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ABSTRACT

Two major agricultural transformations are currently being promoted worldwide: digitalisation and ecologisation, that include different practices such as organic farming and sustainable intensification. In literature and in societal debates, these two transformations are sometimes described as antagonistic and sometimes as convergent but are rarely studied together. Using an innovation system approach, this paper discusses how diverse ecologisation pathways grasp digitalisation in the French agricultural sector; and do not discriminate against organic farming. Based on interviews with key representatives of conventional agriculture, organic agriculture and organisations that promote or develop digital agriculture, we explore how these actors perceive and participate in digital development in agriculture. We show that although all the actors are interested and involved in digital development, behind this apparent convergence, organic and conventional actors perceive neither the same benefits nor the same risks and consequently do not implement the same innovation processes. We conclude that digitalisation has different meanings depending on the actors' paradigm, but that digital actors fail to perceive these differences. This difference in perception should be taken into account if digital development is to benefit all kinds of agriculture and not discriminate against organic farming and more widely, against agroecology.

1. Introduction

This paper deals with the relations between two major transformations of agriculture: ecologisation and digitalisation. Ecologisation is defined as "the growing importance of environmental issues within agricultural policies and practices" (Lamine, 2011; Lucas, 2021). Digitalisation refers to the increasing use of digital technology throughout the economy and society in general (Lange et al., 2020). Our aim was to understand how different ecologisation pathways grasp digitalisation. The originality of our approach is addressing the issue through the perception of actors of the French Agricultural Innovation System (AIS). AIS can be defined as the set of diverse actors, networks, institutions and knowledge that enable innovation in the agricultural sector (Klerkx et al., 2012).

Ecologisation is promoted as a way to cope with the adverse effects of farming. These effects include loss of biodiversity, water, soil and air pollution, and climate change as well as food safety and occupational health issues. Schematically, two main ecologisation pathways coexist in agriculture, which their promotors each claim address these challenges (Dalgaard et al., 2003; HLPE/FAO, 2019; Plumecocq et al., 2018). The first corresponds to the sustainable intensification of the industrial model of agriculture. It consists in optimising inputs to increase efficiency and reduce negative externalities on the environment. The second promotes new practices that stimulate ecosystem services. It involves a more transformative and systemic reconfiguration of production systems mainly grouped under the general term 'agroecology' (Duru et al., 2015). Organic agriculture is usually recognized as belonging to the second ecologisation pathway, even if academic debate concerning their links or similarities continues (Abreu et al., 2012; Bellon and Penvern, 2014). Most research addresses the coexistence of ecologisation pathways through their ontological basis (Ollivier et al., 2018), their values (Plumecocq et al., 2018) and their actors' perceptions (Van Hulst et al., 2020). With the notable exception of institutional analyses of specific technological lock-in of certain crops or varieties, the role of agricultural innovation systems in the ecologisation of agriculture is much less widely studied (Magrini et al., 2016; Vanloqueren and

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Baret, 2008).

Alongside the promotion of the ecologisation of agriculture, digitalisation is also accelerating in the agricultural sector, with a bundle of new and diverse technologies (Van Es and Woodard, 2017; Wolfert et al., 2017). Digital technology consists of the codification of information through numbers which facilitates its transfer and storage. In agriculture, digitalisation covers a wide range of technologies including digital platforms or precision agriculture or connected objects or digital social networks. Here we focus on digitalisation at farm level. Through the hard-, soft- and orgware components of technology (Dobrov, 1979), digitalisation can transform not only farming tools, but also practices, knowledge processes, and work organisation. Digitalisation has led to the development of new products and services for farmers, to new knowledge and uses, but also to new actors and networks in agricultural R&D (Fielke et al., 2020). On the other hand digitalisation can be framed by institutions, knowledge and actors from the digital sector as well as from the agricultural sector targeted here (Jakku et al., 2019), where it can lead to a specific digital agricultural innovation system (Fielke et al., 2019).

Although the relations between digitalisation and ecologisation are the subject of academic debate (Clapp and Ruder, 2020; Rotz et al., 2019; Wolf and Buttel, 1996), little work has directly addressed this issue. Some papers highlight the potential of digital technologies to support ecologisation of agriculture, to provide new knowledge, improve management of complexity and diversity, foster exchanges and innovations and reduce the agroecological workload (Bellon Maurel and Huyghe, 2017; Bonny, 2017). However, most social science papers are more critical of the compatibility between ecology and digital technology. Digitalisation could lead to simplification and homogenisation of production systems, loss of autonomy and of knowledge and instead promote a high-capital agriculture (Carolan, 2017; Plumecocq et al., 2018; Wolf and Buttel, 1996).

The development of digital technologies in agriculture is a process that involves a set of innovations with a strong systemic dimension (Klerkx et al., 2019). Digitalisation transforms not only exchanges of information and farmers' decisions, but also potentially the very knowledge and actors of agricultural innovation system (Fielke et al., 2019; Ingram and Maye, 2020). In other words, like other innovations, digitalisation is not neutral. It fosters system transformations and affects actors, knowledge, and power relations (Bronson, 2018). However, the systemic aspect of digitalisation and its directionality remains to be further explored.

The notion of Agricultural Innovation Systems (AIS) has been used at national scales to study the '*interactive development of technology, practices, markets and institutions*' in agriculture (Klerkx et al., 2012, p. 465), leading to a growing literature (Touzard et al., 2014). But AIS are not homogeneous. A "*plurality of socio-technical configurations,* supported *by different key actors pursuing different aims, and shaped by different rules, lock-in effects and path dependence, can potentially coexist in the current socioeconomic and political context*" (Dumont et al., 2020, p. 107). The diversity of agricultural models is embodied in a multiplicity of practices and is supported by a variety of institutions, organisations, and infrastructures. In other words, different paradigms built around ecologisation can coexist within AIS (Beus and Dunlap, 1990; Gaitán-Cremaschi et al., 2019). Paradigms are framed by actors and institutions, who structure power relationships (Sonnino and Marsden, 2006), thereby influencing the dynamics of agricultural systems and shaping their directionality (Pigford et al., 2018). Conversely, AIS can structure the coexistence of different forms of agriculture (Stassart and Jamar, 2009; Vanloqueren and Baret, 2009). The coexistence of paradigms may not only result in co-evolution and convergence, but also in differentiation, and divergence (Hervieu and Purseigle, 2015). As pointed out by Pigford et al. (2018), AIS tend to promote the dominant paradigm which frames technological trajectories and locks in other possible trajectories. Directionality of digitalisation is beginning to be included in the literature (Bronson, 2019; Carbonell, 2016; Klerkx and Rose, 2020). However, few studies include actors representing alternative paradigms, such as organic agriculture. Structural analysis of AIS makes it possible to account for the heterogeneity within the AIS and understand how it affects trajectory and directionality of the AIS.

The research question we address in this paper is the following: How do actors of the AIS in relation with different paradigms of ecologisation perceive and respond to digitalisation, and what are the points of convergence and divergence? We address the question by referring to the French agricultural context.

The paper is organised as follows. First, we present our analytical framework. We link the issues of digitalisation and ecologisation of agriculture through a structural analysis of sectoral system of innovation using Malerba's categories (2004). We propose an operationalisation of this framework that is consistent with the existing literature on the digitalisation of agriculture. We continue with a description of material and methods we used for our qualitative analysis. Our method is based on 38 semi-structured interviews covering the diversity of actors of the French AIS. The results provide an overview of the perception and enactment of digitalisation according to the actors' paradigm. A perception of impacts and opportunities that is shared in some aspects across actors but with different aims and risk perception. We end with a discussion of our findings and their implications.

2. Revisiting the digitalisation process through an institutional analysis of the agricultural innovation system

2.1. Analytical framework: relations between digitalisation and the four dimensions of innovation systems

The sectoral systems of innovation (SSI) concept was developed to analyse sectoral specificities in innovation (Malerba, 2004). In parallel, scholars have developed the concept of Agricultural Innovation Systems (AIS) specifically for the farming sector (see Hall, 2006; Klerkx et al., 2012). In the framework of AIS studies, innovation is considered as a '*complex web of related individuals and organisations – notably private industry and collective action organisations – all of whom contribute something to the application of new or existing information and knowledge'*. It *'includes the farmers as part of a complex network of heterogeneous actors engaged in innovation processes, along with the formal and informal institutions and policies environments that influence these processes*' (Spielman and Birner, 2008, pp. 1, 2).

Actors' perceptions of innovation systems can be analysed from different perspectives (Klerkx et al., 2012), with the focus on processes (Nelson and Nelson, 2002), and interactions (Spielman et al., 2011), functions (Hekkert et al., 2007) or on structures (Knierim et al., 2015). We use Marlerba's analytical framework of the structures of sectoral systems of innovation (Malerba, 2002), which was already applied to digitalisation of agriculture by Busse et al. (2015). This structural analysis appears to be an appropriate way to grasp how the different paradigms connect to digitalisation within AIS. First, the framework is used to characterise change, i.e. the *transformation and evolution* of the variables of a sectoral system (Malerba, 2002, p. 258). Second, the framework is useful "*when the transformation of sectors involves not just traditionally defined sectors […], but the emergence of new clusters that span over several sectors*" (Malerba, 2002, p. 259). Third, Malerba himself acknowledged the importance of describing heterogeneity within the sectoral system of innovation (Malerba, 2002, p. 262).

The different ways of conceiving agriculture can be considered as different paradigms, i.e. different outlooks, along with the definition of relevant problems and of the specific knowledge required to solve them, supplemented by production, marketing and distribution conditions (Djellal, 1995; Dosi, 1982). The nature of the paradigm defines its boundaries, along with a framework for possible technological trajectories (Dosi, 1982) that are supported by specific institutions and organisations for knowledge exchange and innovation. Our aim is to point out how actors involved in different agricultural paradigms, perceive and make sense of digitalisation, how they themselves grasp the digital

Table 1
Analytical framework, inspired by Malerba (2002).

Category	Description	Questions	Literature informing the questions
Actors and Networks	Beliefs, assumptions, purpose Organisations, learning processes Collaboration - Competition Interactions Communication - Exchange	What do actors expect from digitalisation? Which risks do they perceive? How does digitalisation affect interactions within or between organisations? Does digitalisation result in collaboration or in competition between organisations? Do digital actors include/exclude certain AIS organisations?	Dufva and Dufva (2018) Jakku et al. (2019) Eastwood (2017) Rijswijk et al. (2019) Bronson and Knezevic (2016)
Technologies	Development of technologies Constraints and interdependencies of technologies	How do agricultural organisations engage in the development of technologies? Are digital technologies on the market include the two paradigms? Do they account for their specificities? How are the technologies perceived? What curbs 'AgTech' development?	Jakku and Thorburn (2010) Rijswijk (2019) Bronson (2019) Carbonell (2016) Lioutas and Charatsari (2020)
Knowledge	Knowledge and skills within the organisation Learning process	How do organisations develop knowledge and skills for digital innovation? Has digital innovation led to new sources of knowledge?	Rijswijk et al. (2019) Eastwood et al. (2019) Jakku and Thorburn (2010) Ingram and Maye (2020) Eastwood et al. (2012)
Institutions and public policies	Laws Regulation Public policies Values Routines Practices	What roles do formal institutions play in digitalisation? How does digitalisation change formal institutions? How do institutions that are concerned with digitalisation articulate paradigms and digitalisation? How do informal habits, routines, practices, affect digital innovation in the paradigms and inversely?	Rijswijk et al. (2019) Wolf and Buttel (1996) Wolfert et al. (2017) Eastwood et al. (2012) Jakku et al. (2016)

concept, i.e. how they understand, are aware of, expect and transform digitalisation (Dufva and Dufva, 2018).

We analyse how actors engage with digitalisation using Malerba's categories: actors and networks, technologies, knowledge, institutions and public policies. Table 1 below provides an overview of our analytical framework, the categories and the actors we analyse and links them with the questions we aim to answer together with literature on digitalisation. Some of these studies show that the different actors of AIS (researchers, advisors, industry, farmers) have different expectations and perceptions of the risks involved in digitalisation (Fielke et al., 2019; Jakku et al., 2019). Depending on how they understand and enact digitalisation, the process of digitalisation can affect their identity and their organisation (Rijswijk et al., 2019). Moreover, the use of digital technologies can foster new learning processes and create new networks, new kinds of interactions (Eastwood et al, 2012, 2017). Digitalisation may exclude some actors, or reinforce the power of others, including upstream and downstream industries (Bronson and Knezevic, 2016; Ryan, 2019). Digitalisation can also encourage the entry of new actors into a sector, in particular digital firms. Digital technologies are based on information. They influence information and knowledge processes (Higgins et al., 2017). Codification of information and knowledge makes them easy to diffuse and organise. But the codification process can change the nature of information, for instance by suppressing tacit knowledge or transforming it into explicit knowledge. In addition, organisations can benefit from knowledge creation and knowledge diffusion thanks to digital technologies. Interdependencies between humans and technologies influence workers' skills and capacities (Richardson and Bissell, 2019). Organisations can develop specific knowledge and skills to cope with digitalisation (Eastwood et al., 2019; Rijswijk et al., 2019). Digitalisation also affects both formal institutions (legislation, especially on data, public policies, etc.) and informal institutions (new ways to act, to communicate etc.), and reciprocally, institutions affect digitalisation. Institutions play an essential role in technology trajectories in agriculture (Hayami and Ruttan, 1971), and this role is underlined by many authors including Wolf and Buttel (1996), Wolfert et al. (2017), Eastwood et al. (2012), and Jakku et al. (2016).

2.2. Organic and conventional as paradigms

To illustrate the diversity of paradigms within the French AIS, we focus on conventional and organic farming.

"Conventional farming" refers to mainstream agriculture, i.e. "*capital-intensive, large-scale, highly mechanised with monocultures of crops and extensive use of artificial fertilizers, herbicides and pesticides, with intensive animal husbandry*" (Knorr and Watkins, 1984 in Beus and Dunlap, 1990). This type of agriculture emerged in France in the post-World War II period in response to the political aim to achieve food security and has been supported by scientific, political and technical actors (Brechet and Schieb-Bienfait, 2006). In France, the development of conventional farming led to an increase in farm size (from 19 Ha in 1970 to 63 Ha in 2016), a reduction in the total number of farms (from 1 588 000 in 1970 to 436 000 in 2016), an increase in yield (e.g. for wheat from 4T/Ha to 7T/Ha) and of the use of inputs (+60 % in volume).[1] Conventional farming does not only involve the farm level, but the whole value chain including input suppliers, the food industry and retailers (Darnhofer et al., 2010). It has been supported by professional unions, advisory organisations, research and education. Hence, the construction of the AIS is inherent of the development of conventional agriculture (Labarthe, 2009). In France, conventional farming is mainly based on family farms, a component of the wider agro-industrial food system and has been studied as a paradigm by institutional economics (see Touzard and Labarthe, 2018 for a review). It supplies around 80 % of French food (Fournier and Touzard, 2014). Criticized in France for its adverse effects on the environment and health, French conventional farming has changed over the last twenty years, notably through the integration of environmental concerns, supported by public policies (Duru et al., 2015). Some of the farmers linked to this paradigm have in fact opted for different forms of ecologisation, by optimising inputs or adopting more emblematic practices such as integrated pest management or no-till (Barbier and Goulet, 2013).

Organic farming emerged from social and ideological struggles against the development of productivist farming. The acknowledgment of organic farming within AIS, which was also framed by and for conventional agriculture (Brechet and Schieb-Bienfait, 2006), was one dimension of the confrontation between organic and conventional agriculture. The first organic group was created in 1959, followed by the creation of the French Association for Organic Agriculture in 1962. This movement led to the institutionalisation of organic farming with the creation of the Research Group on Organic Agriculture in 1978, official recognition of organic farming in 1980, followed by the creation of the

[1] The data come from the official census of the French Ministry of Agriculture available at: https://agreste.gouv.fr.

Table 2
List of interviewees (n = 38); Nat: National level; Reg: Regional level (Occitanie region).

Group		Organisation	Role
Transversal (n = 5)	Tr-Minis	Ministry of Agriculture (Nat)	Digital manager
	Tr-PubAdm	Public administration (Nat)	Innovation manager
	Tr-PubRes	Public research institute (Nat)	Scientific programming manager
	T-Advis	Private advisory company (Nat)	Manager
	Tr-Journ	Journalist (Nat)	Author of a book on digital farming
Conventional (n = 12)	Conv-ProfUn	Professional Union (Nat)	President
	Conv-AppRes	Private applied research institute (Nat)	Manager
	Conv-coopUn	Cooperative Union (Nat)	Innovation manager
	Conv-coop 1	Cooperative company 1 (Reg)	Director
	Conv-coop2	Cooperative company 2 (Reg)	Innovation manager
	Conv-comp	Private company (Reg)	Innovation manager
	Conv-advis	Advisory Services (Nat)	Innovation manager
	Conv-coop 3	Cooperative company 3 (Reg)	Technical manager
	Conv-farm1	Farm 1 (Reg)	Vice president of local professional union
	Conv-farm2	Farm 2 (Reg)	Vice president of local professional union
	Conv-farm3	Farm 3 (Reg)	Elected member of professional union and technical institute
	Conv-farm4	Farm 4 (Reg)	Member of a cooperative bureau, and president of an advisory company
Organic (n = 10)	Org-advis1	Advisory Service (Nat)	Manager
	Org-advis2	Advisory Service 2 (Nat)	Innovation manager
	Org-ProfUn	Professional Union (Nat)	Deputy director
	Org-advis3	Collective organisation (advisory + applied research) (Nat)	Manager
	Org-ProfOrg	Professional organisation (Nat)	Director
	Org-PubRes	Public research institute (Nat)	Scientist
	Org-farm1	Farm 1 (Reg)	President of a professional union
	Org-farm2	Farm 2 (Reg)	Member of a national professional union bureau
	Org-farm3	Farm 3 (Reg)	Member of a collective organisation bureau
	Org-farm4	Farm 4 (Reg)	Elected member of a chamber of agriculture
Digital (n = 11)	Dig-StUp	Start-Up (Nat)	CEO
	Dig-Res1	Research (Nat)	Project manager
	Dig-Res2	Research 2 (Nat)	Project manager
	Dig-Educ1	Education project (Nat)	Manager
	Dig-Educ 2	Agro-digital observatory (Nat)	Manager
	Dig-firm1	AgTech firm 1 (Nat)	CEO
	Dig-firm2	AgTech firm 2 (Nat)	CEO
	Dig-assoc	Firms' association (Nat)	Director
	Dig-firmTIC	TIC firm (Nat)	Manager
	Dig-farm1	Farm 1 (Reg)	Sales and training agent in an AgTech firm
	Dig-farm2	Farm 2 (Reg)	Former sales and training agent in an AgTech firm

organic farming technical institute (1982) and the organic label (1985) (Piriou, 2002). Thus, the development of organic farming is not only characterised by different practices and values at the level of individual farmers and consumers, but also by specific institutions and organisations which frame the balance of power in the AIS. Today, in France, organic farming is the most 'institutionalised' alternative paradigm. Its growth rate has been more than 15 % for the last 15 years. Since 2018, organic farmers have been supplying more than 6 % of French food and account for more than 8 % of the agricultural area (Agence Bio, 2020).

Conventional and organic farming constitute two different paradigms, framed by specific actors, institutions, knowledge and organisation systems. Farmers who refer to one of the two paradigms co-exist in all the French regions, although organic agriculture has greater weight in the South of France (Gasselin et al., 2021). However, the limit between paradigms is sometimes blurred. At farm level, the ecologisation of conventional farmers can lead to practices that are very similar to those used in organic farming, and organic farmers can use external inputs similarly to conventional farmers. At the other stages of the food systems, economic organisations such as supermarkets may also choose strategies that combine organic and conventional products under general policy of food greening, which is sometimes confusing for consumers (Le Velly and Dufeu, 2016).

3. Material and methods

3.1. Delimitation of innovation systems

The AIS framework underlines the importance of including a diversity of stakeholders who shape innovation in the farming sector (Hall et al., 2005). The AIS includes agricultural research and education organisations, advisory organisations, private sector actors in the value chain, agricultural cooperatives, public organisations, professional organisations and farmers (Klerkx et al., 2012; Spielman and Birner, 2008). We interviewed members of these different categories along with a number of digital actors who characterise the dynamic frontier of this AIS (Fielke et al., 2019) (for a list of interviewees see Table 2). We interviewed different categories of AIS stakeholders representing each of two paradigms (conventional and organic agriculture). The categories include farmers, value-chain actors, advisory and political organisations, research and education systems, and public structures.

Digitalisation brings new actors dedicated to digital farming. Those actors may originate i) from digital firms which extend their activities to the farming sector, ii) from new organisations specialised in "AgTech" or iii) from existing organisations which create new activities (notably research and education) dedicated to digital farming. We interviewed actors who can play a key role in digitalisation directionality in agriculture, by selecting or prioritising one model, thereby strengthening or weakening organic or conventional agriculture.

Another important aspect of an SSI is the technological profile of farm businesses, the demand of users of digital technologies, i.e. the farmers. We consequently conducted on-farm interviews which included the farmers' use of digital technologies, their opinion on, and their role in the AIS. For this purpose, we selected both farmers with a representative role in organic or conventional agriculture, and farmers who play an active role in promoting or expanding/demonstrating digital innovation in agriculture.

3.2. Sampling and interviews

We purposively selected interviews representing this diversity of actors (Etikan, 2016). Most interviews were conducted at national level, but in the case of farms and cooperatives, the interviews were conducted at regional level to ensure the homogeneity of the context. We chose the French administrative region Occitanie, which is characterised by the coexistence of organic and conventional farming. The farmers we interviewed were crop farmers because this sector has been the scene of digital and ecological development for many years. All the interviews were conducted in French, recorded, transcribed, translated into English by the authors and checked by a professional.

The semi-structured interviews were divided into four parts. The first part covered general information about the organisation, its history, its functions. The second part concerned the digital activities of the organisation. The third part addressed the interviewee's knowledge about farmers' use of digital technologies. The fourth part was more forward looking as we wished to collect information concerning the potential and the risks associated with digital technologies, and the links between digital technologies and agroecology. In the interviews, we mainly asked open questions to allow the interviewers to express their opinions freely without attempting to guide their responses too much. We had a list of Malerba's categories and if certain items on the list did not come up, we then asked the appropriate questions. This approach made the interview more flexible while ensuring nothing was forgotten. The interview was more natural, and the interviewees had more opportunity to talk spontaneously. In the interviews with the farmers, we first collected data concerning their farm and the rest of the interview was focused on their use of digital technologies, farming practices, micro-AKIS and their opinion on digitalisation.

3.3. Data analysis

All 38 interviews took place between March 2019 and March 2020. The interviews lasted between 50 min and 2 h and were recorded and transcribed.[2] The transcriptions and documents provided by the interviewees were processed using MaxQDA© software. Data analysis was inspired by the methodology proposed by Ayache and Dumez (2011) and Miles and Huberman (1994). First, we read the transcriptions with no attempt at categorisation (Dumez, 2013). Next, we coded the transcriptions based on Malerba's broad categories as outlined above: actors and interactions, technologies, knowledge, and institutions. In each category, we created inductive sub-topics grouped in the eight sub-categories listed in Table 3. The first author coded all the interviews. Results of coding were discussed with the two co-authors, which led to a second coding process. Consistency was achieved by saturation. We condensed data using summary sheets of interviews and a matrix that cross-referenced themes of analysis and interviewees (Miles and Huberman, 1994). After listing the different results per actor and category in the first level of analysis, we added an inductive level of analysis to highlight the main transformations, gaps, and stakes involved.

4. Results

Our results show how the different categories of actors, i.e., those belonging to digital organisations and those who represent conventional and organic paradigms, perceive and enact digitalisation. Table 3 summarizes the actors' statements concerning the different categories used for the data analysis. The following sections present the results according to the five major stakes that emerged: the diversity of expectations, the key role of knowledge and technologies, the new interactions between actors generated by this cross-sectoral transformation, the specific role of digital actors in the AIS, and the crucial issue of perceived risks.

4.1. A diversity of expectations partly linked to organic vs conventional paradigms

The actors mentioned different expectations concerning digitalisation (cf. The *global vision* column in Table 3). Some impacts of digitalisation were expected by all. This includes optimising practices, accessing information and advice, gaining traceability, managing hazards and risks, or improving technical and economic management of the farms. Farmers also mentioned convenience and time saving. However, divergences can also be noted referring to communication with consumers, knowledge and value creation. Digitalisation is considered by conventional actors more as a way to create new economic opportunities while organic actors consider it more as a way to develop knowledge.

A set of opportunities identified by the interviewees concerned communication with consumers. Conventional actors mainly mentioned traceability as a way to improve communication and the marketing of agricultural products. One interviewee cited a statement heard at a meeting with a mass distribution actor: *"We're selling a product, it's true, but what we're missing is the story of the product."* Using digital technologies, organisations can ensure increasingly precise traceability and hope to gain added value. Organic farmers see digital technologies more as a way to improve sales, to deepen interactions with consumers, or create direct marketing chains.

The development of environmental regulations and private standards (such as implementation of the HVE[3] certification in wine, or CRC[4] in cereals) promote digitalisation tools that are consistent with traceability.

> "The regulatory obligation to register practices, manage organic fertilisation, register for the Common Agricultural Policy etc., are what actually drove farmers to digitalisation." (Conv-advis)

Another set of opportunities concerned the emergence of a new market based on data and digital technology. Some conventional agricultural organisations consider engaging in digitalisation and being able to propose digital services to their farmers as an economic strategy. They invest in digital technologies to ensure they will still be present on the advisory market tomorrow and to find '*new economic models*' in the current legislative context (especially the obligation to separate sales and consultancy). For some of these organisations, the objective is clear: it is to sell services. Moreover, digital technologies are considered to be essential to cope with farming issues: environmental impacts, animal welfare, profitability, working conditions, attractiveness. Digital technology is seen as 'the future of agriculture' and as a precondition for their future survival. And also as a way to improve the image of the agricultural world in the eyes of society because it vehicles an image of a modern sector that embraces environmental issues.

> "So, we've got a market [plant protection products] that's probably going to decline. And so we have to position ourselves with respect to other niches that can be vectors of profit." (Conv-comp)

> "It will help farmers show society [...] that they are doing better and better and that they are willing to profit from all the new technologies to improve their production." (Conv-ProfUn)

In the same line of thought concerning digitalisation, agri-digital actors underline the potential advantages of digital technology: gains

[2] For technical reasons, interviews with two farmers were not been recorded and could thus not be transcribed.

[3] HVE stands for 'High Environmental Value'. It is a public French certification launched in 2011 to label the global management of an environmentally friendly farm ("HVE," 2020).

[4] CRC stands for 'Controlled Reasoned Farming'. It is a French label which testifies to the sustainable cultivation of cereals ("Filière CRC® - Culture Raisonnée Contrôlée," 2020).

Table 3
Summary of actors' key perceptions and enactment of digitalisation.

	Knowledge		Technologies		Actors		Institutions	
	Capabilities	Creation/ Exchange	Development	Constraints	Global vision	Interactions	Formal	Informal
Organic	Developing farmers' skill is essential Lack of projects about digital and organic farming	Digital technologies enable sharing of experience, capitalisation of knowledge, ecological processes and the analysis of practices. Complementary to real exchanges	Internal development of technologies to capitalise on and exchange information/ knowledge	Many of the technologies not suitable for technical, organisational, or economic issues	Possibility to manage complexity and the global technical, economic, social system Risk of dependence, of loss of know-how and power	Few partnerships with digital actors due to differences in global vision of digitalisation; some informal exchanges	Environmental norms are associated with digitalisation There is no public support for digital technologies aimed at collaboration	Some actors' conception of farming may be against digitalisation because they can be based on costs/ investment reduction, autonomy …
Conventional	Important development of digital skills within human resources of organisations to enact digitalisation	Need to develop data management to create value for their organisations – Added value is expected from the use of traceability data	Adoption of new technologies, co-development and development. Economic strategy: sell services, meet the demand for precise traceability	Problem of data ownership – of misuse by farmers – For farmers: need to better account for field realities	Digitalisation: a way to renew the economic model of farming organisations, change the negative image of farming, increase efficiency. Risks concern data ownership	Collaboration with digital organisations to test, to promote or co-develop digital tools. Could lead to market foreclosure	Legislation drives digitalisation -Need to adapt formal institutions to protect farmers' ownership of data and to ensure interoperability	Farmers' routines and culture are seen as a major obstacle to digitalisation
Specialised in Digital	Farmers' lack of skills curb the use of digital technologies. Digital organisations have the necessary skills to process data	Data and digital technologies could help experiment, model and predict, undertake global analysis …	Technologies are needed to help farmers digitalise their farms. Technologies are adapted to all kinds of farming including organic farming	Issues of data access, data quality, compatibility, complexity, economic models	Digitalisation is still in its infancy. Digitalisation is necessary for economic and environmental stakes. Data is an immaterial capital	Need for agricultural organisations to reach farmers. Digitalisation requires data sharing. Issues of governance	Legislation and regulation is at the basis of digitalisation but can curb some digitalisation	Farmers routines are a major obstacle to digitalisation
Transversal	Early investment in digital through regulation – Need for digital training for farmers	Data generated by digital tools could create knowledge but there is need for cooperation, sharing and means	No development of technologies	Potential of digital tools for environmental sustainability? Issues of adaptation to a diversity of farming systems	Digitalisation is seen as a potential for policy implementation – Digitalisation has potential but can have unintended negative effects	Digitalisation generates more interactions between agricultural actors. Need to keep a watch on digital evolution	Legislation is a major development factor but innovation is not in their hands but in the hands of economic actors	Agricultural sector needs to change its habits to enable radical innovation

in productivity, yield, time saving, security, forecasting, better management and communication, simplification, and efficiency. Data are seen as a value, as "*intangible capital" (Dig-firm2)*. For these actors, digitalisation is seen as essential for the future of farming to cope with agricultural stakes including environmental problems, climate change and new societal expectations. They mention a necessary and inevitable transformation that will revolutionise farming. The use of digital tools in farming practices is seen as intrinsically good and sustainable, as an objective per se. This development of digital technology "*is highly supported politically" (Dig-Res2)* and is strongly supported by funders and by research.

Members of organic organisations add expectations concerning learning and helping conceive the system, help in achieving systemic management of farms, creating links, exchanging knowledge, sharing experience and being able to make better observations.

4.2. Knowledge and technologies at the heart of digitalisation for conventional and organic organisations

Beyond these expectations and promises concerning digitalisation, interconnections between knowledge and technologies were underlined as major stakes by all actors. A need for knowledge is emerging with digitalisation, while digitalisation generates opportunities for the creation of new knowledge.

First, there was a consensus concerning the need for new knowledge and competencies to appropriate digitalisation. Conventional interviewees put more emphasis on knowledge at the organisational level, while organic interviewees put more emphasis on knowledge at the farm level (cf. The *capabilities* column in Table 3).

Conventional agricultural organisations emphasised the importance of developing new kinds of knowledge within their structure, such as agricultural cooperatives. Jobs and dedicated teams are being created specifically for digitalisation, and awareness raising and training are provided. Internal positions in agricultural organisations are even sometimes filled by digital specialists.

> "Farmers are more and more in need of experts (…). It forces us to train ourselves differently, or even to train people in certain aspects, etc." (Conv-coop2)

Organic organisations put more emphasis on the need to develop farmers' skills. The interviewees agreed on the need for new knowledge to increase organic farmers' autonomy to be able to appropriate the basic tools in order to manage their farm.

> "And mastering IT is essential for us[…] for people to be independent. We don't think it is complicated but [some say] it's too complicated for farmers and that it's not their job. We say it is possible to use the basic tools, and it creates critical thinking about their exploitation." (Org-advis2)

Developing skills at other levels, such as research and development, was also mentioned by organic actors, for instance by the French Scientific Committee of Organic Farming. However, these organisations have limited means and have other priorities.

Actors agreed on the fact that the development and use of a new technology create data opportunities that could help build new information and knowledge. The second column in Table 3 summarizes the interviewees' statements, showing that organic actors put the emphasis on knowledge creation concerning agronomic practices whereas conventional actors put the emphasis on the creation of information through traceability.

According to organic actors, digital technologies in organic farming would be useful to obtain information on regulations, trade, and machinery, to analyse and understand ecological processes, to help farmers conceive or think about their own system, to analyse their practices, while letting farmers take their own specificities and choices into account. Capitalising and sharing knowledge appears to be a key advantage of digitalisation, and these actors mentioned a '*conversion-support tool*' or a '*conception-support tools*' to help farmers engage in organic farming. They mainly considered that digitalisation could provide new "knowledge input" for designing, assessing, and sharing their farming practices. This will nevertheless still require physical and concrete approaches. The digital exchange of knowledge is seen as a way to complement real exchanges but not to replace them.

Conventional actors put more emphasis on the creation of information through traceability technologies to "better meet value chain standards and build consumer confidence and knowledge on the products". Traceability is increasingly required by buyers (i.e. mass distributors, wholesalers, exporters) but is difficult to set up. Collective organisations hope to create knowledge as a result of data collection. However, they have difficulties in processing their data, due to a lack of resources.

Through digital technologies, digital companies hope to create new knowledge that will be a driving force for the development of their own business: digitalisation could create new forms of experimentation, new tools to perform global analyses of farming practices and environmental criteria, to improve modelling and forecasting.

> "We are convinced that, as time goes by, a lot of know-how will come out of the vineyard. We are at the very beginning of the process because the speed of accumulation is not very high, so it takes time." (Dig-firm1)

4.3. Different strategies regarding partnerships with digital actors

Cross-sectoral dynamic was perceived as a major factor for the development of the AIS. Digitalisation brings new actors and partnerships to the farming sector. Both start-ups and firms from other sectors invest in agriculture, leading to new kinds of interactions between actors (cf. The *interactions* column in Table 3).

One might think this would limit the role of agricultural organisations, but this is not the case. Agricultural organisations, i.e. cooperatives, associations, chambers of agriculture, commercial firms and advisory providers play a central role, especially in data collection but also in data "redistribution" and in the diffusion of technologies. Many digital actors say that they cannot access farmers directly. They need farmers-based intermediaries to collect the large amount and diversity of data needed to run data-based tools. Agricultural organisations are also needed to legitimise digital projects.

> "The objective [for our company] is not to sell directly to farmers but to sell to cooperatives or traders or management centres – which will be distributors of our solutions to farmers, because they have a self-interest in collecting and federating data to carry out their work […]" (Dig-firm2)

However, we noted differences between paradigms. Digitalisation is seen by conventional actors as an exogenous change and by organic actors as a more endogenous one.

Conventional organisations work in partnership with digital actors at different levels: to test, co-develop, or promote digital tools. These interactions may be informal or formal. When agricultural organisations collaborate with a digital firm, they position themselves as distributors, but also as service providers. They also offer support and training to farmers. In other words, they wish to transform the technology into a service they can sell to farmers. Conventional organisations see digital partnership as strategic. Digital technology is said to be increasingly providing inputs combined with advice, with machinery, with knowledge, via data links. According to one interviewee, that could lead to market foreclosure and reinforces their opinion that digitalisation is an important business strategy for them.

Organic actors are less involved in collaborative projects with new digital actors. On one hand, digital actors do not often call upon and work with the actors of organisations specific to organic farming.

> "But by working with everyone in a balanced way, we mostly work especially with those who are most prominent. And you don't work much with small producers, agro-ecology". (Dig-Res1)

On the other hand, when organic organisations are called upon, it does not necessarily work out well because of the differences in the way they work and differences in values. Additionally, organic organisations have other priorities and do not have the financial means to invest more in digitalisation.

> "Each time, the choice, the cultural difference is a little too strong. Even if we have a similar attitude to environmental issues, our methods are quite different." (Org-advis3)

Although organic digitalisation is thus considered in a more endogenous way, organisations do have informal exchanges with digital actors and follow the development of digital technologies.

Developers of digital technologies consider developing partnerships between organisations to be strategic. They claim that digitalisation will require organisations to set up an ecosystem to develop information systems. Sharing data and ensuring compatibility is essential to achieve efficient digitalisation. Beyond the strategic partnerships, some digital actors regret the limited space accorded to farmers in digital projects.

4.4. Digital actors do not perceive heterogeneity within AIS

Digital actors bring a new perspective to the AIS. They underlined governance issues between the different categories of actors but did not perceive differences between organic and conventional farming.

Digital actors aim to support farming through the process of digitalisation. Digitalisation is seen as an objective per se for the agricultural sector, which will have to digitalise to increase its economic and environmental performances. In the opinion of digital actors, farmers are not aware of the advantage of digitalisation and are not particularly attracted by the idea of using digital technologies. The digital organisations we interviewed either develop technologies directly (start-ups, firms), are involved in projects to develop technologies (research, TIC firm) or test technologies (educational organisations). The TIC firms want to transfer their technologies from other sectors to the agricultural sector.

> "We need to evangelize, to make people understand the ins and outs of what we do" (Dig-StUp)

Digital organisations consider digital technologies suitable for both organic and conventional agriculture. They do not consider 'organic' as a differentiation criterion.

> "In fact, at least since the beginning of the project, I don't have the impression that being organic or not influences the interest we have in it or not. I have the impression that it is transversal." (Dig-Educ1)

Digital organisations see diverse impediments to their development in the agricultural sector. First, concerning access to data, they mention several obstacles including data quality, compatibility and technological interoperability, the cost of the technologies and the constraints caused by the specific farming context, especially long-term temporality, variability and complexity. Second, concerning data management, they underline issues of governance. Third, concerning the acceptability of their technologies, they are aware that digital technologies lead to outsourcing part of the analysis, which may discourage farmers from adopting the technologies. Fourth, they emphasize the capacity of the farmers to pay and to use digital technology.

> "To do big data and analysis, you need good quality data. And that's hard to get" (Dig-assoc)

> "And in all projects, whatever the technology, the weak link is governance." (Dig-Assoc)

> "When we use an interface like ours there is this idea that behind it they [farmers] outsource part of the data analysis and they have to accept that. And I think that's very difficult to accept." (Dig-firm1)

4.5. *The crucial issue of perceived risks by actors from the two paradigms*

The actors emphasised the risks associated with the opportunities they mentioned. Organic actors underlined risks related to knowledge while conventional actors underlined the value of the data.

Both organic organisations and farmers listed many risks: in particular, that these technologies are too expensive, the risk of becoming dependent on them and of losing power, the "risk of standardization", the risk of data-hacking or data appropriation. Other risks mentioned included stress or the time required, loss of concrete interactions between people, loss of connection to the land and loss of local knowledge. Specific problems were mentioned when farmers do not have the necessary digital tools or the necessary skills to use them. Digitalisation sometimes -and in some ways-does not match the philosophy of some organic farmers or is simply too disconnected from their way of life. In particular, organic farming may reduce costs and investments whereas digital technologies may require investments.

Consistently, not all the digital technologies currently under development are considered to be suitable for organic farming, either for technical or socio-economic reasons: they may not suit the economic model, the farmers' ways of thinking and decision making, etc. As one farmer pointed out, he cannot use his farming software properly because it is not designed for a global reflection about the farm: it is designed for a technical itinerary, or plot management rather than for general management at scale of the whole farm. The farmer's reservations are reflected in a comment made by an advisor:

> "But for us, in the way we advise, we consider that in organic farming, decisions must really take the whole farm into account (…). You either have to visit the farm or at least talk on the phone, and give really customized advice." (Org-advis1)

Digital technologies are complex and complete control over them does not seem possible to those actors. This could change the balance of power between actors.

> "Beyond loss of know-how, the balance of power in an agricultural system will be upset. In other words, we're going to be very dependent on the equipment or services provided in connection with these devices, on data processing, which is sometimes a little bit of a black box too." (Org-advis3)

To ensure the technologies meet the organic organisations' own requirements, they may develop them in-house, often through a bottom-up innovation process: an innovation is designed, implemented and tested on a local scale and then, if it works, it is upscaled. Most of the technologies developed by organic organisations concern knowledge management and exchange.

> "So we obtained the tool at the national level, we invested some money in using and improving it based on the feedback we had already received, and that was good because we had a very good basis." (Org-ProfUn)

Conventional actors underlined the risks associated with data ownership, especially the risk that AgTech actors grab all the value created. They also mentioned the risk of farmers being excluded, because of the lack of infrastructure, skills or because of the cost. Farmers mentioned additional risks concerning the reliability of digital technologies and dependence on repairing it, and stressed the risk associated with the extra cost of the equipment when farmers already face economic problems.

Uncertainty concerning the value of the data, farmers' capacity to understand the potential of the technologies, and misuse of tools by farmers are cited as constraints by organisations involved in the development of digital technology. For their part, farmers testified to the need to better account for on-field realities in the design of digital technologies.

It is thus clear that diverse visions of digitalisation co-exist. Depending on the vision of digitalisation they convey, institutions that frame digitalisation could thus influence the directionality of this trajectory.

5. Discussion

In this paper, we address the question of how actors of AIS perceive and respond to digitalisation depending on their relation with the two different ecologisation paradigms. We highlight convergences and divergences.

5.1. *Digitalisation beyond paradigms*

Our research confirms that digitalisation not only changes technological possibilities but is involved in the reorganisation of the whole AIS in interrelationship with multiple factors, as suggested by previous studies (Busse et al., 2015; Fielke et al., 2019; Rijswijk et al., 2019). Interactions among actors, knowledge and institutions are jointly modified by digitalisation within the AIS, revealing characteristics that are shared across different ecologisation paradigms.

i) Whatever their paradigm, agricultural organisations play an important role in digitalisation, by acting as an intermediary between digital firms and farmers, but also by being proactive actors of digital development and in gathering, analysing and transferring information. Digitalisation does not reduce the role of intermediaries, but may even reinforce it, as shown by Busse et al. (2015). This is a further illustration of the role of innovation brokers in agriculture (Klerkx and Leeuwis, 2009).

ii) All the actors we interviewed agreed on the potential of digitalisation to improve working conditions, to optimise practices and to manage risks. They also mentioned possible advantages for economic management of farms, traceability, information for consumers, information and training for farmers. Digitalisation of agriculture is thus a part of the regime of "technoscientific promises" (Joly, 2010).

iii) On the other hand, all the interviewees mentioned different risks that could limit the adoption of digital technology or lead to the exclusion of farmers. Economic risks for farmers are described as being linked to the cost of the technologies, lack of skills or dependence on outsiders to repair the machinery. With the exception of 'digital farmers', farmers agreed on other risks concerning data hacking or data appropriation by value-chain actors. They also referred to the risk of the technologies not being appropriate for small farms. These results are consistent with the perception of digitalisation in the New Zealand AKIS, and of Big Data in the grain industry in Australia (Jakku et al., 2016; Rijswijk et al., 2019).

iv) The need to take control of the ongoing digitalisation was mentioned in both paradigms.Actors of the AIS want to be pro-active agents of digitalisation rather than passive receiver. They aim to reach the final stage of digi-grasping described by Fielke et al. (2021). All those interviewed emphasised that digital technology should complement other kinds of innovation, not only technological innovation. This is recognized by Rotz (2019) as a major challenge to digitalisation.

v) Digitalisation affects knowledge in a back-and-forth movement: it creates a need for new knowledge for digital technology, while simultaneously creating new knowledge. The creation and diffusion of knowledge is a major evolution, as shown by the literature review by Fielke et al. (2020). But making this knowledge effective turns out to be complicated, because of the diversity of needs and the context, and the management of complexity, among others. Several organisations claim they have data but cannot perform the analysis because they do not have the necessary means. Various transversal actors even think the value of the data is a myth: they believe agricultural actors hope to exploit the value of data, which will not happen.

vi) Regulations, standards, and specifications were considered by the interviewees as major drivers of the accelerated development of digital technologies. Digital technology may be both the cause and the consequence of changing regulations, allowing new kinds of regulations to be established and enabling new forms of control and traceability (Pearson et al., 2019).

On all those points, digitalisation appears to be more a source of convergence than of divergence between actors with respect to the conventional versus the organic paradigm. This convergence results from the perception of shared advantages (better information, work made easier, etc.) or problems (autonomy, learning and evaluating the technologies, etc.). Our results provide a basis for reflection or action on digitalisation that incorporates the diversity of farming systems.

Convergence may also be linked to the changing dichotomy between paradigms, as this distinction has become less clear (Sonnino and Marsden, 2006). The rapid development of organic farming is leading to hybridisation mechanisms between organic and conventional organisations. On the one hand 'conventional' organisations, especially co-operatives, are extending their activities to organic farming (Stassart and Jamar, 2009). On the other hand, organic farming organisations are incorporating innovations that allow them to scale up and "become conventional" (Le Velly and Dufeu, 2016). The distinction between the two paradigms and their institutions is still applicable. However, in practice, there is more and more a form of continuum. Thus, some "conventionalised" organic actors may have a "conventional" vision of digitalisation.

5.2. A diversity of desired trajectories of digitalisation

Although this digital transformation is global, it is not perceived in the same way by all the actors and points of divergence exist between organic and conventional actors concerning their 'digi-grasping' (Dufva and Dufva, 2018; Fielke et al., 2021). Digitalisation could reinforce different directionalities of the AIS.

i) The main differences between organic and conventional actors appears to be in the directionality each expects of digitalisation.
   - Digitalisation for traceability is expected by conventional actors whereas organic actors mention the risk of standardization, fearing that the "industrialisation" of organic products may result from norms linked to or imposed by digital technologies aimed at promoting traceability (Klerkx et al., 2019; Ringsberg, 2014; Rotz et al., 2019).
   - Digitalisation for endogenous knowledge is expected by organic actors, who hope digital technologies will help them conceive and analyse their production systems in a systemic way and will support experimentation. However, this is not how digital technologies are currently designed, they are more segmented than holistic, more top down than bottom up. This could lead to discrepancies between digital technologies and organic farming. Organic actors mention the potential risks of loss of power and know-how.
   - Digitalisation for value creation is expected by both conventional and digital actors, who hope to improve the image of agriculture and its attractiveness, to improve profitability, and limit environmental impacts. Conventional farmers and their organisations mention risks concerning the ownership of data.

ii) Here we refer to different innovation processes and strategies of digitalisation. Organic actors underline the importance of farmers' training and of the design specific technologies to support their own vision of digitalisation. Conventional actors collaborate with digital actors with the aim of rendering farmers' activities simpler and more efficient. Thus, actors involved in digitalisation differ because organic organisations focus on internal development while conventional organisations develop technical and economical partnerships.

iii) However, in our interviews, the digital actors did not perceive these different views. They work with the most influential actors and see no difference between organic and conventional farming. They consider that most digital technologies are generic and consequently appropriate for both conventional and organic farmers. However, the knowledge basis differs between organic and conventional farming, and, to be successful, farmers' knowledge must be included in digital technologies (Rose et al., 2018). Including actors in the conception of the tools is essential if the end users are to make sense of them (Bronson, 2019; Jakku and Thorburn, 2010). Not considering the diversity within the AIS, and consequently not incorporating this diversity in the conception of tools could lead to the exclusion of other forms of farming than conventional. It could reinforce the dominant paradigm. Conversely, a diversity of digitalisation could reinforce their differences.

Here, we consider organic farming as one example of the paradigm that embraces the agroecological transition in France, but not as the only one. Moreover, the diverse conception of digitalisation depends on a diversity of factors, not only on paradigms. It opens research opportunities to study digitalisation for new forms of alternative farming, or in other places, or depending on other factors.

5.3. Enriching the analysis of digitalisation of AIS by taking heterogeneity and power relations into account

Structural analysis based on Malerba's framework highlighted transformation of the AIS for and by digitalisation, while accounting for change in the nature of the AIS variables, cross-sectoral dynamics, and heterogeneity within the AIS. This analysis enabled us to highlight both convergence and divergence within the innovation system concerning the process of digitalisation in agriculture. Our conclusions are in line with the results of Fielke (2019), who showed that digitalisation leads to power issues and pointed out that powerful incumbents may capture more gains through digitalisation. There may thus be power issues between the different stakeholders (AgTech actors vs farmers for instance). We add possible power issues between different types of farming systems and different visions of digitalisation. Research by Bronson (2019; 2016) supports the fact that digital technologies are meaningful for conventional farming. Our research is complementary, as it provides insights into how digitalisation could be meaningful for organic farming according to the interviewees. It seems there is no opposition against digitalisation per se, rather against a certain definition of digitalisation that currently predominates. This conception of digitalisation tends to be prescriptive, requires high investment, concentrates power and standardises production. It is supported not only by private actors but also by some public actors (Lajoie-O'Malley et al., 2020).

This situation calls for the inclusion of the paradigm concept and of power relations in the innovation system. It invites scholars to analyse not only how digitalisation happens but also its possible directionality and how it is steered by the AIS. Transversal actors could work with digital actors to make the latter aware of this issue and to promote a diversity of research and development to avoid lock-in in digitalisation. This raises the question of the governance of digitalisation. Governance will influence which opportunities digitalisation responds to, which risks it will avoid, and consequently, which farming paradigm it will encourage. In line with the conclusion of Newton et al. (2020), it is essential to involve farmers and citizens in the decisions concerning the trajectory of digitalisation. We add the need to involve a diversity of farming systems in order to promote their diversity. In that respect, functional and relational analysis could complete this work in identifying blocking mechanisms and incentives (Bergek et al., 2008). Directionality of change also depends on the use of digitalisation by producers and the constraints they face, which, in turn, calls for further research on farmers' concrete uses and practices of digital technology.

6. Conclusion

Our analysis prompt us to take a step back when referring to the concept of digitalisation. In practice, digitalisation is not a single phenomenon with a single definition: it does not mean the same thing to different actors. Digitalisation may have different objectives, occur in different ways, and in different forms. We argue that there are no different 'stages' of digitalisation. All actors are engaged in understanding, awareness and transformation of digitalisation. But we suggest that there are different 'processes' of digitalisation. However, we question whether the coexistence of different processes of digitalisation is possible or whether power imbalances will impose a standardised digitalisation, meaning only the future imagined now by dominant actors will become reality (Carolan, 2020). Our findings thus call for the inclusion of heterogeneity in AIS to enable the development of technologies that suit different trajectories of ecologisation. We provide conceptual and empirical elements to help actors become aware of this heterogeneity. Moreover, many interviewees emphasised that digital technologies are but one component of transformation, others being changes in advisory services, in farm structure, new relations with consumers, new policies supporting open innovation. Thus, the popularity of digitalisation should not mask other dimensions of AIS and there is a need to explore further their interrelations.

Author statement

Eléonore Schnebelin: Conceptualization, Methodology, Formal analysis – Investigation, Writing – Original Draft. **Pierre Labarthe**: Supervision, conceptualization, writing review. **Jean-Marc Touzard**: Supervision, funding acquisition, conceptualization, writing review.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationship that could have influenced the work reported in this paper.

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