Mathilde AUBRY*, Zouhour BEN HAMADI*, Roland CONDOR*, Nazik FADIL*and Christine FOURNES*

Exploring digitalisation in the agri-food sector and its paradoxes: Evidence from a comparative study with small French companies

This paper discusses the results of a study on the digitalisation of the agri-food sector in a French region characterised by small- and medium-sized farms. Our results, which rely on a survey comparing digital practices in the agri-food sector with other sectors, reveal a paradox. While digitalisation is mostly perceived as a panacea capable of increasing agricultural productivity while respecting the planet, it is not widespread in the agri-food sector and even less than in other sectors of the same size. At the same time, the perceived impact of digitalisation is also lower than in other sectors. To increase the digitalisation of this sector, two elements emerge from our results: both the implementation of a global digital transformation strategy and membership of a professional association are required. Here, we refer to a broad definition of digitalisation, which includes organisational and social aspects, and does not only address technological dimensions. Our study challenges the technocentric and productive vision of digitalisation. It suggests that farmers' institutional environments and policies need to take a more holistic view of digitalisation to provide increased sense and generate engagement.

Keywords: agri-food sector, digitalisation, empirical study, organisational impact, small business, farms.

JEL classification: Q16

* EM Normandie Business School, Métis Lab, 20 Quai Frissard, 76600 Le Havre, France. Corresponding author: rcondor@em-normandie.fr

Received: 25 May 2022; Revised: 6 July 2022; Accepted: 11 July 2022.

Introduction

Digitalisation in the agri-food sector takes place in a specific context that faces "major challenges to feed a growing world population in a sustainable way, whilst dealing with major crises such as climate change and resource depletion" (Klerkx and Rose, 2020, p 1). As such, digitalisation appears as a solution capable of maintaining high volumes of production and to limit the negative impact of intensive agriculture (Llewellyn, 2018). It could be a solution for many farmers who are forced to be productive and sustainable.

However, this perspective remains institutional, held by firms providing digitalised solutions, carried out by political actors, and by actors from the agricultural sphere. Little is known about the real impacts of digitalisation (including the negative impacts) and the real practices of farmers. Questioning the future of digitalisation in agri-food sector, Lajoie *et al.* (2020), for example, frame digitalisation through a neo-Malthusian and techno-progressive lens as the solution to future food insecurity. The digital agriculture future is also described as "one much like the present, 'tweaked' rather than substantively reformed" (Lajoie *et al.,* 2020). Risjwick *et al.* (2019) evoke different views on the pace of change and the level of disruptiveness regarding agriculture digitalisation. This is in line with the holistic definition of digitalisation offered by Gong and Ribière (2021, p 10): "a fundamental change process enabled by digital technologies that aims to bring radical improvement and innovation to an entity […] to create value for its stakeholders by strategically leveraging its key resources and capabilities." All these scholars have opened a debate about what agriculture digitalisation is today and what it should be.

Indeed, whatever the point of view and the vision of digital agriculture, many works have emerged in this field (Lajoie *et al.,* 2021), including smart farming (Eastwood *et al.,* 2019; Klerkx *et al.,* 2019; Newton *et al.,* 2020), Agriculture 4.0, or precision agriculture (Trivelli *et al.,* 2019; Santos Valle and Kienzle, 2020). They deal with the benefits, risks, and impacts of digitalisation, but there are few empirical academic articles on the realities of digitalisation in the agricultural sector. Furthermore, such empirical studies focus mainly on regions of the world where farms are intensive, such as Australia (Fleming *et al.,* 2021; Newton *et al.,* 2020) or New Zealand (Risjwick *et al.,* 2019). These studies offer an interesting view of digital agriculture, but it is not representative of digitalisation all over the world. In addition, this paper answers in part to a key question asked by Ehlers *et al.* (2021, p 11) "whether farms, interest groups and government are willing and able to cope with the ramifications of a more encompassing digitalisation of agricultural policy. This would depend on the capabilities and the willingness of government, farms and the other actors involved to use digital technologies". The focus here is mainly on farms' digitalisation; in this way, it completes the work of Ehlers *et al.* (2021).

The aim of this paper is to explore the reality of digitalisation in a traditional agricultural territory – the Normandy – a French region characterised by farms of an average size (around 165 acres) and well known for their production of milk, beef, cider, or flax. We also compare the situation of the agri-food sector there to other sectors. In doing so, we complement existing studies, which often focus on large farms, and which do not provide a correct assessment of the digitization across the entire agri-food sector and neglect any comparison with the global economy. Through the regional lens of digital practices in Normandy, the article proposes an inventory of the digitalisation of the agricultural sector by addressing the following question: What is the reality of digitalisation and its perceived impacts in the agri-food sector compared with other sectors?

We relied on a survey about digital practices in Norman entities. We obtained 2,046 completed questionnaires, including 222 in the agri-food sector. The questions focused on the use of digital tools and perceived impacts, and more general questions about the characteristics of managers and their digital strategies were posed. To analyse the resulting database, we adopted an exploratory approach based on descriptive statistics and data visualisation. We focused our attention on companies with less than 10 employees, which represent the majority of the agricultural sector in Normandy.

Our results show that farmers are weakly digitalised and use digital tools at a level below other sectors of the same size. We also show that farmers are not interested in using digital tools because of a lack of vision about the interests of the digitalisation agenda in general. This point suggests that the digital discourse of institutional actors must not be too technical and must rather provide sense, generate engagement, and present a holistic view of digitalisation.

Our contribution is threefold. First, while the literature mainly focuses on digitalisation in terms of production, our work adopts a more holistic view by including the organisational aspects of digitalisation and considering a variety of digital management tools. Second, our research adds to previous works by providing an empirical demonstration of digital practices in the agri-food sector that have not been sufficiently explored (Schnebelin *et al.,* 2021). Thirdly, our study suggests various public policy options to spread digitalisation more widely within agriculture, based on this holistic vision.

After a synthetic presentation of the academic literature on digitalisation in the agricultural sector, we detail the emerging results of our database. These are then discussed, giving rise to managerial recommendations.

Literature review

Digitalisation can be defined either through a technocentric view or in a much more holistic way (see section 1 below). The issues and the positive or negative impacts of the digitalisation of the agricultural sector have also been studied from economic and societal perspectives. The organisational impacts need to be further investigated (see section 2 below).

Digital agriculture: What are we talking about?

Digital agriculture is often conceived from a technical perspective. As Ehlers *et al.* (2021) mention, "digitalisation is expected to transform the food and farming industry radically as, for example, it assists production with precision agriculture and trade through online platforms and traceability systems*."* Shepherd *et al.* (2018) show that digitalisation in agriculture is a long process that began in the late 1980s with GPS on tractors and yield mapping. Little by little, connected tools have been developed, which is now called precision agriculture (PA). Agriculture 4.0, a part of digitalisation, is composed of "different already operational or developing technologies such as robotics, nanotechnology, synthetic protein, cellular agriculture, gene editing technology, artificial intelligence, blockchain, and machine learning, which have pervasive effects on future agriculture and food systems and major transformation potential." It can dramatically "affect the way food is produced, processed, traded and consumed" (Klerlx and Rose, 2020). In sum, digital agriculture is "often defined in a farm-centric way, referring to the on-farm use of digital tools such as drones, sensors and GPS, i.e., automation and efficiency improvements" (Rijswick *et al.,* 2019).

However, in a general context that includes all the economic sectors, digitalisation is "much more than mere process redesign" (Liu *et al.,* 2011). It is a context for strategy change (Warner and Wäger, 2018) that "involves companies, business models, processes, relationships, products, etc." (Schallmo *et al.,* 2017). In other words, the digital transformation is not just a renewal of tools, but a renewal of the organisation, as new digital tools impact the way farmers work.

According to Rijswick *et al*. (2019), "digitalisation is often used to describe the socio technical processes surrounding the use of digital technologies that impact on social and institutional context that require and increasingly rely on digital technologies." Reis *et al.* (2018) categorise the definition of digital transformation into the following three distinct elements:

- Technological (use of new digital technologies such as social media, mobile, analytics or embedded devices)
- Organisational (a change of organisational process or the creation of a new business model)
- Social (a phenomenon that is influencing all aspects of human life, e.g. enhancing customer experience)

Therefore, digitalisation in agriculture refers to a large spectrum of activities, including not only the use of new technologies but also a reflection and an implementation of organisational changes on the farm. Digitalisation also refers to the generation of data, the creation of business opportunities from those data, and how the data will be used at all stages of the agri-food value chain (Bucci *et al.,* 2018), such as farm production, the processing industry, packaging, sales, and marketing, logistics and distribution, and consumers (Ramundo *et al.,* 2016). The common definition of digitalisation in agriculture lies somewhere in between and consists of being more connected, of using modern technologies such as drones and sensors to collect more data, and of sharing these data for better decision making. In fact, digitalisation impacts not only the organisation of the farm but also the relations between the farmer and his/her partners.

The challenges of agricultural digitalisation

In the literature, the challenges of digitalisation in the agricultural sector are mainly approached from an economic and societal perspective. From an economic point of view, digitalisation allows for gains in productivity and efficiency in the use of resources (Fleming *et al.,* 2021; Lajoie *et al.,* 2020; Risjwick *et al.,* 2019). Production quantity and quality are improved, and costs are optimised (Trivelli *et al.,* 2019). For example, the use of drones (or PA in general) allows for better crop and breeding monitoring and the early detection of pest problems and water shortages (Ayamga *et al.,* 2021). Similarly, agrobots offer labour and input savings and improved yields (Santos Valle and Kienzle, 2020). In general, this gain in productivity and yield due to digital technology allows agricultural enterprises to be more profitable and competitive due to improved adaptability and responsiveness (Trivelli *et al.,* 2019). Likewise, data-driven agriculture increases forecasting capacity, minimises risks associated with production, and creates more value (Lajoie *et al.,* 2020; Santos Valle and Kienzle, 2020). Digitalisation is perceived as a solution to food shortages: it allows farmers to address the problem of inefficiency through optimisation thanks to precision agricultural digital tools. They now have the ability to monitor, make visible (i.e. map), and predict environmental and agricultural systems. Rijswicks *et al.* (2019) mention the analytical possibilities and new sorts of decision support tools for farmers' advisors as well as new services. Digitalisation also allows a better treatment of risk and uncertainty: "For the World Bank, the risk and uncertainty, particularly within the context of a changing climate, means that conventional knowledge about agriculture is no longer adequate". Thus, "data driven agriculture is seen as helping mitigate the risks to farm productivity caused by a lack of predictability" (Lajoie *et al.,* 2020, p 8).

From a societal point of view, in the context of population growth and sustainability, digitalisation appears as a solution to increase production volumes while limiting the negative impacts of intensive agriculture (Llewellyn, 2018). Digital agriculture is thus part of the perspective of ecological intensification (Pretty, 2011) or "sustainable production intensification" (Santos Valle and Kienzle, 2020). This means improving livelihoods with quality nutrition, minimal inputs, and a low impact on soils and natural resources (Santos Valle and Kienzle, 2020). According to Shepherd *et al.* (2018), digitalisation also meets the needs of consumers who demand information regarding, for example, the quality of the products they eat, their origin, the use of pesticides, and the conditions of slaughter and treatment of animals. Beyond this "food sovereignty" and the requirements of this information age, digitalisation allows us to improve the working conditions of the farmer and to offer him/her decent work opportunities with an increase in technological skills. Agricultural activity is becoming more attractive, and the phenomenon of rural exodus is being mitigated (Santos Valle and Kienzle, 2020). Finally, for Bucci *et al.* (2018), another reason for introducing digitalisation in agriculture is to expand herds and improve productivity with livestock while preserving animal welfare.

This positive perception of connected agriculture as a solution to the food crisis is far from unanimously shared. According to Klerkx and Rose (2020) and Lajoie *et al.* (2020), the work associated with food security is techno-progressive, dominated by a Malthusian rationale that sees the rapidly growing population as the central problem and technology as the solution. However, limited access to food is rarely due to a lack of production; rather, it is often due to its unequal distribution. Agriculture 4.0 should not be seen as a panacea (Lajoie *et al.,* 2020). "The solution is not necessarily to produce more food but to distribute food more equitably" (Sen, 1982). The massification of agricultural production raises some questions about its social and ethical impacts. For example, the decrease in human involvement in favour of machines and artificial intelligence (Rijswick *et al.,* 2019) has changed the nature of rural employment and replaced small family farms with fewer, larger, and more commercial farms. Power within the value chain is being strengthened to the benefit of multinationals, including new entrants, such as Google (Birner *et al.,* 2021). Finally, digital technologies require an infrastructure, a level of skills, or, failing that, training and financial investments (Trivelli *et al.,* 2019) that go beyond the means of small- or medium-sized operations. Indeed, a sufficient market size is needed to invest in and make these investments profitable. In short, the unequal access to technologies can reinforce the social divide and inequalities (Birner *et al.,* 2021) at several levels, including rural/urban, small/large farms, female/male agriculture, and industrialised countries/developing countries.

Furthermore, in line with the thinking of Klerkx and Rose (2020) and Lajoie *et al.* (2020), we note a technocentric vision that focuses attention mainly on production tools and obscures administrative tools and support functions. Similarly, the impacts studied remain focused strictly on societal and economic dimensions. To our knowledge, no research has closely studied the organisational impacts that could also contribute to economic and social performance.

Data and methods

Sample and data collection

This research is based on data from a survey initiated by the Regional Council of Normandy and conducted as part of an observatory of digital transformations. This observatory is made up of various actors: chambers of commerce, agriculture and trades, a prefecture, a bank of territories, and academics (including one of the authors of this paper). The questionnaire was developed during several working meetings between May 2019 and February 2021. It was drawn from the field and reflects the concerns of the main stakeholders, including political actors in the region. It was administered to 2,046 companies (in agri-food, services, industry, construction, and trade) located in Normandy in February 2021. The quota sampling method was used. Thus, the sample retains the same characteristics as the population in terms of sectors of activity, distribution in the various departments of Normandy, and size of companies.

The objective of the questionnaire is to evaluate the level of digitalisation of companies from different sectors. It includes 39 questions on the presence of digital tools in the company, the impact of digital technology on the company, and digital strategies. This questionnaire is intended for several sectors of activity and does not refer to tools specific to a sector. It focuses on the presence and the perceived impact of various digital management tools (in communication, production, project management, finance, customer relationship management, etc.). This list emerged from the steering committees and is comprised of researchers, members of the Regional Council, and representatives of each sector (including the agri-food sector) during the construction of the questionnaire. Most of the questions are closed (i.e. respondents have to choose one answer from several choices), while others are semi-open, leaving the possibility for respondents to add an answer that is not among those proposed.

Appendix A provides a summary of the variables (from the questionnaire) used in this research.

In this study, we focus only on 1,159 entities with fewer than 10 employees. This choice is motivated by the desire to compare agri-food companies to companies of the same size in terms of number of employees from other sectors. Indeed, of the 222 agri-food entities in the sample, 213 have fewer than 10 employees.

Figure 1 and Figure 2 give details of the composition of the sample. Proportions represented are close to the sectoral classification of the National Institute of Statistics and Economic Studies (INSEE).

Agri-food is an important sector in the French economic fabric[1] and particularly in certain regions, including Normandy. According to the INSEE, in 2020, Normandy represented 4.3% of the Gross Domestic Product (GDP) of the French metropolitan area. This region is of great interest for our study because it comprises diverse agricultural activities: cow's milk cheese, butter, cream, cider products, textile flax, and leeks. It also ranks first in the number of horses. Moreover, its proximity to the sea allows the development of activities related to fishing and oyster farming.

The distribution of agricultural entities in our sample is presented in Figure 3.

Breeding activity alone is the most common, accounting for 42% of the sample, followed by crop production (20%). Associated crop and breeding activities represent 17% of our sample. 14% of the entities are support activities (e.g. agricultural contractors) for a third party in either breeding or crop production, and 8% have various activities such as fishing, forestry, and logging. All these activities constitute the core of the agri-food sector.

Methods

Our research is inductive and is based on exploratory data analysis; it is an approach based on "discovery, exploration and empirical detection of phenomena in the data" (Jebb *et al.,* 2017, p 265). Since the literature on the agricultural sector remains mostly conceptual, adopting an exploratory analysis responds to the need to discover phenomena previously unknown or very little addressed. According to Jebb *et al.* (2017), data mining promotes the detection of phenomena within organisations.

Although this methodology is not widely used in management science, it meets the objectives of our study. It is a matter of exploring a database without first defining the problem. "Researchers may conduct analyses that contain exploratory elements but then package them within a final confirmatory product. This mixing of exploratory behaviours within confirmatory settings allows the data to simultaneously generate and test the analytic plan, leading to hypothesising after the results are known and immunising scientific hypotheses from falsification" (Jebb *et al.,* 2017, p 266). According to Behrens (1997), exploratory data analysis answers the question "what is going on here?" and allows

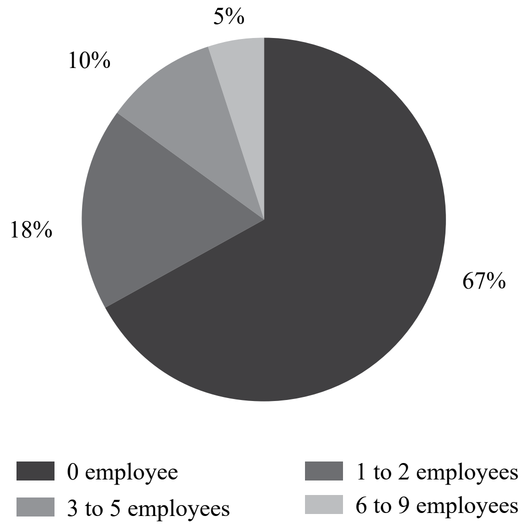

Figure 1: Distribution of the 1,159 companies by number of employees.
Source: Own composition

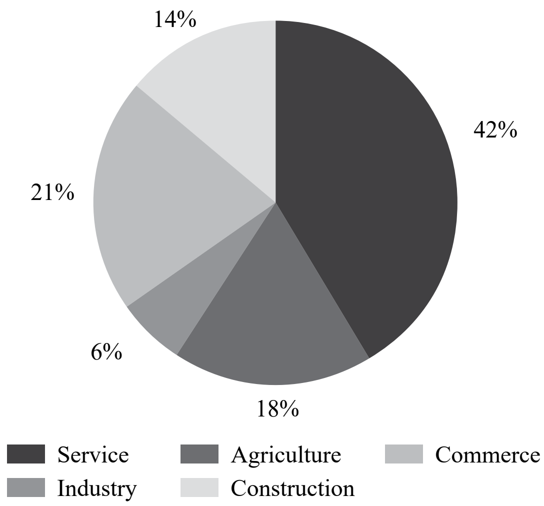

Figure 2: Distribution of the 1,159 companies by sector of activity.
Source: Own composition

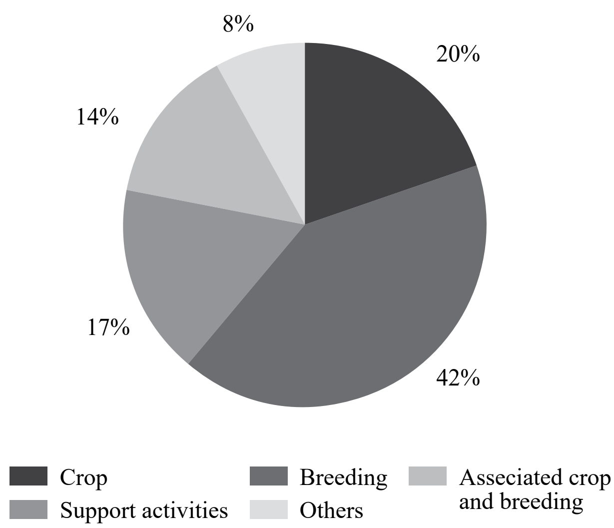

Figure 3: Distribution of 213 farm businesses by activity.
Source: Own composition

[1] It represents 1.7% of GDP, while it represents less than 1% of GDP in the United States and Germany and 1.4% of GDP for all OECD countries according to the latest available data from the World Bank (2020). (https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS)

for the construction of a rich mental model of the data. This is the core of our present research.

To meet the research objectives, quantitative empirical techniques and visualisation are central to exploratory data analysis in that the former maximise the value of the latter (Jebb *et al.,* 2017). We therefore use statistical tests that allow us to compare the agricultural sector and other sectors or to compare agricultural activities with each other. We use chi-squared tests and non-parametric Mann-Whitney and Kruskal-Wallis tests to determine whether independent groups come from the same population, which the null hypothesis confirms.

In a special issue on visualisation in the "Academy of Management Journal," the editors consider that "a picture is worth a thousand words" (Ertug *et al.,* 2018). It is therefore important to represent the data, be it with univariate graphs (such as histograms) or multivariate graphs (such as descriptive plots). Visualisation via these graphs not only allows the reader to understand the content of a study but also allows him/her to remember the same (Ertug *et al.,* 2018). Visualisation, which is common in management studies, helps reflect the quality of the data it represents. Illustrations reveal the characteristics as well as the relationships inherent and implicit in the data. The same authors believe that illustrations provide a comprehensive and quick visual to the reader. Visualisation, in the case of the present study, provides an optimal exploration of the available data.

Overall, to answer our question, we ground ourselves on the definition of digitalisation given by Gong and Ribière (2021, p 10), mentioned in the introduction and work on management digital tools.

Digitalisation in the agri-food sector

In presenting our results, first we focus on the presence of digital management tools in the agri-food sector to understand how agri-food entities are equipped and to compare their levels of equipment with companies in other sectors. Then, we continue this comparative work by focusing on the perceived impacts of digitalisation within the company. Indeed, as we have seen, digitalisation goes beyond the use of tools; it also includes the perception that digitising companies in general are interested in meeting global challenges.

Presence of tools in agri-food entities

Table 1 shows that, overall, agricultural entities are underequipped compared to other very small businesses. However, the differences between the sectors vary, depending on the tools used.

Chi-squared tests were performed to verify whether the differences between the agricultural sector and the other sectors were significant. It appears that belonging to the agricultural sector affects the presence of six different types of digital tools. Agricultural businesses are significantly less equipped than in other sectors regarding communication tools, financial management tools, online document storage and management tools, collaborative work tools, customer relationship management tools, and project management tools. The only tools for which the results are not significant are business management and steering tools, computer-aided design and/or production tools, and big data management tools. It should be noted that the latter are not used very much overall, as they are present in less than 10% of companies. Regarding computer-aided design and/or production tools, we are aware that the terms are not particularly well suited to this sector. This may have been a source of confusion for the respondents and may explain the low level of responses.

Table 2 shows the percentage of agricultural enterprises that employ various tools according to their activity. Businesses involved in crop production and support activities are the most equipped with digital tools, while businesses in breeding most often have the lowest rates. A notable exception is found in the case of design and/or assisted production tools: the rate of presence is higher in breeding farming than in other activities. This is probably due to the digitalisation of the dairy business (e.g. milking robots and the monitoring of animals through connected objects and smartphone applications).

Table 1: Share of enterprises equipped with different tools in the agri-food sector and in non-agri-food sectors.

Tools (percentage of companies for which tools are present)	Agri-food Sector	Non agri-food sectors	Total	Chi-squared
Communication tools	85.0%	93.2%	91.7%	15.607***
Financial management tools	27.2%	41.3%	38.7%	14.568***
Online document storage and management tools	18.8%	31.0%	28.7%	12.623***
Collaborative work tools	13.6%	20.0%	18.8%	4.610**
Management and steering tools for the company	10.3%	9.6%	9.7%	0.099
Customer relationship management tools	6.1%	15.4%	13.7%	12.786***
Computer-aided design and/or production	4.2%	7.5%	6.9%	2.911
Big data management tools	3.3%	5.8%	5.3%	2.194
Project management tools	1.4%	5.0%	4.3%	5.337**

***p < 1%, **p < 5%, *p < 10%
Source: Own calculations

Table 2: Share of enterprises equipped with digital tools in the different activities of the agricultural sector.

Tools (percentage of companies for which tools are present)	Crops	Breeding	Associated crop and breeding	Support activities	Other
Communication tools	92.9%	79.8%	83.3%	88.5%	90.0%
Financial management tools	33.3%	20.2%	25.0%	38.5%	35.0%
Online document storage and management tools	23.8%	13.5%	16.7%	23.1%	30.0%
Collaborative work tools	11.9%	12.4%	19.4%	15.4%	10.0%
Management and steering tools for the company	11.9%	11.2%	11.1%	7.7%	5.0%
Customer relationship management tools	7.1%	6.7%	2.8%	7.7%	5.0%
Big data management tools	4.8%	3.4%	2.8%	0.0%	5.0%
Computer-aided design and/or production	2.4%	6.7%	2.8%	0.0%	5.0%
Project management tools	0.0%	2.2%	0.0%	3.8%	0.0%

Source: Own calculations

Table 3: Perceived impacts of digitalisation.

Impact of digitalisation on: Very positive (2), positive (1), neutral (0), negative (-1), very negative (-2)	Average		Mann–Whitney test
	Agricultural sector	Non-agricultural sector	U
The circulation of information with partners	0.64	0.74	79,948*
Organisation and working methods	0.50	0.69	77,018***
Deadlines	0.50	0.62	78,091*
The visibility of your company	0.41	0.79	59,646***
Quality of service to customers	0.36	0.64	62,389***
Positioning in the sector of activity	0.36	0.63	63,955***
Quality of life at work	0.35	0.48	75,853**
Cost reduction	0.31	0.43	76 424*
The culture of the company	0.27	0.41	69 668***
Internal information monitoring	0.27	0.44	41 325***
The evolution of your strategy (business model)	0.25	0.44	63 606***
Human resources management	0.14	0.26	30 032**

***p < 1%, **p < 5%, *p < 10%.
Source: Own calculations

Perceived impacts of digital tools on agri-food entities

For each of the proposals listed in Table 3, below, respondents were asked whether they perceived a very positive (2), positive (1), negative (-1), very negative (-2), or neutral (0) impact. An average is again taken for each (see Appendix A).

The first column of Table 3, below, shows that respondents from the agricultural sector have a positive perception of the impacts of digitalisation, since the averages obtained are positive. However, they range from 0.14 to 0.64; therefore, they never exceed 1. More precisely, in the perceptions of our respondents, digitalisation has an impact on the flow of information with partners, organisation and work methods, and deadlines. In contrast, its effects are limited in the agricultural world on the company's culture, the monitoring of information internally, the evolution of its strategy (business model), and the management of human resources. Respondents in this field seem to view digital technology more as a means of interacting with the outside world (customers, suppliers, etc.) than as a means of managing internal flows. While this can be explained by the size of the companies for aspects related to human resources, it is surprising that digitalisation does not seem to be part of the strategy or the culture of the companies. Agricultural companies do not yet seem to be deeply concerned with digital technology.

In Table 3, the second column presents the scores of the perceived impacts of digitalisation in the other sectors and reveals that they are always higher than in the agricultural sector. We used the non-parametric Mann–Whitney test on independent samples to assess the differences in perception. The results are all significant; farmers perceive a lesser impact compared to companies in other sectors, regardless of the field. This means that beyond the low use of the tools, they hardly perceive their positive impacts and reveal a limited vision of digitalisation: dematerialisation without real transformation, or the transformation of the business model.

We constructed an "impact score" variable comprising the average of all perceived impacts, presented above, for each company. This impact score variable is presented in Figure 4.

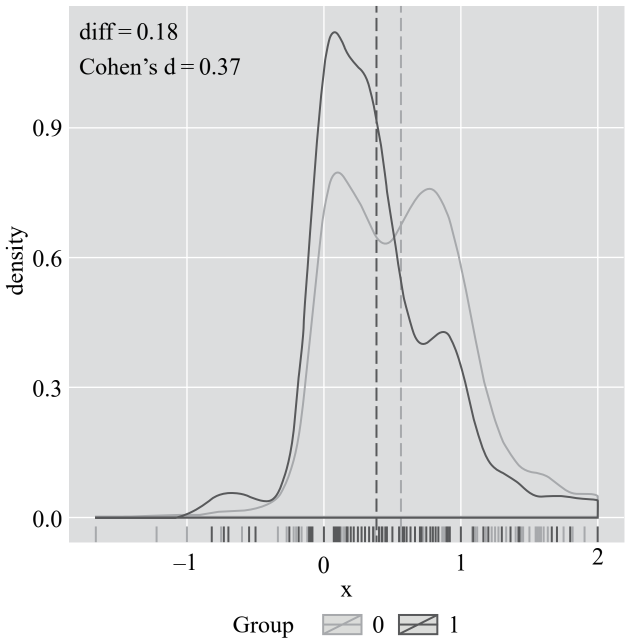

Figure 4: A group-means plot depicting impact score across sectors.
Note: The dotted lines represent group means.
Source: Own composition

This plot shows how the impact score differs by sector (agriculture in green-1 and the other sectors in red-0). From this plot, we observe that the estimated distributions of both agriculture and other sectors also do not appear to be approaching normality. This result is also confirmed by the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. These tests are presented in Appendix B. In both cases, we observe an important asymmetry once again. Most of the firms in our sample, regardless of their sector, have scores between 0 and 1. Concerning the agricultural sector, the scores are mostly concentrated between 0 and 0.5. There are no scores lower than -1. Moreover, the agriculture distribution seems to have a smaller mean and variance. The average impact score is 0.39 for agricultural enterprises and 0.56 for other sectors. Cohen's d is again 0.37. The non-parametric Mann–Whitney test (presented in Appendix C) confirms that the two distributions are not equal *(p < 1%)*. Firms with low scores are relatively more numerous in the agricultural sector than in other sectors. In addition, firms with high scores are relatively less numerous in the agricultural sector than in other sectors.

The impact score averages according to the activities of the agricultural sector are presented, using boxplots, in Figure 5 below. The box plot whiskers range from no perceived impact to very positive.

The non-parametric Kruskal–Wallis test (presented in Appendix D) reveals that there is a significant difference between activities in terms of the perceived impact of digitalisation on agricultural businesses. The impacts of digitalisation are particularly and positively felt in support activities. Alternatively, the perceived impacts of digitalisation are weak in breeding and associated crop and breeding and may even be negative. Concerning the dispersion of the distribution, the size of the boxes shows us that it is particularly important for the support activities and the "other" categories, which include forestry and fishing activities. This can easily be explained by the diversity of the respondents in each of these categories. The dispersion is also particularly important in crop activity.

Relationship between usage score and impact score

Figure 6 shows a scatterplot linking the usage score and the perceived impact score. Here, we differentiate between agricultural businesses (shown in red-1) and businesses in other sectors (shown in blue-0). The usage score allows us to consider the frequency of use of the digital tools and not only their presence. Indeed, a company can have tools and not use them or use them infrequently. The usage score is obtained as follows: for each tool presented above, we assign a score of 0 if the tools are absent or never used, 0.25 when the tools are present but rarely used, 0.5 when they are used sometimes,

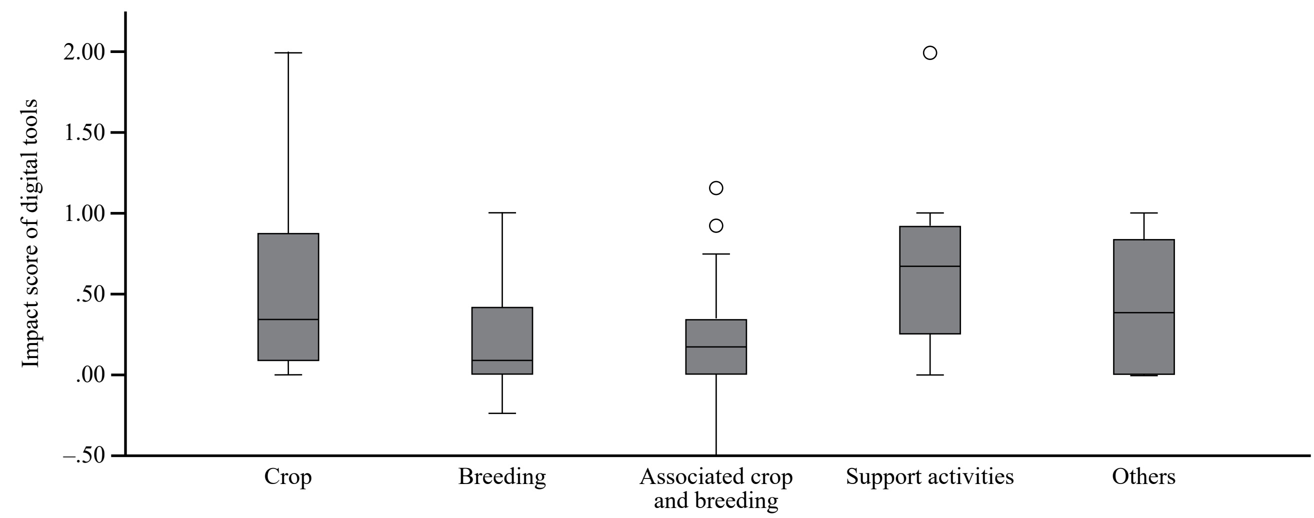

Figure 5: Distribution of perceived impacts by agricultural sector activities.
Source: Own composition

0.75 when they are used often, and 1 when they are used very often. To obtain an overall usage score, we average the nine tools presented in Table 1 and Table 2 above. Thus, for each respondent, we obtain a score ranging from 0 if none of the tools mentioned are used to 1 when all the tools are both present and used very often (see Appendix A). In this study, tool presence and frequency of use were highly correlated.

First, the graphic confirms that the usage score is lower in the agri-food sector than in the other sectors. The tools are not only less present, but also less frequently used. Second, the correlation coefficient for the agricultural sector between the two variables is 0.38 (*p < 1%*). It is 0.44 (*p < 1%*) for the other sectors. Therefore, both coefficients are positive and significant. Logically, the more frequently tools are present and used, the greater their perceived impact on the company. From this point of view, the agricultural sector is no exception. The lack of tools may explain why the perceived impact remains low in agriculture.

An attempt to understand the digital development of the agri-food sector

In this section, we seek to understand which variables may explain why some companies use digital tools more than others. Our results show that two variables are significant. The first is related to the way in which technologies are introduced into the company, and the second concerns the manager and his or her integration into professional networks.

In agricultural businesses, regardless of their activity, digital integration is mostly done on an *ad hoc* basis as opportunities arise (for 94.2% of businesses). In non-agricultural sectors, the integration of digital tools is done in 14% of businesses, according to a global and precise digital transformation plan (compared to 5.8% in the agricultural sector).

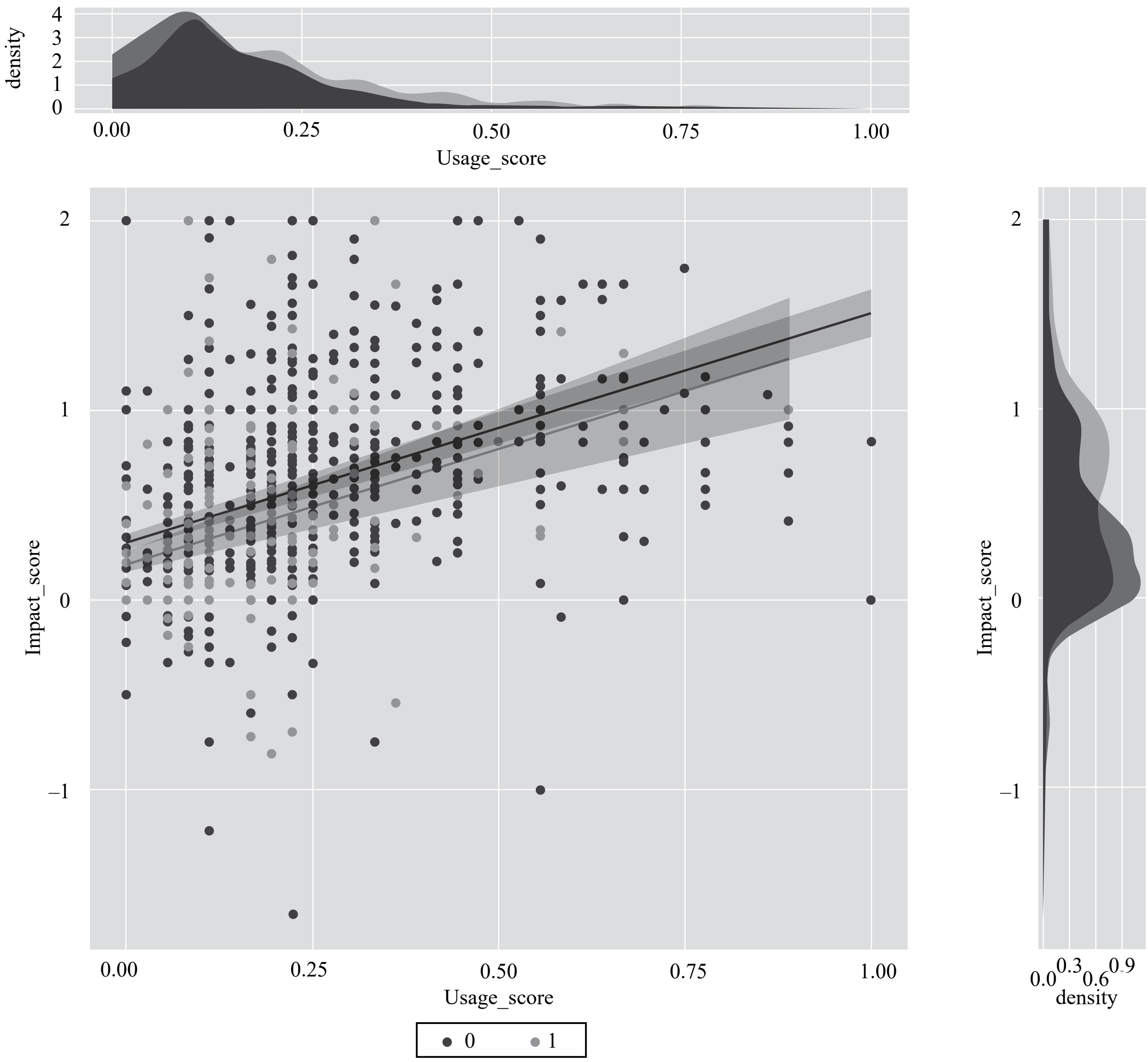

Figure 6: Point cloud (1-agri, 0-other sectors).

Source: Own composition

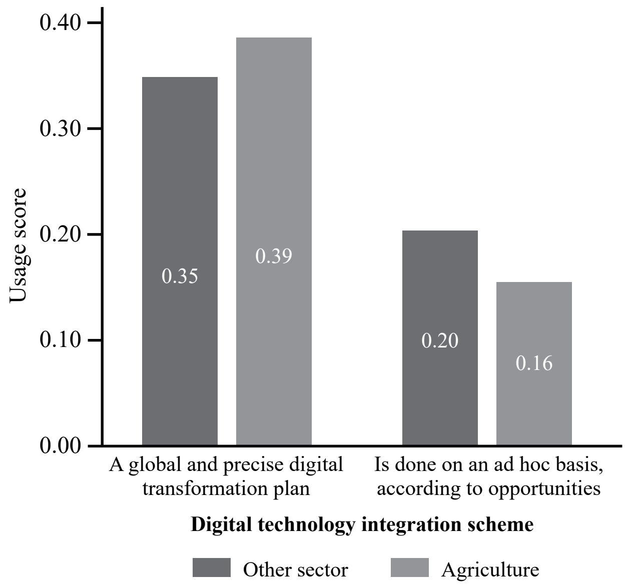

Figure 7: Distribution of the score for the use of digital tools according to the integration strategy of digital tools implemented and the initiator.

Source: Own composition

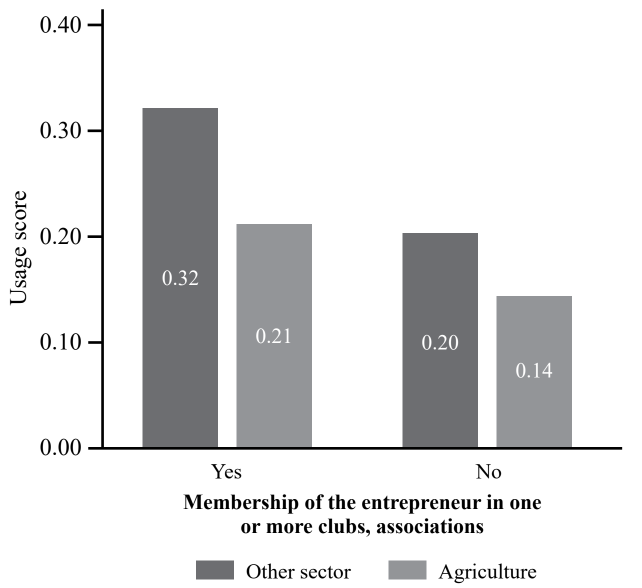

Figure 8: Distribution of the frequency of usage score according to the fat that the entrepreneur is a member of one or more professional clubs or associations in agriculture and in other sectors.

Source: Own composition

Table 4: Kruskal-Wallis tests on the usage score according to the integration strategy of digital tools.

Usage score	Agri		Others	
	H of Kruskal-Wallis	Sig.	H of Kruskal-Wallis	Sig.
Digital technology integration scheme	13.870	0.000	51.621	0.000

***p<1%, **p<5%,*p<10%

Source: Own composition

Table 5: Kruskal–Wallis tests on the usage score according to the profile of the manager.

Usage score	Agri		Others	
	H of Kruskal-Wallis	Sig.	H of Kruskal-Wallis	Sig.
Membership (Yes/No)	5.75**	0.015	28.275***	0.000

***p<1%, **p<5%,*p<10%

Source: Own composition

According to the graph presented in Figure 7, which represents the role of the integration strategy of digital tools on the score of their use, we observe that the score for the use of digital tools is significantly higher when the integration of digital tools is done according to a global and precise digital transformation plan. This result is particularly salient for the agricultural sector. The usage score is statistically higher than in other sectors when a global and precise digital transformation plan exists (0.39 for agricultural companies and 0.35 for others), whereas it is lower when this is not the case (0.16 for agricultural companies and 0.20 for others).

Table 4, below, presenting the results of the non-parametric Kruskal–Wallis tests, reveals that the digital technology integration scheme intervenes in the score of the use of digital tools for all sectors, including agriculture.

Unambiguously, the fact that the manager belongs to a professional club or association encourages the use of digital tools in the company: the usage score when the manager is a member of a club or an association is 0.21 and 0.32, respectively, for agricultural companies and others. It is only 0.14 (agriculture) and 0.20 (others) when the manager is not a member of a club or association, as shown in Figure 8.

The results of the non-parametric Kruskal–Wallis tests presented in Table 5 show that the differences are significant for all sectors.

These results are interesting because they suggest that farmers will have a greater propensity to adopt digital innovations if innovations are part of a global digital strategy transformation and if farmers are encouraged to use them by their network.

Discussion and policy implications

The agri-food sector is poorly digitalised compared to other sectors and a more holistic vision of digitalisation could lead this sector to an increased use of digital tools due to a better perception of its advantages (Section 1). The debate on the impact of digitalisation must address the organisational level (Section 2). Public policies could be reoriented with a focus on farmers and a holistic strategy that includes all stakeholders (Section 3).

The reality of digitalisation in the agri-food sector

Our study reveals several behaviours from farmers toward digitalisation. First, we highlight an underutilisation of digital business tools and, more generally, a weak perception of the positive impact of digitalisation on performance and strategy. Except for supporting organisations and some farms in crop production, rare are the farms that implement digitalisation, perceive its positive impact, and so understand the necessity to change. The comparison with other sectors (retail, industry, construction, etc.) clearly shows that agri-food seems to be less digitalised. This result is not explained by the size of the entities. Even though the questionnaire sent to farmers did not cover digital and connected tools specific to agriculture, such as GPS on tractors, milking tools, or various sensors, one question confirms that, at the production level, digitalisation is not advanced or perceived as essential. Indeed, our results show that farmers make little use of computer-aided production tools and even less use of big data management tools. The only digital tools broadly used by farmers are communication tools. This can be explained by several dimensions, including the small size of the farms surveyed, the characteristics of the farms, or the discourse of agricultural political institutions, which is more technical-oriented than business-oriented.

Second, we suggest that the farmers' institutional environment should have a more holistic view of digitalisation. Indeed, the dominant vision of agriculture digitalisation is technocentric and production-oriented (Lajoie, 2020). Digitalisation in agriculture is mainly defined as the use of digital tools such as captors and sensors and as the collection of data to better monitor agricultural production. Digitalisation consists of much more than its data-driven, technocentric view; it affects the entire value chain (Bucci *et al.,* 2018; Schallmo *et al.,* 2017; Sibona *et al.,* 2020). Once again, farmers have lagged behind and made little use of digital tools for support functions, while successful digitalisation is based on the interoperability of all digital tools, from production and commercialisation to support functions. Our point of view is that a holistic view that integrates a techno-productive and business perspective should provide more sense and increased engagement from farmers in terms of digitalisation.

Opening digitalisation issues to the organisational level

Even if the literature is not unanimous on the positive effects of digitalisation in the agricultural world, there is consensus on its ability to foster greater sustainable production and thus feed more people while optimising inputs (Fleming *et al.,* 2021; Lajoie *et al.,* 2020; Risjwick *et al.,* 2019). Previous academic papers exposed in the literature review have focused on the impacts of digitalisation on the production itself: growth of production, treatment of uncertainty, and sustainability. They have scarcely dealt with organisational impacts, with a few exceptions, which we present below.

Overall, our exploratory study notes a positive but weak perception of this organisational impact. This confirms some conclusions from the literature regarding the optimization of costs and deadlines and the increase of competitiveness (Trivelli *et al.,* 2019). They are more mitigated, however, when it comes to the improvement of the quality of working life (Santos Valle and Kienzle, 2020) and changes in strategy and business plan (Kolsh *et al.,* 2017). Other ignored by the literature, such as the internal and external flow of information, corporate culture and marginally human resources management, are added. The positive perception of the impact of digitalisation on these aspects of organisational performance remains common, regardless of the branch of agricultural activity (e.g. culture and/or livestock). However, it remains significantly lower compared to the perceptions of managers in other sectors, such as service, industry, and commerce. Thus, the best perceived impacts are in line with external relationships, such as the flow of information about stakeholders, delays, and the visibility of the company. Internal impacts are seen by the respondents as less important. For instance, the impact of digitalisation on the monitoring of internal flows of information, company culture, and strategy is not well perceived in the agri-food sector. Thus, our results give the impression that no link exists between the production and management functions of agricultural companies, while the data potentially made accessible by the production tools could otherwise be considered in decision-making and in improving internal management processes.

Policy implications

Our results suggest a reorientation of public policies. In Europe, the digitalisation of the agriculture sector mainly consists of supporting innovation by favouring transversal workgroups, including elected representatives of farmers, academics, start-ups and large farms or cooperatives. It also contemplates financing innovative projects to transform ideas into digital products or services that could be sold to the farmers. The objective of this public policy is to accelerate the digitalisation of the agricultural sector and build sustainable agriculture without altering the productivity of farms. This public policy is justified by the ecological transition, the need to feed a growing population, and the preservation of food sovereignty. However, farmers are not sufficiently targeted by policies and not sufficiently involved in local innovative projects.

Our research suggests that farmers should be placed at the centre of public policies. As we explained previously, most farmers do not see the interests of digitalisation. For some of them, digitalisation is comparable to modernisation after World War II: large firms in equipment and chemistry were the first beneficiary of the modernisation of the agricultural sector. Some farmers anticipate the same situation in the case of digitalisation: they experience the pressure of some start-ups and large farms trying to impose their solutions on the market. This research and innovation focus does not attract them in transversal working groups, even creating mistrust, particularly concerning the use of data (Gardezi and Stock, 2021; Wiseman *et al.,* 2019). Thus, they see participation in innovative projects more as a constraint than as an opportunity.

Farmers should be attracted by propositions that bring them immediate value added. As such, it would be interesting to balance the support between innovation and implementation, i.e. between innovation ecosystems and the farmers themselves. Farmers should be better supported through investing in digital solutions such as, for example, grants.

These grants could be given to specific farmers who have a global digital transformation strategy or/and those who are engaged in deeper sustainable transitions. Encouraging a holistic digital transformation avoids financing digital tools for production exclusively. The Food and Agriculture

Organisation (FAO, 2021), for example, explains that in some countries, investments in infrastructures, e-commerce or digital food supply chains, farmer training, and social media are as important as production-related digital tools[2]. However, all systems are connected; for example, a farmer may have an interest in investing in both a captor and software to manage his/her production. Encouraging farmers with a sustainable transition strategy is also preferable, as there is a need to accelerate the ecological transition of the agricultural sector. All these propositions allow us to target the attribution of the grants, control the public expenses, and cause a catch-up effect in terms of digitalisation of the agri-food sector compared to other sectors.

A factor that seems to be predominant in the process of digitalisation in agriculture lies in its affiliations to communities. The membership of an entrepreneur in one or more clubs or associations is the most key success factor of digitalisation. However, farmers do not seem to look sufficiently for support from their networks when implementing digital tools. In this sector, dependence on various stakeholders, especially regarding administrative issues, is strong. Thus, it is necessary that decisions, policies, and the promotion of agricultural digitalisation include all partners. This is the *sine qua non* condition for farmers to take full advantage of holistic digitalisation that integrates and links all their activities without any technological break.

This is consistent with Rijswick *et al.*'s (2019) conclusions that digitalisation in the agricultural sector "requires an organised reflection, anticipation of and responsiveness to the consequences of digitalisation in agriculture, for example including trust in technologies, data ownership and security, as well as inclusion of all relevant stakeholders to prevent growing inequality within the agricultural sector, e.g., the digital divide." Furthermore, in agricultural businesses, regardless of their activity, the integration of digital technology is mostly done on an *ad hoc* basis according to opportunities. This situation seems paradoxical because, in the agricultural sector, a holistic and precise digital integration plan is an even stronger lever on the score of tool usage than in other sectors. We thus confirm the need to implement a holistic strategy that considers the specificities of the sector and includes all stakeholders.

Conclusions and future research

The aim of this paper is to explore the reality of digitalisation in a traditional agricultural territory and to address the following questions: What is the extent of digitalisation in the agricultural sector compared with other sectors? What are its perceived impacts?

First, our results reveal a paradox. Indeed, while digitalisation is perceived as a panacea and encouraged by public authorities to increase agricultural productivity while respecting the planet, the reality is that the digitalised agricultural sector is underdeveloped and unequal compared to other sectors. This gap between actual and desired practices might originate from a production-oriented and technocentric vision. A key part of digitalisation is thereby neglected: digital management tools. An essential link is missing for the appropriate digitalisation of the sector: the digitalisation of non-productive functions. It is only under this condition that digital tools will be able to deliver on their promises, allow production, optimise all activities, and save resources.

Second, even if the perceived impacts of digitalisation are positive, their effects remain insignificant. Furthermore, the actors of the agricultural world seem to privilege the impacts on external relations and to neglect those on the internal organisation of firms. We suggest that public policies should develop a holistic view of digitalisation to better engage farmers in this transformation and to include all stakeholders. The technocentric view seems to be insufficient for promoting digitalisation in the agri-food sector, and the organisational issues must be addressed.

The literature on the digitalisation of the agricultural sector is recent and remains mainly theoretical. Our research provides a complementary empirical demonstration that considers organisational issues, going beyond broad economic and societal concerns. Thus, it leaves the techno-progressive framework that is focused on production tools and decried by certain authors, including Lajoie *et al.* (2020), and proceeds to examine management and administration tools. Admittedly, production is the dominant link in the agricultural value chain that would benefit from the positive effects of digitalisation. However, it is also true that all links in the value chain, including support functions, should be involved in digitalisation for improved optimisation of yields (Schallmo *et al.,* 2017) while ensuring sustainability in the management of all resources.

We identify three limitations to our study that may provide avenues for future research. First, our research focused on companies with less than 10 employees, the main characteristic of farms in our empirical study. However, it would be interesting to expand the sample to include larger companies. These are indeed more digitalised (Birner *et al.,* 2021; Rijswick *et al.,* 2021), and it would allow us to assess differences in practices. Second, the questionnaire used for this study focused on general tools without considering sector specificities. This allowed us to compare agriculture to other environments to put the digitalisation of the agricultural world into perspective and to compare practices. After highlighting the state of digitalisation in the sector and its limits, particularly in terms of organisational aspects, it would be interesting to analyse the agricultural sector in greater detail using a specific questionnaire. Thus, a future study should deepen the investigation into the digital practices of farmers, especially including the use of production tools (connected objects, sensors, etc.).

Finally, our study finds that the agricultural sector is less digitalised than other sectors as regards the tools used, which do not seem to be sufficiently anchored in all stages of the value chain. It would be interesting to explore this aspect further through a qualitative study to gain a better understanding of this situation. Another complementary issue can also be explored through a qualitative approach: What does digitalisation change in the farmer's daily life?

[2] See also a webinar organized by the FAO in 2021: https://www.youtube.com/watch?v=it13EvasgvY.

References

Ayamga, M., Akaba, S. and Nyaaba, A.A. (2021): Multifaceted applicability of drones: A review. Technological Forecasting and Social Change, **167,** 120677. https://doi.org/10.1016/j.techfore.2021.120677

Behrens, J.T. (1997): Principles and procedures of exploratory data analysis. Psychological Methods, **2** (2), 131–160. https://doi.org/10.1037/1082-989X.2.2.131

Birner, R., Daum, T. and Pray, C. (2021): Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. Applied Economic Perspectives and Policy, **43** (4), 1260–1285. https://doi.org/10.1002/aepp.13145

Bucci, G., Bentivoglio, D. and Finco, A. (2018): Precision agriculture as a driver for sustainable farming systems: state of art in literature and research. Calitatea, **19** (S1), 114–121.

Eastwood, C., Klerkx, L., Ayre, M. and Rue, B.D. (2019): Managing socio-ethical challenges in the development of smart farming: From a fragmented to a comprehensive approach for responsible research and innovation. Journal of Agricultural and Environmental Ethics, **32** (5), 741– 768. https://doi.org/10.1007/s10806-017-9704-5

Ehlers, M., Huber, R. and Finger, R. (2021): Agricultural policy in the era of digitalisation. Food Policy, **100,** 102019. https://doi.org/10.1016/j.foodpol.2020.102019

Ertug, G., Gruber, M., Nyberg, A. and Steensma, H.K. (2018): From the editors—A brief primer on data visualization opportunities in management research. Academy of Management Journal, **61** (5), 1613. https://doi.org/10.5465/amj.2018.4005

FAO (2021): Digital agriculture report: Rural E-Commerce development Experience from China, Rome, Italy.

Fleming, A., Jakku, E., Fielke, S., Bruce, M.T., Lacey, J., Terhorst, A. and Stitzlein, C. (2021): Foresighting Australian digital agricultural futures: Applying responsible innovation thinking to anticipate research and development impact under different scenarios. Agricultural Systems, **190,** 103120. https://doi.org/10.1016/j.agsy.2021.103120

Gardezi, M. and Stock, R. (2021): Growing algorithmic governmentality: Interrogating the social construction of trust in precision agriculture. Journal of Rural Studies, **84,** 1–11. https://doi.org/10.1016/j.jrurstud.2021.03.004

Gong, C. and Ribière, V. (2021): Developing a unified definition of digital transformation. Technovation, **102,** 102217. https://doi.org/10.1016/j.technovation.2020.102217

Jebb, A.T., Parrigon, S. and Woo, S.E. (2017): Exploratory data analysis as a foundation of inductive research. Human Resource Management Review, **27** (2), 265–276. https://doi.org/10.1016/j.hrmr.2016.08.003

Klerkx, L., Jakku, E. and Labarthe, P. (2019): A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS-Wageningen Journal of Life Sciences, **90–91,** 100315. https://doi.org/10.1016/j.njas.2019.100315

Klerkx, L. and Rose, D. (2020): Dealing with the game-changing technologies of agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? Global Food Security, **24,** 100347. https://doi.org/10.1016/j.gfs.2019.100347

Lajoie-O'Malley, A., Bronson, K., van der Burg, S. and Klerkx, L. (2020): The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. Ecosystem Services, **45,** 101183. https://doi.org/10.1016/j.ecoser.2020.101183

Liu, D.Y., Chen, S.W. and Chou, T.C. (2011): Resource fit in digital transformation: Lessons learned from the CBC Bank global e-banking project. Management Decision, **49** (10), 1728–1742. https://doi.org/10.1108/00251741111183852

Llewellyn, D. (2018): Does Global Agriculture Need Another Green Revolution? Engineering, **4** (4), 449–451. https://doi.org/10.1016/j.eng.2018.07.017

Newton, J.E., Nettle, R. and Pryce, J.E. (2020): Farming smarter with big data: Insights from the case of Australia's national dairy herd milk recording scheme. Agricultural Systems, **181,** 102811. https://doi.org/10.1016/j.agsy.2020.102811

Pretty, J., Toulmin, C. and Williams, S. (2011): Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability, **9** (1), 5–24. https://doi.org/10.3763/ijas.2010.0583

Ramundo, L., Taisch, M., and Terzi, S. (2016): State of the art of technology in the food sector value chain towards the IoT. IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 7-9 September 2016, Bologna, Italy.

Reis, J., Amorim, M., Melão, N. and Matos, P. (2018): Digital transformation: a literature review and guidelines for future research, 411–421. In: Rocha, A., Adeli, H., Reis, L.P. and Costanzo, S. (eds.): Trends and Advances in Information Systems and Technologies. WorldCIST'18 2018. Advances in Intelligent Systems and Computing, vol 745. Springer, Cham. https://doi.org/10.1007/978-3-319-77703-0_41

Rijswick, K., Klerkx, L. and Turner, J.A. (2019): Digitalisation in the New Zealand Agricultural Knowledge and Innovation System: Initial understandings and emerging organisational responses to digital agriculture. NJAS - Wageningen Journal of Life Sciences, **90–91**, 100313. https://doi.org/10.1016/j.njas.2019.100313

Santos Valle, S. and Kienzle, J. (2020): Agriculture 4.0: Agricultural robotics and automated equipment for sustainable crop production. Integrated Crop Management, Vol. 24. FAO, Rome, Italy.

Schallmo, D., Williams, C.A. and Boardman, L. (2018): Digital transformation of business models - best practice, enablers, and roadmap. International Journal of Innovation Management, **21** (8), 1740014. https://doi.org/10.1142/S136391961740014X

Schnebelin, E., Labarthe, P. and Touzard, J.M. (2021): How digitalisation interacts with ecologisation? Perspectives from actors of the French Agricultural Innovation System. Journal of Rural Studies, **86,** 599–610. https://doi.org/10.1016/j.jrurstud.2021.07.023

Sen, A. (1982): Poverty and Famines: An Essay on Entitlement and Deprivation. University Press, Oxford, UK.

Shepherd, M., Turner, J.A., Small, B. and Wheeler, D. (2018): Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. Journal of the Science of Food and Agriculture, **100** (14), 5083–5092. https://doi.org/10.1002/jsfa.9346

Sibona, F., Chiavarini, L., Bortoletto, A., and Mainiero, S. (2020): Innovation in farming: an engaging and rewarding business model to foster digitalization. CERN IdeaSquare Journal of Experimental Innovation, **4** (1), 9–15. https://doi.org/10.23726/cij.2020.1052

Trivelli, L., Apicella, A., Chiarello, F., Rana, R., Fantoni, G. and Tarabella, A. (2019): From precision agriculture to Industry 4.0: Unveiling technological connections in the agrifood sector. British Food Journal, **121** (8), 1730–1743. https://doi.org/10.1108/BFJ-11-2018-0747

Warner, K.S. and Wäger, M. (2019): Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. Long Range Planning, **52** (3), 326–349. https://doi.org/10.1016/j.lrp.2018.12.001

Wiseman, L., Sanderson, J., Zhang, A. and Jakku, E. (2019): Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming. NJAS – Wageningen Journal of Life Sciences, 90–91, 100301. https://doi.org/10.1016/j.njas.2019.04.007

Appendix

Appendix A: Operationalisation of Study Variables

Operationalisation of the variables characterising the tools		
The variables	**Nature**	**Measure**
Presence of communication tools (e.g. email, instant messaging) Presence Collaborative working tools (e.g. intranet, collaborative communication platform) Presence Project management tools *(Trello, Slack, Microsoft Teams...)* Presence Online document storage and management tools (cloud computing -cloud/drive, shared document management) Presence Customer Relationship Management (CRM) tools Presence of management and steering tools (ERP (Enterprise Resource Planning), PGI (Progiciel de Gestion Intégré), SAP,...) Presence Financial management tools *(e.g.: automated estimates and invoicing, online accounting, etc.)* Presence Big data analysis tools (data and big data) Presence Computer-aided design and/or production tools Presence of other tools	V. Dichotomous	The variables take the value of: 0: if the tool is not present 1: if the tool is present
Frequency of use of communication tools Frequency of use of collaborative working tools Frequency of use of Project Management Tools Frequency of use of online document storage and management tools Frequency of use of Customer Relationship Management tools Frequency of use of management and steering tools Frequency of use of Financial Management Tools Frequency of use of Big Data Analysis Tools Frequency of use of Computer Aided Design and/or Production Tools Frequency of use of other tools	V. Multinomial	A Likert scale ranging from 0 to 5: : DK (Don't know) 1: Never 2: Rarely 3: Sometimes 4: Often 5: Very often
Score for the use of digital tools	V. continuous (variable constructed by the authors)	Average frequency of use of all tools with a scale of 0 to 1: 0 : if the tools are not present or never used 0.25: if the tools are present but rarely used, 0.5 : if the tools are used sometimes 0.75 : if the tools are used often 1: if the tools are used very often
Operationalisation of the variables characterising the impacts		
Perceived impacts on : Organisation and working methods Human resources management Cost reduction The evolution of your strategy (business model) Reducing timeframes Quality of service to customers Internal information monitoring The circulation of information with partners (suppliers, administrations, etc.) Quality of life at work Corporate culture The visibility of your company Your positioning in the sector of activity	V. Multinomial	A scale of -2 to 2: -2 : Very negative -1 : Negative 0 : Neutral 1: Positive 2: Very positive
Impact score of digital tools	V. continuous (variable constructed by the authors)	Average perceived impact of digital tools within the company

Operationalisation of the variables related to the digital technology integration strategy		
The digital technology integration scheme	V.Binomial	Variable with a value of: 1: A global and precise digital transformation plan 2: piecemeal, as opportunities arise
Club/Association Membership	V.Binomial	Variable with a value of: 1 : Yes 2: No
The initiator of digital technology integration	V.Multinomial	Variable with a value of: 1: the leaders 2: Employees 3: an external company
Operationalisation of the contextual variables: description of the companies in the sample		
Number of employees	V.Multinomial	Variable with a value of: 1 : 0 employees 2 : Between 1 and 2 employees 3 : Between 3 and 5 employees 4 : Between 5 and 9 employees
Business sector	V.Multinomial	Variable with a value of: 1: Services 2: Industry 3: Construction 4: Agriculture 5: Trade
Agricultural business activity	V.Multinomial	1: Culture 2 : Breeding 3: Associated crop and breeding 4: Supporting companies 5 : Other (forestry, fishing, ...)

Source: Own composition

Appendix B: Normality Tests for the Usage Score and Impact Score Variables for the Agricultural and Non-Agricultural Sectors

Normality tests[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistics	**Ddl**	**Sig.**	**Statistics**	**ddl**	**Sig.**
Impact_score	.088	917	.000	.971	917	.000
Usage score	.175	917	.000	.869	917	.000

[a] sector_agri = Other sectors
[b] Lilliefors meaning correction
Source: Own composition

Normality tests[a]

	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistics	**Ddl**	**Sig.**	**Statistics**	**ddl**	**Sig.**
Impact_score	.144	194	.000	.927	194	.000
Usage score	.211	194	.000	.827	194	.000

[a] sector_agri = Agriculture
[b] Lilliefors meaning correction
Source: Own composition

Appendix C: Non-parametric Mann-Whitney tests for the variable impact score to compare two samples (firms in the agricultural sector and firms in other sectors)

Statistical tests[a]

	Impact_score
Mann-Whitney U	68,759.500
Wilcoxon's W	87,674.500
Z	-4.981
Sig. asymptotic (bilateral)	.000

[a] Grouping variable: sector_agri
Source: Own composition

Appendix D: Kruskal-Wallis Tests on Impact Score by Activity and Details of Distribution by Activity

Statistical tests[a,b]

	Impact_score
H of Kruskal-Wallis	13.491
Ddl	4
Sig. asymptotic	.009

[a] Kruskal Wallis test
[b] Grouping variable: NAF_code
Source: Own composition

	NAF_code	*N*	*Average rank:*
Impact_score	Crop	40	122.51
	Breeding	79	86.82
	Associated crop and breeding	32	83.81
	Support activities	28	106.09
	Others	15	100.20
	Total	194	

Source: Own composition