

Article

The Impact of the 4.0 Paradigm in the Italian Agricultural Sector: A Descriptive Survey

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Abstract: This paper investigates how much Italian farms are involved in the so-called “Agriculture 4.0” (Agri 4.0) journey. The paper focuses on analyzing the knowledge and adoption levels of specific 4.0-enabling technologies while also considering the main benefits and obstacles. A descriptive survey was carried out on a total of 670 respondents related to agricultural companies of different sizes. The findings from the survey demonstrate that Italian farms are in different positions in their journey toward the Agri 4.0 paradigm, mainly depending on their size in terms of revenues and land size. Furthermore, there are strong differences concerning both the benefits and obstacles related to the adoption of the Agri 4.0 paradigm, here depending on the technology adoption level. Regarding future research, it would be interesting to carry out the same study in other countries to make comparisons and suitable benchmark analyses. Although scholars have debated about the adoption of technologies and the benefits related to the Agri 4.0 paradigm, to the best of the authors’ knowledge, no empirical surveys have been carried out on the adoption level of digital solutions in agriculture in specific countries.



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Keywords: Agriculture 4.0; smart agriculture; digitalization; descriptive survey; digital technologies

1. Introduction

In the coming decades, the world will face major issues that will have massive effects on the agricultural sector. Three main challenges are on the horizon: (1) The world population is set to increase. It is estimated that the human population will reach 9 billion people by 2050, increasing the demand for food by 70%, and water consumption in agriculture is expected to increase by 41% (the sector is already responsible for the consumption of almost 70% of the fresh drinking water on the planet) [1]. (2) In the medium term, climate change will profoundly affect the extent of arable land worldwide [2]. (3) The aging population in developed economies will soon bring the need to automate and digitize the agriculture sector [3].

Agriculture is a fundamental part of all economies in the world and, like all key sectors, is involved in the Fourth Industrial Revolution. The evolution of the primary sector toward digitalization is not dictated by an overall trend but aims to address the main macro issues in the years and decades to come, such as the need to make crops more efficient and effective and to evolve in an environmentally sustainable way. The strong link between sustainability and digital innovation is not limited to the primary sector but involves all major economic ones. From this approach, the phenomenon of Agriculture 4.0 (from now on, Agri 4.0) derives from the broader theme of Industry 4.0, which is considered to have huge potential in providing digital solutions to address the main problems encountered by traditional agriculture, enabling support for farmers to make faster decisions, achieve higher process efficiency, and have the ability to take timely action to meet market demands [4]. The literature sometimes also refers to this emerging phenomenon as “smart agriculture,” basically taking its cue from the concept of smart

manufacturing, which is already widely used in industry [5]. In other cases, scholars have used the term “smart farming” [6,7] or “digital farming” [8]. All these terms can be seen as synonyms, so for the current paper, the term Agri 4.0 will be used for simplicity purposes.

Scholars have focused on how digital technologies impact the agricultural sector [9,10] and how the diffusion of the Agri 4.0 paradigm can transform production processes and business strategy [4].

Although this paradigm has been investigated in the literature, presenting concrete examples of categorization of the possible benefits, obstacles, and dedicated digital technologies, there is no pervasive study focusing on the knowledge of digital solutions in agriculture and their degree of utilization. Moreover, the scientific literature presents no contributions when it comes to surveying the state of knowledge of the solutions among farmers and their degree of use, as well as the impacts received in using these solutions, both in general terms and specifically in the Italian context. In addition, research on Agri 4.0 neglects the use of empirical methods, such as empirical surveys, to develop scientific results from information from farmer practitioners. The few empirical surveys carried out by scholars have tended to focus on other drivers or on a single aspect throughout the whole questionnaire, such as the ones by Bolfe [11] and Chuang [12].

In an attempt to fill the above-mentioned literature gaps, the following research questions have been formulated:

RQ1: What is the level of awareness of Agri 4.0 solutions among farm enterprises?

RQ2: What is the level of adoption of Agri 4.0 solutions?

RQ3: What are the main benefits perceived in adopting Agri 4.0 solutions?

RQ4: What are the main challenges perceived in adopting Agri 4.0 solutions?

The research questions were set based on a reference scheme developed by the authors, which is presented in Figure 1.

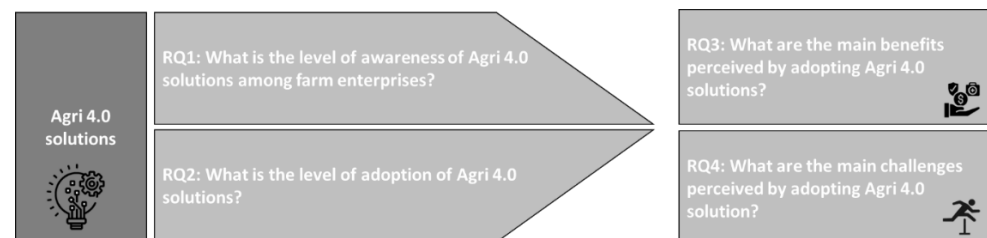


Figure 1. Reference scheme.

In particular, RQ1 and RQ2 aim at investigating the technological issues concerning Agri 4.0, while RQ3 and RQ4 investigate the effects in terms of the benefits and obstacles of the previous research questions.

Therefore, the present paper addresses the Agri 4.0 paradigm, aiming to gather evidence from the current state-of-the-art in the Italian agricultural context. Based on a descriptive survey completed by 670 respondents, the current paper aims to understand the degree of penetration of the phenomenon, covering many different open points of the paradigm and addressing these in multiple dimensions (distinctive solutions knowledge and utilization rate, benefits, and challenges).

The current paper concentrates on the Italian context. This choice was driven by the fact that, given the composition of the research group, the number of companies that could be involved was larger and because the Italian agriculture system is first in agriculture in Europe based on added value and third based on gross saleable production. Italy is also the world’s leading producer of wine by volume and leading European producer of vegetables by value [13].

The present study also provides a systematization of the technological solutions adopted within the Agri 4.0 paradigm. Finally, the current paper provides a rationalization of the benefits and obstacles related to the implementation of the aforementioned digital technological solutions in the primary sector.

The current article is structured as follows: Section 2 gives an overview of the paradigm and presents the Agri 4.0 studied solutions. Section 3 describes the research methodology used, which is followed by Section 4, in which the four main thematic analyses are discussed. Next, Section 5 discusses the results, providing the research implications of the study and proposals for future research agendas in Agri 4.0.

2. Literature Review

2.1. Agri 4.0: Phenomenon and Paradigm Definition

The concept of Agri 4.0 encompasses several different scientific domains, some of which are directly related to land cultivation (water control, crop cultivation, harvesting, etc.), while others are an expansion of the agricultural area to different disciplines, such as engineering, economics, management, and so forth. Advances in different areas of the information and communication technology (ICT) domain, combined with the need to improve agricultural productivity, both for food safety and environmental impact issues, have determined the research area for Agri 4.0. Therefore, Agri 4.0 is derived from the broader concept of Industry 4.0 [9], which aims to define the integration of different technologies (such as Internet of Things (IoT), artificial intelligence, cloud computing, etc.) to automate cyber-physical tasks and processes, allowing for better planning and control of agricultural systems. The relationship of this concept with that of the Industry 4.0 paradigm, that is, the adoption of digital technologies to support the processes of manufacturing companies, is clear.

As reported in the literature, reducing input costs and increasing productivity seem to be the driving forces behind the progress in agriculture. However, the importance of sustainability should not be overlooked, a concept that has emerged as a major issue across the spectrum of human activities. Therefore, one of the goals of Agri 4.0 is to minimize the environmental impact of agricultural activities [14]. Thus, the implementation of Agri 4.0 solutions implies the possibility of farms achieving certain goals and benefits.

2.2. Enabling Digital Solutions for Agri 4.0

Taxonomies to group digital solutions in Agri 4.0 have already been presented in the literature. In particular, some interesting solutions are the ones presented by Lezoche et al. [9] and Liu et al. [10]; in both studies, the authors have presented an interesting categorization and description of the main technologies to be considered in Agri 4.0.

On the other hand, the current study focuses on solutions rather than technologies (i.e., different technologies can be part of the same type of solution); therefore, drawing on information and insights arising from the literature, five different clusters are presented: decision support system software; monitoring systems; systems for precision activities; mapping systems; and autonomous systems. The full list is presented in Table 1.

Table 1. List of the Agri 4.0 solutions considered.

Cluster of Technology Solutions	Solutions	References
Decision support system software	Business management software	[15,16]
	Decision support system (DSS)	
Monitoring systems	Agricultural machinery and equipment	[17,19]
	Crop and soil	
	Enterprise infrastructure	
	Indoor cultivation	

Table 1. Cont.

Cluster of Technology Solutions	Solutions	References
Systems for precision activities	Precision irrigation systems	[9,20]
	Variable rate distribution system	
	On-field treatment with drones	
Mapping systems	Satellite technologies	[18,21]
	Mapping equipment installed on machinery	
	Mapping drones	
Autonomous systems	Robot for field activities	[10,22]
	Satellite guidance	

- (a) **Decision support system software:** This type of software facilitates the decision-making process by helping prioritize goals, evaluate alternatives, and simulate outcomes. Within this category, there are two key reference solutions: (a) Business management software helps in automating the management processes within companies. In particular, this software is useful for various business functions, such as agricultural production, warehouse management, and accounting [15]. (b) Decision support systems (DSS) are computer tools that use data and mathematical models to support the decision maker, here being the farmer [16].
- (b) **Monitoring systems:** Monitoring systems use different technologies, such as smart sensors and pervasive connectivity, to monitor different areas of a farm [17,18]. The Agri 4.0 paradigm diffusion strongly relies on the development of innovative technologies such as sensors, the IoT, and Big Data [19]. Therefore, this cluster is divided into four different application areas that cover the main areas to be monitored within an agricultural company: agricultural machinery and equipment domain, crop and soils monitoring, enterprise infrastructure, and indoor cultivation.
- (c) **Systems for precision activities:** The systems for precision activities enable the targeted use of various agricultural inputs [9,20]. Specifically, in this cluster, it is possible to identify three solutions: precision irrigation systems, variable rate distribution systems, and on-field treatment with drones.
- (d) **Mapping systems:** Land mapping is a fundamental activity of Agri 4.0. Thanks to the knowledge of the spatial variability of soil properties, farm potential in terms of quality, quantity, and yield can be optimized [18,21]. In this regard, the three solutions refer to satellite technologies, mapping equipment installed on machinery, and mapping through drones.
- (e) **Autonomous systems:** The use of increasingly advanced IT (information technology) and OT (operation technology) leads the agriculture industry to use autonomous systems both in terms of moving machines during operations and in terms of deciding on the activities to be performed within the fields [10,22]. The main solutions of this cluster are robots for field activities and satellite guidance.

2.3. Agri 4.0: Benefits and Obstacles

A long list of potential benefits can be listed under different economic areas, as well as environmental benefits with a reduction of pollutants [23,24] and social benefits with positive effects on the well-being of the workers involved and on society in general [25]. At the same time, there are also criticalities involved in implementing new systems, especially digital ones, in contexts such as the agricultural sector. For those who decide to implement innovative systems, there can be challenges of a technological, economic, and implementation nature, as well as those arising from corporate culture and organizational issues [26,27].

The benefits investigated can be categorized into four clusters, which have been identified according to the triple bottom line (TBL; that is, people, planet, and profit) principles [28]. The first two clusters (effectiveness and efficiency) refer to the profit or bottom line. The next two are environmental and social benefits. From these four clusters, a set of 14 benefits was proposed. A full list of the benefits and references is presented in Table 2.

Table 2. List of benefits.

TBL Cluster	Cluster of Benefit	Benefits	References
Profit	Effectiveness	Product quality increase	[24,29]
		Yield increase	
		Soil quality increase	
		Increase in selling price	
	Efficiency	Less water consumption	[30,31]
		Less technical input consumption	
		Less machinery usage	
		Simplification in the cultivation decisions to be made	
		General cost reduction	
Planet	Environmental benefits	Air pollution (CO ₂ , N ₂ O, . . .) decrease	[23]
		Water pollution decrease	
People	Social Benefits	Work safety increase	[25,32,33]
		Reduced time spent on bureaucratic tasks	
		Physical labor reduction	

- (a) **Effectiveness benefits:** The benefit cluster related to the economic part of the TBL. Operational effectiveness encompasses the practices employed to maximize resources and deliver high-quality results [24,29]. Here, the authors investigated four different benefits related to effectiveness: higher product quality, yield increase, better soil quality, and an increase in the selling price of goods produced.
- (b) **Efficiency benefits:** The benefit cluster related to the economic part of the TBL. Reducing the consumption of productive inputs and, thus, the associated costs is critical because it is known that a firm that has lower cumulative costs to perform all value-generating activities than its competitors has a cost advantage [30,31]. Here, the authors investigated five different benefits related to efficiency: less water consumption, less technical input consumption, less machinery usage, simplification in the cultivation decision to be made, and general cost reduction.
- (c) **Environmental benefits:** Sustainability from an environmental perspective is another benefit that can be achieved through the use of 4.0 solutions in agriculture [23]. Reducing the use of pollutants (such as agrochemicals and various fertilizers) increases soil quality, but from a purely environmental standpoint, there are real effects on air pollution decrease (CO, NO, etc.) and decreases in water pollution.
- (d) **Social benefits:** The adoption of Agri 4.0 techniques has the potential to increase farmers' quality of life in terms of increased work safety and decreased work stress. The controllable work environment in a plant factory is much more desirable than field cultivation, which requires a lot of physical energy to complete [32,33]. Specifically, the benefits under this cluster are three: increase in work safety, reduced time spent in bureaucratic activities, and a reduction in physical labor [25].

For 'obstacles,' four main clusters have been identified. The clusters cover the main areas of challenge when introducing a technological evolution in a certain environment:

- (a) **Technological challenges:** This cluster refers to technical and technological issues related to the implementation of 4.0 solutions in agriculture [34]. Technical barriers can be limited or without interoperability (the data collected cannot be reused and different solutions do not work together) and lacking connectivity. However, it is also important to mention the limited or absent flexibility in the sense that the provided solution works only under optimal operating conditions (primarily weather) [27].
- (b) **Economic challenge:** The implementation of innovative solutions and technologies in every field leads to a significant economic effort by the company that intends to adopt an innovative path. For this reason, it takes into consideration the economic return of the investment made in 4.0 solutions [35]. The challenge in question is the low investment return rate.
- (c) **Implementation challenges:** The skills needed to properly implement 4.0 solutions, especially in companies in the primary sector, inevitably lead to the challenge of usage difficulty. Subsequently, the challenge connected to the first one is insufficient assistance because many companies can face obstacles that are difficult to overcome without an appropriate implementation assistance path [26].
- (d) **Cultural and organizational challenge:** Because of the introduction of digitalization in agriculture, the 4.0 revolution in all economic sectors will require a new set of skills related to the introduction of digital solutions in companies [25]; for this reason, the challenge presented in the survey is the lack of key digital skills in the farm.

Out of these clusters, seven different obstacles could be derived. The full list of challenges and references is presented in Table 3.

Table 3. List of challenges.

Cluster of Challenges	Challenges	References
Technological challenge	Limited or absent interoperability	[27,34]
	Limited or absent flexibility	
	Lack of connectivity	
Economic challenge	Low return of investment	[35]
Implementation challenge	Insufficient assistance	[26]
	Usage difficulty	
Cultural and organizational challenge	Lack of key digital skills in the farm	[25]

3. Methodology

Survey research is useful for obtaining information about a specific phenomenon concerning large populations, allowing for an adequate level of accuracy [36,37]. The current research adopts descriptive survey research because the objective is to understand the significance of a phenomenon and describe its occurrence in a population [38,39]. Indeed, descriptive surveys are highly valuable for gathering data from diverse populations because the researcher can extract the attitudes and features of respondents accurately [40]. Moreover, it is possible to provide an effective “picture” of the phenomenon being investigated from which evidence can be drawn. Thus, a descriptive survey is a convenient method when knowledge of a phenomenon is not too poorly underdeveloped, the variables and context can be described in detail, and the objective is to understand to what extent a given relationship is present. The intent of descriptive surveys is not necessarily to determine causal relationships, but they do provide an effective method for investigating a representative sample and enabling data regarding particular issues to be collected, which may be used to form the basis of decision-making activities in the future [41].

Therefore, the primary research objective is not theory development but rather the investigation of the impacts of the Agri 4.0 paradigm in the Italian primary sector by describing the knowledge levels, achieved benefits, and perceived challenges.

To obtain the above-mentioned objectives, a survey research process consisting of three steps was adopted: survey design, pilot testing, and data collection and analysis.

3.1. Survey Design and Pilot Testing

The questionnaire was characterized by 18 mixed open and closed questions, and it was structured into four sections. The first section aimed to collect general information and a registry about the company and respondents. The second section asked about the level of knowledge for each solution proposed; the description of each technological solution was provided through a “link” button to the respondents to provide the same interpretation of technology meaning and avoid bias related to ambiguous questions. The third section inquired about the company’s perceptions of the benefits of Agri 4.0. Finally, the fourth section investigated the challenges and obstacles in adopting the Agri 4.0 paradigm.

To reach the highest number of respondents, a web survey was administered for conducting the research [42]. The trend of conducting surveys online has grown in recent times because they can offer many benefits over paper-based surveys. Indeed, with respect to face-to-face and e-mail surveys, web surveys do not require the manual transfer of responses into a database; the cost is minimal compared with other means of distribution, and greater anonymity is guaranteed, helping to avoid interviewer biases [42]. Online survey research can also allow researchers to isolate specific groups of participants who share common features [43].

Subsequently, to test possible question bias, translation accuracy, and the logical flow of the survey, pilot testing was performed before survey distribution [44]. In the first step, a group of colleagues was involved to check the readability and help pinpoint whether the questionnaire was within the study objectives. After refining the survey, the second step then involved sending the questionnaire to seven beta-tester companies to get feedback from them for further possible improvement. The pilot testing helped assess the content of the questionnaire and guaranteed the validity for the official launch.

Concerning the survey sample, the unit of analysis refers to Italian agricultural companies and farms. Moreover, this research involves all types of agricultural companies—except livestock farms—with no limits concerning their size and cultivation sector. The survey was carried out from January to October 2021, and repeated waves of reminders and recall activities were conducted with the support of the main Italian agricultural associations. The analysis started with a total number of 1273 responses before eliminating incomplete responses, duplicate responses, and test responses conducted internally by the team. As a result, a sample of 670 companies was validated. The survey respondent is the owner of the company to which the questionnaire was sent (or the decision maker in their place), who, therefore, has an overview of their farm.

3.2. Sample Description

Table 4 shows the company size of the cluster. Because there is currently no specific classification for farm size in the primary sector, it was decided to develop five customized clusters. Indeed, it was considered misleading to use the classical criteria related to manufacturing enterprises because of the great diversity in terms of turnover between the sectors. It should be noted in the table that most of the sample, 70%, is below EUR 250,000 in turnover. Only the remaining 30% are above this threshold, of which 17% have a turnover of over half a million euros.

Table 4. Revenue clusters distribution in the sample.

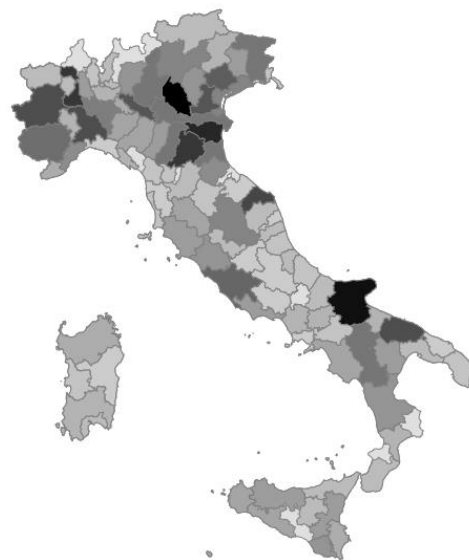
		Number of Farms	(%)
Revenue Cluster	A. <EUR 30,000	147	22
	B. between EUR 30,000 and 100,000	194	28
	C. between EUR 100,000 and 250,000	133	20
	D. between EUR 250,000 and 500,000	84	13
	E. >EUR 500,000	112	17
Total		670	100

For a more complete analysis and because of the peculiarities of the sector under study, an additional proxy for the size of the sample companies was used (Table 5), that is, cultivated hectares. In this case, there is no clear definition of the classes to be considered.

Table 5. Land size cluster distribution in the sample.

		Number of Farms	(%)
Hectares Cluster	A. <10	192	29%
	B. 10–20	112	17%
	C. 20–50	148	22%
	D. >50	218	32%
Total		670	100

Figure 2 represents the Italian distribution of farm locations; to have data with the correct granularity, the data are represented by province rather than by region. Here, the distribution of the sample subject ranges over the entire country, demonstrating a very important capillarity. In detail, there are 178 companies in Southern Italy, 96 in the center, and 396 belonging to Northern Italy.

**Figure 2.** Geographical distribution of companies in the sample.

As a final representative analysis of the reference sample, Table 6 shows the distribution of prevalent cultivation. The classification method presented was developed following two interviews with experts in the field (agronomists), who indicated the categories listed in the table. The sample is highly heterogeneous in this respect as well, reinforcing the generalization of the analyses and considerations made in the current study.

Table 6. Pareto distribution of prevalent cultivation.

Prevalent Cultivation	Sample Pareto Distribution (%)
(a) Cereals	37.4
(b) Vineyards	19.7
(c) Forage	8.2
(d) Olive groves	7.9
(e) Vegetables	5.5
(f) Pome fruit trees	4.7
(g) Stone fruit orchards	4.6
(h) Industrial crops	3.3
(i) Leguminous	2.1
(j) Flowers and ornamental plants	1.6
(k) Nursery tree	1.6
(l) Other arboretums	1.4
(m) Potatoes	1.3
(n) Citrus groves	0.5
(o) Other	0.3
Total	100

3.3. Variable Definition and Measure

Table 7 shows the variables used in the survey. The variable “Agri 4.0 solutions knowledge level” evaluates the degree of knowledge of the various solutions proposed. Four options are considered: “I have never used this solution, and I am not familiar with it,” “I have never used this solution, but I know it,” “I do not currently use this solution but have used it in the past,” and “I currently use this solution.” A variable implicitly connected to the one just described is “Agri 4.0 solutions adoption,” in which the answer “I currently use this solution” was used to represent the results.

Table 7. Variable definition and criteria.

Variable	Type	Nr. of Levels/Clusters	Levels
Company size (revenues)	Ordinal	5	A. Less than EUR 30,000; B. between EUR 30,000 and 100,000; C. between EUR 100,000 and 250,000; D. between EUR 250,000 and 500,000; E. over EUR 500,000
Company size (land)	Ordinal	5	A. Lower than 10 hectares; B. Between 10 and 20 hectares; C. Between 20 and 50 hectares; D. Over 50 hectares
Agri 4.0 solutions knowledge level	Ordinal	4	I am not familiar with the solution; I am a little familiar with the solution; I am familiar with the solution at a theoretical level; I am familiar with the solution at a practical level
Agri 4.0 solution adoption	Ordinal	2	I use the solution; I do not use the solution
Benefits	Ordinal	5	Null; Low; Middle; High; Very High
Challenges	Ordinal	5	Null; Low; Middle; High; Very High

To identify the enabling solutions, benefits, and obstacles related to the Agri 4.0 paradigm, no systematic analysis was carried out, but a narrative literature review was conducted. This type of analysis, which is widely used in studies related to the medical sci-

ences [45], does not involve following a strict protocol or specific standards but still allows for the identification of the main studies describing a problem of interest [46]. Concerning the identification of the articles to be analyzed, the Scopus and Web of Science databases were surveyed using strings formulated from the keywords related to agriculture and digitalization (“Smart Agrifood,” “Smart Agriculture,” “Smart Farming,” “Agrifood 4.0,” “Agriculture 4.0,” “Farming 4.0,” “Internet of Farming,” “Digital Agrifood,” “Digital Agriculture,” “Digital Farming,” “Precision Agriculture,” and “Precision Farming”). The set of enabling solutions, benefits, and obstacles have already been presented in Section 2.

4. Results

4.1. RQ1: What Is the Level of Awareness of Agri 4.0 Solutions among Farm Enterprises?

The first highlight of the analysis derives from the investigation of the current degree of knowledge of Agri 4.0 solutions within the sample considered. Figure 3 summarizes the results. The level of awareness was measured using a 4-point scale, from a low to a high level of awareness of the solutions, specifically (a) I am not familiar with the solution, with no awareness of solutions existence; (b) I am a little familiar with the solution, meaning having only marginally heard of the solution; (c) I am familiar with the solution at a theoretical level, meaning having a good level of theoretical knowledge; and (d) I am familiar with the solution at a practical level, meaning knowing the solution and having knowledge of practical examples in the field.

Figure 3 shows all the solutions proposed within the questionnaire, ordering them from the most to least known. Another important aspect to consider is the statistical distribution of the number of solutions deeply known by the respondents (counting only answers in which the solution is familiar to the respondents). The distribution depicted in Table 8 represents the number of times a certain number of solutions is known at the same time, presenting the percentage over the entire sample and number of respondents.

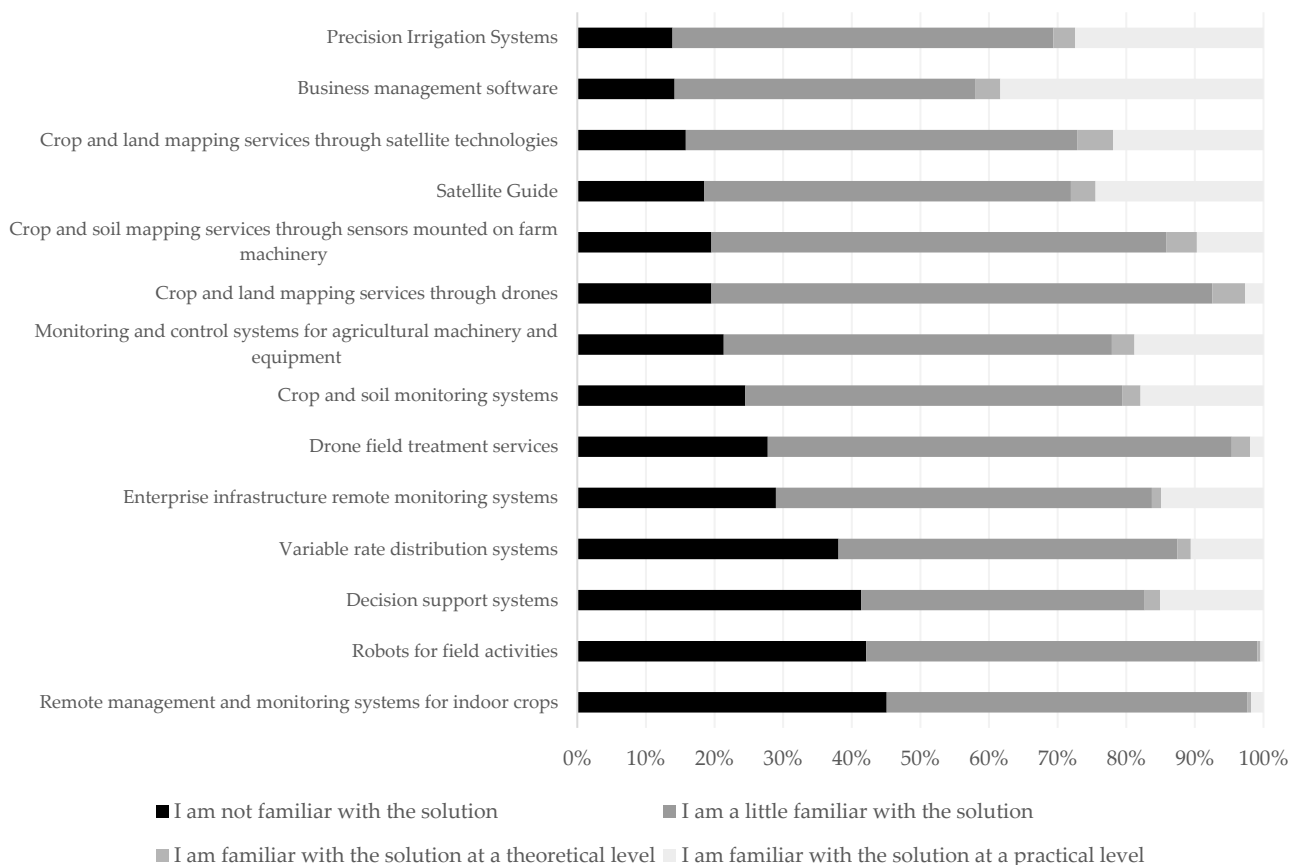


Figure 3. Agri 4.0 solutions awareness level.

Table 8. Statistical distribution of the number of digital solutions known.

Number of Digital Solutions Known Simultaneously	Respondents (%)	Respondents (Nr.)
0	28.4	190
1	17.3	116
2	13.7	92
3	11.2	75
4	9.6	64
5	7.5	50
6	4.2	28
7	3.4	23
8	2.1	14
9	1.3	9
10	0.7	5
11	0.3	2
12	0.3	2
Total:	100	670

The table clearly shows that the number of respondents claiming to know more solutions decreases as the number of known solutions increases.

The most well-known solutions within the given answer set are by far precision irrigation systems and business management software, followed by two technological solutions that share a similar technological basepoint, i.e., crop and land mapping services through satellite technologies and satellite guides. In this case, the management software solution is the most well known in practice, demonstrating that it is the solution most likely to be implemented by companies.

Crop and land mapping through drones deserves a separate discussion, which, despite being in the middle of the ranking for awareness, is one of the least known at the practical level, with only 3% of the respondents indicating that they had seen a practical example of this type of solution. A similar argument can be made for robots for field activities, of which not a single respondent claimed to have any practical knowledge, and remote management and monitoring for indoor crops, as the two least well-known solutions of the solution set.

The level of awareness of the solutions identified in the current study can be correlated with the descriptive variables of the analysis used as control variables to check for the presence of trends and patterns. To calculate the level of knowledge, scores were assigned from 0 to 3 in ascending order, here based on the answers given to the question about the level of awareness. To determine the level of awareness for each respondent, the sum of the level for each solution was divided by the maximum obtainable.

Figure 4 shows an increased pattern of awareness level related to hectare size of the farm, with the cluster of largest companies having a higher average (45%), median (45%), inferior quartile (33%) and major quartile (55%) than any other cluster. Furthermore, an increasing trend in the awareness of Agri 4.0 solutions is evident with respect to the size of the land worked.

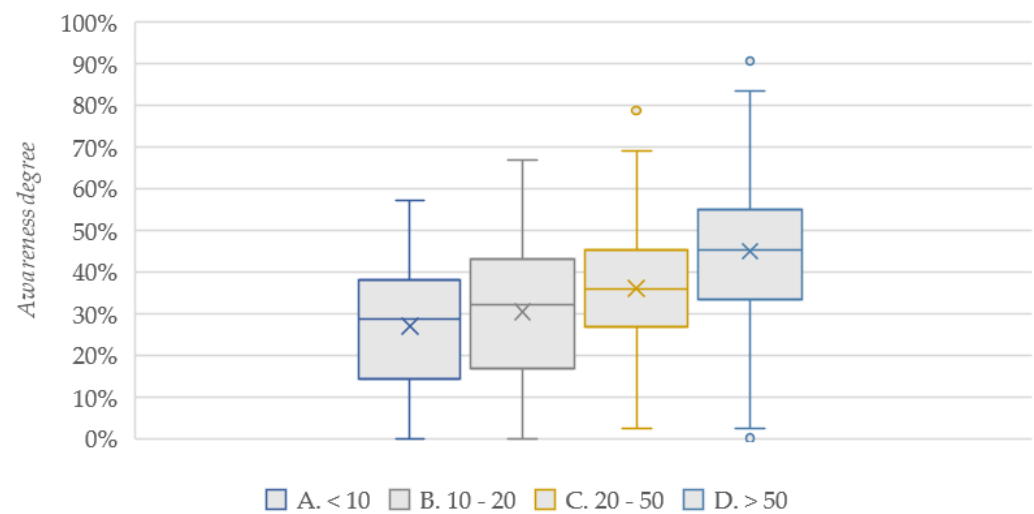


Figure 4. Boxplot graph of awareness level depending on the size of the company (land size).

This trend is further verified and reinforced by the analysis of the relationship between awareness level and turnover (Figure 5), in which it is possible to see how the level of awareness increases with an increase in the revenue cluster. The boxplot graph is particularly significant because each element (minimum, maximum, inferior quartile, major quartile, mean, and median) of the larger revenue class is greater than each element of the smaller revenue class. The boxplot shows that, on average, companies with a turnover of more than EUR 500,000 are currently using half (48%) of the solutions proposed in the survey.

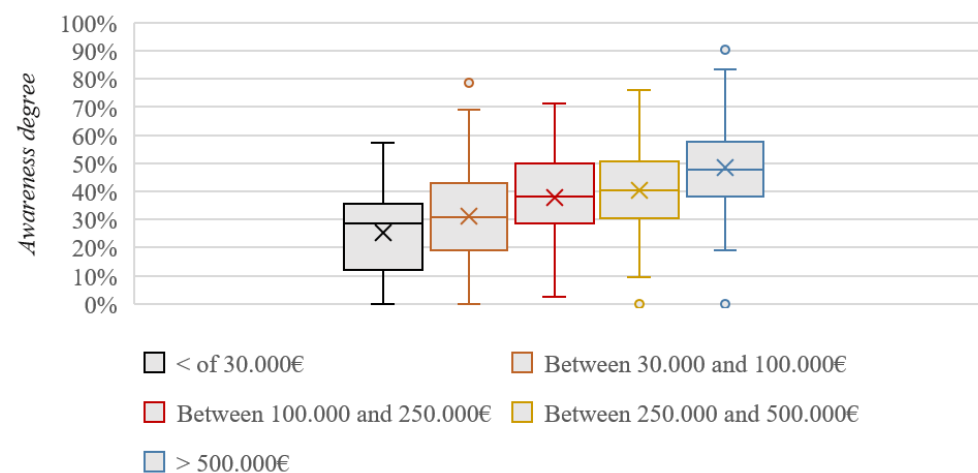


Figure 5. Boxplot graph of awareness level depending on company size (revenues).

4.2. RQ2: What Is the Level of Adoption of Agri 4.0 Solutions?

For each Agri 4.0 solution, the respondents were asked to specify whether they used the solution or not, allowing for the identification of adopters and nonusers.

Comparing the level of awareness versus the level of adoption, as expected, the rate of awareness increases for those using Agri 4.0 solutions compared with those who do not utilize any of the solutions.

Figure 6 links the first two research questions, highlighting higher awareness of different Agri 4.0 solutions among the respondents who used at least one solution compared with those who did not use any.

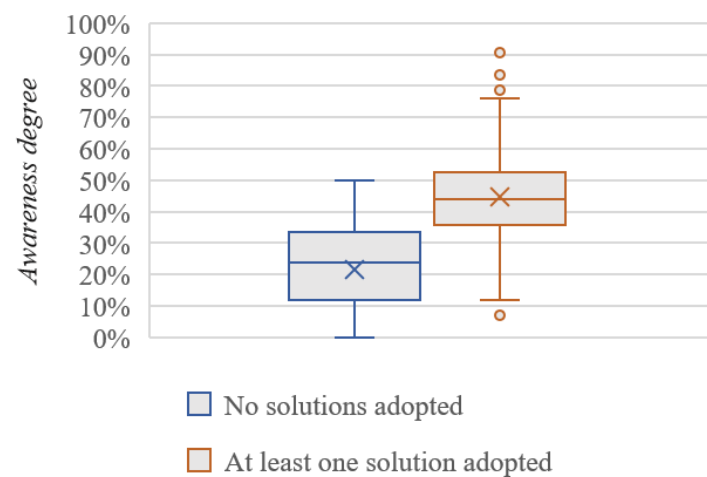


Figure 6. Boxplot graph of awareness level and utilization of 4.0 solutions.

The level of adoption can also be analyzed by comparing it against some control variables relative to the surveyed sample. First, it was examined whether there was a link between the size of companies and rate of utilization of technological solutions.

To assess whether the data and analyses had statistical significance or not, a chi-square test was performed, here measuring the p -value. Typically, its value is a very small number, close to zero. Here, the p -value is the assigned level of significance (i.e., a measure of evidence against the null hypothesis) and, to be statistically significant, this value must be less than 0.05. A significant association was found between revenue size cluster and utilization level of Agri 4.0 solutions (Table 9), in which the Pearson's χ^2 test p -value was very low (3.48×10^{-19}), ensuring the significance of the analysis.

Table 9. Pearson's χ^2 test for adoption level and revenue clusters.

	Agri 4.0 Solution Adoption Level	At Least One Solution Adopted	No Solutions Adopted
Revenue Cluster	A. <EUR 30,000	47	100
	B. between EUR 30,000 and 100,000	98	96
	C. between EUR 100,000 and 250,000	97	36
	D. between EUR 250,000 and 500,000	63	21
	E. >EUR 500,000	91	21

Pearson's χ^2 test: p -value = 3.48×10^{-19} (significant).

The growing trend in the level of adoption depends on the size (in terms of turnover) of the companies. This trend is further confirmed by the boxplot presented in Figure 7. To calculate the levels of adoption in the boxplot graphs, the sum of the usage responses for each respondent for the various solutions was analyzed and then divided by the total number of proposed solutions.

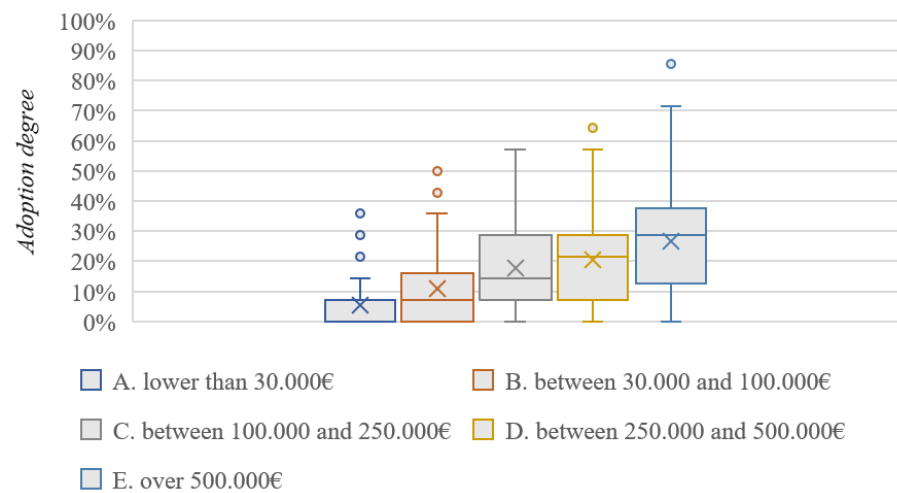


Figure 7. Boxplot graph of the adoption rate depending on company size (revenue).

The association is clear in Figure 7, in which, from the lowest to the highest revenue class, all significant adoption-level metrics increase. The sample presents an average of 5% from the smallest class of revenue to an average of 27%, also taking into consideration the fact that the sample shows a maximum percentage of adoption level that goes from 14% to 71% for the most significant turnover class.

The analysis represented in Figure 7 indicates that companies with higher turnover not only have more knowledge of the available solutions, but also a higher degree of use, perhaps because of the greater capacity to spend resources on these solutions.

The trend shown above is also confirmed when using the size of the cultivated area as a proxy for farm size. This can be proved by the strong association between these two variables (utilization rate–size in hectares) with a Pearson's χ^2 test p -value equal to 4.618×10^{-15} (significant).

Table 10 shows the increase of utilizers as the farm's size increases. At the same time, the number of farms not using 4.0 solutions drops, resulting in a strong relationship between these two variables. Moreover, from a visual perspective (Figure 8), the boxplot graph helps in seeing the main message of this analysis: the utilization values increase as the number of hectares increases, but it is interesting to note the strong increase from 50 hectares onwards.

Table 10. Pearson's χ^2 test for adoption level and land size cluster.

	Agri 4.0 Solution Adoption Level	At Least One Solution Adopted	No Solutions Adopted
<i>Hectares Cluster</i>	A. <10	57	53
	B. 10–20	26	56
	C. 20–50	46	66
	D. >50	94	54

Pearson's χ^2 test: p -value = 4.618×10^{-15} (significant).

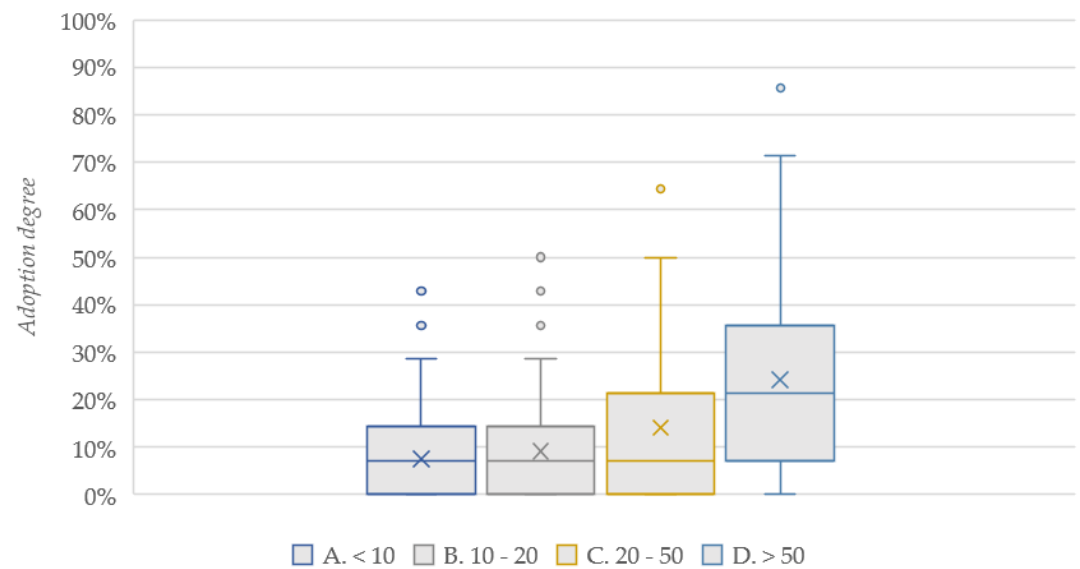


Figure 8. Boxplot graph of the utilization rate depending on company size (land size).

Subsequently, the focus of the analysis shifted to another important control variable in the questionnaire: the respondent's educational qualification (whether agricultural or not).

In Table 11, it is possible to see the strong relationships between the degree of utilization and type of education received by the business owner. The Pearson's chi-square test p -value results in a very small value, ensuring the statistical significance of the analysis.

Table 11. Pearson's χ^2 test for adoption level and type of education.

	Agri 4.0 Solutions Adoption Level	At Least One Solution Adopted	No Solutions Adopted
<i>Agricultural education</i>	A. No	205	194
	B. Yes	191	80

Pearson's χ^2 test: p -value = 7.98×10^{-7} (significant).

The graphical relationship of the effect that the control variable has on the degree of adoption is depicted in Figure 9. The subgroup of respondents with an educational background in agriculture presents a greater degree of adoption of Agri 4.0 solutions than the subgroup without this type of background. This can be seen in all aspects of the boxplot, from the minimum to the maximum, as well as for the interquartile range (0–21% vs. 7–29%), the mean (13% vs. 18%), and the median (7% vs. 14%).

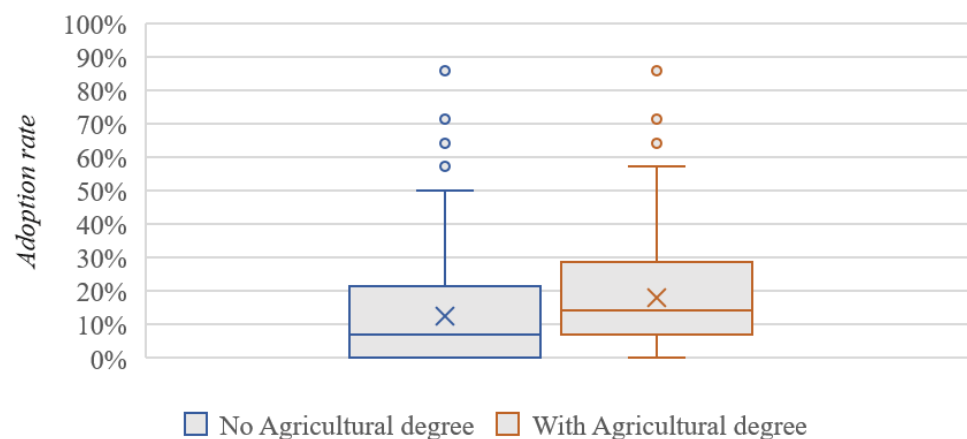


Figure 9. Boxplot graph of adoption level and type of education.

4.3. RQ3: What Are the Main Benefits Perceived in Adopting Agri 4.0 Solutions?

Figure 10 shows a boxplot that compares the benefit (divided into 14 different classes of benefit) obtained from the implementation of 4.0 solutions by users with the expected benefit by those who are not currently using any of the 4.0 solutions proposed in the questionnaire. This analysis highlights how the expectations of nonusers exceed the reality of users in terms of the level of benefit.

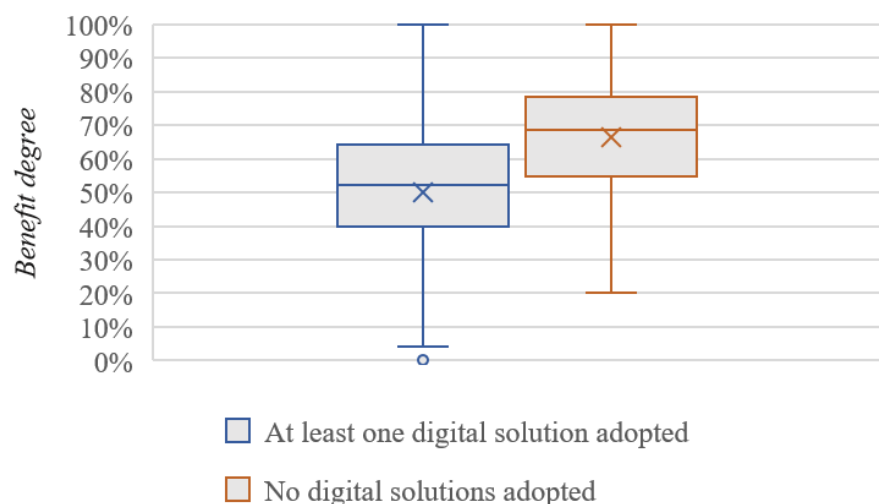


Figure 10. Boxplot graph of the level of benefit between users and nonusers.

This result deserves a more specific analysis; in Figure 10, the average of the benefit obtained and that expected from the two types of different actors, here unpacked in the 14 different obtainable benefits, is visualized. Figure 10 also represents the average benefit perceived by large users, which means those users who are currently operating many solutions (above eight different solutions).

Figure 11 represents what was previously summarized in Figure 10, providing more detail regarding each benefit presented to the respondents. It is interesting to note that, for all benefits (except for the benefit of reducing water consumption), the respondents who are users of 4.0 solutions present an average level of benefit lower than the average benefit that nonusers expect. In particular, it is possible to see how this gap is wider for “increase in sales price,” which reports a rather low value (1.7 average value) for users while showing a potentially higher benefit for nonusers. In general, the benefits that have brought the most benefit to the sample under analysis are “lower consumption of technical inputs,” “lower water consumption,” and “soil quality improvement.” However, it is also interesting to notice an upward trend. As previously stated, the average of the users is clearly lower than the expected benefit of the nonusers, but it is also true that the average of the large users (in this case, those respondents declaring that they use eight or more different solutions) increases considerably to the level of the expectations. A takeaway from this trend is that to reach (at least at the level of the average) the level of benefit expectation, it is necessary to use several solutions in parallel to exploit the joint work to achieve the desired benefits.

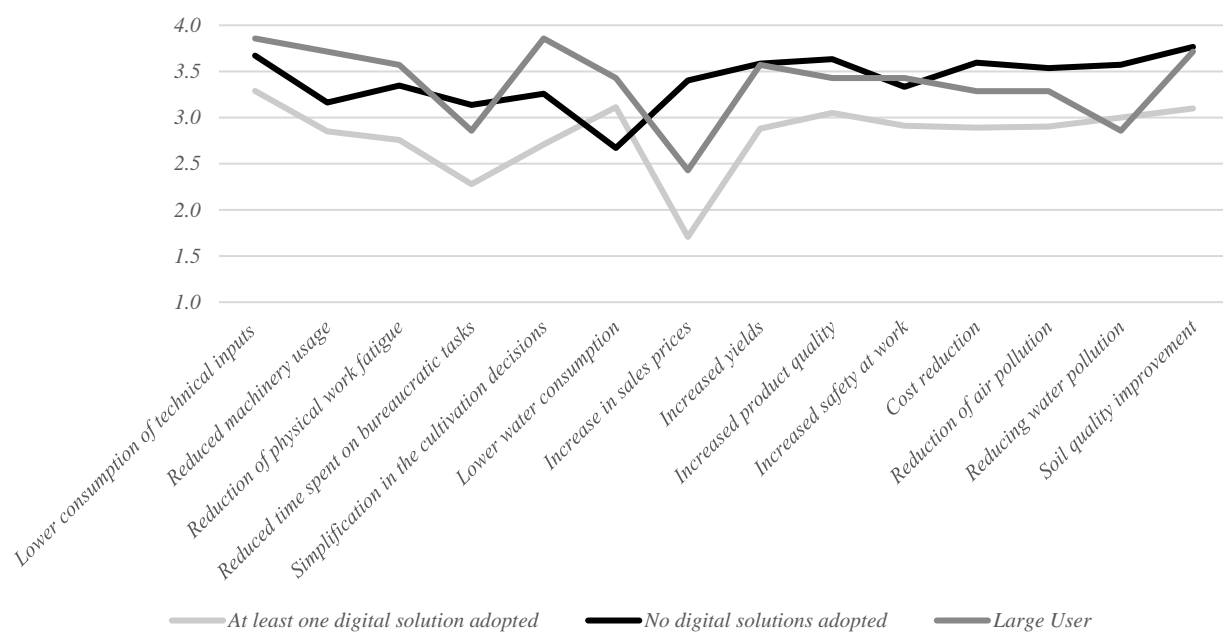


Figure 11. Benefits of Agri 4.0 solutions.

To gain a better understanding of the differences between users and nonusers, a ranking of benefit levels for users and expectations for nonusers was drawn up in descending order to identify the relative position of each benefit in these two lists. The results are shown in Table 12. The columns of “position” represent the relative position for users’ benefits, and, in brackets, the position difference for nonusers’ expected benefits is given.

Table 12. Relative position of benefits.

Benefit	Position: Users	Position: Nonusers
Lower consumption of technical inputs	1	2 (−1)
Lower water consumption	2	14 (−12)
Soil quality improvement	3	1 (+2)
Increased product quality	4	3 (+1)
Reducing water pollution	5	6 (−1)
Increased safety at work	6	10 (−4)
Reduction of air pollution (CO ₂ , N ₂ O, ...)	7	7 (−)
Cost reduction	8	4 (+4)
Increased yields	9	5 (+4)

Table 12. Cont.

Benefit	Position: Users	Position: Nonusers
Lower consumption of technical inputs	1	2 (−1)
Lower water consumption	2	14 (−12)
Cost reduction	8	4 (+4)
Increased yields	9	5 (+4)
Reduced machinery usage	10	12 (−2)
Reduction of physical work fatigue	11	9 (+2)
Simplification in the cultivation decisions to be made	12	11 (+1)
Reduced time spent on bureaucratic tasks	13	13 (−)
Increase in sales prices	14	8 (+6)

The message that emerges from Table 12 is indicative of whether the various benefits perceived by users are in line (at least from the point of view of relative position) with expectations or not. Maintaining this approach but aggregating the benefits by cluster, we find interesting results.

As depicted in Figure 12, it is possible to notice that the “people” and “planet” clusters have an average position in line between the two samples. The “profit” cluster is a different matter. In this case, the analysis should be divided into subclusters of efficiency and effectiveness. In the first one, the perceived benefit is higher than the expected one, demonstrating the usefulness of 4.0 solutions in this area, while the relative position of the effectiveness subcluster is lower than expected (on average 2.2 positions lower in the ranking).

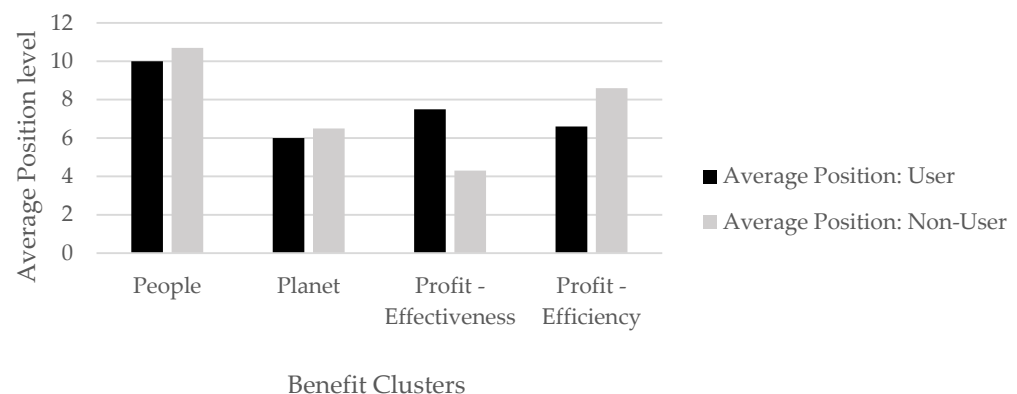


Figure 12. Aggregate positioning of benefits.

4.4. RQ4: What Are the Main Challenges Perceived in Adopting Agri 4.0 Solutions?

The analysis aimed to describe the barriers to implementing 4.0 systems in agriculture and expected difficulty in overcoming these barriers. In this paragraph, the aim is to replicate the structure of analysis presented in the previous research question, replicating the same type of analysis to identify analogies between the two research questions.

As a first analysis, Figure 13 represents the level of challenge declared by respondents, dividing the sample between users and nonusers, with users defining their perceived level and nonusers defining their expectations of the proposed challenge. The analysis of the boxplot depicted in Figure 13 contrasts with the analysis seen for benefits. In this case, on average, users experience a lower level of obstacles than nonusers. However, the analysis is at an aggregate level, and one cannot see the obstacles one by one. For this reason, the analysis of the level per obstacle has also been replicated (Figure 14).

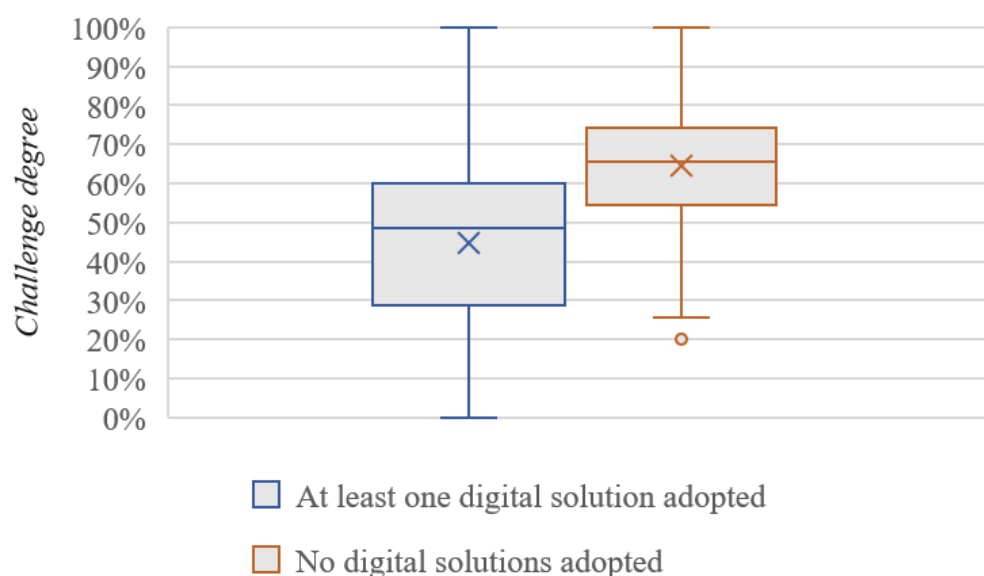


Figure 13. Boxplot graph of level of challenge between users and nonusers.

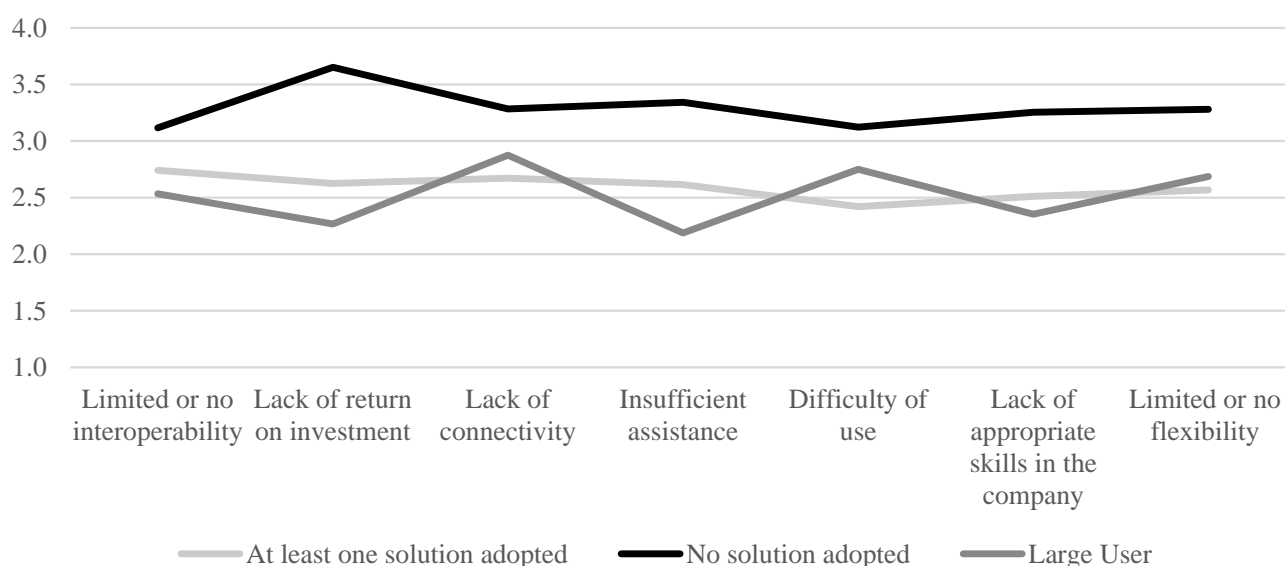


Figure 14. Challenges with Agri 4.0 solutions.

In this case, unlike the analysis carried out for the benefits, there is not the same trend, and the analysis depicted in Figure 14 contrasts with the findings of the previous research question. In this case, it is significant that each of the barriers has a lower challenge level found by users compared with the expectations of nonusers. In addition, the trend for those who use many different solutions in parallel does not lead to a particular increase or decrease in the challenge level for each obstacle proposed, thus identifying a constant trend in the challenge level as the number of solutions used increases but with an increase in the variability of the level per item, as can be seen in Figure 14.

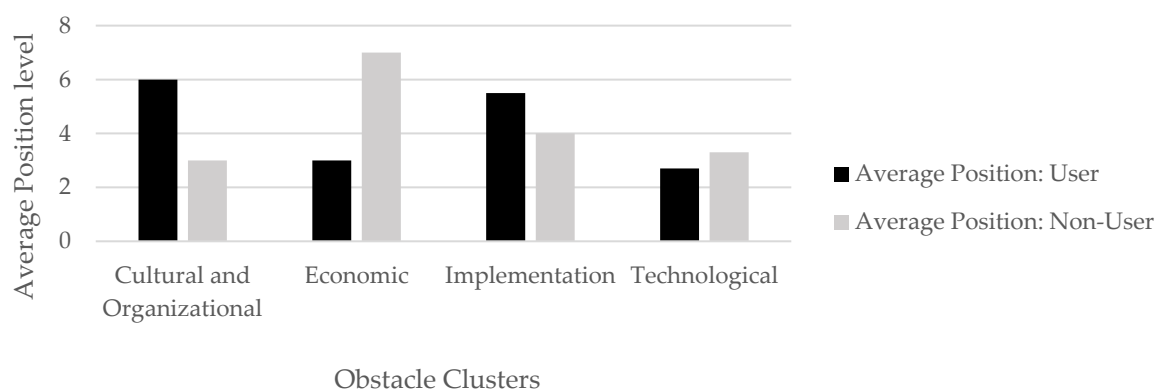
To better understand the challenge level and relationship for each item in the list between users and nonusers, a ranking of the items from the highest level of perceived challenge to the lowest level was again drawn up (Table 13).

Table 13. Relative position of challenges.

Challenge	Position: Users	Position: Nonusers
Limited or no interoperability	1	1 (-)
Lack of connectivity	2	5 (-3)
Lack of return on investment	3	7 (-4)
Insufficient assistance	4	6 (-2)
Limited or no flexibility	5	4 (+1)
Lack of appropriate skills in the company	6	3 (+3)
Difficulty of use	7	2 (+5)

In contrast to the same table presented for benefits, in this case, a higher position corresponds to a more serious problem for respondents. The first important consideration that is possible to see from Table 13 is that limited or no interoperability is at the top of both the problems encountered by users and expectations of respondents who do not use any Agriculture 4.0 solution, demonstrating the centrality of the issue for Agri 4.0 and, more generally, in the 4.0 paradigm. Furthermore, in this case, it is interesting to compare the clusters, as carried out in the benefits, and compare the relative position in the case of user response and expectations of nonusers.

As presented in Figure 15, in this case, economic obstacles hold a higher position, so the perceived problem is greater than the expectations of nonusers; here, even four positions differ between the two types of respondents. As far as the technology category is concerned, the position is relatively stable between the two samples. It is also interesting to note that technological challenges rank first among the problems encountered by users. Less serious than expected are cultural and organizational challenges and implementation problems, both of which have a lower relative position than expected for these clusters.

**Figure 15.** Aggregate positioning of obstacles.

5. Discussion and Conclusions

The current study aimed to map the state-of-the-art in Agri 4.0 within Italian farms through a descriptive survey, here adopting the perspectives of the awareness and adoption level, understanding which benefits users value the most and the differences between nonuser clusters, as well as identifying the critical factors and challenges that impact a company's adoption level regarding Agri 4.0 solutions. A large sample of 670 agricultural companies in Italy was analyzed. In particular, the digital solutions presented to respondents refer to five different clusters: DSS software, monitoring systems, systems for precision activities, mapping systems, and autonomous systems. In addition, this study considered the benefits by clustering the specific items by referring to the TBL, that is,

economic, social, and environmental benefits, while analyzing several kinds of challenges: technological, economic, implementation, and cultural and organizational.

At a general level, our study shows that Italian farms display a heterogeneously distributed level of knowledge of the proposed solutions, but few farms know more than one solution in depth. Moreover, the current study shows that some control variables influence the level of awareness more than others; as turnover and cultivable area increase, an increase in the average level of awareness of Agri 4.0 solutions can be seen. The first is the level of awareness of each digital solution, which is still not pervasive over all the different solutions identified. Extensive knowledge of the solutions is still far from common. Above all, it is possible to see that the percentage of those who claim to know examples of practical implementation is low for each solution. The other important point is the degree of adoption. Here, the key message is that the average level of adoption increases as the turnover and size of the arable land increase. The level of maturity, therefore, is still low on average, and the market is not very dynamic if smaller companies are more out of the change process. In fact, smaller companies have less capacity to invest, and in line with the result of the barriers to adoption (which puts the economic problem at the top), this leads to a greater shift in adoption toward larger companies. At the same time, a similar increasing trend can be noticed in the degree of adoption. Although the average penetration rate is not particularly high, companies that have embarked on the journey to Agri 4.0 transformation have generally perceived lower barriers than companies that have yet to begin this journey. Finally, the present article has also investigated the benefits and potential obstacles to implementing Agri 4.0 solutions. The analysis shows that the main benefits perceived by the user are the reduction of technical inputs and water, which, in turn, benefit the entrepreneur economically but can also be said to have a positive impact on the environment. It is also interesting to note that the main problem encountered is the limited, even lack of, interoperability between 4.0 systems in the field. This obstacle is the point at which the actors and technology providers of the Agri 4.0 value chain must focus on to extract the maximum value from the digitalization of agricultural systems.

5.1. Research and Managerial Implications

For the current study, there are several implications, both for scholars and for practitioners.

The first aim of the proposed study was to provide evidence in a developed economy market of the state of adoption of Agri 4.0, here trying to define through concrete numbers the state of adoption of the paradigm in Italy, which can be representative also of other European economies. As defined above, there is no study analyzing the state of penetration of Agri 4.0 in Italy or Europe. Hence, the current study paves the way for scholars to pursue empirical research regarding the paradigm and state of the art. Some of the key insights of the proposed study are that Agri 4.0 is gaining more momentum, mainly because of the continuing need to be more sustainable, efficient, and using increasingly circular means while using digital leverage. However, within the main applicable solutions, it appears there are different levels of awareness that make up the digital solutions because some solutions are probably not yet mature enough to fit the needs of farmers.

The same applies even more so to the level of adoption because, on paper, the expected benefits are far greater than those perceived. This seems to me an important implication, and there is probably a mismatch between practical application and theory. A further implication is that the more solutions are used simultaneously, the more there is an alignment between expected and actual benefits.

The results of the exploratory survey presented in the current article provide several insights that can be useful for professionals working in the agricultural sector, technological suppliers of Agri 4.0 solutions, and public administration decision makers. First, it is clear that the approach to the digitalization of agricultural processes is currently possible for all companies, regardless of size, here in terms of revenue and arable land, even though an increasing trend is noticed in Figures 7 and 8.

The identification of the most known solutions within the sample leads to two possible implications for practitioners: (1) from the point of view of public institutions, it helps us to understand which solutions or clusters of solutions should be invested in from a communication and knowledge point of view as a way to inform potential users of the potential of these solutions; (2) it helps the companies providing the different solutions to identify the most well-known ones and, ultimately, which solutions can be used the most (at least in the short term).

In addition, the benefit analysis has shown that the average benefit among users is lower than the expectations of nonusers, but that, for those who use a large number of solutions in parallel, the average benefit per solution is similar to the level of expectations. At the same time, challenge expectations are higher than the challenges experienced by users. Furthermore, the results highlight that, for both nonuser and user expectations, the technological obstacle (particularly from the point of view of interoperability between different systems and lack of connectivity in the fields) is the worst and, therefore, the most important to pay attention to, particularly from the point of view of policy-makers, who must focus on these aspects to entice and channel investment from farms that have not yet invested in Agri 4.0. In fact, one of the main difficulties that can undermine the success of a digitalization strategy in agriculture is the risk of not being able to connect the new technologies with the infrastructure already in place on the farm or even with other solutions in parallel. To overcome this constraint, it is important to develop an integration strategy plan that allows for effectively linking not only the solutions to each other, but also the people who must be properly trained and whose skills must be properly aligned. In this way, it is possible to properly implement Agri 4.0.

5.2. Limitations and Future Research Directions

As with any other research, the current study also comes with limitations. First, the sample investigated in the present study is not perfectly aligned with the current Italian agricultural context in terms of revenues and land size. Indeed, the sample differs from the Italian landscape, which is smaller in terms of the size of arable land and turnover [47]. Thus, there is still extensive room for improvement. Moreover, the current study focused only on Italian agricultural companies, which may limit the generalization of the results. Despite this, however, it is necessary to specify that the Italian agricultural sector is one of the best performers in the Italian economy, with one of the highest added value to the gross domestic product (GDP) in Europe.

A possible limitation lies in comparing the benefits and barriers from two “parallel” clusters, potentially creating bias. To overcome this problem, it would be interesting to perform a longitudinal study as a follow-up. Here, the current survey could be repeated in a few years, comparing the cluster that is not currently adopting any solution and evaluating their evolution over time; this can be done mainly to compare the evolution from the point of view of adoption and analyze what the new users see as the benefits and barriers compared with initial expectations.

Another interesting future direction of work could be to compare the level of awareness and adoption with other countries, both with a similar sector structure (such as Spain or France) and others that are among the early adopters of Agri 4.0 and precision farming (such as the Netherlands), to carry out specific benchmark analyses. Further areas of research can be derived from adopting the same research also in companies from another sector, such as breeders of livestock for meat production and meat, eventually comparing the differences between the internal branches of the agricultural sector.

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