative tools and regarding the principles of environmental and social sustainability without neglecting the profitability of the operators. This activity has the pivotal role of disseminating and exchanging knowledge between the various actors involved in the project, stimulating a debate on the relationships between technologies, Smart Farming, sustainability and SDGs.
3) Training internships: training internships will be activated for university students and upper secondary school students to allow the new generations to gain work experience in the companies involved to guarantee future highly professional figures in the agri-food industry. They can put into practice what they have learned thanks to the notions of their study course and in the meetings promoted by the Santa Chiara Lab. They also are intermediaries between companies and technology providers by providing support in the implementation of Precision Farming practices and the collection of necessary data.

As mentioned before, the project is structured following the "*quadruple helix*" model involving various actors and institutions.

First of all, the University of Siena which, through the Santa Chiara Lab, represents the academic environment in which dialogue and a meeting point are established between the various interested parties on issues relating to Precision Agriculture and other innovative solutions to be applied to the agricultural sector. Moreover, thanks to its excellence in the field of research, it highlights the scientific evidence that supports and motivates the implementation of project's activities by evaluating their effects and impacts on business performance.

The project was made possible thanks to the Monte Dei Paschi Foundation, which is a non-profit organization operating in the province of Siena and which finances and monitors the project.

The two technological partners: AGRICOLUS and IBF Servizi. The first "*is an innovative start-up, founded in Perugia, that develops solutions for Agriculture 4.0. It aims to support farms and professionals in simplifying and enhancing work in the field*."[43] The other is a "*partnership between ISMEA, a public company, and Bonifiche Ferraresi, the largest agricultural enterprise in Italy. Its strategic objective is to improve the competitiveness of Italian agriculture, by increasing quality, reducing costs and minimizing environmental impacts. Above all, it is one of the first companies to supply precision agricultural services, by making these services available to farms of all sizes with transparency in the consultation's contracts and support in all phases of cultivation*."[44] The two providers give Precision Agriculture services to companies, through business programs designed according to the needs and structure of the companies. They actively follow the companies during the process of implementation and use of the technologies provided.

Students have the opportunity to live professional experiences in farm's environment involved in the project, coming into contact with the world of work and acquiring concrete skills and knowledge to be included in their cultural background. They also be able to make their knowledge acquired in the academic world available to the companies themselves, and support them in the use of the new innovative solutions provided by the project.

Farms and farmers as end-users of the technologies provided are at the centre of the project and the analyses related to it. They will have specific equipment available for monitoring activities and collecting data and information on crops, water management, pesticides and fertilizers, soil management and erosion. The impacts that Precision Agriculture practices have on farms will be periodically analysed, to understand the advantages and problems related to the application. While farmers' associations are stakeholders that can support the adoption of Smart Farming and can have an active role

[43] https://www.agricolus.com/ Last access on 28/02/2022
[44] https://www.ibfservizi.it/ Last access on 28/02/2022

in the ongoing debate for reinforcing awareness towards technological development.

Finally, the audience of people who attend the Academy's lessons, which will involve professionals from the sector and who will contribute to broadening knowledge by providing a means of dialogue and exchange of views between the participants.

In light of what Galan-Muros and Davey (2019) examined regarding the exchange of benefits between the different actors involved, in particular between universities and companies regarding the support in the implementation of innovations and consequent results, the project has created a system of relations between the various actors. This system defines, as shown in figure 1, how the actors interact during the project. Universities and companies exchange knowledge and needs that bring out possible fields of application and provide practical evidence on the results. Students trained by the University have the opportunity to deal with the business reality and in turn to support companies, further acting as a link between universities and companies.

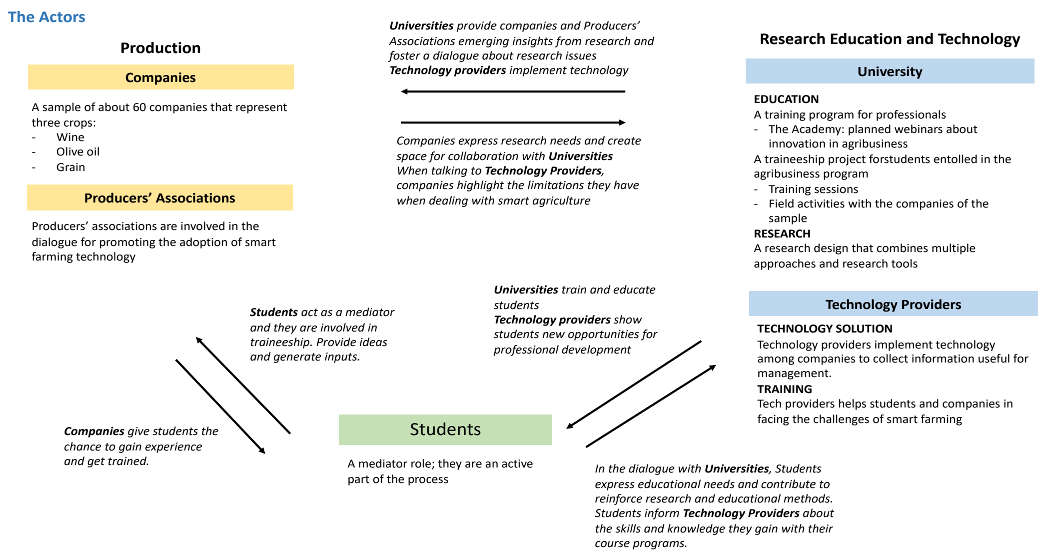

Figure 5. Project system of relationships. Source: own elaboration.

The scope of the SFL project is to generate value for the local community and to study and test the impacts that Precision Agriculture has on the farms. In particular, it aims to generate value in many aspects. Primarily the economic value, thanks to the implementation of innovation-oriented strategies, companies will be able to grow and obtain better profitability in the medium-long term. It also wants to enhance business processes which, with the introduction of innovations, have to be reorganized, improving efficiency. Further thanks to innovations, the perceived quality of the product by the customer increase, allowing a differentiation in the market. Finally, it enhances and encourages the dissemination of the culture of innovation by promoting the development of new skills capable of responding and dealing with changes.

So, SFL promotes the creation of an ecosystem of innovation and sustainability consisting of multiple actors, good practices, tools and methodologies that guarantee not only high levels of sustainability of companies and territory, but also returns in terms of profitability, productivity and competitiveness of the companies themselves, favouring employment growth in the area.

3.2 Methodology

The research on the Siena Food Lab aims to evaluate and study the activities pursued for introducing innovations to farms in the province of Siena. Therefore, as previously mentioned, in conducting this research we had to examine many different elements: companies, technological solutions, facilitators.

The methodology includes a phase of desk research and a phase of field research.

Desk research aimed to collect insights from literature review and to explore the following issues: the relationships between Smart Farming, competitiveness, profitability and sustainability. Furthermore, from the desk research it emerges an overview of the relationships between company structure and openness to adopt Smart Farming. Emerging insights are presented in chapters 1 and 2 and we can also find recalls in this Chapter. From desk research some outputs emerge: first of all, we have completed a list of KPIs that can be employed form measuring the impact of Precision Agriculture on companies. The definition of KPIs has been carried after an analysis of available technologies and solutions in the field of Smart Farming and, following the emerging insights from background literature, we have tailored KPIs according to the specific features of the three selected type of production (wine, olive oil and cereals). Secondly, we have created a survey that combines the features of the company (from size, type of production, dimensions, and so forth), the degree of integration of the company (number of phases internal to the company) and the type of innovative solutions in terms of Smart Farming that have been adopted by the companies.

Field research aimed to collect data through the administration of the proposed survey.

A representation of research phases and methodology is available on *figure 6*.

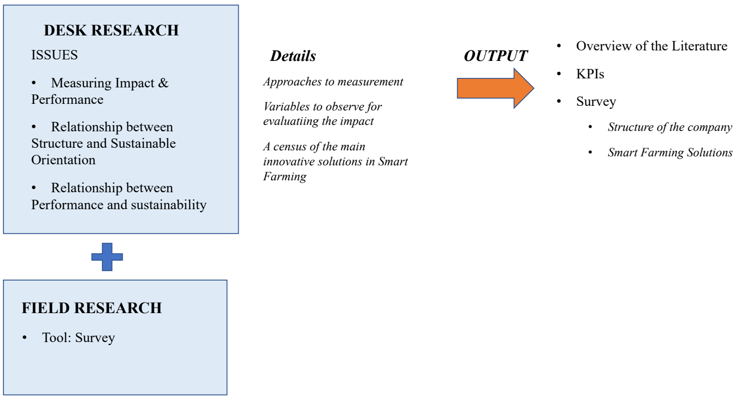

Figure 6. Research phases and Methodology. Source: own elaboration.

In carrying out this Thesis, the use of multiple case study was chosen. It was necessary to observe and evaluate through empirical data and analysis of the practice what was found in the literature regarding the implementation of innovative and sustainable practices and new technologies in farms and the possible effects.

In particular, contextual and company information was collected and analysed, as well as evidence from previous research results. Then, through a dialogue with experts and professionals in the sector, the fields of action were defined based on the needs of local companies. The goal of this research activity is to get a picture of the sample of companies and their peculiarities; define the degree of innovation adoption and evaluate the orientation towards the introduction of innovation.

Then, at the end of the two-year duration of the project an assessment will be made to establish how participating to the Siena Food Lab has changed the orientation and perception of Precision Agriculture and Smart Farming in general by companies. The sectors of interest have been selected based on their relevance in the territory. As it emerged in the previous paragraphs, the olive oil, wine and cereals supply chains are certainly the three main supply chains in Siena's territory, on which it was deemed necessary to apply and observe the effects of Precision Agriculture. The companies were selected through a call for applications with minimum requirements and evaluation criteria linked to company characteristics.

To collect information both on farms and entrepreneurs and on the practices adopted, a Survey was prepared through the Survey Monkey platform. This survey is the result of a dialogue between the researchers of the Santa Chiara Lab and professionals in the sector. It consists of about 20 questions and has been adapted to the three different sectors: olive oil, cereals and wine. It has been tested and evaluated both internally and externally thanks to the collaboration of the technological partners (Agricolus and IBF) and the involvement of some agricultural companies. The survey was carried out during the farms visits that were made in the period April-May 2021 and September-October 2021. These visits allowed the direct observation of the various farms' contexts and the acquisition of fundamental data and information useful for research and for the implementation of tailor-made Precision Agriculture services for each farm.

Thanks to these activities, an initial picture of the characteristics of the sample companies and their technological orientation were drawn.

Finally, as said before, with the contribution of agronomists and experts, a set of KPIs was identified and prepared to evaluate and measure the impact that Precision Agriculture practices have on the economic, sustainable and social performance of the farms. In this way, it will be possible to obtain field evidence on the real effects of these practices on the companies involved.

3.3 Analysis of the three sectors

3.3.1 Olive Oil Sector

Regarding the olive oil, eighteen farms provided their data through the Survey, out of the twenty-one[45] selected by the project, and were therefore subject to analysis.

The characteristics of the companies were first considered. Most (61%) of the farms interviewed are Ditta Individuale with some s.r.l (17%) and Società Agricola Semplice (22%), while there are no S.p.A, Consorzi or Società Cooperative. A company has not described its legal form (presumably, as it is connected to the Istituto Tecnico Agrario di Siena).

[45] Initially, the selection call selects twenty-one farms but it is possible to examine only eighteen. Three companies did not fill in the survey, one provides data on the wine sector of the farm and is included in the wine analysis and one that is selected in the call for cereals is inserted here since the olive part predominates.

The company size is generally small, with one exception (57 hectares). By removing this extreme value, we get an average of 9.2 hectares per farm.

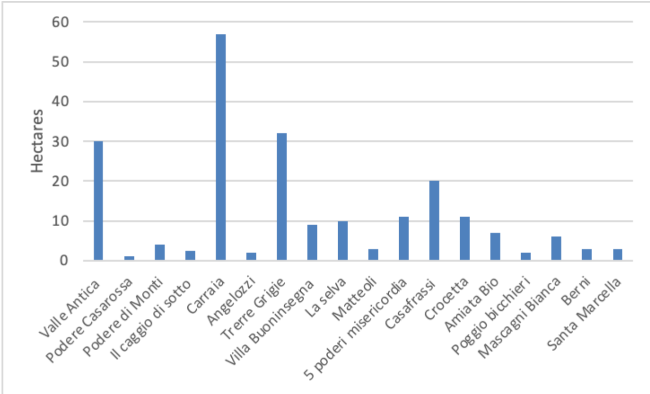

Figure 7. Farm dimension in hectares. Source: own elaboration.

By observing the sample examined, we note how, under the small size, farms opt for a unique production method, avoiding fragmenting production. In particular, 44% of farms cultivate olive trees according to the organic method, 39% use the conventional method and 11% have cultivations in conversion (from conventional to organic). A farm did not provide this information. There are no cases of use of the biodynamic method.

Another characteristic to analysis is revenue. Regarding this information, most of the farms either have no way of tracing the revenue (for example a specific company that sells olive oil only to volunteers who work during the harvest) or has no idea about the amount of revenues that are generated by the company or by the production of olive oil. In fact, many farms have other activities or crops more consistent than olive oil. This shows that company are not used, especially if they have a small size, to monitor their income flows and to define the source of their revenues: this situation limits the forecasting and monitoring capacity of companies.

We can say, that according to the collected data, companies are generally small, not exceeding € 20,000, except for one that has revenues of about € 400,000. This farm produces about 30,000 bottles a year in addition to the sale of olive oil in cans, thanks to the average annual production of about 1200 quintals of olives. This is the largest in the sample by extension, revenues and production. It should be specified that in smaller companies it is often difficult to establish the contribution of the single product to the realization of the revenues as there is no subdivision of the information by product category where the companies carry out more activities or crops.

To provide a complete analysis of the farms' size, the staff used is observed. Also, in this case, the size is extremely small. The number of people employed with a permanent contract does not exceed 3 units. Only four farms have from 4 to 7 permanent employees. A company only employs volunteers. It should be noted the low presence of women in this sector, only three farms have a female presence among employees. The largest farm by extension has a relatively low number of employees but makes use of a particularly high number of seasonal workers (from 20 to 30 seasonal employees) during the olive harvesting phases. Seasonal workers are a fundamental characteristic of the olive oil sector, there is a presence in more than half of the sample during the harvesting phases.

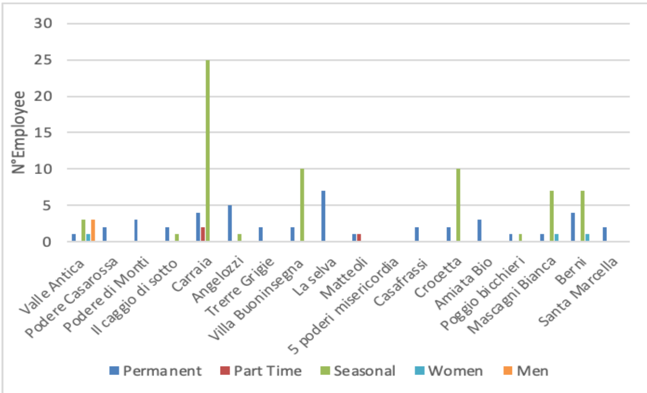

Figure 8. Number and type of employees for farm. Source: own elaboration

Finally, observing the age of the employees, this turns out to be high with an average of around 50 years.

Moving on to the analysis of the farms' production structure, the following characteristics are observed.

The farms in the sample mainly have ancient olive trees often recovered from trees that were damaged by the frosts that characterized 1985. This year was disastrous and 90% of the olive trees in Tuscany and central Italy, in general, were compromised. It was only partially possible to save the olive trees, by growing the suckers from the trees frost-dried. Sixteen farms have the oldest plants dating back to that period, only twelve have invested in new olive trees in the last 30 years. In particular, six farms have invested in the renovation of the trees in the last decade.

About the varieties observed, they are mainly those that characterize the Tuscan territory, namely the Leccino, the Moraiolo and the Frantoio. Only two farms have added new varieties: the Kalamata, a Greek variety, and the Arbequina varieties which have the characteristic of adapting well to intensive and super-intensive cultivation, guaranteeing good management of the tree growth and good yields. A farm cultivates the Olivastra Seggianese variety, native to Monte Amiata and not very common in the rest of Italy but with excellent quality.

As for the production phases covered by the farms, the situation that emerges is that of olive producers who hardly press the olives or bottle the olive oil. Very often they sell the product for direct sales. Only three farms cover all production stages, including pressing and bottling, and these correspond to the largest ones. In addition, smaller farms focus on self-consumption, often linked to the presence of agritourism activities.

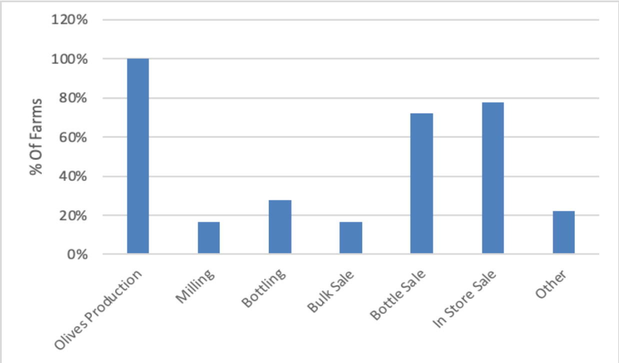

Figure 9. Of production stages covered by farms. Source: own elaboration.

Looking at the type of final product, we found that only a few farms (eight) use a DOP or IGP mark for their products. This choice appears to be typical of larger farms, those with small dimensions choose not to certify the DOP or IGP product.

Then the survey goes on to analyse the current state of adoption and the future technology orientation of farms. All the farms in the sample confirmed that they have a PC or a tablet available in the company and that they have adequate computer knowledge, but the equipment of cutting-edge technologies is currently very lacking.

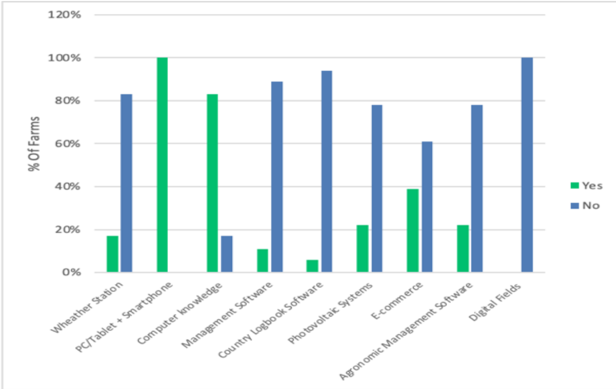

Figure 10. Present Technological Adoption. Source: own elaboration.

On the other hand, the answer "Don't know" referring to the future adoption of technological solutions suggests a favourable desire to turn towards a more technological dimension. In particular, the scarce use of software for management, for management of the country logbook and agronomic management is noted, resulting in the traditional management of company activities. Particular attention is paid to e-commerce which is present in only seven farms but which is in the plans of almost all farms. Also concerning photovoltaic systems and weather stations, the equipment is scarce (respectively four and three companies) but all are in favour of their installation, associated with economic possibilities.

Furthermore, there is an almost total lack of the possibility of using digital fields, but also in this case there is a willingness in future implementation.

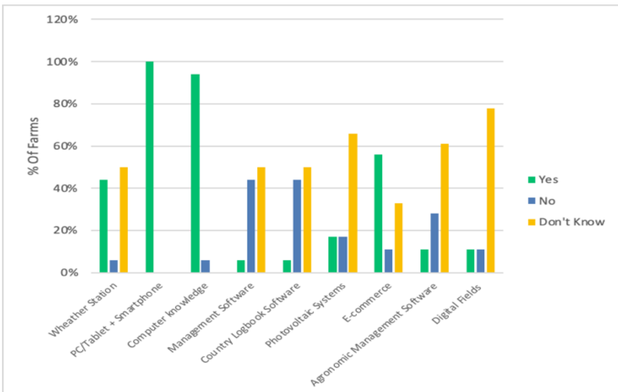

Figure 11. Future Technological orientation. Source: own elaboration.

To conclude the analysis of the technologies, the number of vehicles present in the company and their age is observed. On average, each farm has two agricultural vehicles for field activities. The farms with more machinery are those that have other activities in addition to the olive oil one. The average age of the vehicles is about 20 years, highlighting how the farms in the province have an obsolete fleet of machines, with a few exceptions of vehicles under 3 years old. Only seven farms have other vehicles than agricultural ones and there are no hybrid or electric ones.

Finally, we move on to examine the consumption of companies in terms of water, fuel and electricity. About water consumption, only two companies that have the mill for the olive pressing state that they do not waste water during this activity. One has a recovery system that allows the wastewater to be reused in biodigesters, the other recovers the water and reuses it as compost for nearby fields. The other farms do not measure water consumption, even if only two farms irrigate intensive crops. Fuel is the most measured element also thanks to the fact that farms execute annual fuel orders, and get an idea of their annual consumption. However, it should be noted that it is difficult to associate consumption exclusively with the part dedicated to olive oil. In most cases, consumption is considered as the total consumption of the farm, including other activities. Concerning electricity consumption, the majority have no idea what their consumption is. Only farms that have photovoltaic systems declare that they are self-sufficient and know the levels of consumption and production of electricity, but also in this case considering the total activities of the farm.

3.3.2 Cereals Sector

For the cereals sector, we carried out the analysis on a sample of fifteen[46] farms in the province of Siena.

In this sector, there is a prevalence of Società Semplice (%) followed by the Ditta Individuale (%) and the presence of an s.r.l. and an S.p.A.

The average size of the cereal farms in the sample is about 65 hectares, taking away the 480-hectare farm which has an extreme value. The hectares considered are the total

[46] Of the seventeen selected by the call, one company was included in the analysis of the olive oil sector and one in the wine ones as these were considered the main crops.

owned by the farms, which annually rotate crops and therefore allocate only a part of the total hectares to the sowing of cereals. They often alternate cereal, Egyptian clover and resting soil. Although the size is consistently larger than the sector examined previously, even the cereal companies are to be considered medium-small.

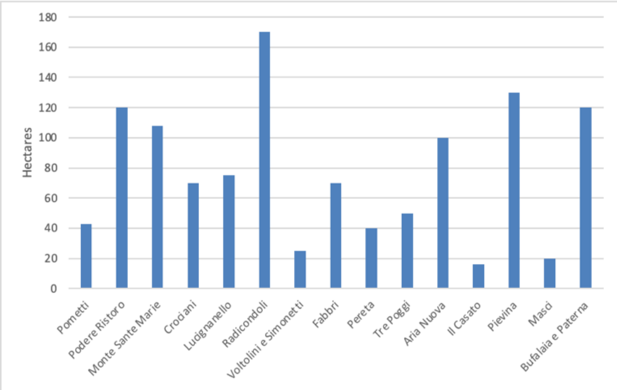

Figure 12. Farm dimension in hectares. Source: own elaboration.

Also observing the number of permanent employees, we note how the farms are on average managed by 2 people. Only one farm has 5 permanent employees and another makes use of some seasonal workers. It should be emphasized that three companies use subcontractors and therefore we do not know how many employees are used. No woman is present among the workers in the sector. In addition, the average age of the employees is about 45 years.

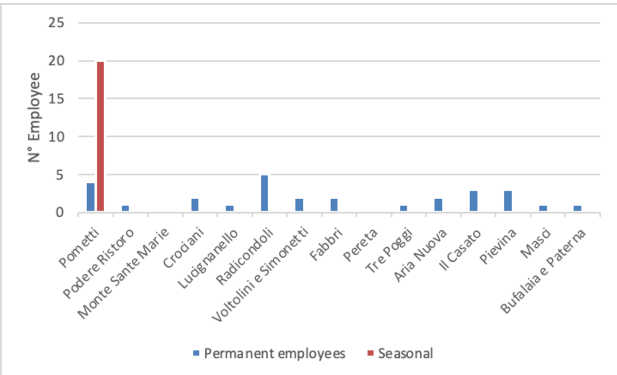

Figure 13. Number and type of employees for farm. Source: own elaboration.

Looking at the revenue, which in this case is more easily associated with individual crops, six companies do not provide this indication, while the average observed is approximately € 65,000 conditioned by the € 280,000 of the highest-revenue farm and € 8,000 of the one with the lowest.

By examining the production structure of the farms, we observe that the most widely cultivated cereal is wheat in the common and durum varieties (16%). Even ancient wheat, such as Verna, which require little treatment and processing, are particularly cultivated (11%). Followed by emmer (10%) and barley (5%). Instead, corn, sunflower, flax and oats are scarcely cultivated. The other crops used for the rotation of the fields are mainly clover (18%) (in particular the Egyptian one), alfalfa and broad beans, few companies use legumes such as chickpeas and lentils. Most farms (10) practice organic farming or are in the conversion period to organic, while the other five farms claim to adopt conventional farming. No farm fragments the type of production, only in two cases there is a part of the organic harvest still in the conversion period; fact due to the recent acquisition of additional portions of land not yet suitable for organic certification. In addition, nine farms certify their products with DOP or IGP to increase their value. From the yields point of view, most farms have an average crop yield of around 20 quintals per hectare. Yields are a complex issue. They change from area to area and from year to year, so the data provided refer to approximations made by farmers based on historical trends.

Regarding the production phases, only three farms rely completely on contractors for all agricultural activities. The other twelve cover all stages independently, from working the land to sowing and only seven harvests with their vehicles. Only few farms have the opportunity to keep the harvest on the farm and only one transforms and sells it directly to the end consumers. This is the case of a farm that has its brewery and that uses its crop to produce and sell beer; it is also the company with the highest revenues in the sample.

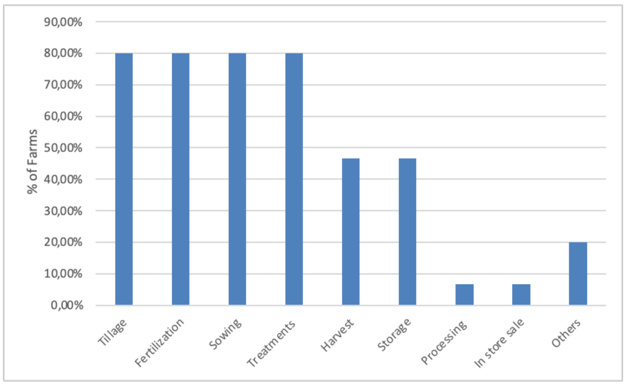

Figure 14. % Of production stages coverage. Source: own elaboration.

Moving on to analyse the degree of technological adoption and the orientation that farms have towards a more technological future, the great prevalence of negative responses to the presence of technological tools or innovative practices immediately stands out. All companies claim to have company PC and tablets and believe they have basic computer skills and knowledge.

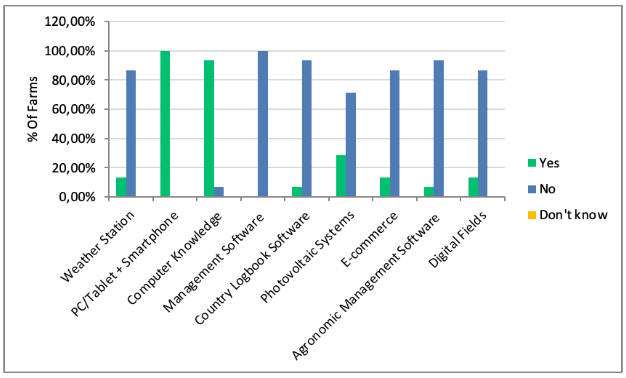

Figure 15. Present Technological Adoption. Source: own elaboration

The first impact of the analysis is certainly negative, but if we look at future intentions, we see a favourable propensity to implement technologies and new management systems. Only two farms have the weather station, but all are considering having it in the future. Two have the opportunity to consult digital fields and have set up an e-commerce service, even if the latter is linked to the presence of other types of products (think of the brewery). Only four farms have photovoltaic systems available.

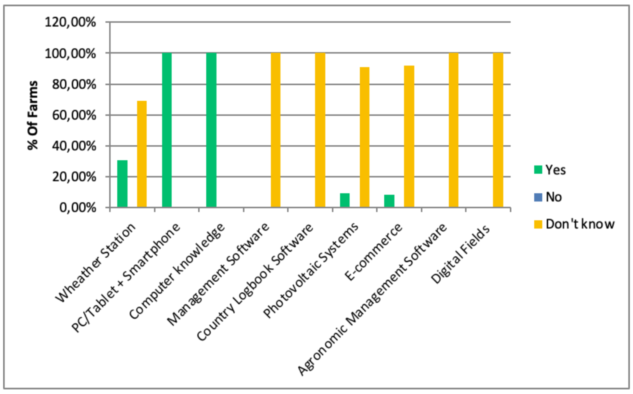

Figure 16. Future Technological orientation. Source: own elaboration

The field and managerial activities are carried out without using technology or innovative practices. For example, the monitoring activities follow processes linked to the tradition and experience of the farmer. Practically all farms claim that data collection in the field is done "by eye".

The agricultural machinery appears to be quite numerous, about four agricultural vehicles per far. We notice that most of the vehicles are old generation, having over 20 years, but almost all farms have invested in a new vehicle in the past 10 years. Furthermore, not all farms have other vehicles, and among those that have them, only one claims to have an electric/hybrid one.

Finally, by observing consumption, it can be seen that farms have the value of annual fuel consumption under control but do not have an idea of electricity consumption. Also, in this case, the fuel for agricultural machinery is ordered and stocked on an annual basis, and for this reason, the quantity consumed in the year is known. Only farms with photovoltaic systems claim to be independent of energy consumption and to sell quantities of electricity to energy providers. A farm is also completely dependent on using a fuel-powered electricity generator.

It was not relevant to ask companies for water consumption as the crop does not require irrigation, although it would have been interesting to observe such consumption in the case of product transformation, such as the case of the brewery.

3.3.3 Wine Sector

We examined twelve companies that belong to the wine sector through.[47]

The farms are mainly Ditta Individuale and three are Società Semplice; there are no other types of companies. The dimensions are not homogeneous: we find two companies much larger than the others, respectively 80 and 52 hectares, and smaller companies ranging from 4 to 8 hectares. The remaining farms' size is between 10 and 30 hectares.

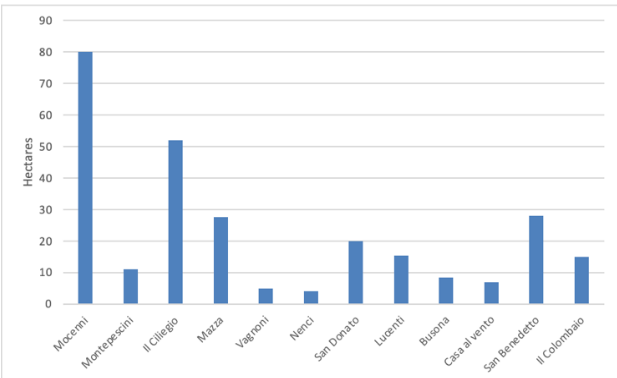

Figure 17. Farm dimension in hectares. Source: own elaboration.

[47] The call had selected twenty-three companies of which twelve did not provide answers to the survey, one was analysed in the olive sector as it was of greater interest, and two belonging to the other sectors were included in this analysis as mainly wine producers.

Also concerning revenues, there is a strong lack of homogeneity related to the different sizes of the wineries. Two farms make more than € 2.000.000, one is in the 1-2-million-euro range, the other six go from € 200,000 to € 500,000 and three invoices less than € 50,000. It should be noted that the company that makes more revenue does not correspond to the winery that produces the most bottles.

From employees' point of view, we note a strong presence of part-time and permanent workers, but there are many seasonal workers: Women are also heavily employed although the number of men remains predominant.

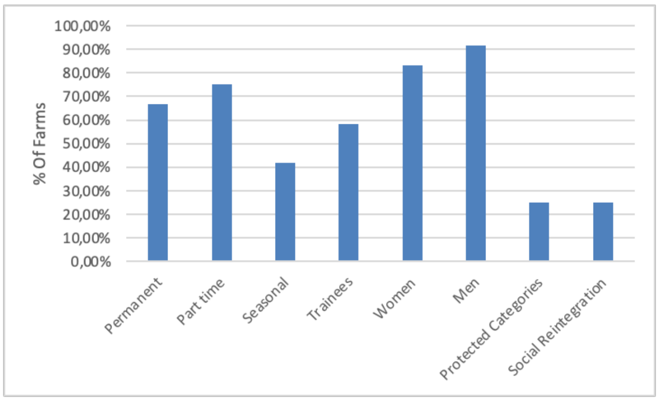

Figure 18. % Of farms by type of employee. Source: own elaboration.

The average age of the people employed in the companies in the sample reaches 42, highlighting the lack of young people in the sector. To underline the use of at least one trainee by six companies.

The production is characterized by strong use of the DOCG, DOC and IGT quality certifications as shown in the graph below.

The prevalence of cultivation methods is organic or in conversion, only three wineries use conventional methods and one company adopts integrated farming practices. The most used grape varieties are the typical Tuscan ones such as Sangiovese, Merlot, Canaiolo and Colorino.

Out of the twelve farms, only three produce grapes without making wine and bottling, they correspond to the companies with the lowest revenues or the smallest dimension.

The other nine farms cover all stages of production up to the sale of the bottled product in the company store and the sale of bulk wine.

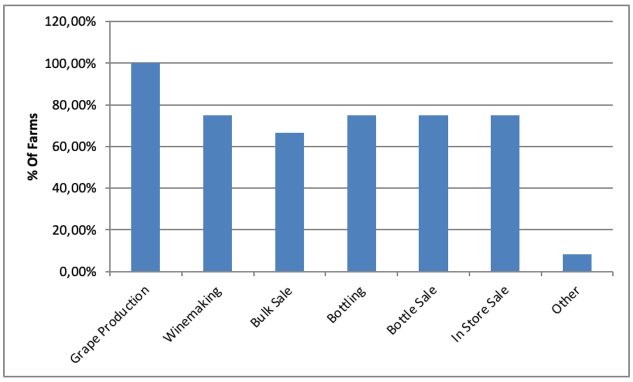

Figure 19. % Of production stages coverage. Source: own elaboration.

Moving on to the technological orientation of wineries, it is immediately evident how technology and innovations are already implemented in this sector. The answer "yes" is evident in the questions relating to the presence and future willingness to adopt technologies. Most farms rely on weather stations, software for business and agronomic management and have the digital version of their fields and vineyards available. Most of the farms (eight) have photovoltaic systems and have activated e-commerce services.

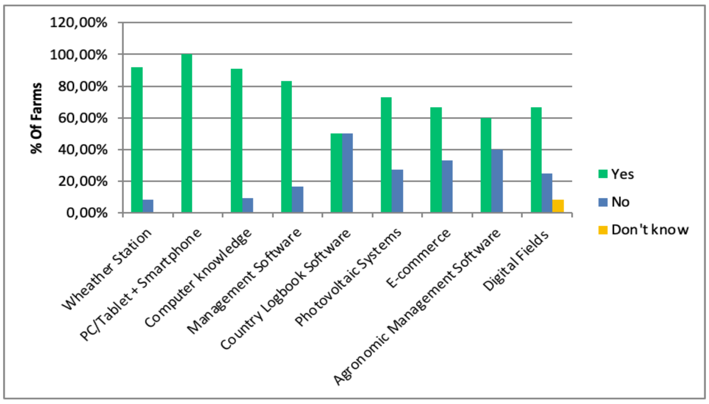

Figure 20. Present Technological Adoption. Source: own elaboration.

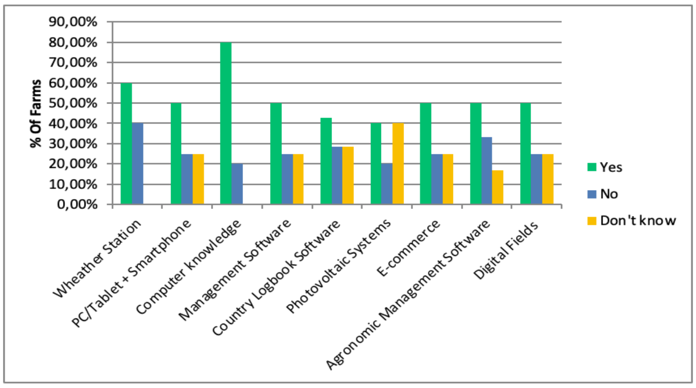

Figure 21. Future Technological orientation. Source: own elaboration

Field monitoring activities are carried out with the help of innovative systems as well as direct observation. Software and satellite images are often used, and soil sampling and chemical-physical analyses are carried out. Automatic traps are used for the capture and detection of possible pest attacks. Looking at the agricultural machinery, we note how numerous it is (forty-three) but relatively young (average of about 14 years, but with the presence of a company characterized by the presence of very old vehicles). We note that most wineries own at least one vehicle less than 10 years old. All but one of the farms have other means than agricultural ones, but none have purchased electric or hybrid vehicles.

Finally, speaking of consumption, no farms irrigate the vineyards,[48] and only two have implemented practices for the recovery and reuse of wastewater. Regarding fuel, the same goes for the other sectors, each company orders and stores the quantity of fuel annually. Only two companies take into account and report consumption and photovoltaic electricity production.

3.4 Results

After having described and analysed the collected data provided, we can provide an overview of results and evidence regarding the sample of farms in the province of Siena.

First of all, we observe how our sample of farms reflects the characteristics found in the

[48] Following the regulations governing the cultivation and production methods of certain wines. In particular, the vines used to produce Chianti cannot be irrigated.

context analysis, both at the local and national levels. The sample consists of small companies, especially in the cereal and olive sectors where few companies exceed €100.000 in revenues. In the case of wine, we observe more structured companies with much higher margins than the other two sectors. This is presumably due to the type of the product; in fact, the wine has greater success thanks to the tradition and quality that bind it to the territory of Siena (think about Chianti, Chianti Classico and Brunello). Instead, from the size point of view, we find a reasonably heterogeneous sample, with the cereals sector significantly increasing the average of hectares compared to the other two sectors. This fact is linked to the type of crops; cereals need more space to ensure a minimum economic return to companies. We also note that the least profitable sector is the olive oil one, which only in a few cases represents the companies' core business and which is often linked to the presence of other activities like the agritourism one. This situation is related to the fact that, in many cases, the agricultural entrepreneur is not aware of the revenues deriving from the olive part. Only a few companies decide to register the product with DOP or IGP brands; this further underlines the lower profitability of olive oil.

Furthermore, we note how farms that can cover all stages of the supply chain from the production of the raw material to the sale, particularly the possibility of autonomously transforming one's product, guarantees a higher level of profitability in all sectors. This is certainly evident in the wine sector, where those who only produce grapes without producing wine have much lower revenues. Even more evident is in the case of cereals, where the only company that directly transforms its product has a much higher income.

From the employment point of view, the company's size seems not to be influenced, as its composition is heterogeneous in all sectors. There is no clear link between farm size and the number of employees. In general, the sample comprises farms with an average of two permanent employees and is characterized by the use of numerous seasonal workers in sectors that have a seasonal nature in the collection of the product.

The survey then focuses on the degree of adoption and the orientation of farms to technology. The data analysis underlines how the degree of adoption of basic technologies, which can allow the correct implementation of Smart Farming, is very low. To analyse the adoption of technologies, we calculated the current adoption rate for companies in each sector. The same has been done for the willingness to adopt such technologies in the future (5 years). This value allows an immediate analysis, even visual, of the situation in which the companies in the sample find themselves. Figures analysing the current adoption and future orientation rate are shown in the Appendix 3.4 and 3.5.

Most of the farms declare that they do not currently have innovative tools for business management, agronomic management and that they often collect and analyse data "by eye." Only the wine sector is more technologically developed. Many wineries use software and tools such as weather stations for data collection, analysis and monitoring in their business activities. However, it is interesting to note that very few companies are opposed to adopting technologies in the company in the future, with the prevalence of "I don't know" and "yes" to the questions asked about future orientation. Furthermore, all the companies that have adopted a technology say they want to continue using it in the future as well.

However, concerning the vehicles present in the sample companies, we note that these are numerous but often very old, with an average of around 20 years. However, the purchase of a vehicle in recent years is widespread, presumably thanks to the incentives granted, such as Agriculture 4.0. The compatibility and predisposition of the new tractors with innovative and even more sustainable practices indicate well for a future-oriented towards technology and no longer characterized exclusively by eye measurements.

From the point of view of consumption, it is clear that farms only consider the fuel on, since it is ordered annually. Only a few farms quantify the energy consumed and/or produced in the case of possession of photovoltaic systems. Only four are committed to reusing wastewater from the processing of raw materials. These data find room for action to introduce sustainable practices in companies, especially when it comes to consumption, you need to have an idea of your own to be able to save in terms of inputs and money.

After extrapolating a complete picture of the farms' characteristics and situation, we analysed how these factors influence the degree of adoption of technologies and future orientation within the company.

A first analysis was carried out by aggregating the dimensional characteristics in terms of surfaces and revenues and their impact on the degree of technological adoption. The employees in the company were not taken into consideration as they cannot define company size in the sample. What derives from this analysis is shown in the figures below.

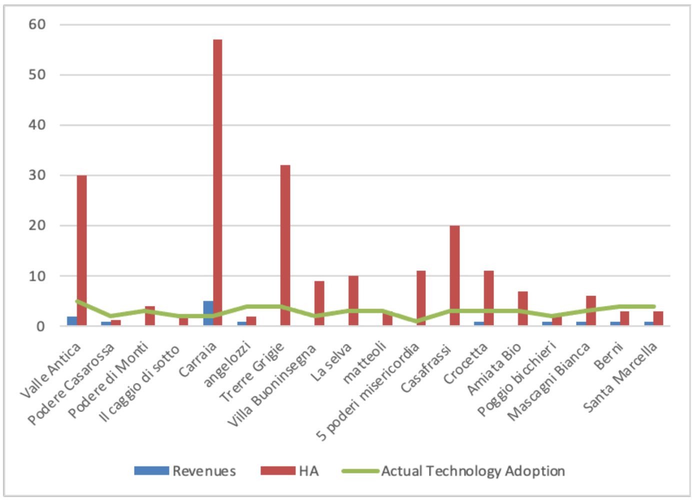

Figure 22. Size and Revenues on Technological Adoption in Olive Oil Sector. Source: own elaboration

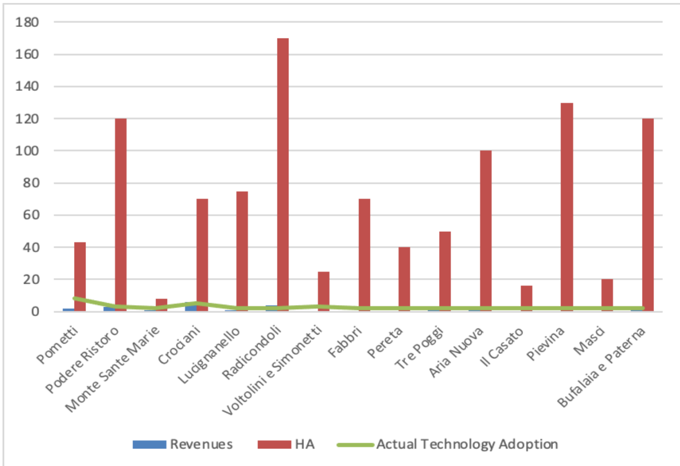

Figure 23. Size and Revenues on Technological Adoption in Cereals Sector. Source: own elaboration

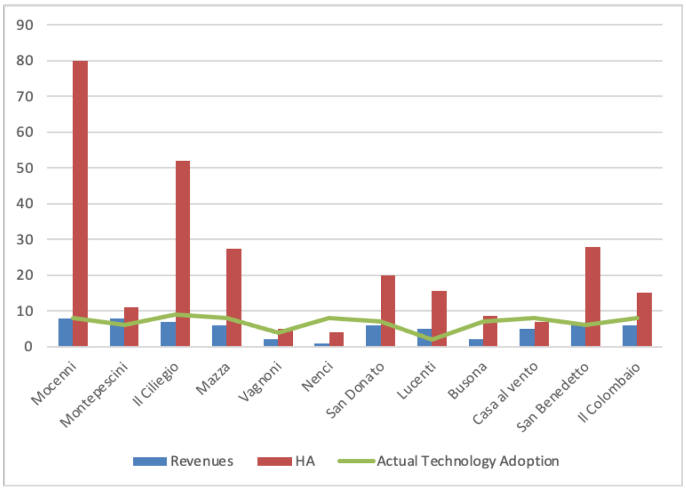

Figure 24. Size and Revenues on Technological Adoption in Wine Sector. Source: own elaboration

We note how the size, especially the revenues, influences farms' technological level. The larger the company, the more it appears to be oriented towards technological adoption, both in the present and future. It is, therefore, possible to state that the revenues significantly affect the current level of technological adoption. This is due to the cost that implementing innovative technologies and processes requires in terms of money and time. This also affects the answer "Don't know" about the future, leading to the presumption that it depends on the economic possibilities of the agricultural entrepreneur.

Those who have adopted technology will rarely want to discard it in the following years; those who have not had the opportunity to adopt it are not opposed to its adoption, not answering "no". Therefore, it can be emphasized that, at least for the future, the vision on technology is not negative, but rather, it can represent a strong point for the future success of the local agricultural sector.

Crossing the data regarding the number of employees present in farms and the degree of technological adoption, we note how those with a more significant number of people available can implement a greater number of technologies. This evidence is also confirmed by the little propensity for implementing technology in the cereals sector, characterized by lower employment of people.

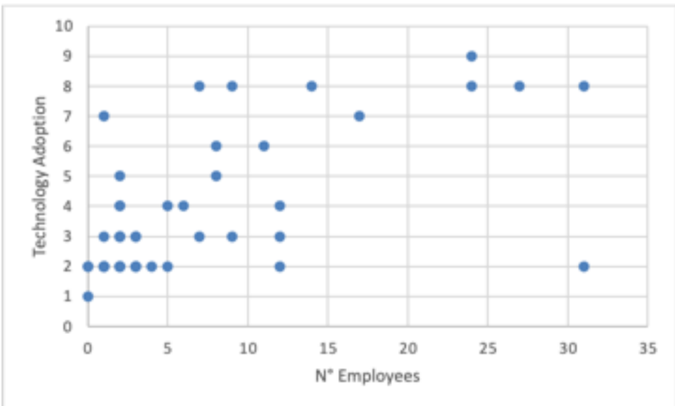

Figure 25. Technology adoption by farms' employees

3.5 KPIs

As we have previously outlined, KPIs can be effective tools for measuring and evaluating the impact of sustainable practices and innovation adoption.

From the analysis of the literature, it emerges that the adaptation of KPIs can help the measurement and evaluation process. In particular it emerges, from background research, that defining the impact of Smart Farming on sustainable practices and company's performance is extremely complex. Therefore, we have explored and classified the type of data and information that can be collected through the data collecting systems that are supplied by service providers. To understand the scope of collected data and the effective implementation of information through KPIs we have established a dialogue with the two companies that have been selected to provide the service. After three meetings, with the collaboration of the Santa Chiara Lab's staff, we have elaborated a set of KPIs that can be employed in a longitudinal study perspective.

The process is represented in the *figure 26*.

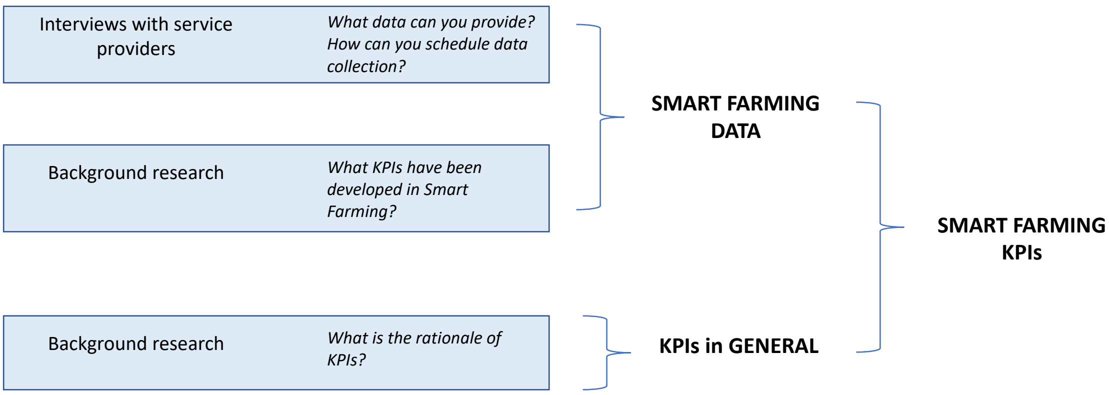

Figure 26. Representation of the KPIs elaboration process. Source: own elaboration

The result of the process is a set of KPIs that will be used in monitoring the effects and the impacts of the implementation of Precision Agriculture practices by the farms that have joined the Siena Food Lab project. We have grouped the indicators into different specific areas: conservation and management of soil, nutrients and crops; production orientation; pesticides, manure and fertilizers management; resource management, efficiency and emissions, yields and revenues, technology; and socio-economic area.

For the details, please see table in the Appendix 3.6.

As for all the KPIs, if, on one side, they can help to measure and assess the performance of a process or a company, on the other side, they show some limitations.

The first problem with this type of KPIs, is that they cannot be monitored upon request: since agriculture is a business that depends on seasons and weather conditions, the variability of results depends on timing and on the moment when monitoring is undertaken.

Therefore, the optimal solution, is to plan a schedule of monitoring activities together with service providers.

Another limit is represented by a lack of knowledge about the role played by KPIs for Companies. This requires service providers to educate companies to the value that the developed indicators might have.

3.6 Further Research

The project's current phase has made it possible to photograph the current situation of Siena's farms concerning the adoption of technology in business processes and activities. The data collected are preliminary and provide a basis from which to start supporting farms in adopting technologies in agriculture. Starting from the current diffusion of technology and the factors that influence it, it will be necessary to understand how to act in the various sectors and the various farms' structures. The help of technology partners (Agricolus and IBF) will be essential thanks to their skills that blend agronomy and technology. Thanks to the periodical collection, they will be able to provide agronomic and non-agronomic data, which, combined with the research skills of the Santa Chiara Lab, will provide fundamental evidence on the effects of technology on performance.

This study represents the first step of a longitudinal study. Given the emphasis on the role of Siena Food Lab project in improving Smart Farming and Precision Agriculture technology, a research question emerges: what is the role of University Business Collaboration based projects for the development and adoption of Smart Agriculture practices among small companies?

We have also outlined that some features of companies can facilitate the adoption of innovative solutions in terms of Smart Farming. Under this perspective, we hope that further research can be carried on a larger sample of companies to confirm the relationship between companies features and openness to innovation adoption.

The implementation of Key Performance Indicators can be particularly helpful in a long-term perspective. In future through the use of the prepared KPIs we will have to measure the impacts that the implementation of the technologies will have on business performance. Therefore, to study the degree of reactivity of the farms in the province of Siena to change and to new national and global trends in the agricultural sector.

It will be extremely interesting to highlight the effects that Smart Farming will have on the sector and the possible solutions to be adopted to break the barriers to its implementation, especially in small contexts such as that of the province of Siena.

Under this perspective, it will be extremely useful to highlight if Siena Food Lab and similar projects can help companies who take part to the initiative to become leaders in innovative practices in local contexts.

Conclusions

We have examined the problems and challenges that will characterize the future of the global economy, in particular those related to the agri-food sector, identifying a possible solution in the application of sustainability and innovation. We focused on the upstream part of the agri-food chain, which concerns agriculture, highlighting how the application of Smart Farming and Precision Agriculture practices embodies the concepts of sustainability and innovation in this part of the sector. However, it emerged that these practices are not yet widespread, especially in the Italian context, due to the characteristics of the sector and the poor perception that its actors have about the related benefits and effects.

We have also outlined that some barriers limit the adoption of Smart Farming solutions.

To help address the sector's challenges and ensure continued prosperity, it is necessary that farmers, now agricultural entrepreneurs, introduce modern business management practices, which other sectors have been implementing for some time.

First of all, through a system that can measure its performance at an economic, environmental and social level and that guides future choices on concrete data analysis. In this, the application of Precision Agriculture techniques is essential as it provides the user with a control and decision tool based on data and analysis systems that are a great help in the farm's monitoring, control, and implementation processes.

For this reason, we have taken the Siena Food Lab project as a reference, which allowed us to define a picture of the situation in the province of Siena to contribute to the spread of Precision Agriculture. Thanks to the analysis of the sample of farms that joined the project, we observed that they have a low degree of current technological and innovative adoption but a positive orientation towards technology for the future.

There is a curiosity for technological solutions, but there is still much to do regarding education to technology.

The factor that has the most significant impact is the revenues class; we found that in the sample, the companies that have the more significant amount of revenues are those with the highest degree of technological adoption. We note that those who have adopted some innovations have no intention of abandoning them, demonstrating that this is the right way forward. In general, we can say that those who have a positive attitude towards innovation are those who, in the future, will improve their technological assets.

Furthermore, in many cases, given the small size in terms of staff on farms, it is not possible to properly devote time to implement these innovations.

The above described scenario introduces a key issue: resources, in terms of time and financial assets are critical. The amount of knowledge, competencies, and time necessary to understand and implement technology influence the orientation of companies towards innovative solutions.

So, investing money and time in implementing technologies is indeed a stumbling block to overcome, but farms cannot be left alone to do this. It is essential to promote and implement projects such as the Siena Food Lab that provide support and accompaniment to farms in the transition to economic, environmental and social sustainability.

This analysis can be used to understand how to act to ensure that Precision Agriculture spreads to the largest number of companies possible. By giving a vision of the situation in a real context, we provide an idea for implementing projects and activities that give the possibility to farms to get in touch with the benefits of Precision Agriculture.

In this way, it will be possible to expand the space of analysis to larger contexts than the Siena Food Lab sample to understand better how to make technologies more accessible and ensure that farms continue their existence with greater success and at the same time address the challenges of the sector.

References

Aberdeen, T. (2013). Yin, RK (2009). Case study research: Design and methods. Thousand Oaks, CA: Sage. *The Canadian Journal of Action* Research, 14(1), 69-71.

AgFunder, 2021 Farm Tech Investment Report.

Aleffi, C., Tomasi, S., Ferrara, C., Santini, C., Paviotti, G., Baldoni, F., & Cavicchi, A. (2020). Universities and Wineries: Supporting Sustainable Development in Disadvantaged Rural Areas. *Agriculture*, *10*(9), 378.

Alexandratos, N., & Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision.

Alshehhi, A., Nobanee, H., & Khare, N. (2018). The impact of sustainability practices on corporate financial performance: Literature trends and future research potential. *Sustainability*, *10*(2), 494.

Bacco, M., Barsocchi, P., Ferro, E., Gotta, A., & Ruggeri, M. (2019). The digitisation of agriculture: a survey of research activities on smart farming. Array, 3, 100009.

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Wal, T. V. D., Soto, I., ... & Eory, V. (2017). Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. *Sustainability*, *9*(8), 1339.

Batie, S. S. (2008). Wicked problems and applied economics.

Baumgartner, R. J., & Ebner, D. (2010). Corporate sustainability strategies: sustainability profiles and maturity levels. *Sustainable development*, *18*(2), 76-89.

Berns, M., Townend, A., Khayat, Z., Balagopal, B., Reeves, M., Hopkins, M., & Kruschwitz, N. (2009). The business of sustainability: Imperatives, advantages, and actions. *The Boston Consulting Group (BCG)*.

Bongiovanni, R., & Lowenberg-DeBoer, J. (2004). Precision agriculture and sustainability. *Precision agriculture*, *5*(4), 359-387.

Brambilla, M., Romano, E., Toscano, P., Cutini, M., Biocca, M., Ferré, C., ... & Bisaglia, C. (2021). From Conventional to Precision Fertilization: A Case Study on the Transition for a Small-Medium Farm. *AgriEngineering*, *3*(2), 438-446.

Bucci, G., Bentivoglio, D., Finco, A., & Belletti, M. (2019, May). Exploring the impact of innovation adoption in agriculture: how and where Precision Agriculture Technologies can be suitable for the Italian farm system? In *IOP Conference Series: Earth and Environmental Science* (Vol. 275, No. 1, p. 012004). IOP Publishing.

Busse, M., Schwerdtner, W., Siebert, R., Doernberg, A., Kuntosch, A., König, B., & Bokelmann, W. (2015). Analysis of animal monitoring technologies in Germany from an innovation system perspective. *Agricultural Systems*, *138*, 55-65.

Calicioglu, O., Flammini, A., Bracco, S., Bellù, L., & Sims, R. (2019). The future challenges of food and agriculture: An integrated analysis of trends and solutions. *Sustainability*, *11*(1), 222.

Cantarelli, F. (2016). Le sfide per uno sviluppo sostenibile del sistema agroalimentare italiano e non solo. *Le sfide per uno sviluppo sostenibile del sistema agroalimentare italiano e non solo*, 229-238.

Cantele, S., & Zardini, A. (2018). Is sustainability a competitive advantage for small businesses? An empirical analysis of possible mediators in the sustainability–financial performance relationship. *Journal of cleaner production*, *182*, 166-176.

Capitanio, F., Coppola, A., & Pascucci, S. (2010). Product and process innovation in the Italian food industry. *Agribusiness*, *26*(4), 503-518.

Castillo-Valero, J. S., & García-Cortijo, M. C. (2021). Factors That Determine Innovation in Agrifood Firms. *Agronomy*, *11*(5), 989.

Chen, H. H., Lee, A. H., & Chen, J. (2017). The relationship between innovation and performance in special nonprofit firms: Social and cooperative agrifood firms. *Journal of Management & Organization*, *23*(4), 587-602.

Cirianni, A., Fanfani, R., & Gismondi, R. (2021). Istat working papers.

Connolly, A. J., & Phillips-Connolly, K. (2012). Can agribusiness feed 3 billion new people… and save the planet? A glimpse into the future. *International Food and Agribusiness Management Review*, *15*(1030-2016-82854), 139-152.

CREA. Annuario dell'Agricoltura Italiana 2019

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food*, *2*(3), 198-209.

Cupertino, S., Vitale, G., & Riccaboni, A. (2021). Sustainability and short-term profitability in the agri-food sector, a cross-sectional time-series investigation on global corporations. *British Food Journal*.

Dang, Y. P., Dalal, R. C., & Menzies, N. W. (Eds.). (2020). *No-till farming systems for sustainable agriculture: challenges and opportunities*. Cham, Switzerland: Springer.

De Martino, M., & Magnotti, F. (2018). The innovation capacity of small food firms in Italy. *European Journal of Innovation Management*.

de Mello, A. M., de Lima, W. D., Boas, E. V., Sbragia, R., & Marx, R. (2008). Innovative capacity and advantage: A case study of Brazilian firms. *RAI-Revista de Administração e Inovação*, *5*(2), 57-72.

De Schutter, O. (2011). Agroecology and the right to food. *Report presented at the 16th session of the United Nations Human Rights Council [A/HRC/16/49]*, *8*.

De Steur, H., Temmerman, H., Gellynck, X., & Canavari, M. (2020). Drivers, adoption, and evaluation of sustainability practices in Italian wine SMEs. *Business Strategy and the Environment*, *29*(2), 744-762.

Delai, I., & Takahashi, S. (2011). Sustainability measurement system: a reference model proposal. *Social Responsibility Journal*.

DELL'AGRICOLTURA, D. P. I. I. (2017). Ministero delle Politiche Agricole Alimentari e Forestali.

Eastwood, C. R., Rue, B. D., & Gray, D. I. (2016). Using a 'network of practice'approach to match grazing decision-support system design with farmer practice. *Animal Production Science*, *57*(7), 1536-1542.

Eastwood, C., Klerkx, L., Ayre, M., & Dela Rue, B. (2019). Managing socio-ethical challenges in the development of smart farming: from a fragmented to a comprehensive approach for responsible research and innovation. *Journal of Agricultural and Environmental Ethics*, *32*(5), 741-768.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of management review, 14(4),* 532-550.

EIT Food: The top 5 trends for the agrifood industry in 2021.

El Bilali, H. (2018). Relation between innovation and sustainability in the agro-food system. *Italian Journal of Food Science*, *30*(2).

Elkington, J. (1997). Cannibals with forks: the triple bottom line of twenty-first century business. Capstone.

Etzkowitz, H., & Leydesdorff, L. (1995). The Triple Helix--University-industry-government relations: A laboratory for knowledge based economic development. *EASST review*, *14*(1), 14-19.

European Commission. (2019). Precision agriculture and the future of farming in Europe. Retrieved from: https://op.europa.eu/en/publication-detail/-/publication/40fe549e-cb49-11e7-a5d5-01aa75ed71a1/language-en.

European Commission. (2020). Technological trends of the agri-food industry.

Faggini, M., Cosimato, S., & Parziale, A. (2021). The way towards food sustainability: some insights for pasta supply chain. *Economia Politica*, 1-24.

FAO. 2014. Developing sustainable food value chains – Guiding principles. Rome

FAO. 2018. Sustainable food systems: concept and framework. Brief. FAO, Rome, Italy.

FAO. 2018. The future of food and agriculture: Alternative pathways to 2050. Rome. 224 pp.

Finco, A., Bucci, G., & Bentivoglio, D. (2018). Lessons of innovation in the agrifood sector: Drivers of innovativeness performances. *Lessons of Innovation in the Agrifood Sector: Drivers of Innovativeness Performances*, 181-192.

Food, F. A. O. Agriculture Organization of the United Nations; 2017. The Future of Food and Agriculture, Trends and Challenges. *FAO, Rome*.

Fox, G., Bergen, P. A., & Dickson, E. (2019). Why are some farms more successful than others? A review. In *Size, structure, and the changing face of American agriculture* (pp. 232-250). CRC Press.

Galan-Muros, V., & Davey, T. (2019). The UBC ecosystem: putting together a comprehensive framework for university-business cooperation. *The Journal of Technology Transfer*, 44(4), 1311-1346.

Gallopin, G. C. (2005). Indicators and their use: information for decision-making. *Sustainability: critical concepts in the social sciences*, *3*, 257-273.

Hammond, J., Fraval, S., Van Etten, J., Suchini, J. G., Mercado, L., Pagella, T., ... & van Wijk, M. T. (2017). The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in East Africa and Central America. *Agricultural Systems*, *151*, 225-233.

Hristov, I., & Chirico, A. (2019). The role of sustainability key performance indicators (KPIs) in implementing sustainable strategies. *Sustainability*, *11*(20), 5742.

Istat, Andamento dell'economia Agricola. Anno 2020

Ivascu, L., Cirjaliu, B., & Draghici, A. (2016). Business model for the university-industry collaboration in open innovation. *Procedia Economics and Finance*, 39, 674-678.

Jia, X. (2021). Agro-Food Innovation and Sustainability Transition: A Conceptual Synthesis. *Sustainability*, *13*(12), 6897.

Jones, A., Takahashi, T., Fleming, H., Griffith, B., Harris, P., & Lee, M. (2021). Quantifying the value of on-farm measurements to inform the selection of key performance indicators for livestock production systems. *Scientific reports*, *11*(1), 1-13.

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards circular economy in the food system. *Sustainability*, *8*(1), 69.

Kahan, D. (2013). *Farm business analysis using benchmarking*. Food and Agriculture Organization of the United Nations.

Kassahun, A., & van der Vorst, J. G. A. J. (2014). Measuring Sustainability Performance of Food Production and Logistics.

Keeble, J. J., Topiol, S., & Berkeley, S. (2003). Using indicators to measure sustainability performance at a corporate and project level. *Journal of Business Ethics*, *44*(2), 149-158.

Kernecker, M., Knierim, A., Wurbs, A., Kraus, T., & Borges, F. (2020). Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. Precision Agriculture, 21(1), 34-50.

Knierim, A., Kernecker, M., Erdle, K., Kraus, T., Borges, F., & Wurbs, A. (2019). Smart farming technology innovations–Insights and reflections from the German Smart-AKIS hub. *NJAS-Wageningen Journal of Life Sciences*, *90*, 100314.

Kuhl, M. R., Da Cunha, J. C., Maçaneiro, M. B., & Cunha, S. K. (2016). Relationship between innovation and sustainable performance. *International Journal of Innovation Management*, *20*(06), 1650047.

Kühne, B., Lefebvre, V., Vermeire, B., & Gellynck, X. (2010). Measuring innovation capacity in the agrifood sector: from single companies to value chains. *Journal on Chain and Network Science*, *10*(3), 145-157.

Kuzma, E., Padilha, L. S., Sehnem, S., Julkovski, D. J., & Roman, D. J. (2020). The relationship between innovation and sustainability: A meta-analytic study. *Journal of Cleaner Production*, *259*, 120745.

Lioutas, E. D., Charatsari, C., La Rocca, G., & De Rosa, M. (2019). Key questions on the use of big data in farming: An activity theory approach. *NJAS - Wageningen Journal of Life Sciences*, 90–91, 100297.

Lundin, M. (2003). *Indicators for measuring the sustainability of urban water systems: A life cycle approach*. Gothenburg, Sweden: Chalmers University of Technology.

Lyons, T.P. 2012. Alltech Symposium. Lexington, Kentucky, USA. May, 20.

Medici, M., Pedersen, S. M., Carli, G., & Tagliaventi, M. R. (2019). Environmental benefits of precision agriculture adoption. *Environmental Benefits of Precision Agriculture Adoption*, 637-656.

Merli, R., Preziosi, M., & Acampora, A. (2018). Sustainability experiences in the wine sector: toward the development of an international indicators system. *Journal of cleaner production*, *172*, 3791-3805.

Mikołajek-Gocejna, M. (2016). The relationship between corporate social responsibility and corporate financial performance–Evidence from empirical studies. *Comparative Economic Research. Central and Eastern Europe*, *19*(4), 67-84.

Morales-Polo, C., Cledera-Castro, M. D. M., & Moratilla Soria, B. Y. (2019). Biogas production from vegetable and fruit markets waste—Compositional and batch characterizations. *Sustainability*, *11*(23), 6790.

Nidumolu, R., Prahalad, C. K., & Rangaswami, M. R. (2013). Why sustainability is now the key driver of innovation. *IEEE Engineering Management Review*, *2*(41).

Osservatorio Smart Agrifood 2021 della School of Management del Politecnico di Milano

Petit, G., Sablayrolles, C., & Yannou-Le Bris, G. (2018). Combining eco-social and environmental indicators to assess the sustainability performance of a food value chain: A case study. *Journal of Cleaner Production*, *191*, 135-143.

Petridis, N. E., Digkas, G., & Anastasakis, L. (2020). Factors affecting innovation and imitation of ICT in the agrifood sector. *Annals of Operations Research*, *294*(1), 501-514.

Petruzzella, D. (2017). L'innovazione nell'agrifood del Mediterraneo. *Edizioni L'Informatore Agrario srl, Verona, Italy*.

Pichlak, M., & Szromek, A. R. (2021). Eco-innovation, sustainability and business model innovation by open innovation dynamics. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(2), 149.

Porter, M. E., & Kramer, M. R. (2011). Creating Shared Value: Harvard Business Review. Jan-Feb, 2011, 1-17.

Pulselli, F. M. (2011). *La soglia della sostenibilità ovvero quello che il Pil non dice*. Donzelli Editore.

Rapporto Ismea - Qualivita sulle produzioni agroalimentari e vitivinicole italiane DOP, IGP e STG, 2021

Rezaee, Z., & Rezaee, H. (2014). Business Sustainability and Key Performance Indicators. *Journal of Business and Economics*, *5*(9), 1484-1490.

Riccaboni, A., Neri, E., Trovarelli, F., & Pulselli, R. M. (2021). Sustainability-oriented research and innovation in "farm to fork" value chains. *Current Opinion in Food Science*.

Rodrigues, V. P., Pigosso, D. C., & McAloone, T. C. (2016). Process-related key performance indicators for measuring sustainability performance of ecodesign implementation into product development. *Journal of Cleaner Production*, *139*, 416-428.

Saccomandi, V. (1991). *Istituzioni di economia del mercato dei prodotti agricoli*. Reda.

Santiago-Brown, I., Metcalfe, A., Jerram, C., & Collins, C. (2015). Sustainability assessment in wine-grape growing in the new world: Economic, environmental, and social indicators for agricultural businesses. *Sustainability*, *7*(7), 8178-8204.

Santini, C., Marinelli, E., Boden, M., Cavicchi, A., & Haegeman, K. (2016). Reducing the distance between thinkers and doers in the entrepreneurial discovery process: An exploratory study. Journal of Business Research, 69(5), 1840-1844.

Schilling, M. A., & Shankar, R. (2019). *Strategic management of technological innovation*. McGraw-Hill Education.

Shafi, U., Mumtaz, R., García-Nieto, J., Hassan, S. A., Zaidi, S. A. R., & Iqbal, N. (2019). Precision agriculture techniques and practices: From considerations to applications. *Sensors*, *19*(17), 3796.

Simpson, P. M., Siguaw, J. A., & Enz, C. A. (2006). Innovation orientation outcomes: The good and the bad. *Journal of Business Research*, *59*(10-11), 1133-1141.

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological indicators*, *9*(2), 189-212.

Sørensen, C. A. G., Kateris, D., & Bochtis, D. (2017, September). ICT Innovations and Smart Farming. In *International Conference on Information and Communication Technologies in Agriculture, Food & Environment* (pp. 1-19). Springer, Cham.

Swinnen, J., Olper, A., & Vandevelde, S. (2021). From unfair prices to unfair trading practices: Political economy, value chains and 21st century agri-food policy. *Agricultural Economics*, *52*(5), 771-788.

Szekely, F., & Strebel, H. (2012). Strategic innovation for sustainability. *International Institute for Management Development [IMD], Lausanne, SW, Available from: www. imd. org*.

Tanzil, D., & Beloff, B. R. (2006). Assessing impacts: Overview on sustainability indicators and metrics. *Environmental Quality Management*, *15*(4), 41-56.

Trivelli, L., Apicella, A., Chiarello, F., Rana, R., Fantoni, G., & Tarabella, A. (2019). From precision agriculture to Industry 4.0: Unveiling technological connections in the agrifood sector. *British Food Journal*.

United Nations Development Programme, Precision agriculture for smallholder farmers (UNDP Global Centre for Technology, Innovation and Sustainable Development: Singapore, 2021).

Van Der Vorst, J. G. (2005). Performance measurement in agrifood supply chain networks: an overview. *Quantifying the agri-food supply chain*, (15), 13-24.

van der Vorst, J. G., Peeters, L., & Bloemhof, J. M. (2013). Sustainability assessment framework for food supply chain logistics: empirical findings from dutch food industry. *International Journal on Food System Dynamics*, *4*(1012-2016-81214), 130-139.

van Winden, W., & Carvalho, L. (2015). Synergy management at knowledge locations. In *Making 21st Century Knowledge Complexes* (pp. 62-81). Routledge.

Vitale, G., Cupertino, S., Rinaldi, L., & Riccaboni, A. (2019). Integrated management approach towards sustainability: an Egyptian business case study. *Sustainability*, *11*(5), 1244.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences*, 114(24), 6148-6150

Warhurst, A. (2001). Corporate citizenship and corporate social investment: drivers of tri-sector partnerships. *Journal of corporate citizenship*, (1), 57-73.

WCED, Our Common Future, Oxford University Press, Oxford-New York 1987.

Wilson, T. (2012). A review of business–university collaboration. Emerald Pub

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming–a review. *Agricultural systems*, *153*, 69-80.

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big data in smart farming: A review. *Agricultural Systems*, 153, 69–80.

Yin, R. K. (1981). The case study as a serious research strategy. *Knowledge, 3(1)*, 97-114.

Zamora-Izquierdo, M. A., Santa, J., Martínez, J. A., Martínez, V., & Skarmeta, A. F. (2019). Smart farming IoT platform based on edge and cloud computing. *Biosystems engineering*, *177*, 4-17.

Ziemnowicz, C. (1942). Joseph A. Schumpeter and innovation. *Socialism and Democracy*, 82.

Website References

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN

https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX%3A52020DC0381

https://www.agricolus.com/

https://www.eitfood.eu

https://www.ibfservizi.it/

https://www.ispag.org/about/definition

https://www.statista.com/statistics/721921/forecasted-market-value-of-precision-farming-worldwide/

Appendix: Chapter 1.

1.1 Italian agri-food chain: percentage composition of firms, revenues, employees and added value.

ECONOMIC ACTIVITY	FIRMS	REVENUES	EMPLOYEES	ADDED VALUE
Farming	69,1	6,6	21,0	19,1
Industry of Food, Beverage and Tobacco	2,6	23,7	11,4	20,2
Warehouse and Storage	0,1	0,6	0,6	1,2
Transport or logistics intermediaries	0,3	2,6	2,5	3,0
Goods Transport	2,9	9,4	8,8	11,9
Wholesale of food products	3,5	24,4	6,6	10,4
Specialised Retail	6,7	4,1	7,4	4,1
Non-Specialised Retail	1,5	18,3	10,7	12,8
Food and Beverage Services	13,2	10,3	31,0	17,3
Total Non-Agricultural Sectors	30,9	93,4	79,0	80,9
Total Excluded Goods Transport	97,1	90,6	91,2	88,1
Total Agri-Food Sector	100	100	100	100

Source: Cirianni, A., Fanfani, R., & Gismondi, R. (2021). Istat working papers.

1.2 Expected environmental gains from main Precision Agriculture processes and techniques

Process	Technique	Expected environmental gains
Timeliness of working under favourable weather conditions	Automatic machine guidance with GPS	- Reduction in soil compaction - Reduce carbon footprint (10% reduced fuel consumption in field operations)
Leave permanent vegetation on key location and at field borders	Automatic guidance and contour cultivation on hilly terrain	- Reduction of erosion (from 17T/ha.y to 1 T/ha.y and perhaps lower) - Reduction of runoff of surface water and fertilisers Reduced flood risk
Reduce or slow down water flow between potato/vegetable ridges to slow water	- Micro-dams or micro-reservoirs made between ridges ("tied ridges") - Ridges along field contours	- Reduced sediment runoff - Reduced fertiliser runoff
Keep fertilisers and pesticides at recommended distances from water ways	- Automatic guidance based on geographic information - Section control of sprayers and fertiliser distribution	Avoidance/elimination of direct contamination of river water
Avoid overlap of pesticide and fertiliser application	Section control of sprayers and fertiliser distribution	Reduce/avoid excessive chemical input in soil and risk of water pollution
Variable rate manure application	- On-the-go manure composition sensing - Depth of injection adjustment	- Reduced ground water pollution - Reduced ammonia emissions into the air
Precision irrigation	Soil texture map	- Avoidance of excessive water use or water logging - Reduction of fresh water use
Patch herbicide spraying in field crops	Weed detection (on line/weed maps)	- Reduction of herbicide use with map-based approach (in winter cereals by 6–81% for herbicides against broad leaved weeds and 20–79% for grass weed herbicides) - Reduction of 15.2–17.5% in the area applied to each field was achieved with map-based automatic boom section control versus no boom section control
Early and localised pest or disease treatment	Disease detection: - Multisensor optical detection - Airborne spores' detection - Volatile sensors	Reduction of pesticide use with correct detection and good decision model (84.5% savings in pesticides possible)
Orchard and vineyard precision spraying	- Tree size and architecture detection - Precision IPM	- Reduction in pesticide use of up to 20 – 30 % - Reduction of sprayed area of 50- 80%
Variable rate nitrogen fertiliser application according to crop requirements and weather conditions	- Crop vegetation index based on optical sensors - Soil nutrient maps	- Improvement of nitrogen use efficiency - Reduction of residual Nitrogen in soils by 30 to 50 %
Variable rate phosphorus fertiliser application according to crop requirements and weather conditions	- Crop vegetation index - Soil nutrient maps	Improvement of phosphorus recovery of 25 %
Crop biomass estimation	Crop vegetation index	Adjust the fungicide dose according to crop biomass
Mycotoxin reduction	Crop vegetation index and fungal disease risk	Optimisation of fertiliser dose and fungicide use on the basis of higher disease risk in areas with high crop density

Source: European Commission. (2019). Precision agriculture and the future of farming in Europe.

Appendix: Chapter 2.

2.1 WBCSD Sustainable Tools and Indicators

Name of the tool	Value to business
Base of the Pyramid Impact Assessment Framework	Understand and measure how your business influences different dimensions of poverty in your customers, local distributors and surrounding communities
GEMI Metrics Navigator	Identify environmental and social performance indicators to measure, and prioritize issues for management response
Impact Measurement Framework	Identify relevant socio-economic indicators to measure impact in four specific sectors: agribusiness, power, financial services, and information and communication technology
Impact Reporting and Investment Standards	Select standard indicators to use within your overarching impact measurement framework
MDG Scan	Estimate the number of people your company is affecting in ways related to the Millennium Development Goals
Measuring Impact Framework	Define the scope of your assessment, identify socio-economic impact indicators for measurement, assess the results, and prioritize issues for management response
Poverty Footprint	Understand your company's impact on poverty reduction working in collaboration with a development NGO
Progress out of Poverty Index	Calculate the percentage of customers, suppliers, and other populations of interest that live below the poverty line
Socio-Economic Assessment Toolbox	Measure and manage the local impacts of site level operations
Input-Output Modelling	Calculate the total number of jobs supported and economic value added by your company and its supply chain on a particular national economy

Appendix: Chapter 3.

3.1 Number of agri-food companies - farms and respective employees (2021).

	Siena (Incidence on total)	**Tuscany**	**Italy**
Agri-food companies	5.756 (20.5%)	43.380	806.201
Farms	5.461 (19.4%)	39.772	735.481
Total companies	28.081	409.304	6.116.416
Agri-food employees	15.206 (13.3%)	91.333	1.712.553
Farms employees	13.017 (11.4%)	68.558	1.114.829
Total employees	113.906	1.366.060	21.523.816

Source: own elaboration from StockView data

3.2 Details on cereals, grapes and olives sector (2021)

Production	Farms (n°)	Employees	Quantity (q)	Hectares
Cereals	2.082	2.442	1.266.041	38.683
Grapes	1.262	5.082	771.322	12.922
Olives	731	652	90.000	15.000

Source: own elaboration from StockView data

3.3 Overview of cereals production (2021)

Type of Cereal	Siena	Tuscany	Italy	Siena on Tuscany
Oat	89.232	269.852	2.393.374	33,1%
Durum Wheat	453.390	1.721.351	41.373.262	26,3%
Common Wheat	365.225	946.296	28.935.247	38,6%
Corn	122.580	866.266	63.758.343	14,1%
Barley	98.268	321.973	10.457.099	30,5%
Rye	100	1.733	128.615	5,8%
Sorghum	14.526	94.596	3.059.595	15,1%
Triticale	9.720	61.280	642.309	15,9%
Others	113.000	191.705	895.627	58,9%
Total	**1.266.041**	**4.475.052**	**151.643.471**	**28,3%**

Source: own elaboration from StockView data

3.4 Current Adoption Rate by Sector and Farm

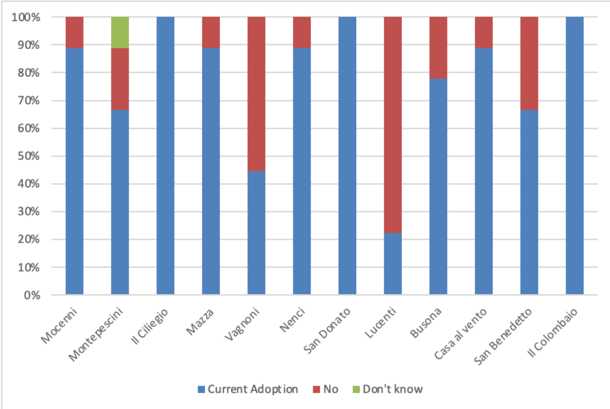

Figure A 1. Current adoption rate per farms – Wine. Source: own elaboration.

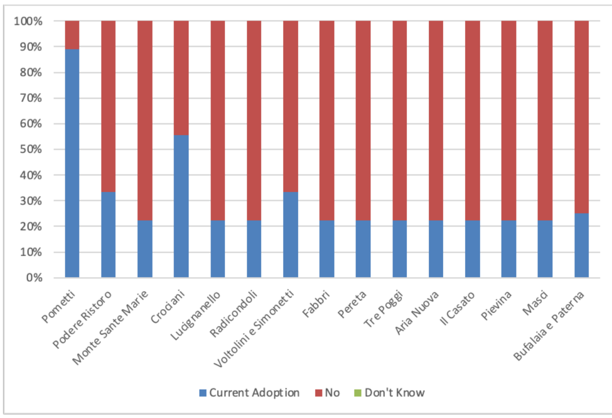

Figure A 2. Current adoption rate per farms – Cereals. Source: own elaboration.

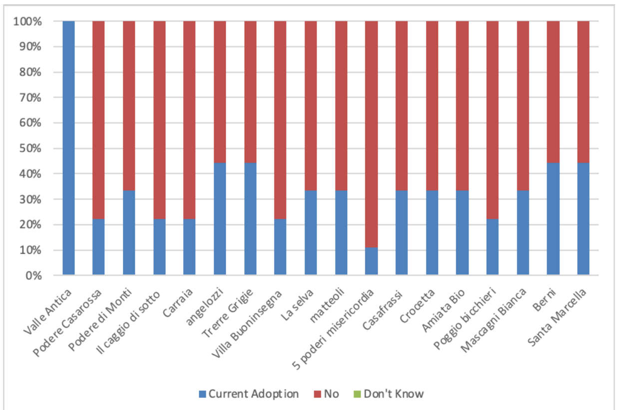

Figure A 3. Current adoption rate per farms – Olive Oil. Source: own elaboration.

3.5 Future Orientation Rate by Sector and Farm

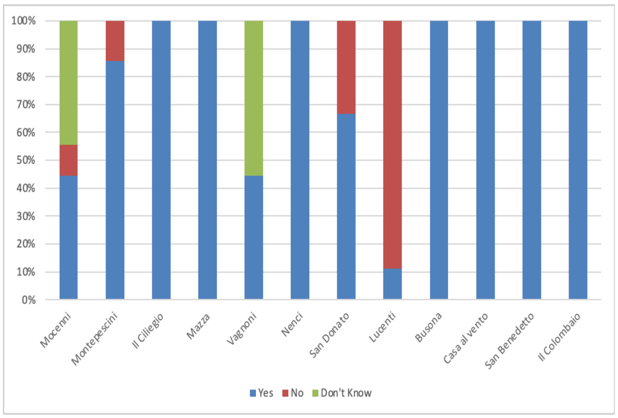

Figure A 4. Future orientation rate per farms – Wine. Source: own elaboration.

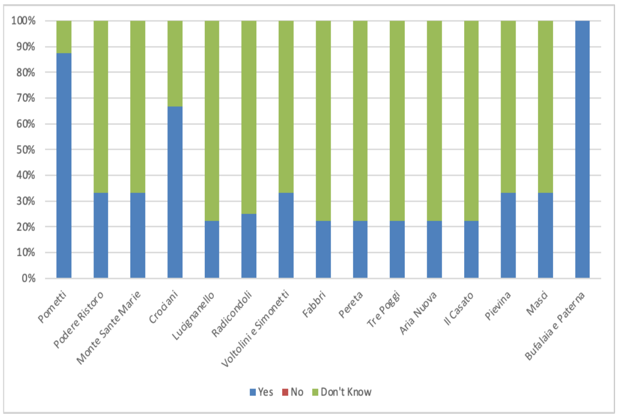

Figure A 5. Future orientation rate per farms – Cereals. Source: own elaboration.

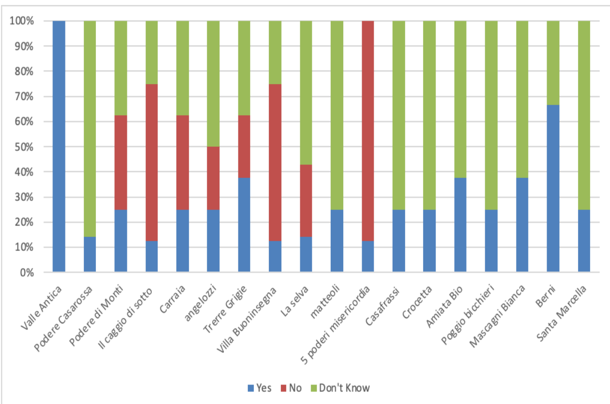

Figure A 6. Future orientation rate per farms – Olive Oil. Source: own elaboration.

3.6 Set of KPIs developed

Macro Areas		Variables/KPIs		Note
CONSERVATION AND MANAGEMENT OF SOIL, NUTRIENTS AND CROPS	**Adoption of crop and soil management systems for the maintenance of micronutrients**	Division by Type of Management	For each type of management i: sum (AC management i)/ Total AC	AC = Field Area
		Division by Title of Possession	For each title of possession i: sum (AC Title of possession i)/ Total AC	
		Average field size	Average AC	
		Division by acclivity	For each type of irrigation area i: sum (AC Irrigation type i)/ Total AC	
		Density of fields	Average of (Σ per field of mc water/ PT)	
		Crop density	Average of the delta from the thresholds of the 3 preliminary indices reaggregated by the weighted average for ha	
		Crop diversity	$\sum_{i}^{n}(P_c \cdot \log_n P_c)$	PC = AC culture n/AC
	Health of Crops	NDVI (Normalized Difference Vegetation Index): index that informs about vegetation development		Indices calculated on extracted variables are used, depending on the best solution. These are indices for the vigor of the plant, for chlorosis and for the calculation of water stress
		GNDVI(Green-NDVI): similar to NDVI.		
		SAVI(Soil-Adjusted Vegetation Index): applies correction to soil. It works well even with low vegetation cover (LAI<0.5), but saturated with highly developed vegetation (LAI>2). It allows you to compare fields with very different soils.		
		WDRVI (Wide Dynamic Range Vegetation Index): works well even with well-developed vegetation. Saturated with LAI>4.		
		LAI (Leaf Area Index): estimate of the leaf area of the plant expressed in m2 per m2. It works well on herbaceous crops while it is less accurate on tree plants (vine rows, olive trees, etc.). It can be taken as a reference to assess which index is most appropriate to use.		
		TCARI/OSAVI (Transformed Chlorophyll Absorption Ratio Index/Optimized Soil-Adjusted Vegetation Index): high index values indicate chlorosis, low values indicate high chlorophyll content.		
		NDMI (Normalized Difference Moisture Index): usable only in the presence of developed vegetation (LAI>1). High index values indicate that the plant does not need water. Not suitable for bare soil. With poorly developed vegetation it is correlated with NDVI.		
		NMDI (Normalized Multiband Drought Index): If the soil is bare, a high index value indicates dry soil. In the presence of well-developed vegetation (LAI>1), a high index value indicates that the plant does not need water.		

Macro Areas		Variables/KPIs		Note
PRODUCTION ORIENTATION	**Product Traceability**	Percentage of Certified production on Total		
MANAGEMENT OF PESTICIDES, MANURE AND FERTILIZERS	**Monitoring for the reduction of Pesticides and Fertilizers**	N. treatments per field	For each nutrient i: average of the sum of element i per ha per field	
		N Lisciviato	$Nl = N_{PL}$ x $K_L/100$	
	Monitoring for Fertilizer reduction	Use of Fertilizers	Average of the sum mm water irrigation operations per field	
		Fertilizers – Economic Efficiency fertilizer	Pt/AC	
		Fertilizers - Efficiency of use	Average of (avg_NPKcum/yield per field)	
RESOURCES MANAGEMENT, EFFICIENCY AND EMISSIONS	**Direct and Indirect Emissions**	Fuel Consumption; Mechanization rate (presence of machinery); Presence of Electric/Hybrid vehicles		
	Energy Efficiency	Presence of Photovoltaic Systems		
	Efficiency of Water Resources	Irrigation Use	Average field yield	
		% Irrigation area	n° Fields /AC	
		Water - Economic Efficiency Operation	Average of (Σ per field of QxPu fertilizers/ Pt)	
		Water - Efficiency of use	Average of (avg_irrcum/yield per field)	
YIELDS AND REVENUES	**Yield**	Average yield	For each type of acclivity I: sum (AA acclivity i)/ Total AC	
		Total Income	Average of the sum of n° of treatments per field	
		Income per hectare	Sum of the product between quantity and unit price of production	
	Revenues	Average Annual Revenues		
TECHNOLOGY	**Technology-oriented**	Presence of Technological Solutions		
SOCIO-ECONOMIC SCOPE	**Gender**	Presence of Women		
	Personal composition	Average age		
		Type of Contracts		
		Presence of Trainees		

Source: own elaboration.

Ringraziamenti

Dedico questo spazio per ringraziare tutte le persone che direttamente e indirettamente hanno permesso il raggiungimento di questo traguardo.

In primis, vorrei ringraziare tutti coloro che hanno reso possible la stesura di questo elaborato.

In particolar modo il Professor Angelo Riccaboni per la fiducia mostrata e l'opportunità datami nello sviluppare conoscenze e competenze che mi hanno guidato durante il percorso di tesi.

Ringrazio la Professoressa Cristina Santini per lo straordinario aiuto, la disponibilità e il tempo dedicatomi; supporto fondamentale nei vari step di stesura dell'elaborato.

Ringrazio la Dottoressa Cristiana Tozzi per la sua disponibilità, professionalità e affetto. Senza il suo aiuto non avrei potuto arricchirmi dell'esperienza intrapresa in questi mesi con il team del Santa Chiara Lab.

Inoltre vorrei ringraziare tutte le persone che sono state per me dei veri punti di riferimento nella vita e durante gli anni di studio, alleggerendo e colorando i momenti più difficili.

Ringrazio i miei genitori per essere le colonne portanti della mia vita, fonti di supporto e sicurezza insostituibili.

Un abbraccio alle nonne che vorrei poter ricambiare di tutto l'affetto dato rendendole orgogliose dei miei traguardi.

Un bacio a Lucia che con le sue attenzioni e il suo sorriso ha reso tutto più leggero.

Ringrazio tutti i miei amici con i quali ho avuto la fortuna di condividere le avventure della vita. Ognuno, a modo suo, ha contribuito a rendere speciale la mia concezione di amicizia.

Grazie.