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The introduction of digital technologies into agriculture: Space, materiality and the public–private interacting forms of authority and expertise

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ABSTRACT

This article examines critically how digital technologies are being introduced into agriculture. The authors argue that this introduction takes place through the interacting forms of expertise and coalitions of authority in relation to both private and public players in smart farming initiatives. The piece adds to current debates about the origins of and driving forces behind emerging technologies for agriculture through the investigation of two case studies, relating to a Swiss drone startup that obtained the first authorisation for crop spraying with their home-made drone, and to a private–public smart farming test compound. It is argued that a way of understanding how digital technologies find their way into the farming sector is to consider not only the complex set of relationships between public and private actors but also the influence of space and materiality on the socio-technical composition of the technologies. The empirical data of the article sheds light upon how in an unprecedented collaboration between private and public actors a new regulatory procedure for digital technologies was established. The article adopts a politico-geographical angle of analysis by grounding its theoretical posture in Foucauldian understandings of power, relational conceptions of space and the agency of materiality, which is anchored in actor-network theory. Within this theoretical stream, the authors introduce the concepts of 'interacting expertise' and 'coalitions of authority' as a conceptual toolkit for comprehending how an interplay between private companies, public institutions and a range of spatial–material arrangements contribute to what is widely understood in Switzerland as smart farming.

1. Introduction

Digital technologies have become increasingly integrated into agriculture. From farm management apps to milking robots and from self-driving tractors to soil disease detection drones, global technology businesses, local startup companies and state authorities are offering and supporting a wide range of solutions aimed at producing the 'smart' farmer. Often, smart farming is defined as agricultural production sites at which 'smart' technologies (Bertschi, 2018) and 'Big Data' (Protopop and Shanoyan, 2016) are used as software-driven systems. These consist of connections, processes and data flows that rely on orchestrated techniques of data collection, analysis and transfer (Carolan, 2018a). Whereas some contributions to the literature underline the possible advantages of using digital technologies in agriculture, that is, they could help to minimise risks and increase efficiency (Bongiovanni and Lowenberg-Deboer, 2004), others emphasise the ways in which they could trigger problems such as a reduction in employment (Van Es and Woodard, 2017) or a lack of sustainability (Walter et al., 2017).

In this article, we examine critically how such digital technological solutions are being introduced into the agricultural sector. We do so by drawing upon two Swiss-based case studies. The first is a startup company called AgroDrone[1], which operates internationally and has developed a sprayer drone for crop protection in vineyards and orchards. The second case study, which is called the Swiss Future Farm (SFF) and is located in Tänikon near Zurich, is basically a demonstration and test facility for the agricultural sector at which public authorities and private companies can experiment with current technologies and disseminate new ones.

To pursue our argument, we have assigned the article particularly to three research streams in recent literature that have closely examined issues of (a) power and governance (e.g. Dürr and Meier, 2005; Carolan, 2018b, 2018c), (b) knowledge, expertise and learning (e.g. Lubell et al., 2014; Higgins et al., 2017; Wójcik et al., 2019) and (c) the implementation of digital technologies, knowledge transfer and public–private collaborations (e.g. Nettle et al., 2018; Rijswijk et al., 2019; Higgins and Bryant, 2020) in digital agriculture. One of the main

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outcomes of the existing studies is that the private and public actors who collaborate to implement smart technologies in the agricultural sector significantly lack knowledge of either farming or digitalisation (Eastwood et al., 2017).

What we contribute to these streams of research is, that by reflecting on the literature and combining this with our empirical results, we foreground the argument that the introduction of emerging technologies into agriculture is produced and shaped by interacting forms of expertise and coalitions of authority in relation to both private and public actors, and bring into play a particular conceptual sensitivity to power, knowledge and the mediating role of space and materiality. This specific conceptual and analytical lens not only adds to the recent advances in research on the digitalisation of agriculture but contributes to the debates that have a research approach grounded in political geography.

The particular focus on Switzerland and on the two case studies is unique for three main reasons. First, in the current literature on smart farming developments, much has been written about large-scale farming projects in anglophone countries (e.g. Bryant and Higgins, 2020) and the participation of big tech companies in these (Carbonell, 2016; Bronson and Knezevic, 2016; Fraser, 2018). This article proposes to look beyond these usual fields of inquiry to shed light on Switzerland as a small-scale farming country outside of the anglophone world. Second, despite the fact that much scholarly attention has been paid to a myriad of technologies and although there are studies looking at drone technologies in agriculture (e.g. Michels et al., 2020), this article sheds light on how the technology is being developed from the very start and provides insights from the side of the idealisers of the technology. This article concentrates therefore on studying the development, implementation and normalisation of emerging technologies from the bottom up and *in the making* by observing at first hand the first steps of the small startup AgroDrone and the initial period of SFF. In both of these, local and global interests intermingle to bring forth innovations in digital agriculture. Third, the article sheds light upon an unprecedented collaboration between the private drone startup and Swiss regulatory institutions that achieved to simplify and establish a completely new regulatory procedure.

The remainder of this article develops as follows. The next section assesses the three streams of literature to which we assign this article. Then, we lay out our theoretical posture and conceptual framework. Following on from this, a methods section details the fieldwork data and the analytical procedure. The analysis unfolds in three main parts in which we consider (a) the private initiative, that is, the drone startup AgroDrone, (b) the public institutions involved in the regularisation of the drone technology in Switzerland and (c) SFF. Finally, the analytical results are brought together in the conclusion.

2. Power, knowledge and the Implementation of smart farming tools

From the rapidly growing body of literature on smart farming (Bronson and Knezevic, 2016; Dodge, 2018; Klerkx et al., 2019), three main strands of scholarship inform our research. The first strand is concerned with issues of governance and the power of digital technologies in agriculture (Carolan, 2018b, 2018c). Here, a series of questions is asked: Who owns the data? (Dürr and Meier, 2005), How can data security be guaranteed (Wolfert et al., 2017)? and How can the data be protected? (Bronson and Knezevic, 2016). This leads to fundamental reflections on how the masses of data are translated into software and, more importantly, who is involved and who controls this process (Lyon, 2007, p. 100). Thus, the data used in agriculture are never just neutral, but at their very creation already reflect ingrained power relations and interests (Thrift and French, 2002; Graham, 2005; Kitchin and Dodge, 2011).

These questions of power and governance are highly relevant for the case studies because they provide us with the opportunity to investigate the nature of the private–public relationships at play. More specifically, they encourage us to investigate closely the interdependence between different private and public experts in the development of new technologies in agriculture and allow for an examination of the different sources of power in these relationships.

The second strand of literature looks at how knowledge, expertise and learning in relation to agriculture are produced and, specifically, how they are produced in the digital age. There is a vast body of literature that looks at knowledge and learning mechanisms with regard to agriculture and how these are transmitted from one generation of farmers to the next (Wójcik et al., 2019), how informal and formal knowledge is important for sustainable ways of growing (Šūmane et al., 2018) and how knowledge exchange between growers and grain suppliers is strengthened through contractual governance (Cholez et al., 2020). Other authors have assessed how knowledge networks can reskill farmers (Coolsaet, 2016) and how agriculture is marked by experiential learning and knowledge transfer (Lubell et al., 2014, pp. 1089–90).

Within this line of investigation in the literature, scholars have explored how digital technologies change the ways in which knowledge and learning in relation to farming are produced. It has been highlighted that these processes cannot be understood without considering that the production of learning and knowledge with regard to digital technologies in agriculture is deeply rooted in its association with both materiality (Henke, 2008; Krzywoszynska, 2016; Legun, 2015) and space. As Higgins et al. (2017, p. 201) maintain, '[g]reater emphasis should be placed on "knowledge in action" – the relationality of materials and the multiple modes of ordering through which materials intertwine with, shape, and are shaped by, farming knowledge and practices'. Techno-material systems and their attendant socio-spatial aspects, should both be part of an analysis that is interested in the multiple ways knowledge about smart farming can be produced.

This research direction invites us to think about linking digital technologies and knowledge production in relation to agriculture with the chosen case studies; the two things do not happen in a political vacuum but are increasingly shaped by the relationships between different experts who are involved in the planning, development and normalisation of technologies for agriculture (Ingram, 2008, 2018; Ingram and Gaskell, 2019). This strand of literature also connects neatly to the first one about power and governance, because knowledge production is related to questions of power and techno-dependency (Carolan, 2017).

Although the above literatures make a significant contribution to the understanding of power and governance with regard to digital technologies in agriculture as well as to an appreciation of how knowledge and learning in the field have developed (also Carolan, 2006), they do not tell us much about the underlying public–private collaborations within specific spatial–material environments, which leads us to the third stream of literature that is important for this article.

This third stream looks specifically at the implementation of digital technologies, knowledge transfer and the public–private collaborations that take place in this process. With the recent emergence of digital tools, the agricultural sector has undergone profound changes because the routine ways of farming are now being transformed and even replaced by smart farming tools (Nettle et al., 2018). It is of note that in referring to traditional working routines being adapted to the new digital ways of farming (Bryant and Higgins, 2020, p.7), scholars mention tech companies having a lack of farming knowledge and, conversely, agricultural experts a lack of knowledge about digital technologies (Rijswijk et al., 2019).

Recent research has also provided insights into the ways in which meso-scale actors, such as agriculture service providers, agronomists and researchers, play an important role in the digital governance of agriculture (Higgins and Bryant, 2020, p.439). More specifically, a way out of the uncertainty felt by farmers during this digital transformation period (Fielke et al., 2019) could be the use of 'cultural scripts', which 'are critical for meso-scale actors in creating a sense of ontological security and thereby securitising uncertainty' (Bryant and Higgins, 2020,

p.7). Others have looked into the role of private and public actors in the complex entanglement of the emerging smart farming technologies. Again, it has been found that the private technology providers lack knowledge of farming (Eastwood et al., 2017).

What we propose in this article is to add to these scientific inquiries by looking at our two examples, the drone startup and SFF. The research described above has analysed in depth how on different scales, the private and public actors who collaborate to implement smart technologies in the agricultural sector lack knowledge of either farming or digitalisation (Eastwood et al., 2017). This article focuses in particular on cases of collaborations between technology companies, farmers and regulatory institutions that work together from the very start of the development, regularisation and usage of new agricultural technologies. Thereby, we hope to supply the missing link between theory and practice.

Drawing upon these three literature streams, we propose in this article to explore and problematise the ways in which private and public entities collaborate in the development of new digital technologies for the agricultural sector and their proliferation throughout it, and also how space and materiality play out together in these processes.

3. Conceptual approach

Our study of the interacting forms of expertise and coalitions of authority that lie behind the introduction of emerging technologies in the agricultural sector conveys a particular conceptual sensitivity for issues of power, knowledge production and the mediating role of space and materiality (Klauser, 2017). More specifically, we ground our approach in three main strands of theoretical thought.

First, our analysis draws upon a Foucauldian understanding of power as a mode of action that 'structure[s] the possible field of action of others' (Foucault, 1982: 790). Foucault insists that power is not a substance or property belonging to specific actors, but 'exists only when it is put into action' (Foucault, 1982, p.788). More specifically, for Foucault, power is always exercised within and through a combination of interacting techniques, or, in other words, through merging and conflicting chains of procedures and knowledge, anchored in specific genealogies. Derived from this posture, our analysis focuses on the techniques and sources of legitimisation that allow particular actors to act on the public–private relationships and on the processes that lie behind the development of novel smart farming solutions.

Second, the concept of space that underpins this article draws heavily upon Henri Lefebvre's and Claude Raffestin's work. The most fundamental insight derived from the former relates to the Lefebvrian concept of (social) space, as both the product and producer of social action (Lefebvre, 1991). Thus, for Lefebvre, space both results from and acts on a given social reality (Lefebvre, 1991, p. 82–83). For our analytical purposes, this implies a focus on the role played by particular places – in both their material and immaterial dimensions – on the development of novel smart farming solutions. Furthermore, Lefebvre's approach to space is of interest here because of its reliance on the concepts of mediation and mediators for capturing the inherent 'hyper-complexity of social space' (Lefebvre, 1991). However, although Lefebvre hints at the importance of mediators in the processes and relationships through which space is socially produced (Lefebvre, 1991, p.165; 207), it is Claude Raffestin who offers a more systematic, mediation-focused conception of power and space (Klauser, 2012; Raffestin, 1980, 2012), focused on the role of concrete and abstract mediators such as objects and tools, discourses and ideas, which clarifies the ways in which space mediates social action (in our case: the development of novel smart farming solutions).

Third, we draw upon the understanding developed by actor network theory (ANT) of the distributed agency of both human and non-human entities in the creation of particular socio-technical systems (Callon et al., 2001; Callon and Law, 1997; Latour, 1987, 2005). We use this approach to show that novel technological solutions, such as AgroDrone's sprayer drone or technologies developed at SFF, must be studied not only by considering the micro-negotiations between the human actors involved, and the spaces concerned, but also by focussing on the role of specific objects that mediate the processes of bringing the socio-technical systems into service.

Two main concepts that we use as analytical tools in this article are derived from these three theoretical assumptions. In utilising the ANT-inspired line of thought, we make analytical sense of the knowledge production that takes place in the relationships between the private and public actors through what is widely understood as 'interacting expertise' and 'coalitions of authority' (Czempiel, 1992; Lipschutz, 1999; Akrich and Méadel, 1999), according to which different experts produce new knowledge in their spatially grounded interactions (see also Klauser, 2009, 2015). Thus, the article is interested specifically in the manifold forms of 'expertise' (expert knowledge) at play in the distribution of 'authority', that is, the power to act and make decisions that is considered legitimate by the actors involved. These various forms of expertise and their impact on authority come together in the development and production of new technologies for agriculture and their management.

The focus on expert knowledge and coalitions of authority in the article is mainly derived from Akrich and Méadel (1999). Taking their example of surveillance systems, they showed that these cannot be understood fully merely by assessing their technical functionalities, but have to be studied through the complex composition and interaction of the differing and interrelating actors, expertise and interests. The production of digital technologies for agriculture cannot be understood without considering the experts who are involved in the associated processes. Therefore, governance in this sense is related to 'authority' (Lipschutz, 1999, p. 260), in terms of 'the capacity to get things done without the legal competence to command that they be done' (Czempiel, 1992, p. 250).

In sum, the paper's interest in the 'interacting forms of expertise' and 'coalitions of authority' that shape the development of novel smart-farming solutions sits in-between these three theoretical strands. Anchored in an ANT- and Foucault-inspired line of thought, we analyse the knowledge production around novel smart farming solutions as the outcome of mediated relationships between various actors, whose positions are defined by differing forms of expertise (expert knowledge) and authority (that is, the power to act and make decisions that is considered legitimate by the actors involved) (Czempiel, 1992; Lipschutz, 1999; Akrich and Méadel, 1999; see also Klauser, 2009, 2015). And connecting with Lefebvre's and Raffestin's work, we are interested in seeing how in both case studies, space makes a difference to these processes.

4. Materials and methods

The research data for this article have been collected during the projects Power and Space in the Drone Age (January 2016–April 2020) and Big Data in Agriculture: The Making of Smart Farms (September 2018–June 2020), both financed by the Swiss National Science Foundation. We conducted semi-structured qualitative interviews and ethnographic observations at both of the research sites, AgroDrone, the agricultural drone startup and SFF, the experimental compound for emerging technologies in farming. Additionally, we were able to interview official representatives from both the Federal Office of Civil Aviation (FOCA) and the governmental research institute Agroscope. All of the interviewees were white males, which may reflect the still overly masculine and white nature of the drone and agricultural technology sector (Olson and Labuski, 2018).

The protagonists in the interviews were six AgroDrone employees, three vine growers who themselves work for or take advantage of the services offered by the startup company, two representatives from FOCA, two representatives from Agroscope and three SFF managers. The interviews and observations took place in two phases. First, we

conducted interviews with the core AgroDrone team and observed their work in the vineyards. The interviews focused on the CEO and the pilots and technicians who worked for the company. In a second phase we carried out further interviews with the vine growers, FOCA, Agroscope and SFF. All interviews were conducted in French or German and the quotations used in this article have been translated into English by us.

The methodological framework that underlies the selection of the interviewees and the research methods is based upon the assumption that the development of new technologies for agriculture can best be assessed when such technologies are observed at their own production sites. The choice of semi-structured interviews enabled the research participants to talk in the language of their own industry using their own familiar terms (May, 2011, p. 136; Hollway and Jefferson, 2013, p. 33). All the interviews were recorded and transcribed, and then coded with MAXQDA. The coding was important to identify narratives that were not just discourses, but considered here as 'temporally ordered, morally suggestive statements about events and/or actions in the life of one or more protagonists' (Presser, 2016, p. 138).

Each of the two case studies was chosen for very particular reasons that we lay out in the following. AgroDrone is the first startup company in Switzerland to have obtained authorisation to spray vineyards using a drone. What caught our attention was that AgroDrone is the only company to have developed its own drone; other similar companies in Switzerland use a standardised and imported sprayer drone. AgroDrone also uses a standard chassis from China; however it has developed a spraying system that has been adapted to the needs of the Swiss vine growers.

Obtaining authorisation to spray from the air onto the ground in Switzerland is a highly complex process involving up to seven federal offices and institutes. In an unprecedented collaboration between AgroDrone, FOCA and Agroscope, a new regulatory procedure was established and ratified at the beginning of 2020. Under very specific conditions, drones can now be considered as ground applications and are no longer regulated under the same rules as helicopters (FOCA, 2020). This opened the door for the use of sprayer drones in Swiss farming.

In collaboration with FOCA and Agroscope, AgroDrone has succeeded in influencing and changing the ways in which flying devices that spray liquids from the air onto the ground are regulated and has obtained authorisation in Switzerland to apply its methods to agriculture. Although the European Union has banned pesticide distribution by helicopter since 2009 (Zwetsloot et al., 2018), Switzerland still allows this practice but has limited it considerably. The crux of the authorisation process is the drift of the liquids and the distances that have to be maintained from houses and other vulnerable objects. In the attempt to apply the authorisation process to drones, FOCA, Agroscope and AgroDrone realised that the drift of pesticides from these machines was a great deal less than if they had been distributed by helicopter, and that with regard to hitting the target they were also able to get very close to the level of accuracy attained by equipment on the ground. Consequently, the way was opened for legally classifying drones into the same category as ground applications, which simplifies the authorisation process a great deal (FOCA, 2020). Thus, it is these unique characteristics that have made AgroDrone and the other public actors associated with the company a particularly relevant case study.

We chose SFF for similar reasons. Established in September 2018, SFF is unique in its approach of uniting three stakeholders at the facility and for being both a place where new technologies are tested and a place where they are advertised and demonstrated to end users. SFF is presented as being one of the most innovative and admired smart farming initiatives in Europe, providing a development site for novel smart farming solutions, the identification of technical and human capabilities and vulnerabilities and for 'professional exchange on concrete applications with farmers' (Federal Office for Agriculture, 2017). The relationship between its three partners, BBZ Arenenberg, the global designer, manufacturer and distributor of agricultural machinery, which is located in the canton of Thurgau, AGCO, the global agricultural tool manufacturer and GVS Agrar AG, the leading importer of AGCO agricultural machinery into Switzerland (Swiss Future Farm, 2020), also made SFF interesting because in this respect it was different from AgroDrone. Whereas in the case of AgroDrone the collaboration between the private company and the public bodies was assembled around one specific objective – to establish new regulatory procedures for sprayer drones – SFF consisted of both private and public actors from the very start. As the analysis will show, all three partners have different but also similar objectives in being part of SFF.

Both initiatives are still in the process of being set up and/or further developed. In carrying out the research it was possible to follow the evolution of both organisations from their past history through their current state to their proposed future development. In both of the case studies, the spatial–material relationships play an important role through which expertise and authority have been constituted and, ultimately, make an important contribution to the introduction of digital technologies into agriculture through the associations between the private and public actors under consideration.

Therefore, the two case studies were not chosen to form the empirical basis of this article by accident. The two are linked because of their relationship to the federal research institute Agroscope, which seems to appear as a mediating force that is involved in providing a substantial amount of knowledge to both actors and has considerable input into their activities. The two case studies allow for the investigation of different stages in the introduction of novel solutions for smart farming: research and development (SFF); and the subsequent application of specific solutions to the real world (AgroDrone). Consequently, there is the advantage of being able to consider spatial–material relationships in one specific place at the Swiss Future Farm, and – in the case of AgroDrone – at multiple and different places. As such, the case studies offer an ideal combination for advancing a wider reflection on how different sites that undertake testing and experimentation connect with and complement each other.

As well as these complementarities, the two case studies also present several important parallels. Both initiatives are constructed discursively as unique cases that will shape future evolutions in the field of smart farming and are framed around notions of efficiency and sustainability. They promote their interventions and initiatives in various ways, for example, by advertising their products as 'the most advanced spraying drone on the market' (Aero41, 2020), claiming that 'from bundled knowledge arises innovation' (Swiss Future Farm, 2020) and by advancing the argument that support for smart farming 'increase[s] the competitiveness of Swiss agriculture through the inclusion of smart-farming technologies by offering decision-making aids for practitioners, with the focus remaining on people in all cases' (Agroscope, 2020). This enables us to trace the crossovers, synergies and divergences in the public–private discursive constructions of Big Data in agriculture. Furthermore, the two are striking examples of the public–private partnerships that underpin contemporary efforts towards smart farming. Importantly, both initiatives are also supported and shaped by the techno-scientific expertise provided by Agroscope, thus making it possible to investigate the relational positioning of and exchanges between the two. Therefore, both case studies offer a unique opportunity for investigating exactly what functions and roles the different forms of expertise and coalitions of authority have in relation to the introduction of smart technologies into agriculture, their regulation and their subsequent dissemination.

5. Analysis

5.1. AgroDrone: the private actor – socio-material and practical–technical expertise

AgroDrone is our starting point when considering how expert knowledges combine in the introduction of novel technologies into

smart farming in Switzerland. This is best looked at in the context of the very beginnings of the company's sprayer drone project. In one of the interview conversations, an AgroDrone pilot said,

> Well, the system in itself is absolutely not programmed for territories like ours. In China, they don't understand that we can actually work under such conditions [laughs]. … This made it simply impossible to work with this application in the beginning. Thus, we had to code it [the drone], so that it could work here (Interview AgroDrone pilot 2, 03.10.2018).

In this interview passage, the pilot explains how the development of the drone proceeded during the first tests. Its flight abilities were programmed primarily so that it could be used in China, but it had to be adapted to the specific environmental conditions in Switzerland. Another pilot and vine grower resumed,

> We had a huge problem with the firmware that was send to us – of course – from China … which was limited in controlling the height. And clearly, in China they don't have the same territories that we have … and for the flat rice fields, this is no problem, and they must have asked themselves: 'Why would you need to fly higher than 30 m?' But as here everything is very steep, you are quickly at 30 m (Interview AgroDrone member of staff and vine grower, 20.08.2018).

According to the interviews with AgroDrone, the first sprayer drones were developed for relatively flat rice fields in China; this includes the chassis, and the software that steers and controls their flight behaviour (Interview AgroDrone pilot 1, October 03, 2018). However, the cultivation of vines in Switzerland is characterised by different conditions, for example, the steep hills, to which the drone software had to be adapted. Therefore, the drone pilots had to deal with constant adaptations of the software and the drone technology to the specific Swiss context.

Although the chassis and the software were imported from China, the spraying technology was developed in Switzerland. As one of the pilots narrates,

> The spraying technology was entirely developed and tested by us. And we still continue to improve it. But basically, we departed from a good spraying capability, and after that, we attacked the machine. We pursued the inverted system of what the drone people normally do: they develop a good drone and then they install a system. We started with the system and then we improved the drone. Because the vine cultivators here want a good spray before anything else (Interview AgroDrone pilot 1, 03.10.2018).

As these interview excerpts indicate, in developing the drone, spatial–material relationships were essential. The expertise that is produced and acquired at AgroDrone and the interests that lie behind the company's efforts to develop its own sprayer drone reveal that it is important to consider material–spatial aspects when decoding the ways in which authority is distributed in the making of particular projects.

Although the flying technology was adapted to the local circumstances, it was at least equally important to develop a spraying technology that fulfilled socio-spatial requirements. Because we understand space as both the product and producer of social action (Lefebvre, 1991), and comprising both material and immaterial dimensions (Raffestin, 1980), we can see here a first indication of how the drone technology as an agricultural tool is developed in direct conjunction with the spatial–material relationships. Consider the following scenario.

During fieldwork with AgroDrone we were able to observe how the pilots had to become familiar with the territory before they could initiate the spraying flights. They had to geomap the field on foot or with a drone so they could feed the information into the sprayer drone software to enable the automatic flight mode. This shows how the topographical field environment is important for the operational capacity of the drone. It is impossible for the fully automated flight mode to be operated over most of the fields in which the AgroDrone machine is used because they often contain obstacles such as sticks and, therefore, the pilot has to control the flight altitude manually. During the fieldwork, we witnessed a situation in which the drone had to be repaired because it crashed into a wall and damaged one of its blades. AgroDrone's staff have developed considerable expertise in using the equipment in the space for which it was intended. This example highlights how important it is to consider the socio-material and socio-spatial aspects of the drone technology.

Departing from the assumption that objects are always the product of the socio-technical combination of human and non-human elements and the mediation between them (Latour, 2005, p. 9), the drone technology as a whole is put together using the network of different actors in the field, and space is an important mediator in this process. Conceptually, this shows that both materiality and space are important components in the constitution of knowledge and expertise. Similar to what we saw in relation to AgroDrone, Higgins et al. (2017, p. 195) have shown that as far as Australian rice farmers are concerned, materiality is central and constitutive with regard to ordering and structuring how they deal with and accept the use of new technologies.

Although the previous example refers to the relationship between materiality, the pilots and the technology, the coding of the software also introduces a non-material element into the mix. During one of our first observations in the field, we noted that it was difficult for the drone to maintain stability in the air and, as a result, it had to be grounded. The newest firmware update from China was not compatible with the Swiss environment. However, following a series of on-site tests, an adaptation was made and the work could continue. In other situations, the pilots told us they can also consult with the technician in their workshop, and depending on the gravity of the issue, they make a decision to either effect a repair in the field or go back to the workshop. In this example, the interplay between space, technology and humans that creates interdependent socio-technical relationships is concretised. Essentially, this is added to the expertise from AgroDrone, which is rooted in the practical–technical aspects of drone development.

Conceptually, this shows even more convincingly how the spatial–material relationships are an important factor in the learning about and the making of new technologies. Indeed, as similar conclusion was reached by Krzywoszynska's (2016, pp. 292–3) study of vine growers, which highlighted the fundamental role played by the fields' materiality in the vine growers' knowledge production and 'enskilment', understood as an 'ongoing exploration and alignment of properties and actions, a never-ending experimental engagement in which both humans and materials change and mutate'.

5.2. Federal Office of Civil Aviation/agroscope: the public actors – legal–scientific expertise and regulatory authority

The public institutions that are involved in the process of introducing new technologies into the agricultural sector in Switzerland are crucial actors. We examine the similar but also differing forms of expertise and authority conveyed by the Federal Office of Civil Aviation (FOCA) and the federal research institute Agroscope. Whereas FOCA is the Swiss institution that regulates, oversees and leads projects concerning civil aviation traffic in Switzerland, Agroscope is an institute that pursues research in agriculture on a myriad of different themes (Interview, Agroscope expert, March 20, 2019). The two organisations collaborated in relation to the regulatory process that was set in motion together with the drone startup AgroDrone. Because there were distinct regulations in place with regard to flying helicopters and recreational drones as well as a considerable number of other regulations pertaining to the agricultural sector, the challenge was to find a regulatory solution for the use of sprayer drones.

The following quotation from one of the AgroDrone staff involved in the collaboration sheds light on the nature of the different relationships

between the private and public actors within this process of finding a solution:

> You really need to do everything by the book. Because otherwise you can get complaints, and if it goes further than that, the Federal Office of Civil Aviation can even come to you. They can tell you for example 'we are going to take your authorisation away' (Interview, AgroDrone technician, 28.08.2018).

The AgroDrone member of staff describes how using a sprayer drone in Switzerland involves knowledge of a set of rules that are defined by FOCA and following them to the letter. In the case of someone not abiding by the regulations, there is the potential risk that FOCA will rescind the flight authorisation. The quote by the drone startup pilot indicates clearly the kind of authority that FOCA exercises. If we consider authority here as being the power to act upon the actions of others and to make decisions that are considered legitimate by others (Foucault, 1982), here, FOCA is exercising its regulatory authority over the industry.

From this authority, the expertise FOCA has becomes clearer too. As one of the interviewees from FOCA said,

> We have an existing legal framework. And this is what I really appreciate from my colleagues, that there is the will to move as flexibly as possible within this legal framework and that we spend energy to enable something and not to disable something. Like that, it eventually gets to an unusual solution. That a drone can be considered a ground application (Interview, FOCA member of staff 1, 30.04.2019).

The interviewee puts forward some interesting thoughts about the expertise demonstrated by FOCA. As mentioned earlier, the innovative and unusual solution of considering a flying device to be a ground application has had a huge impact on the use of drones in the Swiss agricultural sector. As the interviewee says in the quotation, FOCA is bound to a legal framework that has been set up to regulate the way in which flying devices can spray from the air onto the ground. What should be noted about the wording of this quotation is that there is a will to move as flexibly as possible within the legal framework to 'enable' innovation. FOCA's expertise lies in its knowledge of the legal framework and, therefore, it has the authority to bend the rules towards a legally acceptable solution.

However, FOCA understands its role in a very specific way, as one official told us in an interview

> There is a drone ecosystem in Switzerland … from the perspective of the public administration, we consider ourselves as part of this ecosystem. We all know each other, so everyone can be friendly to each other and cultivate a good social interaction and contact. But in such a way that everyone is aware of their own position within this ecosystem (Interview, FOCA member of staff 1, 30.04.2019).

With regard to FOCA's analysis of its own position within the ecosystem, we can best comprehend this in referring to what Akrich and Méadel (1999) have conceptualised as 'coalitions of authority'. These coalitions are perceived to be expert networks, which are equipped with specific expertise and which contribute collectively to the processes of finding a solution. The FOCA official is convinced that each member of the drone ecosystem has his/her own specific position. The differing actors of expertise in this network are together providing input to provide a different and innovative solution, that is, a flying drone is being considered as a ground application for the purposes of spraying. In this network, FOCA is the source of regulatory authority and legal expertise with a clear interest in pushing forward new and industry-friendly legal mechanisms to uphold the status of Switzerland as an innovation hub (Interview, FOCA member of staff 2, March 12, 2019).

However, Agroscope, the other public actor, is a source of similar but also different authority and expertise. Although the organisation is equally interested in helping AgroDrone to 'bring a new solution to zones that are difficult to access to improve the conditions of [vine] production' (Interview, Agroscope mycology expert, March 20, 2019), it has an even more sophisticated role. Consider the following interview extract,

> We have all kinds of demands, either from the cantons or from the producers who ask us, 'These drones, can we use them? Is it worth it? Yes? No?' … We always have a role of consultancy or support to the legislation. In the mandate between Agroscope and the Federal Office of Agriculture, Agroscope is also an institute that needs to answer questions when there is an evolution of a certain legislation and if there are technical questions. It's often Agroscope who delivers the scientific aspect, the expertise to make propositions in that sense (Interview, Agroscope mycology expert, 20.03.2019).

In this quotation, Agroscope is presented as having three interrelated functions. The first is its role in relation to public and private actors who are seeking an expert opinion on technical innovations such as drones. This is interesting, because in this sense, the institute has a different position from either AgroDrone or FOCA: it operates between them. Second, Agroscope understands its mandate, which is linked directly to new legislative developments, not only with regard to the drone sector, but also in connection with all kinds of other changes and innovations in agriculture. This then leads to the third point, in which the protagonist from Agroscope highlights the institute's 'scientific expertise'. It follows from these three interrelated aspects that Agroscope is a source of scientific authority that can influence the introduction of new legislation directly. In essence, Agroscope combines expertise in scientific technology with the scientific authority to evaluate and then approve or reject innovations that are directed at agriculture.

What we observe in this analytical section is that specific expertise in and authority over legislative and scientific matters are concentrated on the side of the public actor. Conceptually, FOCA embodies a typical source of authority in the sense that it is *the* entity that is able to initiate certain legislative initiatives before then approving them. FOCA has the explicit power of decision-making to grant or deny flight authorisations. Thus, in Foucauldian terms, it acts with its power upon the actions of others and puts power 'into action' (Foucault, 1982, p. 790). However, in terms of knowledge production, which arises from the interaction between different experts in the field (Akrich and Méadel, 1999), Agroscope acts as a mediator between FOCA and, for example, AgroDrone, because on the one hand it delivers the necessary scientific approval for FOCA so it can authorise the operation of the drone and, on the other hand, it also provides AgroDrone with the required scientific know-how for operating the drone technology.

In relation to space and materiality, the case of the public actors differs from that of AgroDrone. Whereas AgroDrone's expertise is derived directly from its spatial–material embeddedness, FOCA in particular has a different relationship to both of these elements. Whereas Agroscope still has an unequivocal connection to materiality and space, when tests and experiments on new technologies such as drones or crop protection methods are carried out at first hand, FOCA's expertise and authority is rooted differently – in spatial dimensions. Considering the different developmental stages the drone technology passes through, spatial categories become an important aspect of these. Think, for example, about the different spaces in which the technology – as a concrete materiality and as an innovative idea – has been developed, tested and discussed; whereas AgroDrone has a relationship with the technology itself in a truly material sense, FOCA connects to the technology as a non-material idea. Here too, space is not understood as something that is geographical, but as a socially produced category (Lefebvre, 1991) that plays a mediating role in regulating (Raffestin, 2012) FOCA's attitude towards its decision-making processes, the exercise of its legal expertise and its ensuing actions. As a non-materiality, the drone regulations travel through different spatial dimensions on

different scales (see also McCann, 2011): globally in conference rooms and negotiations, and locally through different federal offices to experts and research institutes, until the technology is finally regulated in legislative form.

5.3. Swiss Future Farm: the hybrid actor as the nodal point of expertise and authority

The previous two sections have looked at the private and public experts and sources of authority that assemble together to introduce a novel technology such as the sprayer drone into agricultural spheres. The interesting twist in relation to the Swiss Future Farm (SFF) is that here, private and public interests come together in an interlinked and intended working and interest coalition. At the time of the research, SFF was financed and assembled through the public education and consulting centre BBZ Arenenberg, the global designer, manufacturer and distributer of agricultural machinery AGCO and the leading importer and manufacturer of agricultural machinery in Switzerland GVS AG (Swiss Future Farm, 2020). SFF is an important case study for this article because it is a project in which different expertise and knowledge production do not come together just for one project or for the development, testing and introduction of just one specific technology, but which is intended as a permanent mechanism for making farming 'smarter'.

At the time of our research, each of the three main SFF financiers employed one member of staff and these together formed the management team at the farm. In the interviews we recorded with the three farm managers, the principal interests the three partners had in being part of SFF were highlighted,

> Our goal is to see which of the technologies proves reliable in practice. Because there is a lot of talk about the potential and the possibilities but what decides in the end is what works … And of course, we can take advantage of the knowledge that we get here … Also, internally of the organisation, so that AGCO can see what machines are used and how, and where the problems are in practice. The same thing for GVS, that they see where the problems are in practice so the organisation can learn from it, this is a real goal from the Swiss Future Farm here. And then, that we can support the science, Agroscope or other research projects. And that we can put a spotlight on this place here so that we have a meeting point where one can exchange, where the practice can come and discuss, that's also an important point (Interview, farm manager 1, 11.03.2018).

This above quotation provides insights into the various interests that come together at SFF. To begin with, a major interest in being part of the farm is that it can produce knowledge about new technologies that are being tested and applied under real conditions. Different interests coalesce in this knowledge production. However, in this interest community, the roles are clear cut. Whereas the public education centre prepares future farmers directly to deal with emerging technologies, the private companies have the opportunity to show what kind of technologies they are developing and intend to use. On the one hand, the farm wants to provide solid practical knowledge about emerging digital farming tools for possible end customers. On the other hand, at the same time, it is a means by which important knowledge about the technologies that AGCO produces and GVS sells can be produced. As the interviewee says, it is about seeing where the problems are in practice. In addition, SFF also expresses an interest in cooperating with research initiatives such as Agroscope that run scientific experiments using the SFF facility. Thus, SFF is a place of technological knowledge production with the external goal of demonstrating to the farmers what works in agriculture and the internal goal of showing the companies that provide the technologies how they can adapt and improve their products; it also provides a link to scientific knowledge production.

The following quotation from another of the three farm managers confirms this approach and specifies what it means for the kinds of technologies that are showcased at SFF,

> The goals that we pursue here are mainly a demonstration of these new technologies under real conditions, under field conditions, make them understandable and tangible to the farmers, but also to other interest groups and stakeholders … And one thing is, I would say, future technology that already exists, but where there are obstacles and lack of knowledge, how to use and apply that … the second thing is technology that already exists but no one knows and the third thing is technology that actually doesn't yet exist (Interview, farm manager 2, 11.03.2019).

Here, it can be seen there are three different technologies at play: one that already exists and is already used to some extent but may encounter resistance from farmers; technology that already exists, but is not yet very well known; and technology that does not yet exist but may be tested at SFF at some time in the future. From an analytical viewpoint then, SFF is arranged around two main aspects of expertise at least: technological expertise, which is squarely focused on technologies that already exist but is also future oriented because of its capacity for testing new technologies that are not yet on the market; and the expertise gained through practical experience of using digital technologies – an expertise that is derived from their material dimension.

This leads us to an analysis of the authority that is assembled in SFF across the three stakeholders. The following quotation is essential, because in this complex entanglement of the different goals of SFF, it becomes clear what kind of coalition of authority is at play here,

> The interest of the three partners is clearly, that the canton [Thurgau] or the vocational training centre [BBZ Arenenberg] wants to be a pioneer in the area of teaching, consultancy and new technologies. AGCO as a producer wants to present itself as a pioneer, show that they are able to offer high-quality smart farming solutions. And GVS Agrar, naturally, is the customer service provider … who has to know how to advise the farmers how to apply such technologies, if they want to get them (Interview, farm manager 2, 11.03.2019).

The above quotation highlights two important points. First, although the interviewee talks about the differing interests of the three SFF partners at the time, the quotation is revealing in its depiction of the role of authority in the development of digital technologies for Swiss agriculture and their subsequent dissemination. The canton of Thurgau and, primarily, its vocational training centre, is at the forefront of agricultural digitalisation. Because it is responsible for the training of future farmers, its authority arises from influencing knowledge directly. In other words, at the very start, before someone officially becomes a famer, the training centre can already influence knowledge production with regard to digitalisation in agriculture. The other two partners, AGCO as a global player in the manufacture of agricultural machinery and GVS as its main reseller in Switzerland, both want to become experts in digital technologies to show they can develop and sell cutting-edge machinery and offer their company's services to the farmers who use their tools. In essence, authority arises here as a form of knowledge that has the capability of exerting influence both at the source and on a growing market as a professional financial power. In conceptual terms, what we observe here is knowledge production in spatially bound environments by a group of experts that interact and coalesce with one another (Klauser, 2009, 2015) and who monopolise the possibility of actions upon other actions – the power to influence, shape and proliferate new technologies in the making.

Second, the above quotation also discloses the ways in which public and private partners are assembled around digital technologies in agriculture. The three partner organisations are building a coalition of authority that brings together specific knowledge and expertise in their respective fields so they can pursue their own interests, but within their collective effort. What we have seen here is much different from what usually happens in agriculture and from our previous examples. From

the smart farming literature, we know that in departing from old routines and work practices to establish new and 'smart' farming tools there is a gap between private consultancies who may have the technological know-how, but lack the faming knowledge, and farmers who lack technical knowledge, are worried about change and who want to stick to their old working practices (e.g. Eastwood et al., 2017, p.2). One possibility for overcoming these challenges is to improve collaborations between private and public players in the field (Bryant and Higgins, 2020, p.7). SFF is a step in exactly that direction.

In a way, the chain of translation through which the coalition works to introduce digital technologies into the Swiss agricultural sector and establish them there, operates like the teeth on a perfectly shaped gearwheel. Whereas the public entity has the knowledge and expertise, the global player contributes the financial power to enable development, and also its established product lines; the reseller and repair service provider picks up this expertise to disseminate the technologies among practitioners. This perfectly shaped gearwheel assembles three kinds of authority in one single consortium. First of all, there is the authority of access to the newest and most developed technologies in agriculture. Therefore, SFF is situated in pole position with regard to any new developments. Second, SFF also has an authority of approval. It is at SFF that new technologies are being developed, tested and improved; the farm is designed for exactly this purpose. Third, but no less important for the gearwheel to work perfectly, there is the authority of producing and distributing knowledge. In Foucauldian terms of power, the production, concentration and transfer of knowledge is the essence of power because it offers the very possibility of 'structur[ing] the possible field of actions of others' (Foucault, 1982, p.790). According to this point of view, SFF itself becomes a powerful player in the field of smart farming, indeed, a respected player that has amassed admired technological expertise and agenda-setting authority.

The spatial–material relations that contribute essentially to the proliferation of smart farming tools in agriculture (Higgins et al., 2017) are equally present at SFF. The interests of the farm's three interacting partners and their respective expertise and authority are closely linked to materiality and space. Consider the following quotation from one of the farm managers in reply to a question about the possible advantages of a construct such as SFF,

> You have everything here. All the technologies are here. Well, if I am interested in a specific technology, or several technologies, I do not have to go to this or that place, or again to a third place, but I can come here and it covers the whole range that exists (Interview, farm manager 3, 11.03.2019).

The farm manager is referring to the fact that SFF enables its members to access in one locality both the technologies that already exist and those that are future oriented and being tested. Although for the manager this is mainly a facilitating factor in his daily work routines, it is helpful in conceptual terms for our analysis of the spatial–material relations with regard to the introduction of digital technologies into agriculture. Our conceptual stance on space as socially produced and as a mediating force for and with materiality (Lefebvre, 1991; Law and Mol, 1995; Raffestin, 2012) is of use here in comprehending SFF's exceptional role in the field of Swiss smart farming initiatives. The technologies that are tested and showcased here, and then employed elsewhere, are being produced in direct association with the concentrated knowledge production and the coalition of authority. It is not possible to produce the expertise on the farm that can then be acquired by others without taking this into account. The everyday and direct association with the technologies and tools at hand means that SFF's material aspect has a direct influence on its own development and on the dissemination of the technologies it is associated with, but also on the production of expert knowledge and the authority arising from this. However, these socio-material relationships are spatially bound to the territory of the farm itself. The farm, which has this spatial–material aspect, becomes a nodal point through which technologies, experts and authority are shaped and, in turn, shape the ways in which digital technologies are disseminated throughout everyday agricultural life in Switzerland.

6. Conclusion

Public–private relationships and the expertise and authority arising thereof are important for understanding how digital technologies are introduced into agriculture. In this article we have drawn upon two case studies (startup company AgroDrone and test facility SFF) to show precisely how expert knowledge and authority are making a considerable contribution to the introduction of smart farming technologies in Switzerland and how this is linked closely with spatial–material dimensions. Our approach was aimed at observing the development and testing of emerging technologies for agriculture and their usage *in the making*. We have argued that in the two case studies we observed different kinds of expertise (practical–technical, spatial–material, legal–scientific) that are informing specific forms of authority (development/innovation, regulatory, scientific). On the one hand, AgroDrone is a standalone private actor interacting with public authorities and, on the other hand, SFF is a hybrid organisation in which private and public actors coalesce and appear as one actor.

In the analysis, we have drawn upon three different kinds of actors that all work closely together. Whereas AgroDrone is a purely private body and FOCA and Agroscope are public organisations, SFF has a hybrid status in which private and public actors are all essential parts of one project and, therefore, merge to become one standalone actor. However, all three kinds of actors are connected through and with the research institute Agroscope. As seen in the analysis, Agroscope has scientific expertise and the authority of evaluation in relation to the ways in which AgroDrone could regulate and authorise the use of its sprayer drone. Although Agroscope is not an active member of SFF, the institute is a direct neighbour and actually uses the farm for its own experiments. That said, although there may not be any legal links between the two, there are certainly informal associations with regard to expertise and authority. Agroscope, in both guises, so it seems, carries out a mediating role by supplying expertise and authority for the development of digital technologies for agriculture.

In this sense, what we were able to discern from the interviews with the three interrelated private and public actors is that there are, indeed, interacting forms of expertise and distinct distributions of authority across the two case studies. Each actor has its own expertise under field experimental conditions: AgroDrone the practical–technical and spatial–material expertise; FOCA/Agroscope the legal–scientific expertise; and SFF the technological and practical expertise. A great deal of emphasis is put on notions of 'interacting' and 'coalition' within the relationships between the three actors (Czempiel, 1992; Akrich and Méadel, 1999; Lipschutz, 1999). The sheer innovative approach of considering a flying drone to be a ground application has been the result of differing expertise that 'interacted' between AgroDrone and FOCA/Agroscope. In the case of SFF, expertise from the different actors involved here also interacted; however, it is important to highlight the coalition aspect of authority that the three partners on the farm together represent. Here, authority is concentrated as the ability to create and pass on knowledge. More than that, SFF is able to decide which technology to further develop, to test and to recommend to the farmers. This practice is not unique, because knowledge in agriculture is often advanced and developed by a network of private and public actors (Ingram, 2018, p. 118) and through a process of experiential learning (Lubell et al., 2014, pp. 1089–90). It even could serve to bridge the knowledge gap between the farming sector and the digital industry if 'greater collaboration between public and private' actors is 'identified as one way of addressing such challenges' (Bryant and Higgins, 2020, p.7).

The analysis has shown that these entanglements are strongly related to questions of power and governance in a digitalised agriculture. We

have emphasised that the public–private entanglements of expertise and authority cannot be comprehended in full without also taking into account their relational and hierarchical power dynamics. Smart farming initiatives are led by powerful coalitions of public and private actors, which all pursue their own or collective interests and contribute their specific expertise and authority to the development, testing and regulation of digital technologies for agriculture and their subsequent dissemination. Global and local actors alike are currently participating in structuring, organising and innovating in the farming sector. We highlight three major points in this respect.

The first refers to the distribution of authority in the relationships under study in a completely relational sense. As outlined in the analysis, the actors in the two case studies are all the source of some kind of authority, which derives from the expertise they hold or, at times, the other way round. According to a Foucauldian understanding of power, this is always the action upon other actions (Foucault, 1982); the diverse sources of authority in the case studies can always only be exercised and put into motion in relation to the respective others. Therefore, for example, the legal–scientific authority of Agroscope only transforms into power when it is exercised upon the actions of AgroDrone or other actors. The regulatory authority of FOCA can only be exercised if there is an action to be regularised in the first place. Or, consider the authority exercised by the vocational centre that trains new farmers; this can only exist through the relational aspects of interaction with the students – through them and their actions.

The second point refers to the power relations that extend beyond the distribution of authority among the human actors in the two case studies and is a return to the socio-material entanglements that we have highlighted throughout the analysis. The authority we have analysed in this article cannot, in essence, only be attributed to the isolated actions upon the actions of the human actors; it has to be understood as the interaction between humans and non-humans. The government's exercise of power is, then, also directed towards 'men and things' (Foucault 2007, p. 97), and the technologies that are being tested and regulated play a significant role in this process. In the case of AgroDrone, for example, the direct relationship it has with the sprayer drone creates the possibility of the company's expertise and source of authority in its respective field. SFF clearly governs human–technological relationships and it is from these that its source of authority and expertise arises.

The third and last point refers to the question of power imbalance and interdependency in the study. The digital transformation of the farming sector is set in motion by startups like AgroDrone, regulatory public actors like FOCA and public–private initiatives like SFF. These kinds of initiatives help to renew farming in Switzerland and advance the digitalisation of the agricultural sector. However, the concentration of authority also merits critical attention. Although some of the farmers may want to adapt to the rapidly growing digitalisation in agriculture, others may not be so keen, but find it difficult to resist and oppose the ways in which the players in the field are shaping the future of their work.

Nonetheless, the force with which this authority can be put into action is not equally distributed. As a startup company, AgroDrone, which relies mostly on investors and assistance from the legal and regulatory authority of the public actors, has a much weaker position within the network of public–private relationships than the agglomerate of private and public actors collected together in SFF; their financial power, their concentration of expertise and their collective endeavour in promoting the introduction of digital technologies into agriculture together form a much broader and wider-reaching possibility of exercising their authority. Effectively, SFF may be considered as a coalition of authority in itself, whereas AgroDrone can only form a coalition in cooperation with the public entities.

As said above, the authority among the actors can always only be exercised through and in relationship with other human actors and things. Using the example of the sprayer drone, it becomes apparent that there is an interdependency between the private and public actors. AgroDrone needs FOCA and Agroscope to regulate the novel technology to be able to spray the vineyards and develop its business. For its part, however, FOCA needs the innovative potential of AgroDrone to reinforce and continuously promote Switzerland's status as a site of innovation. With regard to SFF, a similar interdependency among its three partners can be observed. All of the three bring an element to the relationship that is necessary for the whole to work in the way that is desired and imagined. All three want to be pioneers in their respective fields, which all involve expertise in emerging digital technologies, and they are able to fulfil this expectation through the formation of an interdependent circle of authority and expertise.

We also highlighted the fact that the role of expert knowledge and authority with regard to the introduction of digital technologies into agriculture can best be appreciated by considering their intrinsic relationship to space and materiality. The acquired expertise and authority of the actors we analysed are produced through and are products of their spatial–material embeddedness and their socio-technical relationships. This provides us with a better understanding of the mechanisms that are at play in relation to the proliferation of smart farming in Switzerland. The way in which the specific expertise of AgroDrone and the SFF partners is derived from the spatial–material connections in their respective working fields can reveal a great deal about how the relationship between space and materiality is crucial for the expertise and the authority to become established. This is true of both cases, but especially in relation to SFF, and is particularly important when we think of how materiality is constitutive for the ordering and structuring of the ways in which farmers relate to new technologies (Higgins et al., 2017, p. 195).

What follows from this? Specifically, the point made, that a coalition of private and public actors at global and local levels is advancing the introduction of digital technologies into the Swiss agricultural sector, should in itself become a field of scientific inquiry because it poses questions we have not been able to answer in this article. Although we have outlined how different forms of authority come into being in this field, future research should concentrate much more on private actors such as the global company in the case study. Certainly, there are pertinent scientific interrogations that could be carried out to find out even more about their goals, means and ends, principally with regard to their well-established activity in small countries such as Switzerland. What does this actually mean for local farmers who may not be so open to the idea of transforming their conventional farm into a smart enterprise or do not see the necessity for it?

Considering the public actors, this article was unable to carry out further investigation into the crucial field of knowledge transfer. Although we have categorised the article as belonging to this stream of research, there is much potential for looking into the exact strategies of knowledge production with regard to smart farming at the vocational training centre where the future farmers and consultants are being trained. How can they be given an appreciation of 'digital' right from the very start of their professional training? What will the training consist of and how will it be organised and delivered, and what sort of relationships will be formed with test facilities such as SFF and with other spatialities of agricultural production?

Another aspect this article was not able to cover is the perspective of the farmers themselves. How do they perceive the introduction of smart technologies into their everyday working routines? Or, more to the point of this article, how do farmers experience the influence of the private and public actors in the field in Switzerland? This perspective would be especially interesting to explore in Switzerland with regard to SFF, because it would then be possible to evaluate how demonstrations of new technologies and educational initiatives are delivered to the end user. In addition, the farmers' perspectives would be equally beneficial for research into how exactly they are relating to emerging technologies, tracing back the whole process from the moment of first contact to actual use.

Smart farming technologies are advancing rapidly and are

proliferating in the agricultural sector in Switzerland and elsewhere. This article has shed light on the mechanisms by which these technologies are introduced into agriculture, the role of private and public experts and coalitions of authority within this process and how space and materiality are important factors in the formation of expertise, taking into account the associated underlying power relations. The results of our analysis are also an invitation to scholarship and the wider public to assess carefully and critically the myriad of developments in an agricultural sector that is turning ever more digital.

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Notes

During our research with the drone company (AgroFly), the core team left and initiated a new startup company (Aero41), with whom we continued our study. We therefore chose to use the fictitious name AgroDrone in this article for reasons of clarity.

Author statement

The theoretical and analytical reflection of the paper was conducted mostly in a collective effort by Dennis Pauschinger and Francisco Klauser. Dennis Pauschinger assumed the main responsibility for the writing of the paper and also conducted the fieldwork, on which the paper is based.

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