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Entrepreneurs of the air: Sprayer drones as mediators of volumetric agriculture

Francisco Klauser *, Dennis Pauschinger

Institute of Geography, University of Neuchâtel, Espace Tilo-Frey, 1 2000, Neuchâtel

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ABSTRACT

The article investigates in empirical detail the air-bound practices, expectations and imaginaries that arise from the development and commercialisation of the first authorised drone system in Europe for the automated application of pesticides, which has been developed and sold and is piloted by a Swiss startup company. Sprayer drones make the air relevant for agricultural practices and processes in novel, inherently functionalised and commercialised ways, such is the article's basic argument. Thus, the aerial realm is being encountered as an object of pragmatically motivated alliances and competitions, which depend on the agendas and organisational structures of the stakeholders involved. This leads to a critical discussion of the issues surrounding the increasing instrumentalisation of the air for agro-entrepreneurial purposes, and opens up a wider reflection on how agriculture relates to the air and, indeed, on how to develop a properly 'volumetric thinking' in contemporary rural studies.

1. Introduction

The use of drones in agriculture has increased sharply in recent years (Mazur, 2016; Baraniuk, 2018; Roberts, 2020). Fields of application include soil and field analysis, mapping and animal detection, irrigation, crop spraying and planting (European Commission, 2018; Hunt and Daughtry, 2018; Mogili and Deepak, 2018). According to a quantitative survey conducted in 2017 amongst professional drone users in Switzerland (Klauser et al., 2017), 90% of the farmers who use drones would not use the airspace without the technology and 88% expect other farmers to use the technology in the future. The Food and Agriculture Organisation of the United Nations maintains that "Applications of UAVs [unmanned aerial vehicles] are only limited by our imagination" (Food and Agriculture Organisation, 2018, p. 6). In 2018, the European Commission portrayed agriculture as "one of the primary sectors expected to see sharp uptake of drone technology in the near future" (European Commission, 2018). The US-based Association for Unmanned Vehicle Systems International expects 80% of the future drone market to relate to agriculture (Association for Unmanned Vehicle Systems International, 2013). Indeed, although drones proliferate in many professional fields, the technology seems particularly fitted to the agricultural sector if the legal constraints imposed on drone usage above more densely populated urban spaces are taken into account.

Moving beyond these generalised discourses and expectations, the actual extent to which drones have permeated contemporary farming practices needs pondering. In Switzerland, it appears that drones have been adopted but in some specific fields of agriculture. Amongst these, media attention has focussed in particular on drone usage for purposes of aerial spraying of pesticides in viticulture (Agirinfo, 2020). In the three cantons of Aargau, Zurich and Thurgau alone, 60 wine growing farms currently use the technology (Moser, 2020). What is most remarkable, however, is not the absolute number of drone-using farms, but the rapid evolution thereof, given that spray drones are legal in the country but since 2019. This reiterates the high potential of the technology, if legally permitted. Contrary to Switzerland, however, aerial spraying by drones remains to date banned in other European countries.

Drawing upon research projects on civil drones and on Big Data in agriculture (supported by the Swiss National Science Foundation; grant nos. 100017_162462 and FN 10DL1A_183037), the present article focuses on the very moment in which drones have started to be used for aerial spraying in Switzerland. More specifically, the article investigates in empirical detail the air-bound practices, expectations and imaginaries arising from the development and commercialisation of the first authorised drone system in Europe for the automated application of pesticides, which has been developed and sold and is piloted by the Swiss startup company AgroDrone (fictitious name). The company

* Corresponding author.
E-mail addresses: francisco.klauser@unine.ch (F. Klauser), Dennis.pauschinger@gmail.com (D. Pauschinger).

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specialises in viticulture in Western Switzerland.

This empirical focus allows exploration of the corporate interests laying behind the production, diffusion and use of spray drones, and of the ways in which these invest, indeed "capitalize" (Richardson, 2018) the air in agriculture. If drones make the air more accessible for agriculture, such is the paper's key argument, they do so in inherently functionalised and commercialised ways. The aerial realm is being appropriated as an object of pragmatically motivated alliances and as a contested space of tensions and competitions, both of which arise from the agendas and organisational structures pertaining to the stakeholders involved. The resulting instrumentalisation of the air for agro-entrepreneurial purposes raises all kinds of critical issues that deserve careful attention, both from an academic and a socio-political standpoint. What are the interests laying behind, and implications of, the ways in which the air is being appropriated in contemporary agriculture? What chances, risks and societal struggles does this imply?

The article offers an exploratory take on these questions, thus advancing a number of preliminary arguments that will require further refinement and extension in future research. In so doing, the article also pursues a wider theoretical project, which has been initiated elsewhere (Klauser, 2021), consisting in the development of a properly 'three-dimensional approach' to the study of the ways in which digital technologies today transform the 'spaces of the everyday' (Di Méo, 1996), understood not only in their earthly dimensions (i.e. as the ground), but also in their voluminous, aerial and subterranean dimensions (Graham, 2016).

2. Aircraft in farming

Aircraft have long been used in agriculture, but this has been accompanied by heavy controversy, especially in connection with spraying. The European Union has banned all aerial spray applications since 2009, mostly for ecological reasons (Zwetsloot et al., 2018). Switzerland, in contrast, adopted a more liberalist approach, aiming to limit the use of helicopters to the spraying of specific terrains and crops (Bauernzeitung, 2014). In 2019, the country was the first European nation to allow the use of sprayer drones (Keystone-SDA/dos, 2019). The relevant regulatory framework treats sprayer drones in the same way as ground-based equipment for the application of pesticides, unlike helicopters. Hereby, the key argument was that drones produce less spray drift than helicopters and as such resemble more precise and thus ecological technologies deployed on the ground. The company AgroDrone, i.e. the object of the present case study, has contributed in differing ways to this legal arrangement, as shown below. On April 15, 2019, the company's sprayer drone obtained the first certification in Switzerland for a 'ground application system' (Pflanzenschuetzer, 2019).

Thus, applying pesticides from the air is not new, but sprayer drones bring the air ever closer to the agricultural everyday, both in spatial terms, because they fly lower than helicopters, and in legal terms, because of the simplified regulatory procedures. Furthermore, sprayer drones also make it cheaper, technically simpler and, thus, much easier to farm through the air than does the use of helicopters. For example, AgroDrone's sprayer drone can be bought for 49,500 Swiss francs (Eppenberger Media, 2017) and used after a 2-h training course (Interview AgroDrone pilot, 2018).

3. Big Data and the air in agriculture

The article's investigation of how sprayer drones change the relationship with the air in agriculture brings into dialogue two main literatures. First, the article draws upon the growing body of work that explores the driving forces, functioning and implications of software-driven technologies in the farming sector, channelled through notions such as precision agriculture, smart farming and Big Data agriculture (Klerkx et al., 2019). These literatures highlight a range of opportunities that arise from the digitisation of agriculture in terms of increased productivity, profitability and sustainability (Bongiovanni and Lowenberg-Debower, 2004; Jullien and Huet, 2005). However, scholars also point to a number of risks, including techno-dependency, problems of data security, concerns about privacy (Wolfert et al., 2017; Klauser, 2018), the potential impact on agricultural employment rates and product diversity (Bolman, 2016; Protopop and Shanoyan, 2016; Van Es and Woodard, 2017; Walter et al., 2017), the asymmetries of power between individual farmers and global companies, and the digital divide between capital-intensive farms that benefit from smart technologies and those unable or unwilling to follow (Fraser, 2018).

Thus, the use of smart digital technologies in agriculture has been a recurring theme, especially in its economic dimensions and implications. From these literatures, the paper distills an overall sensitivity for the study of the role of IT companies that shape agricultural practices and processes through the provision of novel technology solutions, technical expertise and labour (Fortané and Keck, 2015). More specifically, the article connects with those studies that explore the public–private practices of collaboration and experimentation through which novel smart-farming solutions are being developed, implemented and stabilised for more normalised use. Starting from the premise that smart-farming solutions are not value-free, but are produced by and, in turn, reproduce specific power relations (Bronson and Knezevic, 2016), such studies question what lies behind particular technologies by looking at where, by whom and how they are produced and, subsequently, disseminated as exemplars to follow, with a view to understanding better how they shape the agricultural future (Van Es and Woodard, 2017; Moreiro, 2017).

Linked to the above, further emerging work also studies and questions the discursive activity and storytelling surrounding and promoting specific smart-farming projects. Such discursive–analytical investigations offer a crucial insight into the questions of how and where particular understandings, imaginaries and expectations around smart farming are being established, and how these favour specific evolutions in the field (Carolan, 2018a). They invite a focus on smart-farming initiatives not only as products of technological innovation, but also as achievements of discursive engineering (McMurry, 2012), considering the ingredients of the storytelling around smart technologies as "operators of power in an emergent field of thought and action" (Söderström et al., 2014, p. 310).

In its use of the AgroDrone case study, the article starts from the assumption that thought and practice are simultaneously present in, and constitutive of the drone-mediated encounter with the air in agriculture. The company's taking to the skies is approached as a process that involves not only a wide range of practices of collaboration and experimentation, but also a multitude of discourses, both of which need to be unpacked empirically if we are to understand the resulting engagement with the air and the issues arising thereof. In so doing, the article adds two main aspects to existing literatures. First, it moves beyond the predominant focus of existing work on the role of big corporate players and interests – by companies such as John Deere and Monsanto – and the subsequent dissemination of corporate power over land and people (Fraser, 2018; Carbonell, 2016; Carolan, 2018b). Although there are many good reasons to question the ways in which companies operating globally have an impact on agricultural practices, the role of local, regional and national agency, motivation and expertise in smart farming should not be forgotten. Innovation and change can also emerge from bottom-up initiatives. The AgroDrone case study makes a contribution towards filling this research lacuna.

Furthermore, the article adds a third, aerial dimension to existing work on agricultural 'techno-politics' (Mitchell, 2002). This addition is all the more important because truly empirical studies on the use of drones in agriculture are still extremely rare (Michels et al., 2020), although there is now a growing literature that discusses the opportunities and risks associated with the technology on a general level (Bolman, 2016; Krishna, 2016). This leads neatly to the second body of

research that is of relevance to the analysis suggested here, revolving around the problematics of civil drones and the air.

Existing social–scientific research broadly ignores drones in agriculture. However, there is now an increasingly sophisticated literature that explores drones in other professional fields, with a particular focus on military and policing applications (Williams, 2011, 2013; Wall and Monahan, 2011; Chamayou, 2013). The relevant studies ask what difference it makes that drones operate in, from and through the air and problematise, for example, the asymmetries produced by the fact that the machines allow their users to see and, indeed, act from a vertical and horizontal distance (Gregory, 2011). Scholars have also shown how drones redefine the aerial sovereignty and supremacy of the state (Neocleous, 2013), how they operate within, and affect the national and international struggles between various actors and interests with regard to airspace (Aubout, 2011) and, in turn, what security and regulatory issues arise from the increasing occupation of airspace by public and private drones (Bassi, 2020).

Thus, in its portrayal of drones as both the product and producer of novel regimes of 'aerial governmentality' (Adey et al., 2013, p. 179), existing academic work shows that drones make airspace become not only more visible and available for political and social reflection and action, but also increasingly commercialised (Crampton, 2016; Jackman, 2016) and contested in the sense of being a space in which and through which all kinds of interests are being conveyed (Klauser and Pedrozo, 2017). Connecting with this, there is today a rapidly growing literature that highlights the inherent functional and spatial malleability of the drone, thus pointing at the multiple ways in which the technology exceeds its militarized and police-related usage and opens-up a range of socially more widely distributed possibilities of acting in and through the air (Jensen, 2016; Jablonowski, 2017; Choi-Fitzpatrick, 2020). This line of argumentation invites a more systematic reflection on the aerial realm as a socially produced and carefully managed socio-political reality in a Lefebvrian sense (Lefebvre, 1991) and, indeed, on space as a three-dimensional volume, rather than as a planar surface (Kaplan, 2006; Williams, 2011).

Adding to these literatures, the AgroDrone case study affords insight into the drone-mediated appropriation of the air from a specific agro-entrepreneurialist viewpoint, thus moving beyond the predominant foci on urban space and on state actors that characterise contemporary engagements with the drone problematic (Garrett and Anderson, 2018). Pursuing Adey's claim "to expand our knowledge of airspaces and the social relations they enhance and make possible" (Adey, 2010, p. 15), the article studies the specific relationship that AgroDrone has established with the air in its sprayer drone project, both discursively and in a practical sense.

This investigation is structured into three main parts, which correspond to three overlapping phases in the company's appropriation of the air. The first analytical part, entitled 'Novices of the air', traces the discovery of the airspace by AgroDrone in its elemental, legal and economic dimensions as a space in which and through which specific business interests may be pursued. The second part is entitled 'Experts of the air' and studies the ways in which AgroDrone positions its services and types of expertise with regard to the airspace, to ensure this is a space that is carefully defended from other competitors. Third, under the heading 'Capitalists of the air', the article highlights the third phase of AgroDrone's inherently commercialised relationship with the air, which is channelled through the company's quest for rentability and further expansion.

4. Methodology

The article addresses the drone-mediated discovery of the air in agriculture from the perspective of the specific range of collaborations and discourses surrounding the Swiss startup company AgroDrone. Since 2016, facilitated by a long-term exchange of correspondence and several previous meetings with the co-founder and CEO of AgroDrone, the authors of this article have been allowed insight into the various stages of development, commercialisation and homologation of the company's sprayer drone.

A total of 11 in-depth interviews were conducted with employees and pilots from the company, and with representatives from public authorities, involved in the homologation of AgroDrone's sprayer drone. All interviewees are listed below:

- Co-founder and CEO, AgroDrone: June 21, 2018
- Technician-in-chief, AgroDrone: August 28, 2018
- Chief pilot, AgroDrone: October 3, 2018
- Drone pilot 1, AgroDrone: October 3, 2018
- Drone pilot 2, AgroDrone: August 20, 2018
- Head winemaker, city of Lausanne: March 24, 2019
- President, local spray helicopter programme in viticulture: April 10, 2019
- Project leader, mycology viticulture, Agroscope: March 20, 2019
- Leader, UAS Integration Programme, Federal Office of Civil Aviation: April 03, 2019
- Co-leader, Innovation and Digitalisation Unit, Federal Office of Civil Aviation: March 12, 2019
- Head of Research Group, Digital Production, Agroscope, March 11, 2019

The five interviews conducted in 2018 were arranged after discussion with the company's co-founder and CEO, taking into account both the company's internal organisation and functioning and the specific forms of expertise required in the development of the sprayer-drone project. This first series of conversations then informed the selection of a second group of interviewees, composed of internal collaborators and policy makers, which played a fundamental role in the homologation of the drone. Thus adopting a micro approach, as developed by Actor Network Theory (Latour, 1987), the aim was to study, from the specific perspective of AgroDrone, the making of its spray-drone project and of the company's unfolding relation with the air.

For different practical reasons, arising from the limited duration of the research project, and to give strong focus to the case study, the decision was taken not to interview representatives from the companies or academic institutions that provided the specific hardware parts and software solutions, which AgroDrone then assembled and further developed in its sprayer-drone project. Such interviews with high-tech experts unrelated to the field of agriculture would have offered but very limited insight into the practical and discursive aspects of establishing sprayer drones in Swiss agriculture and in opening up the air as a context and perspective of agro-entrepreneurialist practices and interests.

Yet importantly, the AgroDrone case study also included extensive non-participant observational research in a variety of settings, from specific drone missions to internal meetings and training sessions. This allowed the exploration of the situated emergence of particular ideas and practices, associated with the company's spray-drone project, and with its logics of relating to the air.

Finally, the case study relied on the examination of existing reports and grey literatures from the institutions relevant to the case study. These included secondary sources such as media coverage and websites of relevant stakeholders, which were used to trace the emergence of the discursive and practical elements involved in the manufacture and use of the sprayer drone. Conversations held with other competing companies at technology fairs also provided important information about a range of contextual issues and debates surrounding the use of spray drones in Switzerland. While these will not be explored in detail in this article, they provide important background insights for the analysis outlined below.

5. Novices of the air: encountering the air in its economic, legal and elemental dimensions

Registered as a limited company in April 2017, AgroDrone quickly gained national and international media attention and business acclaim. The startup company was given the Innovation Award from the Banque Cantonale du Valais in 2017 for its sprayer drone, which went into commercial production in the following year (Startupticker.ch, 2017). However, what sounds like a smooth taking to the air was in reality a far more complicated process:

> They [the Swiss federal offices of agriculture and civil aviation] requested us to do all kinds of tests and assessments, including deposit quality, spray drift, airflows generated by the drone, spraying homogeneity, etc. It cost us a fortune! Each time, I had to go back to my investors to tell them 'yeah … you should put on some more because we have to do this and that'. In parallel, there was this Swiss German guy … – it still annoys me, just talking about it … – who used to spray with his DJI drone, without any kind of authorisation (Interview, Co-founder and CEO, AgroDrone, 21.6.2018).

The preceding account from the company's co-founder and CEO provides insight into the initial phase of the company's drone-mediated appropriation of the air. First, it underscores the economic rationale underpinning AgroDrone's engagement with the air. From the start of the project, the air was invested with monetary value and made explicit through logics of capital investment and return. The nascent drone-mediated relationship with the air was driven by commercial hope and competition. In other words, the air was discovered as an economically instrumentalised realm of action.

Second, the account recalls the long series of tests and assessments necessary for AgroDrone to be granted legal authorisation to spray from the air. At AgroDrone's launch in 2017, there was no legal framework in place in Switzerland for the application of pesticides to crops by agricultural drones. Therefore, AgroDrone faced the financially demanding and time-consuming task of contributing to the development of a novel type of certified air usage. The aerial realm was encountered not only as economically coveted and contested, but also as a politically administered and legally regulated space.

Third, the quotation highlights that in the unfolding process of experimentation and testing, the air was also discovered in its very elementality as a more or less drone-affected and, thus, agitated and risky gaseous reality. This gave rise to an additional set of considerations and air-related knowledge practices, ranging from specific measurements and risk calculations to technical questions in relation to spray drift, homogeneity and deposit quality.

This initial picture of the drone-mediated relationship with the air as an economic, legal and elemental reality can be further refined from the perspective of the policy-makers involved:

> For crop productions such as viticulture and arboriculture, we consider drones as a ground application [of pesticides], meaning that you can spray all products approved on the ground. For helicopters, you have a specific list and cannot use all spray products. … This approval of agricultural drones is based on a risk evaluation, which takes into account our spray drift measures. Then, for field crops, we've seen that up to 15–20 m, drones generate more spray drift than a horizontal boom control device that is close to the ground. Above 20 m, however, the spray drift is smaller, because the drone's air flow is quite vertical. … So simply put, you can say that for three-dimensional cultures, all approved products can be used. For all other crops, there must be a 20-m distance (Interview, Project leader, mycology viticulture, Agroscope, 20.3.2019).

The above quotation not only summarises the legal framework in Switzerland in relation to sprayer drones that was put into place in 2019 as a result of the aforementioned test phases, it also offers an additional viewpoint on the drone-mediated encounter with the air in agriculture. First, the point about the legal difference between sprayer drones and helicopters with regard to the approved spray products is worth reiterating; it emphasises the fact that the air is being occupied and invested by differing technologies and legal principles. If drones are not the first technology to create an instrumentalised relationship with the air in agriculture, functionally, they extend and simplify this relationship.

Furthermore, in pointing to the relationship between crop production on the ground and authorised spray practices in the air, the quotation illustrates that the air masses in which drones fly must be understood as situated volumes, which are linked intrinsically to the material and practical realities on the ground. In the quotation, this 'vertical reciprocity' between the air and the ground (Adey, 2010, p. 3) is expressed in regulatory terms, but it can also be seen on other levels, as shown below. Here, it is interesting to note in particular how the Swiss regulatory framework for sprayer drones deals with the question of verticality. (Flat) field crops imply a minimal flight altitude of 20 m, whereas vertical crops, such as those in vineyards and timber plantations, can be flown over at whatever height the pilot sees fit. The crop's verticality defines the drone's verticality. The vertical organisation of the ground is bound up with the vertical organisation of the air. However, in this picture, the drone itself, in both its hardware and software, should not be forgotten, as the following quotation stresses:

> We authorise [specific types of] drones. … But air drift measures need a lot of work and are complicated to do. We don't do this for every machine, but stick to measuring its air flow only. As we've already done all the air drift and airflow tests for two models, we've now got a [predefined] range. So if we see that the airflow [of a new model] is within this range, we consider that its air drift also falls within the acceptable range. … The key points [for us] are flight precision, automated flight and spraying nozzles … and the pump's functioning, to avoid that it [the drone] sprays outside of the defined zone (Interview, Project leader, mycology viticulture, Agroscope, 20.3.2019).

Our interviewee's insistence on the legal approval of specific types of sprayer drone emphasises that the drone-mediated relationship with the air also involves a technical dimension. Precision and automation are required for the drone to be allowed action in the air. Thus, the relationship with the air is also software-mediated. Spraying pesticides not only requires specific hardware and practical expertise (in relation to farming, piloting, etc.) but also a range of technical equipment, predispositions and skills.

It is, indeed, on this level that AgroDrone's tests and experiments fed most directly into the nascent regulatory framework around sprayer drones in Switzerland. In providing one of the two drones on which detailed spray drift and airflow tests were carried out, as mentioned in the quotation above, the company contributed to the definition and subsequent institutionalisation of the acceptable range within which drones are allowed to have an impact on the air (and, thus, on the ground). It is on this basis that the regulatory understanding of drones as ground-based equipment for the application of pesticides has been built. In shaping the appropriation of the air as a field of agro-policy intervention, AgroDrone not only depended on, but also co-produced the novel drone-related 'regime of aerial governmentality' in Switzerland (Adey et al., 2011, p. 179).

6. Experts of the air: practical and technical engagements with the air

This discussion can be further refined if we focus on how sprayer drones make the air explicit not only as an object of economic hope and competition and as a problem of governance, but also as a lived reality. To this end, the section that follows explores how AgroDrone sees its role and expertise, and what kinds of practical and technical engagement

with the air result from this. Consider the following quotation:

> When we sell a drone, myself and X, we go to our client. We spend two hours with them to explain how it works, although even two hours aren't enough. If you're not passionate about it, you'll quickly forget things. Even myself, at the start, I was afraid of flying [with the drone]. It's really impressive. Then also, piloting and using the drone above a steep vineyard are two completely different things. You start here and you have to use it up there [shows]. So there's also a whole logistics of the field. If you don't have a spot to take off, all the time you lose until the engine is up there will be lost time for spraying. … It's these kinds of things that we've come to understand in practising ourselves. People who'll use the drone will also develop their land accordingly (Interview, Technician-in-chief, AgroDrone, 28.08.2018).

It is interesting to note how in the above account, AgroDrone's expertise is being related to the air. Flying is described as something 'impressive' and something a person could easily be 'afraid of', especially above steep vineyards. However, because of the experience and passion of its pilots, AgroDrone offers reliable, field-tested services in and through the air. Indeed, throughout our interviews, manual piloting skills as a means of flying better and more safely have been highly valorised as a source of pleasure and pride for pilots and as a factor that makes sprayer drones economically more interesting for farmers. In the quotation above, AgroDrone's pilots are praised for not only knowing how to fly, but also because they know how to use the air most efficiently in logistical terms. Passion and practical expertise are of immediate economic concern and relevance.

In this respect, the quotation also recalls that AgroDrone not only sells a service (spraying) but also a product (its drone), together with a 2-h introductory course on the skill of flying. The company not only prides itself on knowing the air, but also on its ability to teach people to fly a drone. It sees itself as a key player in the formation and transmission of the knowledge and practices related to how best to use the air in agriculture. Indeed, AgroDrone's co-founder also launched the first 'Swiss Drone Academy' a few months before AgroDrone.

Finally, the quotation ends with a seemingly banal but important comment with regard to the fact that sprayer drones also affect the organisation on the ground. Here, this is connected with the use of platforms for landing and takeoff. In other interviews, the drone's impact on the ground was also related to the actual practices of cultivation themselves:

> You have to accept some cultivation changes if you want to operate by drone. Doing like we've always done, with a light leaf thinning of the grapes' zone, will be complicated. For me, operating by drone implies a much heavier leaf thinning (Interview, pilot AgroDrone who is responsible for the vineyards in the city of Lausanne, March 24, 2019).

In this account, the reciprocity between the air and the ground lies in the way in which the use of the former has an impact on the organisation of the latter. Specific knowledge and practices in relation to the air also produce specific knowledge and practices in relation to the ground. In this respect, sprayer drones also form a novel relationship with the ground. Interestingly, our interviewee continues:

> It's organic and it's ultra-precise. … These are things that are very positive, which also produce a more dynamic, modern and interesting image. I think there's a possibility here to favour the promotion and commercialisation of our wines, if we put more emphasis on these kinds of new technologies. We are losing the youth amongst the wine consumers. They drink beer, no more wine. And here, we may have something to interest them, to prove that it's something modern (Interview, pilot, AgroDrone who is responsible for the vineyards in the city of Lausanne, 24.3.2019).

The quotation emphasises that sprayer drones affect agriculture not only in a practical sense, in that they change existing farming practices and force adaptations to be made to the crops and fields that need spraying, but also symbolically, in that they bring particular values and imaginaries into the farming sector. Of course, a much more detailed study of how agricultural drones are being perceived by the population would be necessary to differentiate our interviewee's vision of the technology's additional marketing potential for farmers. Here, I am content to take this comment as an indication of (1) the link AgroDrone has made between the symbolics of its technology and the symbolics of farming, and (2) the way in which the company's drone-mediated relationship with the air is bound up with wider questions concerning society's perception of the technology, of farming and, indeed, of the air.

Moving beyond the different facets of AgroDrone's practical expertise, our interviews also show how the company's position is defined by its technical know-how, which arises from the development of its drone. The quotation below testifies as much, referring to AgroDrone's ambition to develop its own flight controller.

> Basically, the flight controller is all the electronics that manage the drone's flight. From the programming of the exact path and height of the drone, to the opening and closing of its spraying nozzles. … For this we work with a Chinese company that produces industrial flight controllers for agriculture. We have a firmware, a software that is adapted to our needs. But we realise that we must have technological partnerships with Swiss companies, to develop our own controller and with research institutions such as the EPFL [Swiss federal institute of technology] and the HES [University of Applied Sciences and Arts] who can be here, see the actual reality, in an hour and a half. The Chinese fabricate flight controllers for rice fields that are quite flat and rectangular. The level of complexity is very different from the vineyard terraces that we have here, in Switzerland, with its steep slopes and manifold parcels of land (Interview, Co-founder and CEO, AgroDrone, 21.6.2018).

Again, the quotation tells us a lot about the company's relationship with the air. The technical challenge of developing a novel flight controller is bound up intrinsically with the challenge of optimising the drone's stability and precision in the air, both horizontally (taking into account the material conditions and administrative geometries on the ground) and vertically (following the terrain's varying degrees of steepness, whilst also avoiding dangerous obstacles such as power lines and posts). The issue of verticality in particular was mentioned repeatedly in the interviews. The more complex the ground in its verticality, the more complex is the use of the air. The air, therefore, depending on its connection with the ground (here in a material sense), also obtrudes as a technical problem relating to the automated management of verticality. Because of the drone-mediated appropriation of the air, the vertical dimension becomes a new opportunity and a new challenge in unexpected ways.

Furthermore, the quotation is interesting in that it shows how in the search for improved precision through automation, the air is being integrated within a wider coalition of expertise, in which the drone itself – in its software and hardware – plays an important role. To understand AgroDrone's relationship with the air, we also need to understand the company's relationship with its partners and competitors. These relationships are not only about technical expertise, but also about geographical proximity. Collaborating with Swiss institutions is important because they know the reality in which AgroDrone operates, and they can intervene or be visited more easily in case of a technical problem. This positions AgroDrone within a complex field of stakeholders and interest, which also affect the company's relationship with the air.

In sum, the ways in which AgroDrone sells its services and its drone make the air an explicit object of professional expertise, both in a practical and a technical sense. Relating to the air becomes a profession

that is embedded in all kinds of interactions and considerations – from how far and how high to fly and what obstacles to avoid, to how to improve the technical elements and cooperation between stakeholders. What emerges is a complex, inherently commercialised 'socio-technical assemblage' of the air, in a Latourian sense, i.e. as a reality composed of combined and co-constituted technical and social elements (Latour, 1993, p. 62).

7. Capitalists of the air: the quest for increased profitability

Throughout the interviews that were conducted, the issue of economic profitability was raised repeatedly and can be divided into three sub-aspects: how to increase the company's efficiency, autonomy and (geographical and functional) reach. As shown below, these three aspects are also related to the question of the air. Consider, first, the role of the skilled pilots employed by AgroDrone in its search for increased economic profitability:

> Between our first applications and the most recent ones, we have reduced by half the time needed. So inevitably at the start of the season it didn't seem profitable. At the end of the season we realised that we were approaching more competitive times. So I think it's all a question of pilots. To offer a service, you need enough pilots. And this will be the challenge of the coming winter, to find people, to train them (Interview, Drone pilot 2, AgroDrone, August 20, 2018).

The quotation is interesting because of its emphasis on practical experience as a way of becoming quicker and, thus, more profitable and competitive when compared with peer companies and other spray technologies (by helicopter, tractor, etc.). Consequently, the air is being invested not only with novel spatial logics of action, for example, those revolving around the issue of verticality, as seen above, but also with novel temporal logics of action, revolving around the need for acceleration and speed that is both technically possible and practically achievable in the particular context. As Paul Virilio has put it "if time is money, as they say, then speed is power" (Virilio, in Armitage, 2001, p. 26). As far as AgroDrone is concerned, speed is the power to strengthen its economic position and profits.

Linked to the question of temporality, the quotation also bears witness to AgroDrone's annual working cycle in its reference to the training of new pilots over the winter months. AgroDrone's relationship with the air follows an annual rhythm, from the recruitment, training and preparation phases to the actual spraying period. The relationship with the air is fundamentally dynamic, both in its gradual evolvement over time, for example because of the accumulation of practical expertise, and in its cyclical logic that follows the cultivation phases of the crops being treated.

Furthermore, the search for increased efficiency and profitability also has a technical component. This goes back to AgroDrone's quest for improved precision in the air and greater autonomy in its technical range of action and evolution through the development of its own flight controller:

> The problems we've had here in the Valais, they've never had in China, you see? Our modifications we give them, it's great for them. They have these modifications and they know that in all European valleys they will be able to use this kind of firmware. These are precious things that we've needed years to find out, develop, change, and which we'd prefer to remain internal. If we don't have the money, we can't develop new things and we're always limited. That's why we've just joined forces with a French company specialising in the drone business. We will try to accelerate the whole movement, we need a lot of money. But that's how it is. We'll have to sell many machines and then we can develop. The big aim is to develop our own flight controller. To make sure that everything we've learnt so far remains with us. For the time being, we rather help others (Interview, Chief pilot, AgroDrone, October 3, 2018).

With regard to the issue of profitability, what stands out from the above quotation is the interviewee's frustration with AgroDrone's dependency on its Chinese software provider. As far as he is concerned, this means to add value to and therefore help the dissemination and subsequent standardisation of another company's software. Knowledge of how to use the air is portrayed as a precious economic good, which accumulates over the years and subsequently translates into software. To keep this knowledge internal, AgroDrone needs additional research and programming capacities, which, in turn, require further capital investment and strategic partnerships. The sprayer drone-mediated appropriation of the air also becomes a matter of corporate interest. The emerging socio-technical assemblage of the air is being internationalised and complexified.

Linked to this, AgroDrone's quest for increased profitability is also, fundamentally, tied up with the strategic objective of further expansion, both in a functional and a geographical sense.

> The drone permits going where people cannot or where this becomes complicated. But of course, we also like to use it above potatoes, field crops, flat terrains … We have an enormous amount of demands, everywhere. The main problem is that the law in other countries is different. Switzerland is very flexible … but others aren't. Like France, with its many vineyards and crops, who starts to think about it, which is very interesting for us. … With our drone, we can spray almost everything, painting, cleaning of greenhouses, we were asked to spray solar panels and even to spray above 747s [jumbo jets]. It's a small company that will become a big one (Interview, Drone pilot 1, AgroDrone, October 3, 2018).

Our interviewee dreams of a big company that will use the air for many additional types of crop spraying and whose reach will extend far beyond the farming context. His drone-mediated expectancies and imaginaries of an expanding horizon, which will result in additional business profit made in other countries, imply a two-sided idea: making the company's use of the air ever-more standarised and trivial. This depicts an increasingly important field of 'exemplified actions through the air', which AgroDrone aims to provide, thus moving from country to country and from place to place, reproducing and exporting its inherently technocratic and entrepreneurial vision of the air. Legitimised by its technical and practical expertise, our interviewee sees AgroDrone as an 'obligatory passage point' (Latour, 1987) in the organisational settings and coalitions of authority that underpin and shape the technically enabled and economically motivated instrumentalisation of the air.

In sum, driven by AgroDrone's quest for profitability, what emerges is a tripartite capitalist engagement with the air, which is channelled through logics of capital accumulation and investment, increasing efficiency and expansion, and which pushes towards a standardised technocratic instrumentalisation of the air in agriculture and beyond.

8. Conclusions

The AgroDrone case study shows that in bringing the air to prominence in novel ways as an object of agricultural imaginaries, concern and practice, sprayer drones generate an inherently entrepreneurial way of relating to the air, understanding it, approaching it and of acting in and through it. This analysis is important for at least three main reasons.

First, the article offers a rare empirically grounded perspective on the making and functioning of contemporary techno-politics (Mitchell, 2002) in the agricultural sector, which complements the almost exclusive focus in existing literatures on Anglophone contexts and on big corporate players, who specialise in ground-based technologies. Of course, many particularities from the case study explored might differ in other fields of agriculture, in other national contexts or in relation to other smart-farming technologies or stakeholders. Case by case, smart-farming schemes vary significantly in terms of the actors, strategies, interests and instruments involved. Yet, and in accordance with the

growing social–scientific literature on smart farming, it may be asserted that the insights provided into the commercially motivated interests, practices and relationships lying behind the drone-mediated appropriation of the air, all with the promise of more efficient and sustainable farming, are likely to be of more general and, hence, exemplary value.

An important issue arising from this relates to the question of how the increasing importance and scale of high-tech companies in farming changes the very ways of dealing with the spaces and crops to which the technology is being applied. Exemplified by AgroDrone's self-confident ambition with regard to further geographical and functional expansion, there is good reason to assume that the technical expertise of companies that are operating increasingly on a global scale is likely to become ever more important in future years. Such companies might tend to challenge the position of traditional decision-makers and farmers not only with regard to agricultural matters, but in relation to the governance of everyday rural life more generally. It is, therefore, fundamentally important to investigate further the effects of these developments on how farming is understood, regulated and practised, and to reflect critically on how entrepreneurial goals, particularly when they intersect with public goods such as the air, should be formulated with regard to wider considerations of food security, sustainability and quality of life. More specifically, in the case at hand, a critical question for further research is how AgroDrone changes the very ways in which farmers themselves relate to their cultivated land and to the air above it.

Second, the exploratory analysis presented by the current article is important in that it opens up a more systematic reflection on how agriculture relates to the air and, indeed, on how to conceptualise the air as a lived and socially produced and instrumentalised reality in a Lefebvrian sense (Lefebvre, 1991). The AgroDrone case study is a first step in this direction, highlighting a series of significant dimensions of the air that need further empirical attention and theorisation. Namely, the drone-populated air has been described as an economically contested, coveted and instrumentalised space and as a problem of governance, but also as a vertically and horizontally organised volume that is being invested with all kinds of expectations, imaginaries, forms of expertise and practices. Thus, the air should be understood not only in its elementality, but also as a social, economic and legally defined reality that is, inherently, connected with the material, administrative and social reality on the ground and bound up with all kinds of actors and technologies that are situated on varying geographical scales. The emerging socio-technical assemblages of the air are not value-free, but shaped by complex relationships and interactions that also have an impact on the ways in which farming is practised and understood today. This discussion could be taken as a starting point for a wider enquiry and more systematic research agenda that would study, question and conceptualise the relational configurations of material and non-material realms, practices, technologies and imaginaries that co-produce and are a result of the present-day encounter with Big Data and the air in agriculture.

Third, and following on from the previous point, the present case study is important in that it pushes towards a more systematic reflection on the possibility, scope and basic vocabulary of a properly three-dimensional, volumetric thinking in contemporary rural studies. All too often, rural studies are concerned exclusively with farming as an ensemble of practices and processes that occur on the ground and, thereby, create specific forms of spatial organisation that imply all kinds of border lines, field grids, infrastructural networks and flows of people and things. Although these studies are of crucial importance, they convey a two-dimensional terminology and thinking, which approaches the spaces of farming as planar surfaces, rather than as three-dimensional volumes. As seen, farming also deals with and works though manifold issues and logics of verticality and voluminosity. The drone problematic could offer one possible prism through which to develop further a more systematic consideration of the complex three-dimensional spatialities of farming as it is lived, perceived and conceived today.

Author statement

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

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