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The Rise of "Agriculture 4.0" Technologies and implications for the sector

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Chapter I

Introduction: The rise of "Agriculture 4.0": technologies and implications for the sector

This thesis investigates the application in the agricultural industry of technologies that foster digitization, connectivity, and automation. The analysis starts with the current state of the European agricultural sector: what are the peculiarities of its companies and the operators working in it, and in particular what is the state of innovation in the companies of the sector is why agricultural companies are less prone to innovation than companies in the industrial or service sector.

In the first chapter it is worth comparing the Italian agricultural industry with its counterparts in other EU countries in order to explore the differences in terms of profits, level of sustainability, and innovation, to identify the structural deficits of the agricultural sector and its future challenges. In this sense, it is necessary to analyze some aspects of the agricultural sector, such as the high average age of its operators, the level of innovation of companies, the geographical distribution of farms across the country and the distribution of innovative companies. In fact, it is useful to understand how these factors influence the innovation processes of companies. In the coming years, the sector will face a wide range of challenges related to sustainability and economic performance. This chapter will present some of the most common challenges, such as managing resources and production inputs (especially water) and mitigating the risk associated with natural events in order to maximize production. To address them, it will be strategic to innovate and increase efficiency; to this end, it is useful to adopt a smart agriculture approach based on the use of tools and strategies that enable the farm to employ advanced information and telecommunication technologies (ICT) in a synergetic and interconnected manner, to make production more efficient and sustainable. This innovative approach based on the use of these technologies is called Agriculture 4.0

In the second chapter, it is explored how Agriculture 4.0 technologies and processes can be integrated by companies and how the adoption of these technologies affects cost structure, quantities produced, and labor utilization. Under the label 'Agriculture 4.0' fall a large number of technologies and processes that are used for the most diverse purposes. Therefore, to be as orderly and clear as possible, it's important to focus in particular on innovations related to the technologies of the Internet of Things, automation, big data, and precision agriculture. I have chosen to focus on the latter because I believe they are the most widespread innovations and best represent the profound transformation of the agricultural industry. The chapter will highlight how this approach has wide-ranging positive effects The potential of Agriculture 4.0 benefits farms in the first place, but also consumer goods suppliers, distributors, processors, etc. The intelligent processing of data (such as, for example, the detection of physical and biochemical soil characteristics by sensors in the field) has been a value, with positive externalities for the entire community.

The last chapter aims to provide a practical view of the application and use of 4.0 technology and their impact on business processes. In order to best carry out this study, the thesis proposes to analyse the agricultural sector of a region, namely Sardinia, Through this in-depth study, the performance of companies that have adopted Agriculture 4.0 and in particular how the technologies have impacted on production and sustainability will be analysed. . The choice to examine the region of Sardinia stems from a number of reasons. Indeed, the island has an extraordinary agricultural vocation and is famous for several excellent productions. However, the region is characterised by companies that are very tied to tradition and innovation rates are low, and it also has many of the structural deficits analysed in the first chapter. It is essential to understand why in many areas, such as Sardinia or more generally in the southern regions, despite their great potential, companies are reluctant to innovate and remain conservative. To carry out this analysis, the thesis makes use of information from databases (such as Istat) and reports from regional and national agencies/observatories dealing with agriculture.

An important part of the last chapter are the business cases selected for a practical example of 4.0 innovation on the island. At the same time, it is important to highlight how, despite the fact that the agricultural context of the island is characterised by a traditional approach to agriculture, there are innovative realities that over the years have undertaken a path of business innovation that has led them to implement a Smart Agriculture model.

In order to delve into the innovation process undertaken by these agricultural realities and highlight its concreteness, the thesis examines three business cases: a fruit and vegetable company, a wine company and a company that cultivates extensive crops. The need to consider three companies from different sectors stems from the fact that not all agricultural sectors have the same level of innovation. Depending on the sector, companies adopt different technologies and implement different innovation processes in terms of both type and ambition. For example, the wine sector is generally the most innovative and often implements process and product innovation, while the others generally focus only on process innovation. Furthermore, taking into account companies from different sectors is useful to compare the different results that companies achieve through the innovation process in terms of sustainability. Secondly, I believe that the three sectors examined are the most representative of the Italian agricultural sector. The analysis of the business cases will be based on what technologies the companies examined have adopted, what results they have produced, and how much the innovation has improved company performance in terms of economic efficiency (increased yield, labour utilisation and impact on cost structure) and sustainability (water use, energy consumption, use of chemicals). Analysed company cases show that in this region, too, the use of new technologies makes it possible to achieve results similar to those achieved by other companies in the rest of Italy.

Chapter II: Overview and structural deficits of Italian agriculture

The chapter paints a general picture of the situation in Italian agriculture, highlighting: the peculiar crops, the distribution of enterprises in the territory, the propensity of Italian agricultural enterprises to innovation, and various economic data such as the average revenues recorded by agricultural firms.

A second aspect explored by the chapter is the structural weaknesses of Italian agricultural enterprises to understand which limits hinder the economic development and innovation of companies in the sector.

2. 1 Overview of Italian agriculture

Italy is characterized by a high agricultural vocation, in fact, its considerable extension in latitude and its geographical position in an area of mild climate allows it to have very varied soil and climate characteristics that favor crop diversification and consequently highly specialized agri-food products. (CREA, 2022). Over the past decade, farms have declined significantly. If in 2010 we could identify about 1.6 million farms; today they have dropped by about 30 percent. Despite this, the SAU has remained fairly stable at 12.5 million hectares; the most obvious consequence of this is the increase in the average SAU from 5 hectares in 1982 to over 11 hectares in 2020. (CREA, 2022)

The change in the number of companies did not affect all regions equally; some experienced radical reductions such as Campania, which experienced a 40 percent drop.

Even in terms of SAU, the situation among regions cannot be said to be homogeneous: some territories such as Liguria and Calabria have values well below the national average, while others, such as Sardinia and Lombardy, are significantly above the same average. Land use appears equally varied: the country's special climatic and geographical conditions allow for good crop diversification. Most farms are devoted to arable crops or permanent crops. In terms of area, arable land is the most significant, covering more than seven million hectares; the area used for pastures and meadows is also significant, with about three million hectares. (CREA, 2022)

Another important segment for the agricultural sector is certainly livestock farming. Italy can boast a remarkable tradition in this regard, and there are more than 246,000 livestock farms in the country, about 20 percent of the farms surveyed by the Census; in some regions this percentage is growing, even exceeding 50 percent of the total. In absolute terms, livestock farms are more widespread in the north of the country, except for Sardinia; about 60 percent of the livestock population is concentrated in Lombardy, Veneto, and Emilia-Romagna. This finding is also confirmed when analyzing in detail species by species; in fact, Lombardy has about half of the pigs raised, and out of more than 6,000,000 cattle, about 1.5 million are raised in Lombardy. In the case of cattle, the only exception is Campania, which boasts over 400,000 head, mostly buffaloes that represent a specificity of the territory. In the case of poultry, it is Veneto that is the most relevant region with more than a third of the heads raised. In contrast to this picture is the breeding of sheep and goats more widespread in the southern regions, with about half of the heads located in Sardinia. (CREA, 2022)

On average, farms in the agricultural sector in Italy record 74,232 euros in total farm revenues and 43,639 euros in value added. This translates into a net farm income of 28,116 euros and accounts for 38 percent of farm revenues. In terms of income and production, farms are not homogeneous; in fact, northern regions characterized by intensive type farms and large livestock farms have better economic performance. In this context, Veneto, Lombardy, and Emilia-Romagna stand out, where large cattle and granivore farms are concentrated and rank high in terms of production and income results, while Calabria, Abruzzo, Molise, and Sicily, where more extensive farming practices prevail, are at the bottom. (CREA, 2022)

A distinction must be made here between crop and livestock production. In the case of the former, it should be pointed out that among the main plant systems, farms specializing in cereal cultivation are characterized by large average areas to which, however, high economic performance does not correspond. In contrast, farms specializing in horticulture, which are characterized by very small areas and high labor use, record the best production and income results. Fruit and wine farms show similar economic results and are the most efficient in terms of income on total farm revenues. The lowest performance is recorded in olive growing, a sector in which the profitability of family labor is just over 17,000 euros. In the livestock sector, farms specializing in granivorous livestock, which are characterized by large (402 UBA/ha on average per farm) and intensive (on average 19 UBA/ha) herds, stand out in terms of high value of production and income. Excellent performances are also obtained in the dairy cattle sector. Decidedly more modest are the economic results recorded by farms specializing in mixed cattle, which are generally of a more extensive type (1.1 UBA/ha), and by farms specializing in sheep and goat breeding, which are also mainly of an extensive type (0.6 UBA/ha). In contrast, sheep and goat farms are the most efficient in their ability to translate much of their income into income: 49 percent. (CREA, 2022)

The comparison of Italy with major EU countries, by economic performance of production factors, is made based on FADN data for the last available three-year period (2018-2020). In the livestock sector, our country shows excellent economic results in line with those obtained by other more developed agriculture. Regarding the profitability of family labor, Italy ranks first in the granivore and mixed cattle sector and second in the dairy cattle sector. In the crop sector, the performance of our agriculture is affected by the modest structural endowment in terms of SAU and labor units, which reduces its ability to compete at the community level. However, our country by land profitability ranks first in fruit growing and second in cereal growing, horticulture, viticulture, and olive growing. In viticulture, Italy competes well with France and Germany, while in olive growing it does not reach the results of Spain but does better than Greece and Portugal. (CREA, 2022)

2.2. Critical issues:

a) Agriculture and environmental sustainability

One of the future challenges of the agricultural sector will inevitably be the need to have more sustainable production processes without at the same time compromising the economic performance of farms. Agricultural activities have considerable environmental impacts, especially in terms of emissions and consumption of scarce resources such as water and soil.

In 2021 in Italy, land consumption (CoS) is estimated to increase by 6,910 hectares (an average of 19 hectares per day) from the previous year. (CREA, 2022)

The percentage of artificial land cover reaches 7.13 percent of the national territory, equivalent to an area of 2,148,500 hectares (ISPRA). These data show a worsening of natural soil loss and an increase in artificial areas, especially in eight regions, with Lombardy, Veneto, and Campania leading the way. Considering the main land uses, in 2021, CdS mainly affected agricultural areas, with arable crops (-2,659 ha) in first place, followed by forage crops (-407 ha) and permanent crops (-476 ha). (CREA, 2022)

While land stewardship is one of the benefits that the presence of farms provides to the national community, their environmental impact is significant. In fact, in recent years this sector has often come under fire because it has been an environmental sustainability problem due to its high water consumption, volume of manure, and high emissions.

The impact the sector has in terms of emissions is significant; in fact, the agricultural sector produces 32.68 million tCO_2 and 9 percent of national emissions. The trend of reducing total national emissions in 2020 amounted to about 348 million tCO_2 and, however, these reductions are still not enough to meet the targets set by the climate-energy package for 2030, which calls for a 55% reduction in emissions compared to 1990. Data from the National Inventory Report 2022 testify to a slight increase in agricultural emissions from 31.35 to 32.68 million tCO_2 equivalent to 9 percent of national emissions. (CREA, 2022)

Methane contributes 59% of the sector's emissions, followed by nitrous oxide (39.5%). The main source of emissions from the agricultural sector remains animal husbandry, which contributes 17.7 million tCO_2 and in percentage terms 60.4 percent, mainly from enteric fermentation (41.4 percent) and manure management (19 percent). Agricultural land management also generates a high amount of emissions corresponding to 10.82 million tCO_2 e (33.1%). (CREA, 2022)

The challenge for the agriculture of the future will be precisely its ability to innovate to reduce its environmental impact while preserving its presence in the different territories. In this sense, companies must develop "Green Competencies," which will be strategic in addressing the ecological transition of the European agricultural sector; in fact, green competencies are key to developing the new skills and attitudes on which new ways of thinking about business and their role in society will be based. Especially with the growing importance of Corporate Social Responsibility in all economic sectors, it will be strategic to implement new business approaches based on greater empathy and responsibility towards the planet and public health without compromising the ultimate goal of business activity namely: profit. Investing in eco-sustainability is the intention of 49 percent of companies; the percentage rises dramatically in the case of women-owned businesses (61 percent) and the case of those under 35 (55 percent) while companies in the South lag. In terms of company type, a greater propensity to invest in eco-sustainability can be observed from fruit and vegetable companies while forestry with only 31 percent of companies interested in making investments in eco-sustainability lags probably due to the high energy requirements that characterize companies in the supply chain. (Centro Studi Tagliacarne, 2023)

However, the shift to more environmentally sustainable forms of business is a challenge for the industry companies mainly encounter two problems: finding the necessary professional figures and the high cost of sourcing green raw materials.

According to the data collected, companies that have sought greater eco-sustainability over the five years 2017-2021 have recorded concrete results such as reducing waste or production waste (63 percent), using renewable energy (47 percent), and saving water (39 percent). Importantly, many of these achievements bring the company a return not only in terms of sustainability but also in economic terms. (CREA, 2022)

2.2 Critical issues:

b) The lack of generational turnover.

Another critical issue in the agricultural sector, especially in the Italian sector, is the high average age of those working in the sector. Although this is a significant problem in all European countries, Italy seems to have a more serious problem most of the operators in the sector turn out to be over forty years old. Here, among other things, we find a certain homogeneity between north and south in that both companies in northern regions and those in southern regions show an advanced average age (CREA, 2022). Although, as mentioned this is also in line with other European nations, so much so that the problem has been identified at the EU level as one of the main fronts for action, and the European Commission aims to encourage generational change among the Union's agricultural entrepreneurs and allocates in each Rural Development Plan, strong incentives for young farmers. The importance of lowering the average age of those working in the sector and introducing new energy within enterprises is crucial to fostering innovation and the spread of novel approaches and technologies. Fostering a greater propensity for innovation in the sector will be strategic in the coming years, as the economic and environmental challenges facing European agriculture involve change that can only be achieved through the implementation of new technologies that enable the optimization of scarce resources used as production inputs (e.g., water) and a more efficient cost structure. However, the propensity for innovation is closely linked to the average age of entrepreneurs. According to the 2022 National Rural Report, about 3 out of 4 firms made innovative investments in the five years 2017-2021, and the propensity to innovate is higher in firms run by under 40s. Also, according to the report, most innovation in agriculture focuses on product-process innovation and technological innovation (Ronga, 2022).

The lack of generational turnover questions policymakers and practitioners. At the moment, three reasons seem to be slowing this process down: low attractiveness of agricultural activities for new generations due to: lower profitability compared to other sectors; greater physical exertion and higher daily hourly commitment; and location in rural regions that are often poorly serviced.

On the first aspect, the European Community has sought to intervene by guaranteeing farmers an increase in income by rewarding certain categories of production to ensure greater profitability, also in view of the strategic importance that agricultural production has for the community states and the positive externalities that the preservation of the territory guaranteed by farms represents for local communities and to counter depopulation of inland and rural areas.

The second aspect concerning increased physical fatigue and the difficulty of obtaining leisure time is the one that is most difficult to resolve in view of the small size of farms and the low capitalization of many farms, especially those located in southern Italy. These structural data prevent a faster innovation that could have allowed to improve both these aspects by reducing physical fatigue and working time.

The third and final factor is related to a structural fact that is often a discriminating factor in the choice of employment sector: the location of the farm. Despite repeated interventions by the state with different lines of financial intervention: SNAI strategy, Mountain Law, funds for small municipalities, etc., and despite EU policies in favor of rural development, some territories in the country continue to be marginal, lagging in development, lacking essential services such as education, personal and health services, inadequate transportation and complaining of undersized computer networks. The framework described results in a propensity for abandonment of these territories and leads to ever-increasing rates of depopulation, making these contexts unattractive to young people who intend to set up a business and plan for the future development of their lives.

Although there is also a reverse flow of those who, after living for years in chaotic and overpopulated cities, rediscover a slower lifestyle and the charm of living in a small community, at the moment, there is a greater flow of people leaving rural areas to live in highly urbanized settings that provide greater quantity and quality of personal and business services.

2.2 Critical issues:

c) Poor innovations.

Unlike age, the supply chain does not appear to be a determinant of whether or not to innovate. The propensity to innovate despite appearing to be slightly higher for livestock farms seems to be poorly correlated with the supply chain to which they belong.

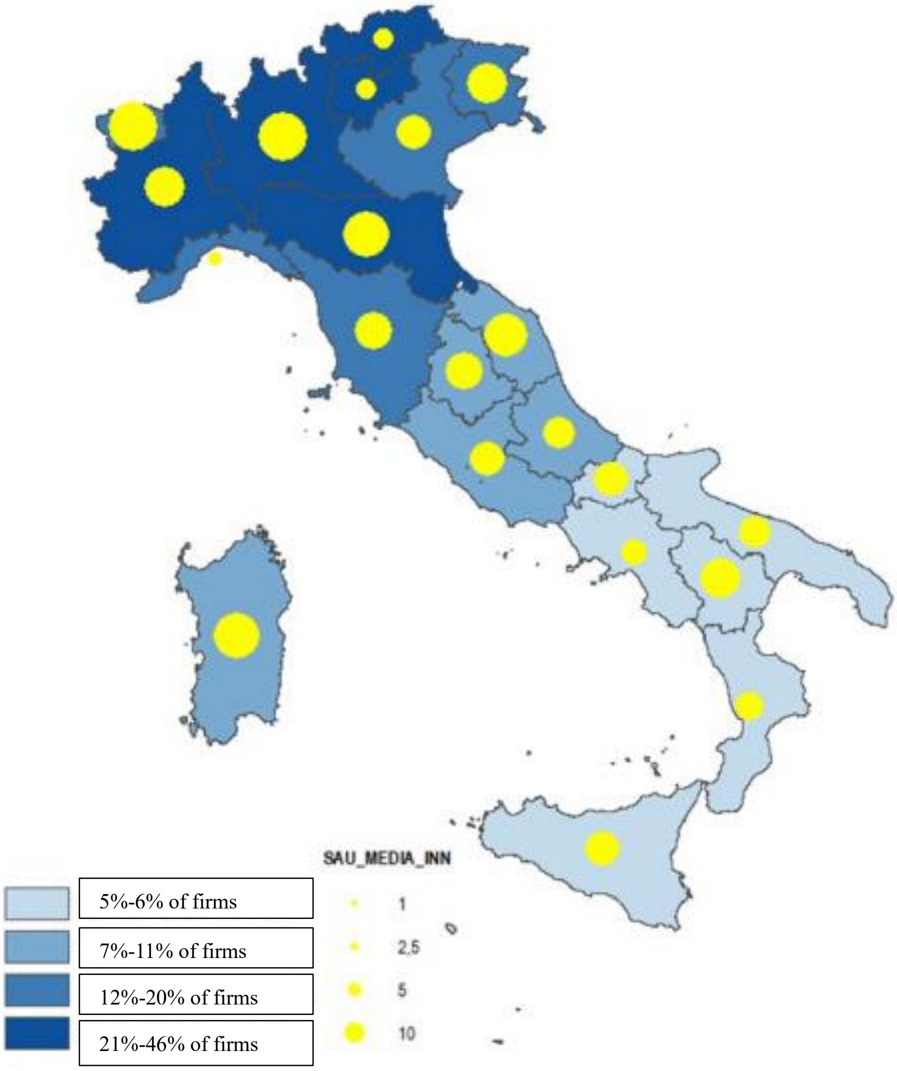
At the same time, the supply chain is decisive for the innovation orientations of farms; that is, it influences the type of investment that farms make. In fact, according to the data collected, most livestock farms have as their main goal greater sustainability of their activities especially if they are active in wastewater management and input reduction. While for companies in the fruit and vegetable and wine production sector, the areas of fertilization and crop protection are more important (Ronga, 2022).

Companies that have innovated in the past five years showed a high degree of satisfaction with the investment made, as the percentage of those who believe that investments in innovation have been effective exceeds the 70 percent threshold, especially concerning perceived improvements in working conditions (78 percent), yields/outputs and input utilization (75 percent), reduced consumption of technical and energy inputs (74 percent) and soil quality (71 percent) (Ronga, 2022).

2.2 The critical issues:

d) The size of the companies.

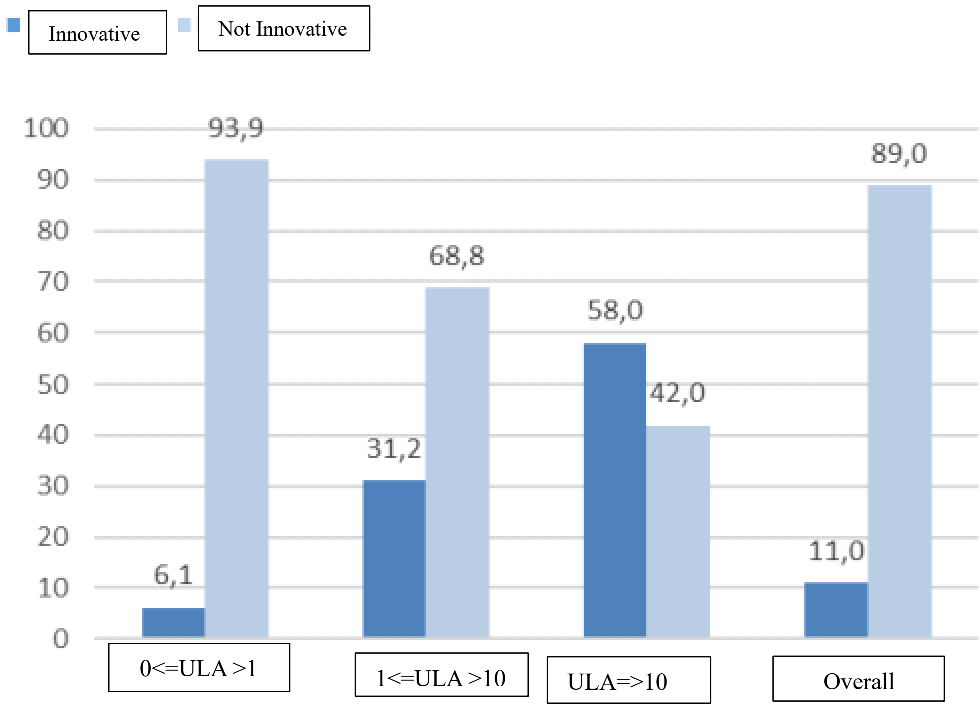
One limitation to the activation of innovation processes is the size of enterprises. The propensity to innovate is greater in larger firms, not surprisingly, the firms themselves point out that the greatest obstacle to innovation is small size. This also affects the geographical location of the most innovative firms, which are mainly concentrated in northern regions. According to the 7th Census for Agriculture compiled by ISTAT Firms making innovative investments are much more prevalent in the North, both in the Eastern (22.6 percent) and Western (21.7 percent) distributions, being twice as high as those in the Center (10.9 percent) and four times higher than in the South (5.4 percent) and three times higher than in the Islands (7.1 percent). Far above the national level are the Autonomous Provinces of Bolzano (45.6%) and Trento (32.0%), followed by Piedmont (23.2%) and Emilia-Romagna (22.2%). Despite the overall lag in the South, Sardinia has an incidence of innovative firms at 11.3 percent, significantly higher than all other regions in the South. (Gnesi, 2022)



Graph 1: Map of holdings divided by UAA classes
Graph Source: 7° Censimento Generale Agricoltura 2022

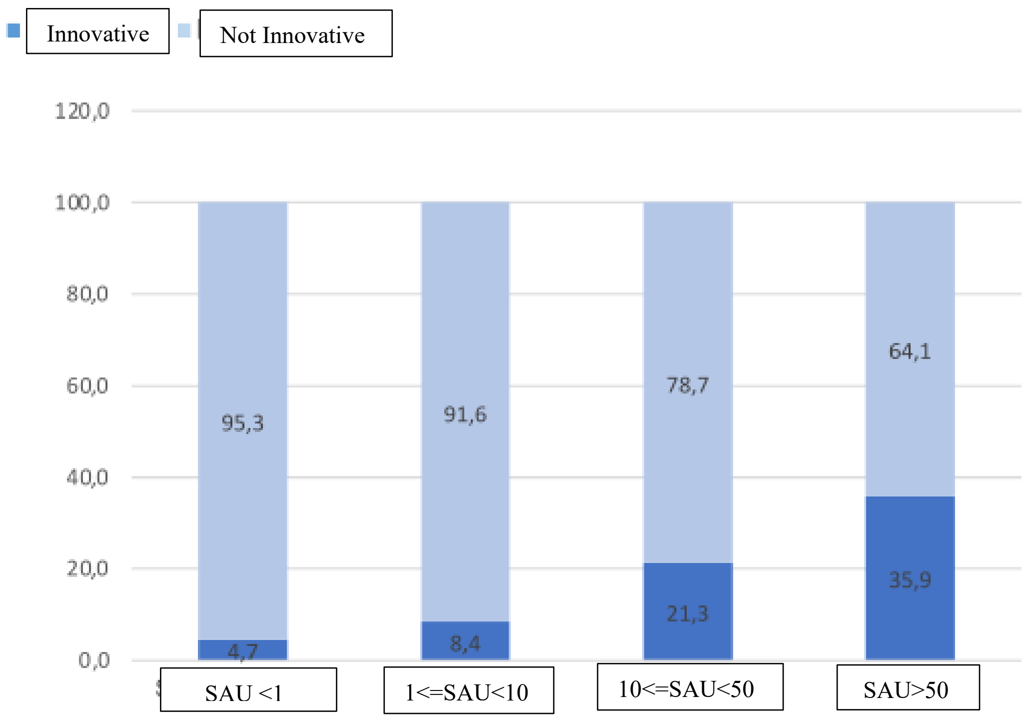
One of the main reasons explaining the gap between the north and south of the country is related to firm size. Northern firms are larger and more structured than their Southern counterparts, which influences the propensity to innovate, and the extent of investments faced by the firm. This trend is clear from the Seventh Census data, which analyzes the influence of three size units and their impact on firms' innovativeness. The three units considered are respectively: ULA, SAU, and UBA.

Census data show that size in terms of employees has a major impact on the ability to make innovative investments. In firms with 10 ULA and above, the incidence of innovative firms exceeds that of firms that do not make innovative investments, at 58 percent and 42 percent, respectively. Taking into consideration firms with fewer employees (between 2 and 9 ULA), however, we can see how the share of innovative firms falls to about one-third that of firms that do not innovate (31.2 percent versus 68.8 percent), this difference becomes sharper if we take into consideration those firms with up to 1 ULA (6.1 percent versus 93.9 percent) (Gnesi, 2022).



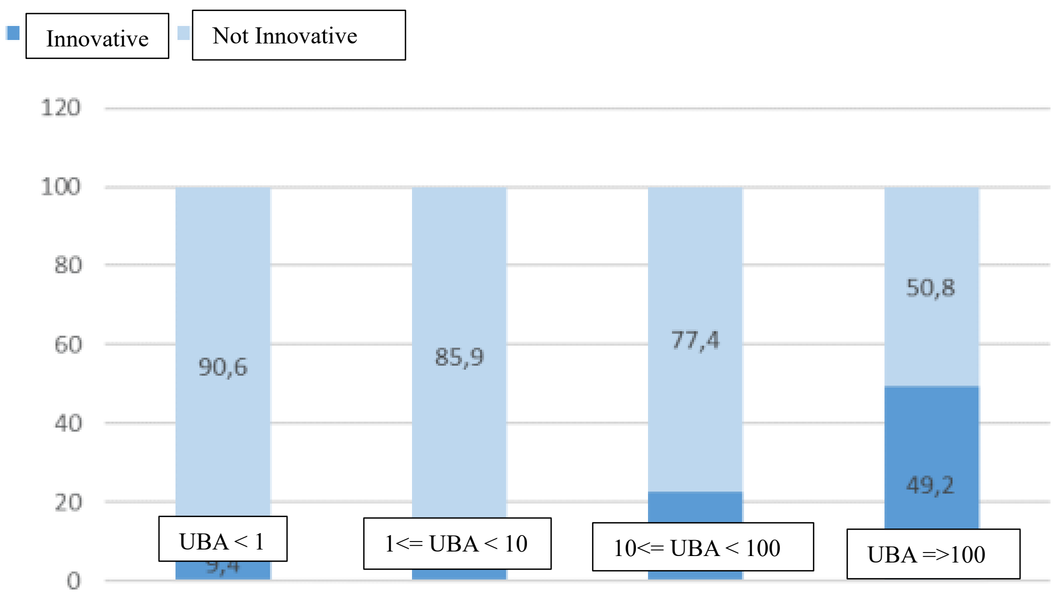
Graph 2: Innovative enterprises by class of AWU
Graph Source: 7° Censimento Generale Agricoltura 2022

This same argument can be applied when examining SAU (unit of measurement indicating the Utilized Agricultural Area) taking the three years 2018-2020, larger farms made significantly more widespread innovative investments than smaller ones: 35.9 percent of farms with more than 50 hectares of SAU compared with 21.3 percent of those with 10-50 hectares of SAU, 8.4 percent of units with 1-10 hectares and 4.7 percent of those with up to 1 hectare. (Gnesi, 2022)



Graph 3: innovative enterprises by class of SAU
Graph source: 7° Censimento Generale Agricoltura 202

Size in terms of UBA (unit of measurement indicating the Adult Livestock Units) also greatly affects the propensity to innovate. In the three-year reporting period, 49.2 percent of companies with more than 100 LUs made innovative investments compared with 22.6 percent of those with 10-100 UBA, 14.1 percent of units with 1-10 UBA, and 9.4 percent of those with 0-1 UBA. (Gnesi, 2022)



Graph 4: innovative enterprises by class of UBA
Graph Source: 7° Censimento Generale Agricoltura 2022

2.2 The critical issues:

e) Poor capitalization

The adoption of new technologies in recent years has become an increasingly attractive prospect for farms. The new technological frontier, from the perspective of agricultural entrepreneurs, is an excellent tool for increasing the competitiveness of farms in the market. Compared to other business realities, the agricultural sector is more inclined to make investments in human capital to improve its skills and to encourage employee participation in the development of innovation projects, in a logic of sharing. However, innovation is difficult to implement for most Italian companies (Centro Studi Tagliacarne, 2023). A structural deficit in the Italian agricultural sector is that of poor capitalization. Companies do not have sufficient financial resources to deal with investments. According to data compiled by the Tagliacarne Study Center, about 86 percent of agricultural enterprises resort to equity or family capital for current management and making investments. Self-financing is a typical trait of businesses in this sector, where corporate capital is mixed up with personal capital. When companies resort externally to find the necessary resources, 52 percent turn to credit institutions while just 25 percent use direct public financing. In the case of technological innovation, this problem becomes particularly relevant because of the exorbitant investment for new technologies (23 percent) which is added to the lack of information on the procedure for investing in digital technologies that makes it complex and frustrating for companies to activate the funds made available by institutions (21 percent). A change of this magnitude must necessarily go through a modernization of the entire supply chain through the development of targeted policies that are accessible to most companies in both economic and bureaucratic terms (Centro Studi Tagliacarne, 2023).

An important aspect that could be exploited to mitigate the problem of poor capitalization is the ability of farms to network with other players in the supply chain. According to the data collected, 35 percent of agricultural companies develop partnerships with other companies this in a sector characterized by small companies and low capitalization allows companies to structure themselves and strengthen their competitiveness in the market. This also results in shared and more efficient management of supplies and different stages of the value chain as well as simplifying access to financing. In addition, agricultural companies are more likely than their industrial and service sector counterparts to establish collaborations with employees and trade associations: 42 percent of companies favor the participation of employees in the development of innovative projects compared to 30 percent of industrial companies and 31 percent of service companies; while 37 percent establish collaborations with trade associations compared to 30 percent of manufacturing companies and 25 percent of service companies. However, even in the ability to network, greater dynamism is shown by youth-led firms and by firms located in northern regions (Centro Studi Tagliacarne, 2023).

2.2 The critical issues:

f) the training deficit.

The agricultural sector suffers much more than other sectors from the impact of weather and natural disasters. Digital technologies are crucial in this regard since through their implementation we can try to manage variability rather than ignore or eliminate it. In addition, perhaps for the first time since we have based our survival on agricultural production systems, we have to deal with the scarcity of natural resources, so it becomes urgent to use them better and more efficiently. In recent years, this has led to the emergence in agriculture of a wide range of tools, which have already been adopted in industry and are usually marked by the acronym "4.0." This acronym characterizes digital products such as tractors that can communicate with operating machines and the farm center, satellite and optical guidance systems, and software to better manage production inputs (Cutini et al. 2022)

The use of "4.0" technology constitutes a process innovation in agricultural production, and this implies that you cannot just buy it but need to learn how to use it. (Cutini et al. 2022)

Therefore, the most relevant barrier to smart agriculture may not be economic, but cultural. Research and education are crucial for practitioners to be more aware of the opportunities presented by innovation; moreover, this will allow technology to be more usable for agricultural practitioners. A multitude of studies have demonstrated the positive impact of computerization and innovation: a substantial share of agricultural productivity growth over the past fifty years has been generated by investment in innovation and research and development. (ISTAT, 2021)

It is useful to note, however, how technology diffusion in the sector may be hindered by the structural deficits listed above in particular the high average age of the operators. In fact, according to the different reports reviewed youth-led firms are markedly more likely to innovate yet they constitute a minority. This runs counter to the challenges that will characterize the industry in the coming years. Entrepreneurs to meet future challenges will need to develop and disseminate digital skills, which in parallel with green skills, will be strategic in designing the agriculture of the future as digital skills can become a vehicle for disruptive changes in the agricultural sector in the coming years. (D. Paudel et. al., 2022) Digitalization is a particularly versatile tool that companies can use: to innovate communication or to automate production processes and optimize efficiency. In addition, digital skills enable the enterprise to cope with global competition while remaining competitive in an environment that is always complicated for farms.

The current economic scenario is characterized by the very important growth in this period of the overall movement underlying the digitization of the agri-food supply chain. The Smart AgriFood Observatory, in its 2022 paper, highlights how, the Italian market for agriculture 4.0 solutions, products, and services has grown from 100 million per year in value recorded in 2017 by the first report to more than 1 billion euros at the end of 2021 (Cutini et al., 2022).

In parallel with this very important market growth, the area cultivated with Agriculture 4.0 tools by Italian farms is also increasing. Certainly, among the factors that have played a key role and promoted the growth of the cultivated area and the intensity of investments made are the tax incentives related to tax credit, a measure borrowed from industry and extended from 2020 to agriculture as well, which has contributed to the renewal and modernization of the machinery fleet (Cutini et al., 2022).

According to data collected by ISTAT, computerization in 2020 is 15.8 percent, four times higher than that found with the 2010 Census (which was 3.8 percent). Over the decade, the intensity of the increase in computerization was on average much greater in the South (+247%), the Islands (+241.9%), and the Northeast (+205.5%), while in the other geographic distributions, it remained below the national average, particularly in the Northwest (+137.3%) and the Center (+183.7). The territorial distribution is particularly unbalanced, penalizing the South (6.7 percent) and the Islands (10.3 percent), which suffer a large gap compared to the Center (16.1 percent), the Northwest (32.9 percent), and especially the Northeast (33.5 percent). (Gnesi, 2022).

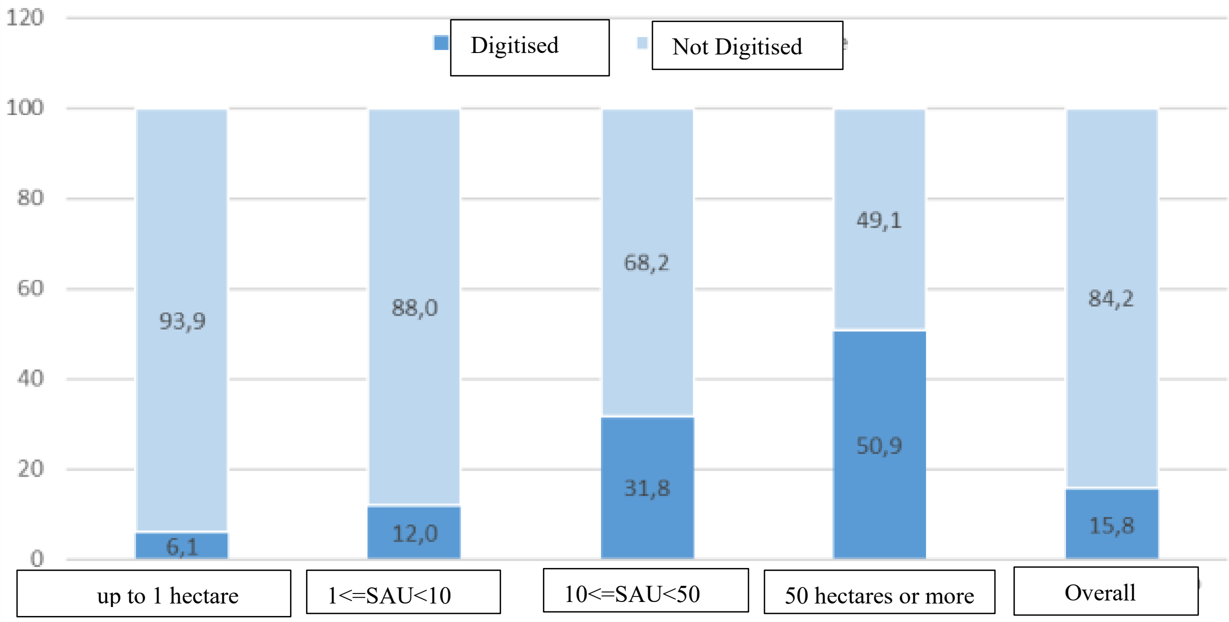
From the perspective of predominantly agricultural land use, it is farms that cultivate permanent grassland and pastures that are most computerized, with an incidence of 22.4 percent, followed by those with arable crops (17.8 percent) and agricultural woody crops (12.3 percent). Farms that cultivate mainly family gardens are those where digitization is least prevalent (9.8 percent) (ISTAT, 2021).

In particular, the most digitized farms are those engaged in related remunerative activities (61.7 percent), specifically the activities of agritourism (69.3 percent), social agriculture (71.5 percent), and educational farm (76.6 percent). Within the most digitized farms, certain trends can be observed that characterize them:

- suffer from the gender effect: companies run by men are more computerized than those headed by women (17.7 percent vs. 11.6 percent).

- have a young business head: ranging from over 32.2 percent for business heads under 45 to 7.6 percent for business heads over 64.
- are managed by an educated and specialized farm manager: in particular, digitization is more prevalent in the case of agriculture-related degrees.
- are associated: two out of three computerized companies are members of producer organizations, business networks, or are associated with other organizations (64.8 percent). (Coldireti, 2023)

Again looking at the three units of measurement considered by the Census for innovative investment, it becomes clear how firm size influences firms' propensity to digitize. Considering firm size in terms of Units of Labor (ULA), the differentiation between computerized and non-computerized firms is very evident for both large and small firms. For large ones, 78.2 percent are computerized while 21.8 are not; in contrast, for small ones, only 8.8 percent are computerized versus 91.2. In medium-sized companies, the gap is smaller, in favor of companies that use digital equipment, 44.7 percent, compared to those that do not digitize (55.3 percent). (Gnesi, 2022).

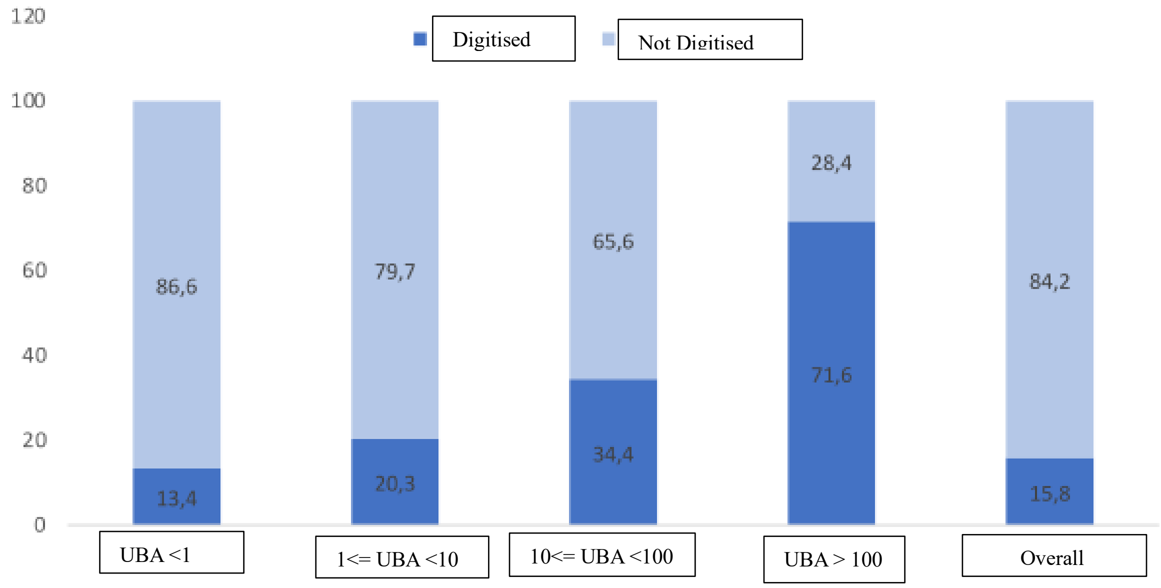


Grap 5: Digitised Firms for class of SAU
Graph Source: 7° Censimento Generale Agricoltura 2022

The effect of size is also found using the SAU as an indicator. The share of computerized farms is 50.9 percent in farms with at least 50 hectares of SAU. The gap in digitization increases sharply as

SAU decreases, especially penalizing farms up to 1 hectare of which the incidence of digitized farms is 6.1 percent. (Gnesi, 2022)

Considering the farm size in terms of UBA, the computerization rate is 71.6 percent for farms with more than 100 UBA, decreases to 34.4 percent in the case of units with LUs between 10 and 100, and stands at about 20.3 percent both in the case of UBA between 1 and 10 UBA down to 13.4 percent for units up to 1 UBA (Gnesi, 2022).



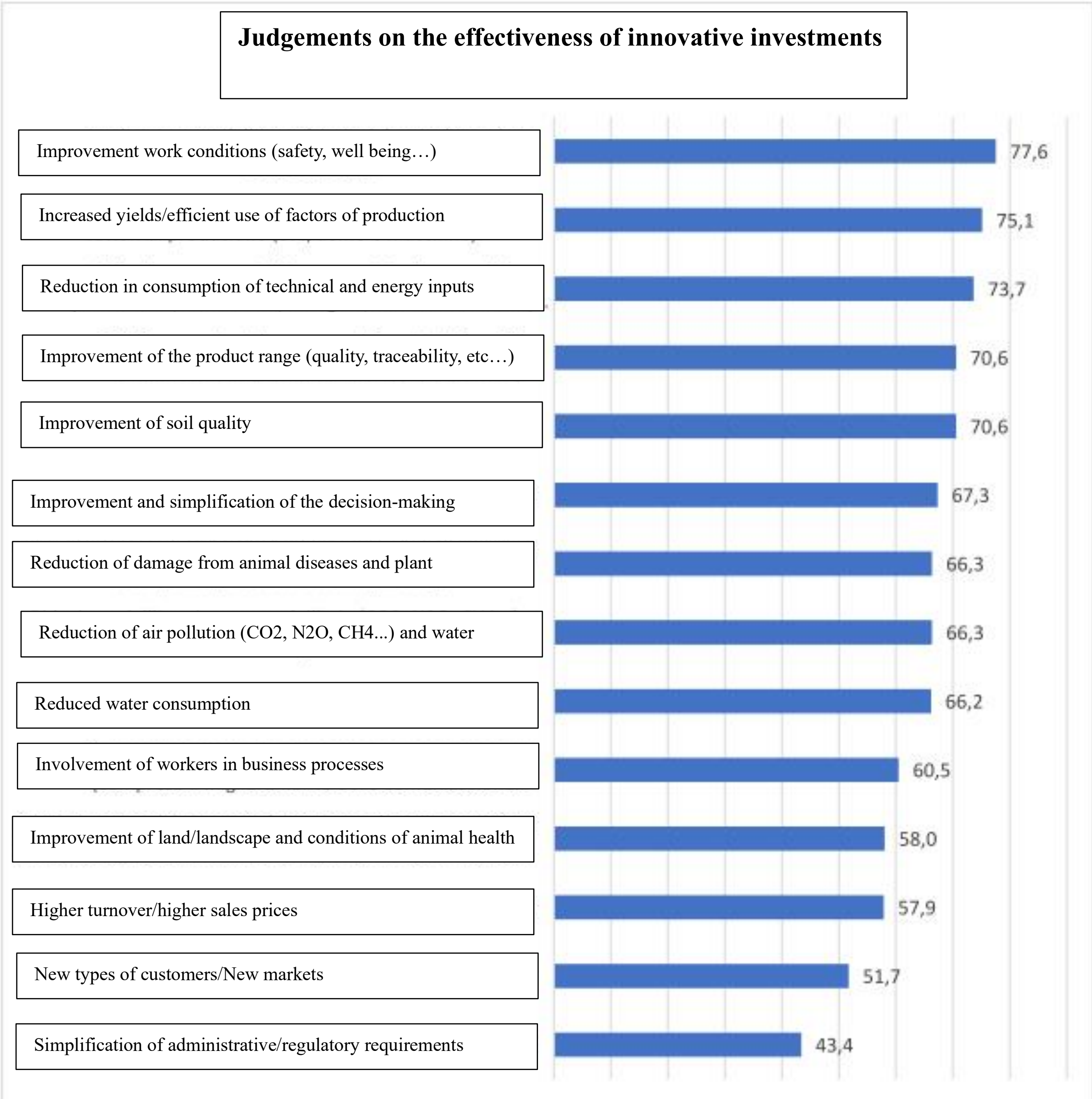
Grap 6: Digitised Firms for class of UBA
Graph Source: 7° Censimento Generale Agricoltura 2022

2.3 Innovation's response to some of the critical issues highlighted.

In the product-process sphere, a large part of the innovations concern experimentation with new fertilization and/or crop protection techniques (50 percent), soil tillage (42 percent), irrigation and water management (39 percent), and new varieties, both in the context of crop production and animal production (28 percent). In the area of technology, the research particularly investigated the adoption of agritech solutions, focusing on digital agriculture applications. The component related to farm management systems is prevalent (27 percent), as is that related to management software for carrying out administrative/legal practices (21 percent); other important technologies concern the introduction of systems installed on vehicles that integrate GPS/RTK (19%), innovations related to sensor/IoT for managing crop production in the open field, such as weather stations for collecting climatic data, in-field sensors to record leaf wetting or the presence of plant diseases (17%), and satellite or remote sensing monitoring systems (17%). Robotics and autonomous systems still play a marginal role being far less prevalent, although there is beginning to be some investment in them. (Ronga, 2022).

The majority of companies that have undertaken product, process, or technological innovations are satisfied with the investment made. Investments are considered effective (effectiveness rating: high + medium) relative to perceived improvements in working conditions (78 percent), increased yields/production and efficient use of inputs (75 percent), reduced consumption of technical and energy inputs (74 percent), and improved soil quality (71 percent). Insufficient satisfaction expressed, however, for innovative investments aimed at expanding the customer base (52 percent) and simplifying bureaucratic requirements (43 percent) (Ronga, 2022)

Businesses in the sector have access to a large number of tools that can provide the coverage needed to support innovation processes. Among those most widely used can be identified, the Regional Rural Development Plan (cited by six out of 10 companies); and the agriculture 4.0 Plan (Ronga, 2022)



Graph Source: Report RRN

Graph 7: Typologies of innovations adopted by the firms

The challenges facing the agricultural sector call for a new approach that can ensure greater respect for the land by guaranteeing an optimization of available resources: reducing waste and enabling better working conditions for those working in the sector. To be able to achieve these results requires a method based on the use of sensors, automation, computers, and GPS. Modern Precision Agriculture is a concept launched in the United States beginning in the 1980s (Misturini, 2020) and is a farm management strategy based on a cyclical process of observing and acquiring data, followed by interpreting them and evaluating the information acquired that will be used to implement decisions based on these observations. The purpose of precision agriculture is to search for the most suitable solution for any type of agricultural production. The search for the most suitable solution is done through a scientific study and application of the available information to obtain the desired outputs. Another of the purposes is to attune soil and crop management to the specific needs of a heterogeneous field to improve production, minimize environmental damage, and raise the quality standards of agricultural products. It was born from the need to meet three conditions: doing the right thing, at the right time and in the right way (Servizio Studi Camera dei Deputati, 2022).

According to Misturini, the advantages associated with precision agriculture are considerable in that it allows the productive capacity of each plot to be increased by increasing yields and reducing production inputs. This leads to a greater speed in the execution of operations, and greater efficiency both in economic terms because the use of the technologies leads to a reduction in labor, more efficient use of productive inputs therefore a consequent decrease in costs; however, it is also efficient in terms of eco-sustainability because a more conscious use of productive inputs leads to less waste and a less extensive use of polluting chemicals such as artificial fertilizers. (Misturini, 2020)

2.4 Conclusions

Our descriptive analysis of Italian agriculture shows an overall picture from which the sector's lights and shadows, crises and opportunities emerge. Agriculture is confirmed as a strategic sector for the Italian economy, capable of generating income and jobs and feeding an important agro-food industry for our exports. Italy confirms its leadership and leading position in several sectors: wine and dairy production, olive growing and processed agricultural products, excellence and branded production.

However, in recent years the sector has been facing major difficulties. Companies have decreased in number, although the size of those remaining has increased in terms of UAA used; companies are struggling to implement a generational change that is becoming increasingly important and strategic in order to be able to meet the challenges posed by the new millennium: adaptation to climate change; the search for sustainable agricultural production; positioning on the global market.

The criticalities identified concern: the high environmental impact of agricultural production and in particular of livestock breeding in the northern regions of Italy; the lack of generational change that affects all regions, but particularly the south and the islands; the low propensity to innovation; the small size of farms and their low capitalisation that does not allow for significant investments in business structuring; lack of adequate training and low schooling.

On average, Italian agricultural enterprises have little propensity for innovation. This conservative approach to business management is partly to be found in the advanced age of most of the farm managers, partly in the low level of schooling and finally in the small size and low capitalisation. This produces a fabric of small and poorly structured enterprises still relying on traditional farming and breeding methods. It is easy to see how a sector structured in this way is not an environment conducive to innovative processes. This, however, clashes with the reality of a sector that in the coming years will have to face challenges that are not easy to solve. In fact, the agricultural sector, in order to remain competitive, will necessarily have to structure itself in such a way as to be able to produce in a more sustainable way and achieve better income results. Not all the critical issues identified represent only negative aspects. Some of these critical issues can be read as opportunities for growth and improvement of the sector. In particular, many of them can be addressed and resolved with the use of those new technologies that we will analyse in the next chapter

Chapter III: The revolution of sensor and Big Data in Agriculture

The chapter, in its introductory part, explores the state of Agriculture 4.0 in Italy and then focuses on specific technologies. Since it is not possible to cover all 4.0 technologies adopted in agriculture, the chapter examines three types of innovations in particular: real-time monitoring and the use of data in agribusiness, automation and the global navigation satellite system. The analysis of technological solutions focuses on how they are implemented in the field and the benefits they bring to farms.

The last section of the chapter presents the barriers to the adoption of 4.0 technologies and their limitations.

3. 1 Precision agriculture

Agriculture is a sector that has been undertaking profound changes in recent decades to adapt to the new economic and environmental challenges facing those working in the sector. From a primarily productivist primary system, the sector is moving toward product quality and territoriality, the production of personal services, and environmental protection.

How companies aim to revolutionize agriculture are technological innovations capable of reducing production costs and limiting the release of pollutants into the soil, water, and air, without underestimating the reduction of wasted raw materials. For several decades now, there has been a need within the agricultural sector to find new approaches to innovate traditional farming methods; Precision Agriculture has developed on precisely these assumptions and has its basis in the evolution of methodologies and technologies in the sector as well as in new regulatory frameworks at the EU and national levels. (A., Scheibe, R., Poudineh, R. 2023)

This type of farming originated in the United States in the early 1990s, the name comes from the English Precision Agriculture or Precision Farming or Site Specific Farming Management.

The establishment of the new paradigm is based on the widespread application of new solutions that have revolutionized the primary sector. Precision agriculture is based on the implementation in agricultural production processes of technologies, principles, and strategies for spatial and temporal management of variability associated with aspects of agricultural production, concerning the real needs of the plot. We can therefore define precision agriculture as a form of advanced farming, which is based on the use of technology and new techniques for variable application of production inputs within the land. The use of inputs (whether water, fertilizer, or plant protection products) is based on the actual needs of the plant and after a study of the chemical and physical properties of the soil plots.

The goal is to obtain better production performance from crops through rationalization of inputs and reduction of cultivation and environmental costs. (Colonna et al.)

3.2 Precision Farming in Italy

Agriculture 4.0 is the application of several innovative technologies in the field of agribusiness and can be considered an "upgrade" to precision agriculture. This is due to the 'integration within the production processes of agriculture of so-called 4.0 technologies. The strength of this approach is based on the analysis of data that farmers collect through sensors placed in the field and the possibility of automating harvesting or irrigation processes. (A. Sheikh, M. Alnoukari, 2011).

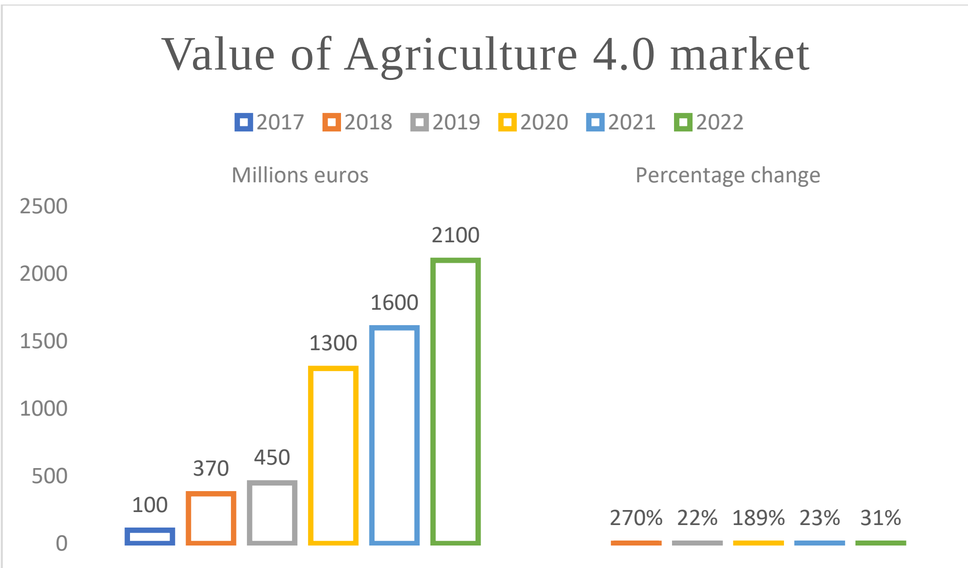
The application of digital technologies 4.0 has a twofold task, firstly, to innovate the everyday life of the farm by innovating its production processes making them less burdensome and more dynamic, secondly, digitization changes the strategic planning of the company by giving the entrepreneur a more solid foundation on which to build his or her business strategy. This should foster value creation not only for the individual farm but for all its partners by generating a cascading effect from which all components of the value chain will benefit.

Smart Agriculture solutions are provided by tools such as IoT and artificial intelligence, which enable the analysis of large amounts of data, self-driving satellite tractors, to the use of drones. Farmers develop a production framework capable of ensuring higher profits, greater economic sustainability, and reducing the social and environmental impact of the farm. (Salerno Agrifood tech, 2021)

We can consider precision agriculture, the necessary prerequisite for the development of Agriculture 4.0, but it is also one of the cornerstones of the latter. The vision behind precision agriculture is to orient the production process to the needs of the moment by focusing on individual problems and solving them in a timely and precise manner. To do this, the farmer needs real-time data on his or her crops and plots (Salerno Agrifood Tech, 2021). This data is extrapolated through the use of sensors, installed on fields or farm machinery, which transmit information, based on which operators then make timely and effective decisions, which can also be entrusted to automated systems. (Salerno Agrifood tech, 2021)

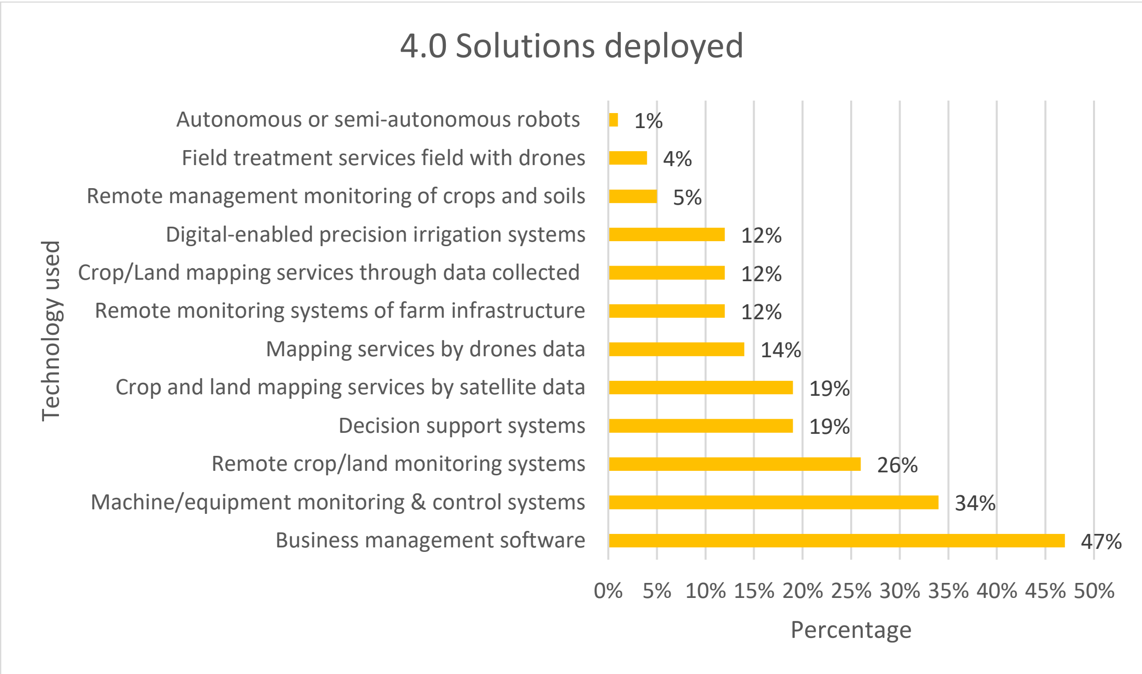
From data collected in 2022, it is estimated that in the United States, farmers using GPS-enabled automatic tractor guidance systems are 69% of those using precision farming technologies. Farmers using GPS systems for sprayer section control are about 63% and for planting 51%. Variable rate fertilization is adopted by about 49% of farmers, while 9% use *precision farming* tools for phytosanitary treatments. 68% of combines are equipped with yield mapping systems. (Erickson et al., 2022) According to the same study also in Canada, it was found that a higher percentage of farmers use automated guidance, 75 percent. Farmers using GPS systems to control sprayer sections are equal to the U.S., about 63 percent, in contrast to automated seeding where the percentage is in less use and stands at 36 percent. The adoption of these new technologies is very similar in North American countries, as farm sizes are larger in these countries and consequently farmers are more willing and able to adopt new technologies. (Say et al., 2018). In contrast, in Europe, the low adoption of *precision farming* technologies can be explained by small farm size, lack of knowledge on the part of farmers, and insufficient economic support for the initial investment. (ECPA et al., 2019). Italy is no exception; however, Agriculture 4.0 has been growing in importance in recent years. According to data compiled by the Osservatorio Smart Agrifood and the RISE Laboratory, "Research & Innovation for Smart Enterprises," it has been found that by 2022 the Italian agricultural area affected by technological and digital innovations has reached 8 percent of the UAA, with ample room for growth, especially thanks to the growing spread of big data analytics and the so-called "Internet of Things." (Smart Agrifood, 2021; Antares, 2022)

In Italy, the Agriculture 4.0 market in 2022 reached more than 2 billion euros in value, with an estimated growth over 2021 of +31%. To understand the magnitude of this figure, just think that in 2018 the market was worth about 370 million while in 2017 we were around 100 million euros.



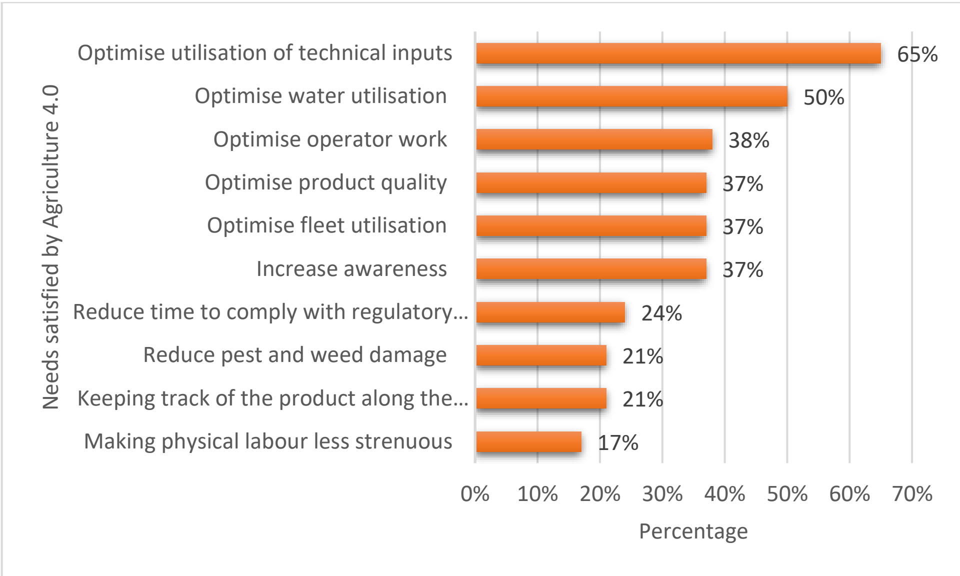
Graph 8: The value of Agriculture 4.0 across the years Source of graph:

The data collected by the Observatory show that the most popular technologies with 47% are management software, implemented mainly in the wine sector; followed by strong growth at 34% in remote monitoring systems for machinery, crops and soils; the use of Decision Support Systems (DSS) and services for mapping soils using satellite data both continue to increase with 19%. In recent years, there has also been an increase in digital technologies used for precision irrigation, which stands at 12%. While robotics and drone technologies for field treatments remain in the minority, albeit on the rise, with 1% and 4% respectively.



Graph 9: Solutions deployed by the firms
Source of graph: Osservatorio Smart AgriFood- Laboratorio RISE

Also, according to the Osservatorio Smart Agrifood, most farms using precision farming technologies are focused on optimizing inputs. Another need strongly felt by 50 per cent of the companies is that of water saving, which is increasingly crucial given the ever more frequent hydrological crises affecting most of the Italian regions. Companies indicated as priorities the optimisation of operators (38%), of the machinery fleet (37%) and product quality (37%), with the latter being particularly felt by wine producers. Another aspect that 37% of companies consider fundamental is raising awareness through new approaches based on data collected with sensors. While easing the workload of operators and product traceability within the supply chain are not at the top of the list of needs, they are nevertheless among the benefits noted and among those that are attracting increasing interest from producers.



Graph 10: Needs satisfied by Agricolture 4.0
Source of graph: Osservatorio Smart AgriFood- Laboratorio RISE

3.3 Monitoring System and Data Use

a) Use of data

The digital revolution in agriculture, often referred to as "smart agriculture" or "smart farming," involves the integration of various digital tools and technologies into traditional agricultural practices. (Thongnim et al. 2023). These technologies aim to improve the productivity, efficiency and sustainability of agricultural operations.

According to the Food and Agriculture Organization of the United Nations (FAO), the world population is expected to reach 9.73 billion by 2050. Food shortages and population growth are major obstacles to global sustainable development (FAO, 2021). It poses the challenge for humankind to be able to feed itself by producing enough food for everyone without depleting the planet's resources, Advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), UAVs and the mobile Internet can offer practical solutions to sustainable development problems by enabling farms to meet the food needs of the world's population without resulting in negative externalities to the environment. (Thongnim et al. 2023; Soori, 2023, FAO, 2022)

The potential of smart agriculture lies in the use of AI, IoT, UAVs and cyber-physical systems in farm management. (Thongnim et al. 2023). This integration between advanced technologies and traditional agriculture can lead to results that enable the transformation of some of the inherently environmentally critical agricultural practices into sustainable farming practices. (Elsayed Said Mohamed, 2021).

A key role in this field is played by IoT technology, seamlessly connecting various remote sensors including: robots, ground sensors, and drones. These interconnected devices operate automatically, facilitating real-time data collection and analysis. Real-time data insight enables, with the adoption of smart agricultural technologies, farmers to have greater control over crop cultivation, resulting in greater predictability and efficiency: water use is reduced, fertilizer and pesticide use is reduced, and the environment is greatly benefited. There are, at present, a number of digital technologies, which make it possible to monitor not only crops but also soils and livestock in real time. The monitoring is done through sensors whose purpose is, as mentioned, to collect information on the health status of plants, but also animals; study the chemical composition of the soil, use resources more efficiently, reducing waste and at the same time having better animal and plant production in terms of quantity and quality. (Thongnim et al. 2023)

Currently, more and more farms are using comprehensive data analysis tools to make smart and cost-effective use of smart farming data. Therefore, the adaptability of big data in smart farming analysis is demonstrated by several common smart farming applications. (Thongnim et al. 2023) These examples demonstrate how big data can help farmers gain useful information and improve their farming methods. In addition, big data includes large amounts of information characterized by high volume, generated at high speed, and available in a variety of formats and types. It is difficult to manage and analyze agricultural data with traditional procedures because the volume of data exceeds the capabilities of standard data processing technologies. Specialized technology and cutting-edge analytical techniques, such as data mining, machine learning and artificial intelligence, are being used to extract valuable information and create value from agricultural data. With the help of these technologies, companies and industries can transform raw data into useful knowledge to improve processes and gain a competitive advantage in today's data-driven environment. (Thongnim et al. 2023)

3.3 Monitoring System and Data Use

b) Monitoring in precision irrigation

Precision agriculture, with data extrapolated from sensors, can respond to growing challenges related to climate change, such as drought, or problems related to the nature of plants themselves, which may require different amounts of water depending on environmental conditions (Yusuke, 2018). Precision irrigation is the combination of information technology in the irrigation process to more efficiently manage a productive input, namely water. (Shibusawa, 2001; Zacepins et al., 2012; Aboye et al., 2020).

It should be considered that we are talking about a relatively new technique that professionals are working on to improve precision and effectiveness. The next frontier in precision irrigation is to deliver water and other nutrients directly to the roots of each plant to maintain soil moisture at optimal levels, eliminating surface runoff and deep percolation as the design process is conducted based on the soil's ability to absorb water and the amount of water required by the crops (Daccache et al., 2015).

However, to provide efficient precision irrigation, IoT integration for data acquisition, monitoring, control theory, and water resource management and monitoring, control, and decision support technologies must be considered as a whole in irrigation management (Pham and Stack, 2018); Zamora-Izquierdo et al., 2018).

In control theory, advanced control strategies refer to a wide range of techniques and technologies implemented within an industrial process and control system, while control theory is defined as a subfield of electrical engineering and mathematics that deals with the dynamic behavior of systems. Achieving the desired dynamic behaviors defines the precision of the output and is determined by the pattern of controlled inputs and parameters. In precision irrigation, plant properties and weather parameters are monitored through the use of sensors and different patterns to provide the desired control of irrigation. (Abioye, 2020)

For important plant growth and development, adequate water supply is essential. When rainfall is insufficient, water must be supplied to crops through irrigation (Brouwer et al., 1990b; Abioye, 2020).

We can divide irrigation techniques into modern and traditional based on two key factors: the first is whether or not they tend to provide water savings; the second is whether or not these techniques are precisely monitored, scheduled, and controlled. The amount of water for irrigation depends on the irrigation method adopted, the water requirements of the plants and the irrigation system adopted, the water requirements of the plant, and the type of soil. Any irrigation method adopted will affect nutrients, infiltration rate, evaporation, water uptake and deep percolation in the soil.

Traditional surface irrigation methods are characterized by the application and distribution of water on the soil surface through gravitational flow, without any form of sensing and control. This is undoubtedly the oldest and most commonly practiced irrigation method worldwide (Yonts, 1994, Abioye, 2020). Examples of this method are furrow, flood, and hand irrigation. However, these methods require good leveling of the soil surface to ensure adequate water distribution, preventing applied water from runoff (Zhang et al., 2004). In addition, the water-saving capacity of these methods is low because of the potential water losses due to the massive evaporation process and uncontrolled irrigation volume. (Gillies, 2017, Abioye, 2020).

The counterproductive aspect of these techniques is that plants receive too much water and this often leads to surface runoff and deep percolation, which in turn increases the tendency for leaching, reduces soil nutrient levels, and results in reduced crop yields (Adamala et al., 2014). Therefore, surface irrigation can be improved to achieve precision irrigation through the adoption of modern water-saving technologies and necessary monitoring and control strategies to increase water use efficiency (Koech et al., 2010).

A modern irrigation system relies on efficient monitoring of various parameters that influence plant growth and development, this is very important to design an efficient irrigation control system and improve food production with minimal water loss. Monitoring, in the context of precision irrigation, implies that data collection reflects in real time and as accurately as possible the state of the soil, plants, and weather conditions in plant irrigation areas. This is done through the use of wireless sensor networks (WSNs) and the Internet of Things (IoT) (D. Gupta, et. al., 2023). To develop a real-time monitoring system, IoT has pioneered the use of low-cost hardware (sensors/actuators) and communication technologies (Internet) to improve the irrigation monitoring and control system. (FerrándezPastor et al., 2018; Abioye, 2020). Similarly, distributed WSN nodes also play a significant role in real-time monitoring for precision agriculture. They are a network of sensor nodes interconnected wirelessly to detect, calculate and transmit information on various parameters and are designed for large-scale and long-term deployment (Hamouda, 2017; Abioye et al., 2020). The implementation of IoT to monitor essential parameters in precision irrigation has become a trend in which sensors, cameras, unmanned aerial vehicles (UAVs), drones, and satellites are seamlessly connected for data acquisition and transmission through a cloud services platform. (Karim et al., 2017; Dubravko Ćulibrk et al., 2014; Singh et al. 2015; Abioye et al., 2020).

In this regard, it is important to note how WSN nodes play a strategic role in real-time monitoring. The network of sensors interconnected via wireless enables companies to calculate and transmit information on various parameters. This type of innovation lends itself to large-scale and long-term implementation (Hamouda, 2017).

IoT implementation enables interconnection and synergy among the technologies employed, seamlessly linking them for data transmission and delivery via a cloud services platform. (Karim et al., 2017; Dubravko Ćulibrk et al., 2014).

The cloud platform offers services such as data analysis of monitored parameters from sensors for decision making, visualization of monitored data for decision making, visualization, and actions. (Rajeswari et al., 2017). Farmers and researchers can remotely access the IoT cloud server, via smartphones or stationary devices, to benefit from better understanding and improve real-time decision making (Jayaraman et al., 2016; Pongnumkul et al., 2015). Therefore, the process of monitoring soil, crops, and weather parameters will become more efficient and convenient for farmers, which will further improve the effectiveness of precision irrigation control system and can ensure quality food production (Abioye et al., 2020; Singh et al., 2015; Andrew et al., 2018; Mohanraj et al., 2016; O'Grady and O'Hare, 2017; Rajeswari et al., 2017; Saiful et al., 2020; Uddin et al., 2017).

3.3 Monitoring System and Data Use

c) Soil monitoring

Rational water use cannot be achieved without soil monitoring. Soil moisture is one of the most important parameters for plant growth (Zhu et al., 2014; B. Ruszczak, D. Boguszewska-Mańkowska, 2022); high spatiotemporal monitoring of soil moisture content is necessary to ensure optimal irrigation scheduling. Several IoT-based soil moisture monitoring systems for irrigation management use Raspberry Pi and Arduino prototyping boards. These are interfaced with different sensors to obtain real-time soil moisture fluxes to monitor crop water use, useful for irrigation decisions and scheduling (Divya, 2019; Rao and Sridhar, 2018; Anusha et al., 2017; Rajalakshmi and Devi, 2016; Chate and Rana, 2016; Kothawade et al., 2016). The type of soil moisture sensing is a low-cost capacitive type based on the working principle of dielectric devices. According to Shigeta et al. (2018), real-time soil moisture sensing using capacitance-based sensors is applicable for practical measurement of soil moisture fluxes by correlating the volumetric water content (VWC) of the soil and the capacitance of probes inserted into the soil with reasonable accuracy (Abioye et al., 2020).

A more accurate approach to soil moisture detection can be achieved by using a time domain reflectometry (TDR) sensor. However, this type of sensor, although effective, is a very expensive technology for farmers and few use it.

However, data on water needs are not the only data collected in companies using 4.0 technologies. We can give an overview of the various categories of data collected, which include: environmental data; agricultural data and sensor data.

The first, environmental data, include information on climatic conditions, soil properties and water characteristics, which are essential for making informed decisions on irrigation, fertilization and pest control. These are the most commonly used and the most useful for achieving quality production.

Instead, when we talk about agricultural data, we mean to refer to data on crop- and animal-related aspects of the farm. It includes information on plant growth, crop health and soil characteristics, as well as data on animal welfare, weight, activity levels, health and feeding patterns. The integration and analysis of crop and livestock data enables farmers to make well-informed decisions, increase productivity, and implement sustainable and efficient farming practices.

Agricultural data provide the farmer with information related to cultivation and livestock management on the farm. They include a variety of information about plant growth, crop health, soil characteristics, weather conditions, irrigation schedules, fertilization practices, and control measures, but they also do a similar job on the livestock farm by providing any useful information to the farmer about the individual animal in real time, monitoring its health and welfare so that any problems or deficiencies can be resolved and remedied in a very short time. (Bauer et al., 2018)

The analysis and use of crop and livestock data play a crucial role in implementing precision agriculture practices, conserving resources, and achieving sustainable agricultural production, and are critical in organic farming. (Bauer et al., 2018; Thongnim et al. 2023).

The use of these data acquisition-based technologies leads to the production of an unprecedented amount of data and has as an immediate consequence the growing demand for data processing and storage and digital telecommunications, which has led to a significant expansion of the data center industry. Data centers play a key role in modern computing infrastructure, as they are specialized facilities designed to house and manage the computing equipment used for data processing, storage, and communications networks (Thongnim et al. 2023). In these spaces, data, after being collected, are stored in an appropriate model according to their structure, structured or unstructured (primary data, secondary data, real-time data). The next stage involves classification and filtering of the data, depending on the specific type of analysis required. (Thongnim et al. 2023)

The capacity of data center networks is determined by the effective communication between devices and the responses of data center networks. Data centers serve as critical industrial infrastructure for dynamic computing and storage needs. The data center network is tasked with managing a huge number of elements within the network. (Thongnim et al. 2023). Through the use of cloud computing, the 21st century farmer has a tool that facilitates data accessibility and collaboration. Stakeholders in different locations can seamlessly access, analyze, and share agricultural data through cloud-based platforms. (Thongnim et al. 2023). This confrontation between farmers and ranchers allows for an exchange of tips, best practices, and know-how, never seen before that coupled with the benefits of using IoT and smart agriculture the making available to the agricultural sector a truly considerable amount of solutions to almost any type of problem.

3. 3 Monitoring System and Data Use

d) Network organization:

The emergence of Big Data and Smart Farming has led to significant technical changes in the agricultural sector, and this requires understanding the network of stakeholders surrounding the farm (Thongnim et al. 2023). Data center integration in smart farming enables centralized storage, management and analysis of the vast amount of data generated by various IoT devices, sensors and other smart farming technologies. For fertilization, the data center considers factors such as soil nutrient levels and crop growth stage. Based on this information, it determines the appropriate amount of fertilizer and other supplements needed to support healthy plant growth. (Hassan et al., 2023; Thongnim et al. 2023)

Collaboration between smart agriculture and data centers results in better farming practices, increased productivity, resource efficiency, and greater sustainability. By harnessing the power of data analytics and advanced technologies, farmers can make informed decisions to optimize their operations and contribute to the transformation of the agricultural industry. (Thongnim et al. 2023; (Hassan et al., 2023; Thongnim et al. 2023).

The data center will also foster collaboration and knowledge sharing among different stakeholders in the agricultural ecosystem. This data center will be a valuable repository of time series data, particularly secondary data, obtained from various government organizations.

As the data centers evolve and expand to cover other eastern territories, they can become a center for agricultural information and innovation. Farmers throughout the region will have access to valuable insights and historical data, which will help them adapt to the challenges posed by modern agriculture and make informed choices for their farming activities. After classifying the data, a variety of analysis tools are used, such as data visualization, machine learning, and other data science techniques. Data can be exported as CSV files, allowing users to select and view information. (Thongnim et al. 2023; Hassan et al. 2023).

IoT continuously captures and stores data in real time. IoT devices and sensors are equipped to collect data directly from the source, such as agricultural fields, livestock, weather conditions and other relevant aspects. The data collected by IoT devices is transmitted in real time to a centralized system or data center, where it is processed, analyzed and made available for further use. In addition, data collected by drones are stored in the data center for future analysis. (Hassan et al., 2023)

By combining data collected in real time from IoT devices with drone imagery, the data center can provide a comprehensive view of farm performance. This integrated approach to data collection and analysis enables farmers to make more accurate decisions based on a wide availability of data to optimize resource allocation and improve overall crop yield and farm productivity. (Thongnim et al., 2023; Fastercapital, 2023; Hassan et al., 2023). SAM, which stands for "Smart Agricultural Management System," is a blockchain-based solution designed to improve traceability, transparency and security in the agricultural supply chain. SAMs can significantly improve agricultural data management and sharing. The context of the SAMs application demonstrates that durian traceability refers to the ability to track the journey of durian fruits from their point of origin. Traceability of durian through SAMs enables stakeholders along the supply chain, including farmers, distributors, retailers, and consumers, to have greater confidence in the origin, quality, and grade of the product. (Thongnim et al. 2023; Hassan et al., 2023)

Information on durian variety, harvest data, farming practices, and quality control measures can be documented on the blockchain. Consumers can access this data by scanning a QR code on product packaging and obtaining information about the authenticity and quality of the product (Thongnim et al. 2023; Hassan et al., 2023). In addition, details about the origin, handling, processing, and transportation of each durian are securely recorded on the blockchain. SAMs promote consumer trust. Consumers can make informed decisions by supporting sustainable and ethical practices in agriculture. Data on farm equipment (operating status, fuel consumption), market and price data, satellite, drone, and remote sensing data, energy consumption data, water use data, agricultural operations data, and financial data (Weersink et al., 2018; Hassan et al., 2023). This diverse range of data enables precision agriculture, efficient resource use, and informed decision making for optimal agricultural practices (Weersink et al., 2018). What are the preferred applications of agricultural data in smart agriculture? There are several preferred applications of agricultural data to optimize farm management, increase productivity and ensure sustainability. The integration of a data center and a smart agricultural management system (SAM) further enhances the capabilities of these applications; data center-supported data applications play a key role in promoting sustainable agricultural practices by enabling farmers to monitor and optimize resource use (Thongnim et al. 2023).

3.4 The use of Agriculture 4.0 in the wine sector

The wine sector deserves a separate discussion because it is the segment of the agricultural sector most prone to innovation and is the sector where technological innovations have been implemented across the entire supply chain. Innovation has not affected only one segment but has extended to all its strategic components. Indeed, wineries are adopting 4.0 solutions both in the field and in the cellar, which are based on the use of solutions with hardware and software components that allow increasing yields in the field, optimizing inputs, and thus reducing costs and the environmental impact of activities and, in parallel, improving wine quality. These types of solutions aim at constant real-time monitoring of the vineyard and winery and give the winemaker the ability to make timely and targeted interventions.

The goal of these systems is to create up-to-date maps in four dimensions, thus also in time and space. Concerning the vineyard, a series of technological sensors (e.g., multispectral video cameras) capable of detecting a range of information that will then be reused to process decisions are integrated into the agricultural machinery in use. Tractors (of any make or model), through the sensors and multispectral cameras, capture a series of images and data. The captured images in turn are analyzed with Artificial Intelligence models developed by TopNetwork. These models provide operators with information about the vegetative state of the crop, and soil conditions. (Topnetwork, 2023).

This integrated system benefits from the presence of agro-meteorological stations, which allow the winemaker to combine the data collected and identify in advance the areas of the field that require a certain type of intervention such as relief irrigation interventions, identify which areas are most likely to have a proliferation of fungi such as Downy mildew and Oidium, and act in advance with phytosanitary treatments. Thus, the need for more traditional calendar interventions is eliminated to the benefit of resource optimization and greater environmental sustainability of the production process (Topnetwork, 2023).

Wine companies 4.0 have also innovated wineries by developing a fully atomized system to monitor the wine maturation process and its chemical composition. The companies employ steel containers equipped with a series of sensors, which allow them to monitor some crucial parameters such as temperature, oxygen, and pH of the wine.

A good portion of these containers have actuators, which are capable of adjusting parameters. The logic behind the actuators is to monitor and improve the quality of the wine through artificial intelligence models that influence and adjust the temperature, oxygenation, or acidity of the must.

This type of system brings a crucial advantage to the winery in terms of quality because the quantities since production inputs are used no more than the necessary quantities (Topnetwork, 2023).

3. 5 Livestock Sector

The livestock sector after the wine sector is the segment of agriculture where 4.0 technologies have been implemented the most. In particular, livestock companies are focusing on the implementation of robotics and automation systems within production processes to improve the quality and quantity of production, making human labor less burdensome.

Automation can be used in ration management, and in recent years several more or less complex systems have been developed to perform this task. Automation systems can also be very different from each other and can also be combined with other technological solutions. CREA has developed a division into levels for automation systems.

In level 1 there are optical sensors that automate the analysis of individual feeds and the subsequent chopping and mixing process, to reduce human error and promote rationing efficiency. At level 2, on the other hand, we find robots that approximate the ration distributed in the trough and gradually move away from the animals in their action of ingesting and selecting a feed, which can be set to work frequencies that would be unthinkable if performed manually, with positive repercussions on feeding, waste reduction, and animal behavior. Finally, Level 3, involves robots that automate the entire process of ration preparation and distribution. (CREA, 2021).

Automation allows farmers to gain flexibility as they no longer need to adopt the rigid schedules required by rationing activities. At the same time, automation leads to a reduction in labor as the workload decreases dramatically. In addition, according to CREA, the reduction in workload and the integration of new technologies can ensure an attraction for young entrepreneurs to try their hand at farming. (CREA, 2021).

The adoption of automation could bring greater sustainability to production processes. Farms that have adopted this technology have experienced lower energy consumption resulting in lower use of nonrenewable fossil fuels and lower atmospheric emissions. Livestock farms in recent years have shown increasing interest in the self-production of energy through solar, biogas, or wind power plants to develop a circular economy logic increasingly popular among European livestock farmers. (CREA, 2021). Finally, automation results in more efficient ration management and consequent lower feed wastage and better utilization, reducing emissions of unwanted nitrogen elements into the atmosphere and groundwater.

The next step in Innovation for th" liv'stock sector will be the holistic integral design of new stables. This is a challenge that has already begun in which the building becomes not simply the container of several assembled technological elements or a shelter for livestock but becomes a complex design within which not only the necessary technologies for milking, feeding, air conditioning, cleaning, lighting, but also all possible interactions with the livestock are provided, enhancing the efficiency of the system and improving animal welfare, which is the basic condition for increasing the quality and quantity of production. (CREA, 2021)

The main advantage of robotic milking is that it allows animals to be milked twenty-four hours a day without human intervention. This new approach is more respectful of the cattle's condition because the animals autonomously approach the machine when they feel their udders are swollen with milk. The machine is also programmed to provide feed to the animal based on milk production. This system aims to increase milk quantities without losing quality at the same time. Farms that have adopted robotic milking have on average higher milk production than farms that maintain standard milking methods. This result can be explained by the greater protection of the animal as it is not exploited to the point of exhaustion, but rather an attempt is always made to milk a certain daily amount of milk from the cattle without pushing them to burnout. The problem of milk quality, on the other hand, is solved by adjusting the ration, which is adjusted by the machine according to the animal's milk production, allowing the milk to reach the optimal amount of fat and protein.

Although robotics is marginal compared to other 4.0 technologies, it is rapidly on the rise this is because it allows real-time management of herd health and production levels and secondly, because the milking robot allows farmers to optimize production costs and cut labor costs. Robotization also alleviates the work of the farm operators; there is no longer the burden of milking hours that were imperative for the farmer forced to milk a certain time in the morning and a certain time in the evening. The robot provides several items on the health status of the cattle by signaling when it comes are in heat or if they are unwell making it easier for the enterprise to manage the herd.

Animal welfare is one of the primary goals of Animal Husbandry 4.0. Livestock farms are increasingly structured to monitor livestock to provide consumers with a quality product. Animal welfare is a dynamic concept and a biological state that is evaluated on scientific parameters; in this sense, one of the most common innovations is that of collars used to detect parameters related to the physical condition, feeding, and night-day cycle of the livestock raised.

An example of this kind of innovation is MooMonitor+ this is a cow collar, capable, through an accelerometer, this device can take more than thirty measurements per second. The collar records heat, ruminations, and how long it takes the cows to eat and rest. The millions of data collected daily are saved in the cloud on a server provided by the manufacturer and then reprocessed every 15 minutes. Any anomalies are reported in real-time to the farmer on the smartphone, thanks to a specific app. (AEFI, 2018)

In line with the demands for higher food quality, the importance of product traceability is growing. Particularly in the Italian market, it is increasingly important for consumers to have greater awareness and transparency about the products that will later arrive on their tables.

A recent example of this is the new traceability system for Mozzarella di bufala campana DOP presented by the Istituto zooprofilattico Sperimentale del Mezzogiorno. Through the QR code, which can be consulted at the point of sale from the smartphone, we can know from which stable the raw material comes, which dairy processed it, and which buffalo produced the milk. Traceability has also attracted the interest of the various protection consortia because they are an alternative to de-marketing, and at the same time provide more transparency about the origin of products. This system is applied, for example, to several products from Campania to certify the origin with the dual purpose of certifying their quality and exonerating them from the accusations made against the Terra dei Fuochi. (AEFI, 2018).

3.6 Global Navigation Satellite System (GNSS)

The innovative element behind the principle of precision agriculture is the development of the satellite navigation system. Global Navigation Satellite System is used to give the position of a receiver in terms of latitude, longitude, altitude, speed, direction, and time. This use of all available GNSS signals generally improves positioning performance. GNSS navigation devices are a crucial means of enabling site-specific management of the enterprise. This represents an excellent opportunity to increase the accuracy, speed, and uniformity of farm operations. Such devices are particularly useful for herbicide and fertilizer distribution, and for monitoring seeders and harvesting machines.

A common use in agriculture of GNSS signals is in satellite tractors. When we talk about satellite tractors we are referring to assisted and semi-automated guidance systems that take advantage of satellite signals to optimize field work, reducing costs and increasing yields and sustainability. Satellite tractors are a strategic tool for Agriculture 4.0 because, in combination with other tools such as sensors, drones, and maps created with satellites, they allow field operations to be carried out with greater efficiency and precision. Thanks to these tractors it is possible to make precise trajectories in the plot or crop avoiding obstacles and limiting possible overlapping. (Selenella, 2023). The operations that most engage the operator driving the tractor or other agricultural equipment are those carried out at high speed or with equipment with a high working width, this is the case when farmers are engaged in fertilization or sanitary treatments of the crop. (Agricare, 2023)

In guidance-assisted systems, the driving operator receives information about his or her position in the field and the trajectory to be followed through visual cues that are supplemented with larger displays in which the track can be followed in real-time or in which the operator graphically displays driving information through icons associated with numerical values (magnitude of deviation from the correct trajectory, number of the pass, etc.), and this makes them easier to use while increasing the operator's familiarity with the technology (Selenella, 2023, Agricare, 2023)

Driving the machines along established paths is automated by assisted guidance technology. The benefit to the farmer is reduced work time and a cut in costs by decreasing field passes, thus preventing overlaps from compacting the soil (Selenella, 2023).

Semi-automatic guidance systems called parallel guidance are based on more advanced technologies integrated into the onboard system that further improve the efficiency and accuracy of work on the plot because through this system the operator can correct the trajectory in real time. Examples of such systems are the electric steering wheel and hydraulic steering, devices that serve to reduce the inevitable driver inaccuracies given by the delay in response following the reading of information. (Selenella, 2023). Assisted or parallel guidance systems are a crucial step because, before the advent of precision agriculture, the interventions that the farmer performed in the field such as plowing, planting, or sanitation treatments were all performed relying solely on human capabilities. This resulted in a state of uncertainty because by relying solely on human skills it happened that some areas were over-treated by operators while others could be neglected. This also implied serious consequences for farms since an excessive amount of fertilizers or pesticides could affect crop production by burning them, while a total absence of treatments could lead to crop loss due to inadequate plant development or diseases and pests.

For this reason, satellite guidance in Agriculture has the primary goal of mitigating human error. However, there are also other non-negligible benefits associated with this technology for farms, first, a reduction in costs related to a more efficient use of production inputs such as fertilizers and plant protection products, and at the same time it results in time optimization, since the GPS-guided operator can work even in low visibility conditions without needing to see the plot. Time savings also occur because the machine can move at higher speeds when this is compatible with the type of operations to be performed.

Of no small importance is the benefit that satellite guidance produces in terms of sustainability. Greater efficiency in treatments and fertilization processes allows fewer pollutants to enter the fields. The goal of Agriculture 4.0 is just that, which is to improve the sustainability of the agricultural sector while increasing land yields. The sector has a non-negligible environmental impact as it consumes a high percentage of soil and ecosystem, puts pollutants into the soil and atmosphere, and uses huge water resources. As for satellite guidance, it allows machines to be used more precisely, saving inputs. Finally, work in the plots is optimized by the fact that the satellite tractor allows tracking of every tillage done.

Crea prepared a study about the benefits provided by satellite tractor technology; this study showed that thanks to satellite tractors it was possible to evenly sow the entire land area avoiding both overlapping and leaving uncovered areas according to estimates farmers could save more than 6 kg of seeds per hectare. While in terms of fuel, a saving of about 1.8 liters per hectare is quantified. Parallel or semi-automatic driving also saved time due to reduced maneuvering and resulted in 1.2 hectares more being worked in a day's work. However, the study found that satellite guidance is mainly convenient for large farms that have land divided into smaller plots, thus requiring a lot of maneuvering. For smaller farms, it is not particularly convenient because of the expensive initial investment to be made.

Therefore, in some cases using GNNS or RTK technologies may be unnecessary or excessively expensive for enterprises. In these cases, other technologies are available to optimize the navigation of agricultural equipment in the field without the use of satellite positioning systems (Agricare, 2023, Selenella, 2023). In particular, operators can take advantage of devices that make field work more efficient. These technologies such as mechanical, optical, and 3D camera sensors mounted on machines help keep their heads aligned with crop rows by acting on the steering or intercepting the edge of the crop, or capable of detecting furrows or swaths (the gaps of soil between rows) and correcting the trajectory in real-time with benefits similar to semi-automatic guidance (Selenella, 2023).

In this sense, the most popular devices are mechanical sensors, which allow the heads of the harvester machines to be in line with the crop rows, acting hydraulically on the steering; optical sensors and laser scanners, which recognize the limit of the crop and guide the operating machine while keeping the harvesting header full at all times; 3D cameras, which detect furrows or swaths and, through real-time analysis of the image, correct the path of the tractor according to the operation. These devices allow, therefore, to perform operational control in all those operations where references on the ground are visible, simplifying the system, without losing the ability to operate optimally and with the typical advantages of semi-automatic guidance (Agricare, 2023).

3.7 The disadvantages of Agriculture 4.0

4.0 technologies as much as they are a key step for the European agricultural sector are often not easily accessible for European and Italian companies. There are many barriers to the adoption of these tools by farmers, these are obstacles related to the structural deficits of the sector and its companies.

The main barrier for European companies is the initial investment required to acquire the technology; despite the benefits in terms of profits and cost cutting, we are talking, however, about long-term effects while a large part of the companies, fail to meet the initial expense. The reasons behind this difficulty are mainly two: low capitalization and small farm size, which, as was pointed out in the first chapter, restrain the innovative drive of farms. Indeed, it is no coincidence that precision agriculture originated in the United States where, on average, farms are more structured and larger in size than their European counterparts. In addition, if areas are small some technologies, such as satellite guidance, are unnecessary because they would not generate adequate returns in terms of productivity and profit to repay the investment.

An important factor in the implementation of Agriculture 4.0 is the interoperability of digital solutions. In order for farms to get a complete and accurate picture of the various operations, from planting to harvesting, the systems and devices used must be interconnected so that they can communicate with each other smoothly.

Interconnection between different systems and devices enables a complete and accurate picture of agricultural operations, from planting to harvesting. However, for these technologies to collaborate effectively, they must be able to communicate with each other smoothly. This requires well-defined communication standards and protocols that ensure seamless synchronization between different platforms. (Salerno Agrifood tech, 2021)

In addition, data security is an inescapable priority. With the increasing amount of information being collected and exchanged among the various components of the agricultural ecosystem, it becomes crucial to protect farm data from unauthorized access and possible cyber attacks. Cybersecurity must be incorporated early in the design of solutions. Companies must implement proper security systems including advanced encryption, multi-factor authentication, and robust backup procedures. Should data be compromised it could not only harm farm operations but could also compromise the quality and safety of the food produced. (Salerno Agrifood tech, 2021)

As anticipated in the first chapter a crucial node that cannot be disregarded for the success of agriculture 4.0 training and acquisition of digital skills are a crucial asset for farmers and practitioners who intend to implement technology 4.0. The adoption of advanced technologies requires a willingness to train and learn new content; farmers must be able to understand and use the various digital solutions available to them. The skills shortage as highlighted by many analyses is, along with the exorbitance of initial investment, the main obstacle to the adoption of new technologies.

For 4.0 innovations to be disruptive, investment in training is needed so that agricultural entrepreneurs can increase their knowledge of how technology works and be aware of the advantages and disadvantages associated with digitization. In addition, access to digital skills could help overcome the resistance to change that sometimes occurs in the agricultural sector. In particular, training farmers can help overcome resistance due to tradition and habits that characterize the sector, fostering an environment more prone to business innovation. (Salerno Agrifood, 2022)

3.8 Conclusions

Perhaps the most important test for tomorrow's agriculture is to be able to respond adequately to the environmental challenge: to be able to produce quality products while taking care to respect the environment and reduce the environmental impact of production. Currently, agriculture is accused of making excessive consumption of water and soil; of using an inordinate amount of fertilizers and pesticides polluting the environment. Added to this are emissions from the use of farm machinery and the consumption of energy from fossil fuels.

Each of these highlighted critical issues can be addressed through the use of new technologies, the use of which we have described to meet the different needs of agricultural entrepreneurs. The opportunities of precision agriculture make it possible to reduce the consumption of water needed for irrigation thanks to sensors that measure the moisture content of the soil and intervene only when and where it is needed with the right amount of water useful to the crops manage to save up to 50 percent of water resources; precision maps applied in self-driving tractors reduce the use of fertilizers and simultaneously save in the use of fuel because the machines perform precise work without passing over already treated soils several times.

Sensors and drones used to monitor crops allow for a significant reduction in pesticide use without sacrificing a quality product; rather, the timely and precise observation conducted through new technologies allows for a more timely and targeted intervention that ensures superior product quality while also lowering the cost of treatments that were previously conducted on all crop areas even where this was not necessary.

Moreover, the use of data sets reprocessed through artificial intelligence systems makes it possible to respond not only to the environmental challenge, but also to what is the challenge of every entrepreneur: to achieve greater labor productivity and increase one's business profit. It is clear that these new technologies are not perfect and they can and should be improved especially to be better adapted to different Italian agricultural realities, mainly because many of them are designed for other territories profoundly different from our own, but they can represent an opportunity for growth for Italian agricultural enterprises.

Chapter IV: The agriculture in Sardinia and the challenges of innovation

Sardinia is an Italian region with a strong agricultural tradition; agriculture on the island plays a significant role in the region's economy and culture. Sardinia has a wide variety of landscapes and climatic conditions that influence the type of crops and agricultural activities practiced. According to data provided by the 7th Census of Agriculture, more than 47,000 farms are active on the island, and more than 90 percent of them are sole proprietorships or family businesses. Most of the companies are small, poorly capitalized, and not linked to collaboration or network agreements with other companies in the industry.

Although enjoying optimal environmental conditions that result in quality productions, the per capita income of island farmers is low because production costs are on average higher than in the rest of the peninsula, with Sardinia paying the cost for its insularity that results in higher energy and raw material costs such as feed and fertilizer due to high transportation costs. Those same quality productions struggle to be exported to the domestic market because the same higher costs also affect the price of the finished product for export.

Among the most relevant segments for Sardinian agriculture is the sheep and goat sector, which raises just under three and a half million animals and is also the most representative in terms of the number of livestock farms; in fact, there are more than 15,000 active sheep and goat farms on the island and about 70 percent do not raise other types of livestock. (CREA, 2018).

In these farms, the persistence of the central role of the family business is a peculiarity in the agricultural landscape, especially in the interior areas of Sardinia, which also often determines a connection with modes of management and production closely linked to an ancient tradition.

Extensive, rather than intensive, livestock and production using biodiversity-rich pastures and pristine environments result in quality productions, but they often use traditional techniques with great expenditure of labor and poor mechanization that impose considerable physical effort, making it unattractive for young people to work in the countryside and resulting in poor generational turnover.

The value of livestock production consists mainly of sheep and goat milk (47 percent) and cow milk (11 percent) followed by beef (13 percent), pork (12 percent), sheep and goat (9 percent), and poultry (4 percent) production. The value of crop production consists mainly of vegetables (41 percent), fodder crops (20 percent), wine products (19 percent), and cereals (7 percent), followed by citrus (3 percent), fruit (2 percent), and olive products (3 percent).

Overall, the value of crop and animal production, hunting and related services, and forestry contribute 4.5 percent to the total value added to Sardinian activities. In other sectors such as accommodation and food services, value-added shows growth (+11.8%) with the contribution to the total of these economic activities increasing from 5.0% to 5.6%. Growth is also recorded in the agricultural sector, although not as strongly. The data indicate that the value added of the primary sector (agriculture, forestry, and fishing) in Sardinia, is well below the national value-added, it is 4.2 percent of the average national value for the 2015-19 period, although the data indicate a growth of 6.8 percent over the previous five-year period.

Within the agricultural sector, the wine sector appears significant, with more than 10,000 wine-producing enterprises. Viticulture appears to be growing in the quantity and quality of wines produced, many of which bear community trademarks such as DOC and DOCG.

Vine cultivation characterizes both the more fertile plains near the sea and the high hills but especially the more inland areas where it is still strongly linked to ancient traditions. The particular orogenetic and territorial conformation allows in Sardinia a moderately intensive cultivation characterized by high-quality wine production. (Laore, 2023).

One of the critical issues in the Sardinian agricultural sector is the fragmentation of supply, which leads to weakness in price negotiations. Concentration processes are still very limited in Sardinia; the few, new experiences and aggregations were formed in 2014 and led to a greater number of companies united in Producer Organizations, increased the value of products marketed by Pos, and improved bargaining power in negotiations.

Sardinian agriculture, suffers as in the rest of Italy from some critical issues related to human capital, already analyzed in the first chapter including the lack of generational turnover and low schooling. New farm managers (sole proprietors or partnerships) who have been running the business for less than three years in 2020 in Sardinia total of 2,824 of whom 42.1% are young farmers. Only 6.1 percent of individual or family farms or farms formed by partnerships (a total of 46,371) are run by a new farm manager, of which only 2.6 percent are young farmers who set up in the years 2018-2020.

Farms by time in business and age of farm manager in Sardinia (1). The year 2020

Time for conducting the activity	Less than three years		3 to 10 years old		For more than ten years	
	number	%	number	%	number	%
Company head with age up to 40 years old	1.189	42,1%	3.521	35,9%	2.283	6,8%
Company head with age over 40 years	1.635	57,9%	6.280	64,1%	31.463	93,2%
TOTAL	**2.824**	**100%**	**9.801**	**100%**	**33.746**	**100%**

Table 1: Farms by time in business and age of farm manager in Sardinia
Data source: Istat, 7th General Census of Agriculture.

In 2020, there were more than 7,000 young farm heads (under 40 years of age) in Sardinia, of which 76.4% were male and 23.6% female. Thus, young farmers account for 15.1 percent of the total number of farm heads in Sardinia, which is significantly better than the figure for the rest of Italy (9.3 percent in Italy). The majority of farms run by young farmers (up to 40 years of age) saw the new entrepreneur taken over by a family member (58.4%) or by a relative (8.2%) while only 5.0% bought the farm from a third party and only 28.4% started a previously nonexistent farm. The presence of new farms is higher among young farmers than when the farm manager Is over 40 years old (20.7%). (Laore, 2023)

Regarding the rate of schooling, it should be noted that a higher level of education is observed among young farmers than among older age groups. In fact, 21.8 percent of farm leaders up to 40 years of age hold an agricultural degree, a higher value than that recorded among farm leaders over 40 years of age (7.1 percent). Participation in vocational training courses is widespread among young farm leaders (51.5 percent) more than that recorded among farm leaders over 40 years of age (36.1 percent). (Laore, 2023).

In general, this figure is not dissimilar to the landscape in the rest of the peninsula because Italian agriculture is marked by a low level of education often connected to the high age of the workers. The data denote that 65.5 percent of the tenant farmers have at most an eighth-grade education (58.8 percent in Italy); - 19.0 percent have a high school diploma with a nonagricultural focus (23.9 percent in Italy); - 7.4 percent have a high school diploma with an agricultural focus (7.6 percent in Italy); - 6.1 percent have a bachelor's degree with a nonagricultural focus (8.1 percent in Italy); - 1.9 percent have a degree with an agricultural focus (1.6 percent in Italy). In contrast, the share of farms with farm managers who have attended agricultural training courses (38.4 percent) is higher than in Italy (29.0 percent), as an effect of the presence of widespread training and information activities in the region.

The figure Is not Insignificant, Ie as pointed out the rate of schooling Is closely related to the willingness of entrepreneurs to face the challenges of innovation and the greater willingness to invest in research and introduce new technologies at different stages of the production process. It is not surprising, then, that in Sardinia, as in the rest of Italy, the companies that have innovated the most in percentage terms are precisely those in which there is a young business leader with a high rate of education, often achieved in professionalizing subjects such as a degree or diploma in agriculture.

On average, this type of company is also the one that achieves the best financial results and can boast higher-than-average corporate profitability. Farms with a young farm manager have the highest economic size (73.3 percent of farms in the 25,000 euro and over classes), conversely, farms with a farm manager aged 55 and over have an economic size of less than 15,000 euro (54.2 percent). The average value of standard output is higher on farms led by young people (85,220 euros/farm) than on farms led by farm managers aged 40-54 (72,203 euros/farm) and, especially, those led by farm managers aged 55 and over (40,367 euros/farm).

However, agricultural income, represented by enterprise income reintegrated by employee wages achieves significantly lower results than other sectors. In 2020, in Sardinia, agricultural income per labor unit represents 53.3 percent of the labor cost obtained in other sectors of the economy in Italy (industry, construction, and services except public administration, defense, and public security). The gap between agricultural income and labor cost increased from 2016 to 2020 while agricultural income per labor unit increased by 1.8 percent, labor cost in other sectors increased by 7.8 percent.

Table 2: Farms by educational qualification of farm manager and/or having attended agricultural training courses and age of farm manager in Sardinia. The year 2020

Educational qualification of the business leader	Company head with age up to 40 years old		Company head with age over 40 years		Total	
	number	%	number	%	number	%
No title	13	0.4%	726	1.8%	739	1,6%
Elementary license	99	1.4%	9.053	22.8%	9.152	19,5%
Junior high school	2357	35,9%	18.265	45,9%	20.802	44,4%
Agricultural Diploma (2-3 years)	217	3,1%	538	1,4%	755	1,6%
Non-agricultural diploma (2-3 years)	250	3.5%	948	2,4%	1.198	2,6%
Agricultural high school diploma	1008	14,3%	1.725	4,3%	2.733	5,8%
Non-agricultural high school diploma	1955	27,6%	5.768	14,5%	7.723	16,5%
Agricultural university degree/diploma	316	4.5%	576	1,4%	892	1,9%
Non-agricultural university degree/diploma	658	9,6%	2.193	5,5%	2.871	6,1%
TOTAL	***7.073***	***100,0%***	***39.792***	***100,0%***	***46.865***	***100,0%***

Data source: Istat, 7th General Census of Agriculture

Concerning the modernization of activities on farms led by young farmers, 21.0 percent made at least one innovative investment in the three years 2018-2020, and 35.5 percent computerized farm activities, mainly for accounting management (24.1 percent) as well as crops (9.0 percent) and livestock (13.3 percent) (Data source: Istat, 7th General Census of Agriculture).

Another challenge facing Sardinian agriculture, just as it is facing agriculture in the rest of Italy, Europe, and the world, is that of climate change.

"*Climate change and extreme weather and climate events result in effects on natural and human systems that vary according to the environmental, economic, and social characteristics of the area, which in turn determine its adaptive capacity, vulnerability, and propensity to risk. Vulnerability, defined as "propensity or susceptibility to be adversely affected," is determined by the combination of susceptibility and adaptive capacity and is one of the components of risk analysis, in addition to the other two components, the source of the hazard and the number of people, goods, places exposed to the hazard"* (Mach, K.J., S. Planton and C. von Stechow, 2014).

The challenge is agricultural resilience to climate change which refers to the ability to maintain the functions and services of the sector in the face of increased extreme events under climate change. There are two ways through which the challenge can be addressed: resilience can be strengthened through short-term adaptation of existing practices and management modes and long-term change in response to the duration and intensity of climate disruption. Numerous factors can influence the sector's resilience to climate change, among them we can list socioeconomic, governance, biophysical, and new technologies.

In the face of these risks to the agricultural sector, the Region of Sardinia has equipped itself with a study that conducts a detailed analysis of Sardinia's climate situation and carries out an assessment of adaptive capacity, vulnerability, and propensity to climate risk, as well as options and priorities related to adaptation strategies.

The estimated synthetic indices of adaptive capacity, for the agriculture, livestock, forestry, water, and hydrological management sectors, are expressed on a scale of 0 to 1 expressing maximum and minimum adaptive capacity, respectively. Synthetic index of adaptive capacity (index 0 = maximum capacity; index 1 = minimum capacity).

Table 3: Climate Change adaptation

Determinants and Components	Sectors				
	Agriculture	Breeding	Forests	Water	Hydrogeological structure
Human and Social Capital: Awareness	0,65	0,64	0,76	0,88	0,88
Economic factors, flexibility, governance, programming: Action	0,58	0,55	0,47	0,54	0,78
Technology, Infrastructure: Skills	0,54	0,73	0,71	0,51	0,63
Summary index of adaptive capacity	**0,57**	**0,63**	**0,63**	**0,66**	**0,81**

Source: Autonomous Region of Sardinia and University of Sassari "Methods and Tools for the Regional Climate Change Adaptation Strategy" (December 2018)

As has already been mentioned there are over 47000 farms in Sardinia of which, however, only just 8000 are computerized. Breaking this down further, we can see that more than 60 percent of these farms have a Ula ranging between 1 and 10; the remaining share of farms instead have a Ula ranging between 1 and zero. On the other hand, the number of companies with a Ula greater than 10 throughout the island is negligible-in fact, there are only 73.

In terms of innovation, Sardinia also does not perform well; in fact, innovative enterprises according to the 7th Census in Agriculture only a little more than 5,000 Sardinian enterprises have made at least one investment aimed at innovating production technique or management. Looking at the different areas in which the island's enterprises have carried out innovation, it can be seen that the largest number of investments involve mechanization, irrigation, sowing, and tillage.

One brake on innovation is the high age of company heads; company heads, as mentioned, are largely of a high average age: about 40 percent are over fifty-nine years old, while if we look at the under-forty-five they are less than 20 percent.

4.1 Business Cases

To delve into the impact of innovation on agriculture, I analyzed three Sardinian companies, these are small and medium-sized enterprises that have implemented various 4.0 solutions in their production processes over the years. The three case studies examined share many aspects they are small family-owned companies, with no less than one hundred hectares of UAA, and they have established realities with a long presence in the market and experience in innovation as well all three embarked on the path of business innovation several years ago. Moreover, the enterprises belong to different supply chains, specifically, one enterprise focused on extensive crops, one on intensive crops, and one on wine production was analyzed. The choice of analyzing three different supply chains stems from the need to provide a clear picture of a complex and uneven sector such as agriculture; moreover, analyzing three different supply chains allows us to highlight the different results that innovation has produced in each sector and the different challenges that enterprises have faced. Although at times the technological standards were similar the results produced were not always convergent.

4.2 Case Study 1: Falchi Company

Figure 1: Falchi Company

As an example of implementing 4.0 technologies in agriculture, we selected the Falchi farm, located in Oristano (OR) and run by the family of the same name.

The Falchi company is a family business with a long tradition, founded more than 220 years ago has now reached the sixth generation, which, is carrying on the family business through innovation in traditional production processes.

The company's main crop is typical Italian rice certified by the Ente Nazionale Risi and C.R.E.A. The company is also engaged in other intensive crops such as wheat, sativa hemp, and lavender; other relevant crops include tomatoes and artichokes. The farm is characterized by its focus on environmental protection and the use of modern eco-sustainable and precision cultivation techniques that allow more efficient and concealed use of scarce resources such as water, soil, and air.

The company has faced several investments in innovation in recent years. Elisabetta Falchi, one of the company's partners, says that the implementation of technologies has been done to achieve greater precision within the production processes. Technology for the company is a vehicle through which to know the land better and to be able i operate in a precise and personalized manner not only on individual plots but also in limited portions of them. As Dr. Falchi pointed out, through the use of sensors it is possible to acquire information about the soils to develop prescription maps. The mapping of the soils was made possible through the sensors installed on the thresher to accurately collect a range of data about the soil on which they then went to work. The use of these maps provides insight into the specific characteristics of each portion of the land. For example, through them, the farm knows more precisely the composition of the soil and can highlight which portions of each plot are the most fertile and those where more fertilization is needed; this allows operators to act in a precise and accurate manner. Greater precision allows for more efficient use of inputs and results in several positive externalities, i.e., it allows the farm to use the right amount of inputs by reducing the waste that would otherwise occur in the different stages of field tillage. In addition, it is important to note how input optimization results in positive externalities for the environment, the farm, and the community.

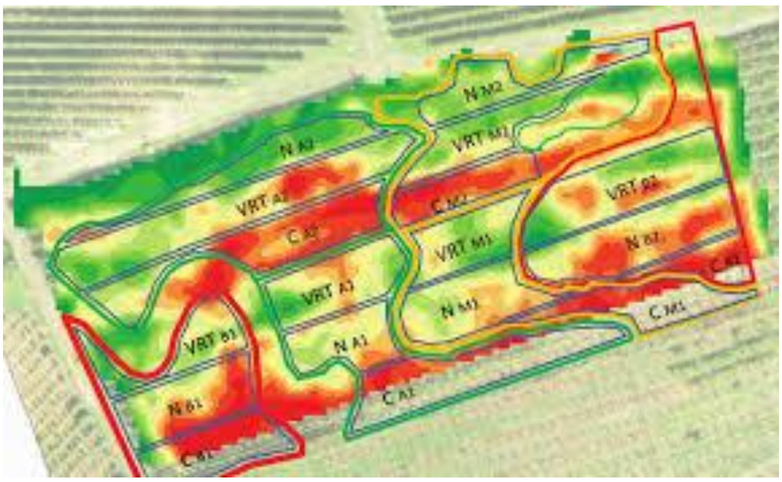


Figure 2: Example of a prescription map showing the different fertilization areas in red for high vigor areas and in green for low vigor areas. Photo Source: Nutrivigna

In the processing of prescription maps, the input of Real Time Kinematic (RTK), or a real-time satellite positioning system, is crucial.

In fact, RTK detects the positioning coordinates of agricultural equipment with great accuracy-partly thanks to the recent upgrade achieved by installing new sensors-and thus makes it possible to employ tractor machines equipped with satellite guidance, create and manage maps, integrate the data collected into farm management systems, and ultimately make the most of the information derived from so-called "precision agriculture." (Echocamere, 2022). This makes RTK technology crucial for variable-rate input metering as it is capable of making farm equipment perform field operations with centimeter accuracy. By using RTK, the margin of error is reduced to about 2 cm and remains constant throughout the operation. This minimizes the overlapping of cultivated and untilled strips, ensuring the most efficient use of distribution inputs and optimization of tillage time and consequently related fuel consumption.

The company's second step of innovation involved the renewal of its fleet. The Falchi company has invested in several self-driving tractors. This type of state-of-the-art machinery allows for improved process sustainability as it consumes significantly less fuel than older-generation machines. Moreover, by being able to take advantage of RTK technology they allow the company to reduce the human error rate and are crucial for the variable-rate seeding processes that characterize precision agriculture. In addition, self-driving agricultural machinery is interconnected to databases and performs maneuvers based on the prescription map of the land on which it operates. The adoption of self-driving machines allows operations within fields to be very precise. In fact, this type of innovation drastically reduces the rate of human error because the operations performed automatically by the machines are based on the dataset made available by the prescription maps. Added to this is the fact that machine movements are tracked, which allows companies to be able to verify and monitor the proper operation of the driving machines themselves. By setting up automatic driving of the machines, work stress for the operator on board is reduced, resulting in improved safety and working conditions. An additional benefit of automatic driving is to reconcile the training gap within the workforce as Dr. Falchi pointed out, due to generational turnover it is increasingly complex to find workers who are as skilled as in the past in the maneuvering of different mechanical means, but setting up automatic driving reduces this problem the technology available to the tractors in use at the Falchi company mounts displays through which the operator can monitor operations in real-time, through the screen and can check if the tractor is following the traced furrow and if necessary correct the trajectory, thus making up for any inexperience of the worker.

Figure 3: Self-guided tractor on the farm. Photo Source: Azienda Falchi website

However, the implementation of new technologies is not without its difficulties for the company. Dr. Falchi pointed out that the company has implemented as many as three data management platforms. Each of these software is interconnected to certain driving machines that work only and exclusively with that precise platform with which they are associated. However, the operation of these platforms has not been without drawbacks and still cannot be said to be perfect. In fact, the lack of dialogue between the different software of the manufacturers is highlighted; this leads to great difficulties for companies operating with multiple software because the data processed by one system cannot be compared with those made available by the other platforms except in an analog way. This is time-consuming for the company and makes it complicated to calculate the benefits gained through smart farming.

The company could have chosen not to diversify the machinery fleet, choosing only one type of machinery all interconnected to a single software, however, as pointed out by the manager, this would not have been an appropriate choice as this would have entailed risks. By purchasing only and exclusively machinery of a given platform, the company would certainly have been able to use only one software, consequently simplifying data processing, but at the same time, this would have forced the Falchi company to rely on a single dealer for the purchase and repair of tractors. In the specific context of Sardinia, this would have exposed the company to the risk of having to suspend activities in the fields in the event of a breakdown or momentary suspension of the dealership's activities. The number of dealerships active in the latest generation of tractors is, in fact, remarkably small in the region, and in the event of closure or unavailability of the dealer, often a monopoly, the company's activities would have been irreparably compromised. In a sector such as agriculture, these kinds of issues could have dramatic effects on production and subsequent earnings because farming is tied to tight timetables within which farmers have particularly tight room for maneuver.

Another shortcoming of the various platforms is the inability to use data extrapolated from field operations in concert with the various accounting and business administration programs. Again, the company is forced to resort to analog solutions; for example, because the two software programs are not communicating, companies are forced to manually upload the hours worked by workers into the system. While seemingly marginal, similar problems limit the ability to evaluate budgets and perform accurate cost-benefit analyses. Having systems that are too closed results in limited transparency and makes it difficult for the entrepreneur to use a significant amount of crucial data to fully evaluate the effectiveness of technologies and their impact on production processes.

This is compounded by a lack of dialogue between executed transactions and accounting programs (e.g., geofolia). This type of software is increasingly important for companies adopting 4.0 technologies Greater ability to evaluate budgets and perform benefit-cost analyses.

Dr. Falchi also pointed out that it is often not easy for most companies in the sector to access these technologies. Although this aspect does not concern the Falchi company specifically, she believes that the calls that provide funding should, not only encourage the purchase of technology but should spur manufacturers to ensure an accurate level of training, which is necessary for entrepreneurs so that then that technology is implemented within the company and usable to as many companies in the agricultural sector as possible. In the future, more structured companies will need to equip themselves with new professionals to be introduced on the farm such as computer technicians, robotics, and drone experts, while smaller companies will need to gain more awareness and knowledge of the new technological standards.

Another issue encountered by the company is that the technologies used are not always reliable, also in a poor digital infrastructure within the region, the technologies adopted do not always work properly. For example, one of the problems encountered is that some machines do not allow the system to read the data collected, even though they are connected to the platform, or sometimes some sensors do not give the results in time useful for agricultural production processes. These problems, due to the IT superstructures in the area, often the companies producing the machines and platforms fail to solve them, basically for two reasons: the first is that those who sell or develop these kinds of technologies very often do not have experience of working in the field and therefore are not always able to meet the practical needs of farmers; the second is that precision farming originated in the United States, in a context where companies are larger, more structured, and more digitized, so many smart farming technologies and practices are calibrated for that specific context and are often not easy to apply in the Italian and Sardinian context in particular. It is therefore necessary to adapt application models of precision agriculture to the cultivation realities of the Italian context.

4.3 Case Study 2: Argiolas Company

Cantina Argiolas is a family business active in the wine sector that has brought Sardinian wine of excellence to the world with its *Turriga*, in 2017 it had a turnover of 16.7 million euros with an export share of 38 percent. It produces 2.4 million bottles, has 230 hectares of vineyards, all owned, and 43 employees. The company has a very innovation-oriented culture; in fact, the company began approaching new smart farming techniques and 4.0 technologies 20 years ago: in 2004. This strong innovative vocation has gone hand in hand with respect for tradition, which is expressed through the preservation and protection of grape varieties and their special characteristics.

Dr. Barbara Pinna, who is responsible for innovation, has been working in the company for 20 years and during this time the Argiolas company has made great strides; a constant growth in turnover has been accompanied by numerous research projects and collaborations both with public bodies such as universities and with other companies; always intending to propose and implement innovations. The company, like many others in the wine sector, has innovated all stages of the production cycle, from the winery to the field, proposing original solutions to adapt to the new challenges and problems of the sector.

Figure 3: Photo Source: Agronotizie

Innovations in the cellar

In the winery, the company can remotely intervene on the majority of the available machines that deal with the different stages of production, this allows the remote control of the different laboratory phases up to bottling; it allows the automation of the different production processes and gives a clear idea of how many hours a particular type of machinery remains on allowing the company to optimize time and in the long run optimize energy costs. Added to this is the fact that remote control makes it easier and more immediate for technicians to intervene remotely in the event of problems, reducing intervention time. An example of this kind of innovation is definitely the bottling plant that can be fully controlled remotely.

Figure 4: Rent bottling plant 4.0 Photo Source: Cantina 4.0

At the barrel level, the company is trying to optimize the management system. For the company to have a large number of barrels, it is important to first proceed to catalog them.

As stated by the person in charge of innovation, the Argiolas winery has equipped itself with an instrument in the laboratory that allows barrel-by-barrel monitoring. In this aspect, the Argiolas winery was a pioneer, but the system in a few years has spread to many companies and several research laboratories have equipped themselves with this crucial tool for monitoring the winery. The strategic nature of this system lies in the fact that it makes it possible to work through a spectrum that not only gives the actual parameters but also has a predictive value. The importance of having accurate and timely data on these parameters allows for action on wine quality.

With the adoption of 4.0 technologies, the company has implemented a data cataloging system to assess how it is working over time. A central system collects all the parameters of the different connected machines so that it has control over the type of processing being carried out and uses the monitoring data to assess their impact on the company over time.

Innovations in the vineyard

The Argiolas company has implemented a programmable and automated irrigation system. Added to this are weather columns that allow the company to monitor weather patterns. In this way, the company can determine irrigation patterns based on the climate on that specific day; following this approach allows the company to achieve significant water savings. In addition, irrigations do not occur intuitively but are targeted and occur according to statistical data collected in different years and based on what the weather column is reporting at that time. This approach produces on average 25-30% water savings in particular there is less water loss due to evaporation from the soil.

Through the processing of time series, the company was able to record and demonstrate that in recent years it had a higher yield concerning climatic conditions and thus was able to reduce losses as much as possible despite unfavorable climatic conditions through technology. The impact of technology on land yield in the wine sector deserves a specific discussion. Wine companies are much more geared toward producing a quality product; then there are adverse weather conditions that force the company to preserve the product and pose the need to guarantee a certain quantity of product. In this aspect, too, the use of technological systems takes over; for example, if weather prediction equipment signals that there will be a high probability of rain the next day, the company can intervene by applying absorbent products that avert the formation of mold. In this way, one can carry out preventive treatments to avert adverse effects that can halve the harvest. This aspect is crucial for the farmer because technology helps him to mitigate what is the main problem for those working in the sector: namely, adverse effects due to natural disasters that can put a major damper on business activity.

The platform through which the Argiolas winery collects and processes data is based on an in-house server that has been preset with the essential processing parameters, all bottling data, and soon all winemaking data. So they will be able to have an account of how they are working on the entire supply chain: from field to bottle. In part, this is already there because all the machines are integrated online with the system allowing them to monitor how the different stages of processing are progressing. The missing aspect, but one that the company is working on, and implementing soon, is the history report. The platform was developed specifically for the Argiolas company; in fact, it is a platform tailored to Argiolas based on the specific needs of the work done by the company. Connected to this system are the bottling plant; the winemaking machines that perform red winemaking; a system that allows for the management of temperatures that are crucial in the different stages of fermentation and storage. Shortly, initial processing systems such as presses, and the gutter system will be integrated with the platform. This will make it possible to have all processing stages not only in the field with climate and irrigation control but also with the processing that takes place in the winery, interconnected using the platform, allowing the winery to have a global view of the entire production process and the ability to intervene on it in real-time and remotely. From the moment the grapes are pressed and the must is harvested, to the processing phase, particularly for what happens with red grapes and the subsequent temperature stabilization phase.

Despite the extensive use of various automation-related technologies, the use of manpower has not disappeared. However, in the event of problems on the plant, the complexity of the technologies implemented is such that it is difficult to employ in-house maintenance workers, which in the vast majority of cases finds itself having to rely on the manufacturer of the innovative sensor and data processing systems, which usually provides maintenance services. On the one hand, there is a lightening of the use of manpower on the other hand 4.0 technologies have brought greater speed of production, and the company has become more and more hectic, which makes the presence of an essential workforce necessary. Therefore, the real impact of technologies on the company's operators can be found primarily in the increase in productivity; in fact, better optimization of time enables the production of greater quantities of products.

The Argiolas winery also has a computerized bottle level control and there is a sensor that indicates if the level is correct; in addition, the winery uses weighing systems, so the Argiolas winery has as many as three levels of control on the bottle to check if the volume is correct and if it is not correct, the bottle would be discarded.

Disadvantages

There are systems to be implemented to facilitate some determinations that always require the presence of the operator and make it so that the presence of the operator cannot be replaced. Some of these technologies are not performing well enough, such as, for example, the use of drones to check the ripeness of grapes; in these cases, sampling is done from the field because the use of drones does not allow the output to be received reasonably quickly. If farms cannot get that kind of data in time, the survey becomes useless. Farmers need that data either in real time or in any case within a few hours if even a few days were to pass between the drone survey and the processing of the result that data would be obsolete as the situation in the field would have already changed.

A second aspect to be considered common to all sectors is undoubtedly that of costs; in the case of Argiolas, the problem is limited since we are talking about a structured company with an excellent turnover that can count on professional figures in charge of using financing. However, smaller agricultural realities could have big problems in dealing with the initial financing.

Bureaucracy and certifying bodies are a major brake on innovation, without proper support on how to move within it for many realities, it becomes complicated. One of the limitations is certainly the lack of clarity of certain regulations drawn up by the Public Administration even in the area of Agriculture 4.0 it is not always clear what the Italian legislator recognizes as belonging to that particular acronym. It is not clear whether to be considered 4.0 it is enough that the tool is simply connectable online, some say, whether the presence of a platform within which all the data collected converges is essential. This forces companies to have to move without leaving room for any kind of dispute this, however, can lead to greater complexity and additional costs. In addition, it is pointed out that public administration employees themselves were sometimes unable to clarify what was required to access the calls and funding made available to implement Agriculture 4.0 technologies.

This lack of clarity also affects the vendors of the equipment; it often happens that they sell machines that are not compatible with the different platforms. Only certain machines can communicate with the server available to the company this also leads to insignificant practical consequences because the machine is displayed online by the system however at the same time it is unable to translate the data collected by the machine. This makes the effectiveness of the technology stunted because it does not allow for the data-driven scientific approach on which Intelligent Agriculture is based and allows for biased and less accurate assessments.

According to Dr. Pinna, the key to solving this problem is greater adaptability of systems to customer needs and to the systems that customers already have in the company. For an enterprise to have only certain machines compatible with its system is a limitation of no small magnitude. As an example, it is useful to imagine a company that has already invested a large sum of money to implement data collection and management software at this point if the company wanted to invest in a bottling plant it finds itself being forced to either buy one of the few bottling plants compatible with its system or it has to replace the software itself. In either case, the company faces very high exit costs. This represents a major constraint.

Often those who develop the technology standard that will later also be used in agriculture do not work in the sector. This, according to farmers, leads to dyscrasia due to a lack of practical experience in a given context, and this results in new technological standards frequently clashing with the day-to-day problems peculiar to the sector. In addition, according to farmers, there should be more collaboration between the manufacturers of the machines or software with the farm staff it would be enough if there were more confrontation between the two parties to make innovations more accessible, understandable, and responsive to the needs of those working in the sector.

In terms of sustainability, new technologies have less impact on the environment. The optimization of processing times allows the winery to save energy, for example, the control of refrigerator temperatures allows for to reduction of waste due to the high energy expenditure of refrigeration an optimal control of temperatures allows for the optimization of the timing of refrigeration and to use the right energy input and this results in significant savings and ensures greater sustainability of production processes. This reasoning can be extended to much of the equipment used in the winery and is useful in optimizing not only sustainability but also other aspects such as: decreasing work time; reducing physical fatigue; and lowering machine uptime.

In terms of sustainability, the company's next step will be to define how to develop a proper energy balance through which to evaluate the energy produced, through the use of photovoltaics and the energy used for the use of 4.0 technologies. To do this, this function will have to be implemented in the platform currently used by the company.

Another frontier of innovation is that of water saving particularly concerning the use of machines to reuse wastewater for surface washing. Also part of 4.0 is the water filtration system in the winery that allows the winery to remotely manage the water filtration and see how the system is working and whether the amount of water is sufficient. Depending on the use whether the water is for surface washing or plant washing.

4.4 Case Study 3: Fruit and Vegetable Company

The entrepreneur prefers to remain anonymous, so the company is not referred to by its original name.

The company is a one-man business in the Oristano area active in the fruit and vegetable sector, the company's main production being processing tomatoes. The founder of the company became interested in precision agriculture issues as many as thirty years ago and implemented smart farming technologies in 2010. The company has a cultivable area of more than one hundred hectares divided into a variable number of plots that are cultivated; generally, between seven and ten plots are cultivated each season, which are normally divided into two. The main innovations introduced by the farm include the precision irrigation system and soil monitoring probes.

The farm can rely on fully automated and remotely controllable irrigation, a crucial part of the system is the two mother controllers whose role within the plot is to collect data. Each control unit "manages" two fields, depending on the data the farmer receives daily from the mother control unit he obtains a crop coefficient, processed this coefficient the control unit also performs the integration of metrocubes per hectare. In addition, each field has its specific requirement in terms of cubic meters per second of water, the requirement being studied according to the peculiarities of the field each appreciation of the amount of water quantity received is customized. This also allows for greater accuracy in monitoring since, for example, if "field 1" is to receive 18 cubic meters of water per second, the farmer can view the progress of irrigation through an app installed on the phone, and if "field 1" is receiving less than 18 he can take action to resolve the issue. This detection is done through flow meters, which after about ten minutes provide an accurate flow rate figure. Although strongly related to the weather patterns of the seasons and the type of soil, the precision irrigation system ensures a reduction in wastage of water resources that averages about 50 percent less water.

The irrigation system is integrated with sophisticated automated grit filters. The grit filter can block the smallest particles present in highly charged water by slowing down the flow through the filter mass. Due to the fractionation of the filter surface area in the vertical multi-chamber filter, the self-cleaning phase of the filter is optimized. While one chamber is washing, all the others continue to filter, ensuring the following advantages: uninterrupted irrigation that stabilizes the water supply to the crops and secondarily lowers energy costs by reducing the total irrigation time. This is a practical and efficient solution: the filters are equipped with a backwash control unit that intervenes periodically to prevent the filter from clogging, thus ensuring continuity of irrigation. In addition, the cylindrical shape of the filter allows the entire filter mass to be utilized, ensuring an even distribution of water.

In each plot of land, the company has implemented probes to detect moisture; this is independent of the irrigation system and serves to confirm that irrigation is working properly. The irrigation system chosen by the entrepreneur not only guarantees water savings, but is equipped with a renewable energy production system based on photovoltaic panels that self-produce the energy the system needs to function.

Photo 5: Self-powered irrigation system with photovoltaic panel. Photo Source: Il Nuovo Agricoltore

The companies newly adopted technological standards have led to two main results: the first is large savings in inputs, and the second has increased production yields. The use of precision techniques has enabled the production of a higher-quality product. The entrepreneur said that since he began widespread use of 4.0 technologies there has been a disruptive impact on land yield, which has increased by more than 10 percent per plot. The innovation has also affected the fixed cost structure since against an initial investment that was certainly exorbitant, the new technologies have allowed for a rather large increase in production and savings. According to the entrepreneur's statement, even in terms of operating costs, the company has achieved high savings. Before the processes were automated two or three people needed to leave to manually open all the taps on the plots. Today, on the other hand, the opening time of the taps is set at the beginning of the season, and the taps, being fully automated, start at the set time each day without the intervention of the farm labor.

In terms of the machinery fleet, the enterprise has been equipped with four self-driving tractors and a robotic transplanting machine. Thanks to the use of satellite guidance, the entrepreneur pointed out that the use of precision techniques now extends to all stages of the production cycle. The farm before transplanting puts in localized fertilizer, and fertilization has to be done in a very precise way, therefore, it is done according to very precise prescription maps.

Figure 6: Displays mounted on self-driving tractors that allow the operator to view and follow trajectories plotted on prescription maps. Photo Source Il Sole 24 Ore

The mapping allows for precise tracking of the plotted furrows and a consequent greater precision in the application of fertilizer, avoiding dispersion of the product, which at the end of the year saves about 30-35%. Unlike the first case study where the company under consideration had used RTKs the company under consideration uses RTXs; this is a similar system in operation, however, it has a higher margin of error of 8-10 cm. In principle, the purpose of RTX does not change compared to RTK, which is to simplify production processes and optimize timing; in fact, although less precise RTX ensures great accuracy of farm machinery drastically reduces waste of production inputs, and also simplifies the work of the machinists by making their work less burdensome.

Figure 7: Parallel-guided tractor suitable for seeding and variable-rate fertilization.
Photo Source: Vocazionalità e semina a rateo variabile.

The next innovation the company will introduce is the use of drones; according to the entrepreneur, drones can be crucial in preventing plant diseases and problems. In fact, with increasing numbers of products being banned to comply with green policies, drones can be a viable alternative to banned products. Drones can be used to launch beneficial insects or to carry out sustainable treatments useful in preventing possible diseases. The use of drones also can be decisive for fertilization, the drone being connected to RTXs can be programmed and based on the inputs of the data uploaded to the system and the prescription map performs its operations autonomously. This could ensure time optimization as according to the entrepreneur in about thirty minutes he could fertilize four to five hectares. In addition, in the case of extensive crops such as wheat, the use of drones would simplify operations as it would not be necessary to enter the field directly with tractors and other machines.

4.5 Conclusions

Agriculture is a complex sector and has been experiencing great transformations and changes in recent years that produce uncertainty for businesses and their operators. The state of uncertainty and crisis in which agriculture finds itself has deep roots that start as far back as the postwar period. In fact, for more than half a century during the boom of industry and the Italian economy, agriculture found itself in the uncomfortable role of follower having to resort to the CAP measures adopted to keep agricultural prices and incomes constant by redistributing some of the additional wealth generated by the development of other sectors.

Italy's agricultural sector paid the price for a failed modernization; agriculture provided the industrial apparatus with raw materials and labor but found itself in a subordinate position that resulted in lower income, lower productivity, and less stimulus for growth. This made European agricultural policy monetary aid indispensable for Italian businesses, which partially plugged the gap that had been created between agriculture and other sectors. However, while this type of measure has allowed farms not to completely miss the rendezvous with the modernization and economic development of the country and the resulting growth in income and productivity, it has also placed the sector in a position of heavy dependence on the welfarist measures launched by European policy.

The major limitation of this position is that it rewarded passive adaptations and did not favor an innovation of business models and business processes adopted by farms. In fact, if policy decides what is produced, in what quantity, and at what price, this inevitably generates a situation in which entrepreneurs who are willing to follow are favored, not innovators-that is, those part of entrepreneurs with ideas that are different from the norm and willing to take risks to pursue different paths. Although there are within the sector several innovative and successful enterprises that in numerous cases have also given rise to emerging and vibrant realities, Italian agriculture, in its vast majority, remains encumbered by the adaptive incentives of the CAP, which is comparatively high, allow enterprises easy gains even without innovating. This leads entrepreneurs, to abandon the risk that investment in innovation presupposes. This system creates a short circuit by being the rule tailor-made for trend-following entrepreneurs.

However, the arrival of the 21st century has brought a crisis to this system. With the abrupt slowdown of the European economy, agriculture has experienced a phase of great uncertainty and disorientation in which the sector has found itself facing new challenges that have challenged old business models. In fact, in recent years new critical issues related to the issues of environmental sustainability, competition with foreign markets, and declining profitability of the sector have taken on great importance. It seems clear that the previous paradigm was fragile and unsuitable for current and future challenges: unstable prices, quantities, and slow GDP growth leave no escape: a cycle has ended and nothing will return to the way it was. Against this backdrop of acute disorientation and uncertainty, there emerges a need for a new competitiveness and a new entrepreneurial culture more inclined to the risk of innovation. Inevitably, innovation brings a discontinuity with the behaviors and axes inherited from the past; this is not a painless process but rather a complex and dense process of challenges, but it appears necessary to revitalize the sector.

The new technological standards of Agriculture 4.0 offer enterprises a means to radically change production processes. This type of innovation allows enterprises to redefine approaches and methods by adapting them to the new requirements that the competitive and social environment demands. In fact, we have highlighted how the technology employed enables businesses to interface with challenges with a precision approach that enables several positive externalities. The greatest merit of Smart Agriculture is that it has built an alternative to traditional agriculture. This new paradigm is built on a scientific approach that relies on building an information set through which the entrepreneur can make more thoughtful decisions and reduce the margin of error. The focus of smart agriculture is precisely this supporting the decision-making of the entrepreneur by offering, through data, an overview of the critical issues and strengths that characterize soils, livestock, and crops. In this way, the decisions made are based on data and make it possible to reduce the aleatory aspect that characterizes agriculture; in fact, having a scientific basis on which to build one's activities makes it possible to achieve better results in multiple respects.

The necessary premise behind any implemented 4.0 technology is precisely that of gaining knowledge; the results of technological standards such as irrigation automation or satellite guidance robotics would be partial if there were no soil mapping and sensors that extrapolate and process a vast amount of data about the health of plants and livestock, the chemical composition of soils, and the operation of equipment in the field. The cornerstone of precision agriculture is precisely to know the agricultural context in which one operates as deeply as possible, and this is amplified by the ability not only to acquire and process data but also by the ability to remotely monitor the various stages of production in real-time and the ability to intervene promptly to solve any problem that may arise. Better crop and soil knowledge has a disruptive effect on production processes in that it allows for the optimization of costs, labor, and time, and this has positive repercussions in terms of both economic income and environmental protection.

Through careful and studied use of production inputs, enterprises can achieve substantial savings as they are used by well-established quantities, furthermore, with technology they can improve land yields and product quality. In addition, mechanization enables faster and more precise processes by limiting product losses.

In environmental terms, innovation makes it possible to reduce the impact that agricultural activities have on the environment. Smart agriculture makes it possible to disperse a smaller amount of productive inputs such as pesticides, fertilizers, or other treatments, the use of which is studied according to the needs of the soils and crops highlighted by the sensors placed in the fields, reducing the quantities introduced to those that are strictly necessary, and consequently, the impact on the environment is reduced. One of the most notable results is undoubtedly water savings, in fact, precision irrigation, especially when assisted by sensors that detect the chemical composition of soils, is one of the most successful aspects as it is capable of bringing significant water savings ranging from 30-40%. This in particular is crucial for the Italian agricultural context since one of the most dramatic effects of climate change in Italy is precisely that of drought that has plagued many regions in recent years especially Sardinia, Sicily, and the Po Valley regions. In the coming years, the effects of climate change will likely become more dramatic, and precision irrigation technologies will become a strategic asset for many of the companies that will find themselves operating with increasingly limited and scarce water resources. The thesis highlighted the case of Sardinia, which periodically faces periods of drought and climates that are increasingly hostile to agricultural activity, however, Sardinia's condition is common to all European Mediterranean regions that are proportionally the most exposed to the adverse effects of climate change.

However, the implementation of these technologies faces barriers to their adoption by enterprises. Part of these barriers can be traced back to structural deficits in the Italian agricultural system as highlighted in the first chapter of the thesis these deficits can be traced back to the structure and size of enterprises that are very often too small and poorly capitalized. This limitation is fundamental because as explained by the case studies the initial investments are certainly large and a relatively long period is needed to repay the investment. In addition, we are talking about an industry where the average age of the operators is quite high this restrains the innovative drive of companies, as they are less familiar with technologies and tend to be less willing to take risks due to innovation. Many studies point out that agricultural enterprises run by young entrepreneurs are more structured, larger in size, and significantly more likely to invest in innovation. However, enterprises run by young entrepreneurs are a tiny share of the sector.

The second limitation in technology adoption is due to the very conception behind these types of technologies. As pointed out by the companies in the case studies for many the main limitation behind the new technological standards is to be found in the fact that they are designed for a different context than the Italian one, namely the United States. We are talking about a context that is markedly different from that of Italy or Europe, in that it is characterized by large companies with significantly larger areas. These technologies require application models that are adapted to the cultivation realities peculiar to the Italian context. Otherwise, the usefulness of these technologies is limited as they are ill-suited to the smaller contexts of Italian agriculture.

Another limitation highlighted by the companies is the lack of cooperation between manufacturers of machinery, equipment, and platforms and agricultural enterprises. The latter points out that it is very often difficult to interface with manufacturers of new technologies in terms of solving the problems of adaptability of machinery with different management platforms and the high problems they face in the daily application of 4.0 technologies.

According to several agricultural entrepreneurs, many manufacturers do not employ professionals with actual field experience, and some technologies suffer from a lack of practicality in the field. In this sense, it could be useful to link incentives and funding for the purchase of 4.0 technologies to a concrete collaborative effort between the different actors in the sector and encourage a more dynamic and open approach to make technology more accessible and easier to use in the field.

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