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Advancing AKIS with assemblage thinking

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ABSTRACT

The establishment of effective national agricultural knowledge and innovation systems (AKIS) became a European policy imperative in the 2010s, lodged in a political ideology which emphasised the importance of innovation to economic growth. We argue that the recent deployment of the AKIS concept in EU policy presents important opportunities for the agricultural sector and associated academic research but has significant weaknesses in terms of the scale of analysis (over emphasis on national levels) and disconnection from academic thinking on innovation processes. In this paper we progress the AKIS approach by utilising assemblage theory. We argue that assemblage concepts – in line with other 'more-than-human' approaches - offer mechanisms for recognising and integrating the role of non-human actants in innovation processes. Inclusion of these actants highlight the co-constructed nature of farm knowledge and associated transition processes. Assemblage concepts of historicity and rupture demonstrate how the path dependencies of farming are embedded in the material conditions of production, and the learning processes which occur when path dependencies are interrupted. We illustrate these contentions with empirical case studies of the 'microAKIS' – self-assembled farmer knowledge networks and associated processes - characterising four innovations across Europe: the introduction of a new commodity (avocado) in Greece, mainstreaming of robotic milking in Norway, retro-innovation of direct marketing in Latvia, and outsourcing of (dehumanised) farm labour in France.

1. Introduction

The acronym "AKIS" (Agricultural Knowledge and Innovation System) has become a commonplace referent for the specific organisational and institutional arrangements established at national scale to develop the agricultural sector. It is increasingly positioned as a central concept for framing innovation support policies for the sustainable development of agriculture (Brunori et al., 2013; Curry and Kirwan, 2014; Maye, 2016). The acronym is widely used in European policy documents, in the global agricultural extension literature, and has been recognised by international institutions (e. g. OECD, the World Bank). In this paper, we offer a critical advancement of AKIS, utilising assemblage theory (Deleuze and Guattari, 1980; DeLanda, 2016). Our aim is to address two specific issues with AKIS thinking: the need to better consider a micro (farm) level perspective on the dynamics of AKIS, and to re-ground the AKIS concept within recent thinking on innovation processes, particularly the relational and 'more-than-human' turns. We argue that use of assemblage theory enables us to ground AKIS thinking more strongly in how farmers are responding to major challenges such as climate change, digitalisation and new labour structures, as well as the materialities associated with these challenges. This critical progression of AKIS will enable scientists, policy makers and stakeholder groups to better

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understand and support contemporary innovation processes.

Academic conceptualisation of 'Agricultural Knowledge and Information Systems' is most commonly attributed to Niels Röling in the late 1980s (Röling, 1988; Röling and Wagemakers, 1998; Röling and Engel, 1991), who drew on extension studies, science communication, interdisciplinary research, and a range of social science disciplines (Röling and Engel, 1991; Hall et al., 2006). Röling's conception of AKIS promoted the idea that farmers exchange and produce knowledge in conjunction with a number of sources, which include – but are not limited to - research, agricultural advisors, and education/training and support services (Röling, 1988; Röling and Wagemakers, 1998). Although Röling's approach initially represented a hard system or 'infrastructural view' to analysing agricultural knowledge systems – emphasising the structures and entities represented in the system – it rapidly evolved into a soft system or 'process view' which implies seeing innovation systems as self-organising, growing networks of actors (Klerkx et al., 2012 p. 464–465).

In the 2010s, interest in AKIS rapidly increased at the European policy level. The European Commission's (EC) Standing Committee on Agricultural Research (SCAR) formed an 'Agricultural Knowledge and Innovation System Collaborative Working Group', effectively redefining the AKIS acronym in line with the EC's emphasis on innovation as a driver of economic development. The most recent SCAR AKIS working group paper defined AKIS in line with preceding EU SCAR reports:

> "AKIS is a useful concept to 'describe a system of innovation, with emphasis on the organisations involved, the links and interactions between them, the institutional infrastructure with its incentives and budget mechanisms' (EU, 2012, 2016)". (EU SCAR, 2019 p. 13)

This shift from AKIS as information to AKIS as innovation was largely policy-driven. It was informed by a series of SCAR foresight exercises, which had found that agricultural knowledge systems in Europe were outdated, focused on linear approaches to knowledge transfer and conventional assumptions (EU, 2012); that is, the type of approach Röling had critiqued in the late 1980s. Reports from these foresight exercises argued that research could play a stronger role if different actors (e. g. farmers, advisors, the private sector) became part of the research process (i.e. through transdisciplinary research). This innovation-focused conception of AKIS has gradually been used as a grounding concept for the design of public policies, although uneven levels of awareness have been observed between policy makers of the different member states of EU (Knierim and Prager, 2015).

The EU SCAR AKIS working group was instrumental in establishing new policy supports that were directed towards boosting knowledge exchange and innovation in the agricultural sector, most notably through the European Innovation Partnership on Agricultural productivity and sustainability (EIP-AGRI) launched in 2012. The policies were designed to promote 'interactive innovation' and 'multi-actor' settings: innovations arising through interplay between actors, particularly farmers and other members of the AKIS (Klerkx et al., 2012; EU, 2016; Moschitz et al., 2015). Related policy instruments of the EIP-AGRI[1] include '*Operational Groups*', '*Thematic Networks' or 'Multi-Actor Projects'*. In these initiatives, farmers are recognised as producers (not simply recipients) of agricultural innovations. Their role as innovators is recognised through supports to networking, collaboration, and innovation platforms (Totin et al., 2020; Berthet and Hickey, 2018; Eastwood et al., 2017; Turner et al., 2017, Sumane et al., 2018).

We see a number of problems with the concept of AKIS as it is currently applied in European policies. In particular, AKIS policies could benefit from a more micro perspective. Although the EIP Agri approach emphasises facilitating direct interactions between stakeholders at local and regional levels, the policies themselves are being formed at national and EU levels, embodying an approach which emphasises how advisory service provision is organised country-wide (i.e. an infrastructural view). Recent up-dates to the Common Agricultural Policy (CAP) emphasise the AKIS infrastructure: requiring each member state to provide a description of the organisational set-up of the AKIS at national level, and description of how advisory services, research and CAP networks will cooperate to provide advice, knowledge flows and innovation services. The emphasis is thus on the actors who receive state support (see Article 102, CAP Regulation). This belies the flexibility and mutability of farmers' needs, access to knowledge and how these play out 'on the ground' (i.e. a process approach). The range of innovations developed and employed on European farms has extended far beyond the technologies addressed by agricultural knowledge systems of the 1960s, and indeed the 1990s, to include new crops, technologies, business practices and means of organising labour and accommodating climate change. The emphasis on advisory services and national-level organisational configuration in the CAP strategic plans risks perpetuating the lack of attention to new or newly recognised players in the sector (such as input suppliers, food processors, retailers and consumers) evidenced by Fieldsend et al. (2021). We follow Pigford et al. (2018) and Klerkx and Begemann (2020) to argue that there is a need for a multi-scalar approach to understand AKIS in a more dynamic way.

In this paper we focus particularly on how better understanding of farm-level processes could improve policies for supporting innovation, assessing farmers' 'microAKIS': the knowledge networks and associated processes that farmers assemble to pursue or develop an innovation (Authors, 2022). Academically, this research is positioned within discussions about the limitations of the national-level application of the AKIS concept for understanding transitions in these systems (Cofré-Bravo et al., 2019; Klerkx et al., 2017). Recent academic approaches to innovation in the agricultural sector have tended to take a systems perspective. Agricultural innovation is seen as co-evolutionary, involving policies, infrastructure and access to funding, as well as the technologies and practices involved (Klerkx et al., 2012). Evolutionary economists who studied innovation systems have long stressed the need to combine various scales of analysis, beyond the specific case of agriculture (e.g. Malerba, 2002, p. 261). Such studies stress that zooming in on specific actors is particularly needed when the boundaries of a sector are shifting. This is the case in contemporary agriculture, which experiences the emergence of a variety of new entrants that transcend the traditional delimitation of the sector. Three dimensions of such changes can be highlighted.

1) The sources of information that farmers use are much more diverse than the 'advisor focus' that is reflected in AKIS approaches (see Faure et al., 2012; Prager et al., 2016; Knierim et al., 2017; Herrera et al., 2018). Recent work by Klerkx et al. (2010) has drawn attention to the specialisation and internationalisation of these services, recognising that there is both topical specialisation within advisory organisations, and extension across national boundaries. Both need to be better acknowledged in AKIS.
2) Farm structures are changing rapidly, with new labour arrangements (e.g. more employees), and a variety of engagement rationales for farming (e.g. career changers/new entrants). In other words, there are new social groups within farming populations who might be hard-to-reach for traditional advisory suppliers and who are overlooked in AKIS studies (Labarthe et al. 2013a, 2013b). New forms of commodification of nature, of work, and of farm products challenge the traditional categories of the farm analyses (Fraser, 2012).
3) Innovation in agriculture comes with new materialities, for instance alien species imported to adapt to climate change, or digital technologies designed by the high-tech sector. The recent materialities literature foregrounds the role of these 'more-than-human' actants in innovation processes, emphasising how the material characteristics of the innovation and farm resources in particular shape associated innovation processes (e.g. Comi, 2020; Higgins et al., 2017; Klerkx and Begemann 2020). These materialities are reflected in different

[1] https://ec.europa.eu/eip/agriculture/en/about.

ways of farmer 'knowing': experiential, tacit knowledge is developed through physical engagement with landforms, natural resources, technologies, animals and human others (Carolan, 2008). As Higgins et al. (2017) state, farmer knowledge is a relational achievement, where tacit and experiential knowledge become entangled with scientific knowledge. The material characteristics of the farm and the innovation are important actants in innovation processes, opening up some opportunities and closing down others.

To address these changes, recent research has disentangled the AKIS into sub-systems related to different groups of farmers (i.e. 'sub-AKIS', Klerkx et al., 2017; Klerkx, 2020). Sutherland et al. (2017) and Cofré-Bravo et al. (2019) found that farmers configure different support networks to support on-farm innovation. Their work particularly emphasised the role of social capital in forming these networks, focusing socio-economic resources available to individual farmers.

In this paper we demonstrate that assemblage theory – based on realist ontology – is a particularly promising approach to develop the conceptualisation of changes in AKIS and assess limitations to current policy applications. An "assemblage" corresponds to relatively stable connections between things of heterogenous nature, for example, a shepherd, a flock of sheep, and a rangeland (Deleuze and Guattari, 1980; DeLanda 2006, 2016). Recent publications have demonstrated the importance of going beyond the 'social' to consider how various more-than-human actants may deeply change farmers' activities and play a role in configuring relationships (e.g. Carolan, 2008; Pigford et al., 2018; Comi, 2020; Darnhofer, 2020). These trends include actor-network theory (Latour, 2005) and related approaches that seek to de-centre human agency and draw attention to the materialities of societal change processes, offering important opportunities for better understanding how innovations come to be embedded – or not – in particular practices and places. Although knowledge is a recognised element of assemblages (e.g. Jones et al., 2019; Forney, 2021), the role of learning in agricultural assemblages has had little targeted research.

To structure the paper, we first present an overview of assemblage thinking (Deleuze and Guattari, 1980; DeLanda 2006, 2016), and identify key points of progression for the AKIS conceptualisation. We then contrast four empirical case studies of innovations in farm assemblages to illustrate how understanding of agricultural knowledge and innovation systems can be advanced through assemblage thinking. We conclude with a synthesis of the implications of study findings for understanding and intervening in AKIS at farm and national levels.

2. Assemblage thinking

Assemblage theory brings together ideas from Gilles Deleuze (a French philosopher) and Felix Guattari (a French psychotherapist and philosopher) with more recent thinking about actor networks (e. g. actor-network theory, Latour, 2005) and the role of material objects in shaping action. The approach has been developed and applied by a range of academics in recent years, particularly in human geography (Müller and Schurr, 2016; Jones et al., 2019; Woods et al., 2021) but also in sociology (Campbell, 2013; Darnhofer, 2020). There are therefore a variety of theorisations and applications of assemblage thinking. In this article, we focus on the approach of Manuel DeLanda (a social theorist not allied with a particular discipline), who draws on Deleuze but also connects his approach to work by French sociologist Pierre Bourdieu.

The overarching principle of Delanda's (2006) approach to assemblage theory is that to understand an assemblage, it is the process of formation that is important, rather than the properties of the actants in the assemblage. In relation to on-farm innovation processes, it is the process of innovation which is therefore the focus. DeLanda positions his conceptualisation of assemblage as a counter to systems thinking; that is, a counter to the notion that systems are the sum of their parts and can be reduced to their components, and that these components are primarily characterised by their roles within the functioning of the system. This distinction is particularly important to the contemporary usage of AKIS in EU policy, where the focus has remained on actors who are primarily oriented towards supporting agricultural innovation (i.e. agricultural advisors).

The English term 'assemblage' is taken from the French term 'agencement', meaning to arrange or lay out. This usage is much less active than the French term assemblage, which means a 'bringing together', implying a unified gathering (Nail, 2017). The heterogeneity and loose affiliations associated with assemblage thinking open the door to considering actors which work across multiple sectors - not solely within agriculture - and who may play a role in farm assemblages for limited but important periods of time. DeLanda's (2006) conceptualisation emphasises that most components or 'elements' of assemblages are part of multiple assemblages (e. g. diversified farmers are both providers of agricultural commodities for actors of the supply chain and providers of service for their rural neighbours and are therefore elements in both assemblages). Assemblages are thus constantly evolving and intersecting. In this paper, we focus on individual farms as the primary assemblages under consideration.

In Delanda's neo-assemblage theory, the properties of the assemblage emerge from interactions between the components, not solely characteristics of those components or 'elements'. An agricultural advisory service may be included in a farm assemblage, but it is the specific services or skills that facilitate knowledge exchange within the assemblage that are important, rather than all of the services on offer. These other services are conceptualised as 'spaces of possibility' (i. e. capacities and capabilities). All of the elements included in the farm assemblage have their own spaces of possibility, some of which they contribute to the assemblage. Mobilising these capacities (e. g. land capability, social networks) and introducing new elements enables the farm assemblage to evolve.

There are a number of critiques of assemblage theory. Although assemblage thinking is based on realist ontologies of the range of actants in a particular grouping, the definition of the assemblage is constantly evolving and academic, in the sense that it is employed as a means of understanding how a grouping comes together, rather than a comprehensive identification of all the potential actants in the assemblage (Jones et al., 2019). A particular risk of assemblage theory is that it can degenerate into endless description if not carefully bounded (Allen, 2011). Non-human elements such as soil quality, fencing, infrastructure, and crops can thus be included in the farm assemblage (e.g. Holloway, 2002; Gorman, 2017), but are only described in the present paper if they are specifically relevant to the innovation process described. Assemblage theory also leaves open the conceptualisation of processes through which territorialisation and deterritorialization occurs (Sutherland and Calo, 2020). To progress AKIS thinking, we draw on three specific attributes of assemblage thinking: territorialisation, historicity, and materialities, focusing particularly on the role of knowledge within these aspects.

Processes of inclusion or exclusion from the assemblage are termed 'territorialisation' – the formation of rules or 'codes' (formal or informal) that influence the structure of the assemblage (DeLanda, 2006). Funding for advisory services, for example, can be considered codes which enable or disable the presence of advisory services in farm assemblages. Social norms around interacting with other farmers, advisors, researchers, farming organisatwebions, input suppliers, etc. Similarly shape the resultant assemblage and therefore could be termed codes, but are less formal. De-territorialisation releases actants from the assemblage. The widespread privatisation of agricultural advisory services across Europe since the 1980s (see Garforth et al., 2003) could be understood as a change in rules or codes, which led to the de-territorialisation of the role of advisors within farm assemblages. The introduction of fees for service and associated business models have made them less accessible to small-scale farmers in particular (Labarthe and Laurent, 2013a, 2013b; Sutherland et al., 2017). Privatisation has thus opened the door for new relationships to develop – or not – as

farmers seek to meet their knowledge needs.

Assemblages are embedded in history. The 'historicity' of the assemblage (DeLanda, 2006) – as a realist ontology, is not only about historical facts but how they are perceived and understood as influencing the present. The way farmers build contemporary farm assemblages reflect a range of past practices, including accessing knowledge through peer learning and formal training, as well as the funding and availability of advisory services, and farmers' own expectations of whether advice should be paid or 'free'. However, ruptures can occur – abrupt points of deterritorialization and new territorialisation where the composition of the assemblage substantially alters. These ruptures are typically the starting points for describing assemblage formation, differentiating assemblage thinking from actor-network approaches (Müller and Schurr, 2016).

Assemblage theory emphasises the inclusion of human and more-than-human elements. Ruptures often lead to new connections between heterogeneous entities, substantially altering the elements in the assemblages and how they are held together. For instance, new links can be built between humans, animals, and plants to accommodate climate change. Material elements are considered to have agencies associated with their material characteristics. The location of the farm can act to resist territorialisation of particular innovations into the farm assemblage, for example through distance to markets, specific climatic conditions, or access to knowledge sharing events (Sutherland and Calo, 2020). Existing landforms and production styles act to limit the imagined futures of farm businesses (Legun and Burch, 2021). Elements can also have expressive capacities – such as the social norms and expected practices that tend to be expressed by human or sentient actants. These expressive capacities similarly include or exclude (territorialise or deterritorialise) other elements from the assemblage; multiple elements in addition to 'the farmer' thus have agency within the farm assemblage.

We progress assemblage theory by considering the role of knowledge in territorialising innovations into the farm assemblage. The cognitive and social components of farmer knowledge and innovation practices are well established (Higgins et al., 2017). Farmers not only have motives for pursuing (or not) innovative practices and technologies, they are embedded within cultural systems which encourage and discourage particular actions (Tsouvalis et al., 2000; Burton, 2004). Delanda's assemblage theory recognises a wide range of types and sources of knowledge, but the conceptualisations of knowledge and learning are under-developed, often implied rather than specified. Knowledge has been identified as an element of an assemblage (Jones et al., 2019); control over knowledge is recognised as an important source of power (Forney, 2021). Power over the distribution and authority of knowledge can restrict or enable assemblages to form and develop in particular directions. Knowledge is also produced in the process of forming or territorisalising an assemblage; farmers' co-production of knowledge is well recognised in the rural studies literature (e.g. Ingram et al., 2020), and indeed in wider European discourses. In this respect, our approach is consistent with Carolan, (2008) work on farmer knowledges – he argues that how farmers know their land and think about it directly reflects the work they have done on it. Farmers come to assess and know innovations through developing and integrating them. The process of territorialising a new element into the farm assemblage necessarily changes the relationships between other elements in the assemblage and both produces and generates new needs for knowledge.

To understand how farmers innovate, we argue that it is important to start from farmers' perspectives. To do that we can observe their microAKIS: the knowledge sources and associated processes farmers enrol to territorialise an innovation. MicroAKIS are similar to the knowledge networks described in the rural studies literature (e.g. Sutherland et al., 2017) in that they are specific to the farmer involved (i.e. the individual's personal knowledge network). The concept of microAKIS is distinctive in including the processes through which these networks are formed. Our analysis of the microAKIS territorialised by farmers into their assemblages will demonstrate the role of knowledge in territorialisation processes. As such, microAKIS represents a 'realist' portrayal of the role of knowledge in contemporary agricultural innovation. In other words, microAKIS will enable us to better understand the messy interplay of elements inherent in innovation processes at farm level, in contrast to a description of AKIS which relies on macro-level representation. We posit that such a perspective will provide insights about current transformations of AKIS (e.g. new actors, new institutions …) which tends to be overlooked in the national descriptions that currently feed policy making.

3. Methods

To develop our understanding of microAKIS within farm assemblages, we drew on four empirical case studies from the Horizon 2020 AgriLink project. The focus of AgriLink was to further understand the roles played by a wide range of advice providers in farmer decision-making, and to enhance their contribution to farmers' learning and innovation. The project was specifically designed to address concerns that the range of actors in AKIS were not being recognised in contemporary AKIS discussions; the research methodology was thus designed to elicit descriptions of knowledge sources and innovations from farmers without pre-defining who or what these knowledge sources could be. The project was specifically tasked by the funder with evaluating the role of agricultural advisors in innovation processes and thus the research had a particular focus on these knowledge sources and their role in innovation processes.

The AgrLink project as a whole considered eight types on-farm innovation, selected to represent the types of innovation needed for sustainable transitions in agriculture (e.g. technological, environmental, social and marketing). The cases presented in this paper represent 4 of the 32 case studies undertaken in the project. The case studies presented in this paper were selected to represent the diversity of AKIS in Europe, as illustrated in Fig. 1, ranging from Greece, where the AKIS is weak and fragmented, with very limited public support for advisory services, to France, where there is a strong, integrated AKIS, with Norway and Latvia falling between these extremes. This classification is widely utilised, for example in the EU SCAR AKIS (2019) working group report. The cases also reflect a cross section of European landscapes (Scandinavia, the Baltics, western and southern Europe). Within each of these countries there were multiple case studies from which to choose. The case studies in this paper were selected to reflect major transformations underway in agriculture (climate change, digitalisation, direct marketing, migrant workers) that can be associated with new configurations of farm assemblages. In other words, the selected case studies can be differentiated in relation to the type of actants in the assemblages studied (Table 1):

- Humans, plants, and climate (e.g. avocado trees in Mediterranean physical environment);
- Humans, animals, and machinery (e.g. robots and livestock husbandry);
- Humans and spokespeople of new economic entities (e.g. farmers with knowledge of traditional food production establishing relations with new types of marketing environment);
- Humans and dehumanized foreign bodies (e.g. farm casual labour, the disconnection between the work and the worker).

All of these cases comprise innovations which reconfigure how farming is practiced, integrating new elements, knowledge and ways of working. For full case study reports see the AgriLink project website (www.agrilink2020.eu).

The research utilised a standardised approach to identifying farmers' microAKIS. Case studies were identified in regions at NUTS 3 level. Study farmers were primarily identified utilising a snowball methodology, with an emphasis on identifying as wide a variety of respondents as possible. In the French case study, a database from another research

Fig. 1. Diversity of European AKISs, adapted by the research team from Knierim and Prager (2015) to include Norway.

Table 1
Case study participants.

Case study	Country	Adopters	Droppers	Non adopters	Key Informants	Total Case Study Participants
New crop - avocado	Greece (Chania)	27	1	9	11	48
Robotic milkers	Norway (Trøndelag)	20	0	9	8	37
Direct marketing	Latvia (Pierīga)	21	3	6	4	34
Labour outsourcing	France (Gers and Pyrénées-Atlantiques "Nouvelle Aquitaine" region)	16	2	15	11	44

project on outsourcing practices was utilised to ensure a broad range of activities was covered. As is characteristic of qualitative research, farmer interviews continued until saturation was reached, typically comprising between 30 and 50 interviews per case study (see Table 1). Farmers were asked to identify who were their sources of information at multiple points during the innovation process, and discuss how this information was acquired, (re)produced and deployed on farm. MicroAKIS was thus deployed as a methodological approach (see Madureira et al., 2022).

The farmer-oriented research was followed by a qualitative survey of the information sources identified by the interviewed farmers. These actors included public and privately funded agronomists and agricultural advisors, current and retired researchers, representatives from farm business organisations and cooperatives, input supply companies and the banking sector. The number of AKIS actors interviewed per case study varied from 5 to 15, depending on the size of the respective microAKIS. This second survey acted as a form of triangulation, and placed farmers' microAKIS within the broader regional context of access to advice (i.e. identifying the extent to which the microAKIS identified by individual farmers reflected the infrastructural AKIS at regional level). In all four case studies, research was undertaken in regions where the innovations had been establishing for several years, so that researchers could assess change over time in knowledge sources. The purposes of the studies were not to be representative, but to garner a wide range of situations.

Data was collected face-to-face or by telephone in 2019. Interviews were audio-recorded with informed consent from the interviewees, transcribed in note form in their native languages, and initially analysed in relation to the overall research questions of the project. This analysis is available in projects reports on the AgriLink website.

The data presented is this paper is a re-analysis of the data collected for the AgriLink project, applying assemblage theory. The paper presents the authors' efforts to test out the utility of assemblage theory for progressing AKIS thinking. Data collection was originally grounded in Sutherland et al.'s (2012) Triggering Change Model of major change at farm level. This model identifies an idealised cycle, whereby a trigger event interrupts the path dependency of farming practices, leading to a period of active consideration of potential innovations, before one or more are pursued, implemented, and if successful, become part of the farm's new path dependency. Sutherland et al.'s (2012) concept of 'trigger' is broadly consistent with the assemblage concept of 'rupture' – a major change which destabilises the assemblage. Associated data was derived from farmer descriptions of the reasons for pursuing the innovation, and microAKIS actor descriptions of the development of the innovation in their region (i.e. it's historicity). The data on materialities was derived from questions about the barriers to adoption, the most important types of knowledge and skills the farmers needed to assess the innovation, risks and uncertainties associated with the innovation, and negative side effects. AKIS actor respondents also offered insights into materialities through their responses to questions about the sustainability implications (social, environmental and economic) of the innovation. The focus of the dataset on farmers microAKIS supported an analysis of assemblages at farm level. Data were reanalysed in table form for comparative analysis across the four cases, with separate lines focusing on the themes presented in this paper: historicity and ruptures, elements of the assemblage and knowledge, and the materialities of the innovation.

Consideration of a dataset from multiple theoretical perspectives is not unusual in rural studies, although there are some limitations to this approach. A dataset specifically designed for consideration using assemblage theory would have more directly interrogated the materialities and territorialisation processes. Pursuing characterisation of the microAKIS as a method necessarily places the farmer at the centre of the farm assemblage, as the primary territorialising force. This is at odds with the orientation of more-than-human research towards decentralising human agency. However, as we demonstrate, the data provides a useful starting point for considering how assemblage theory can advance

AKIS concepts.

4. Historicity of the case study assemblages

In Greece, the case study focused on the introduction of avocado as an export crop. This case relates to changes to farm assemblages made when introducing foreign crops to adapt to heterogeneous local agro-climatic conditions (including climate change). The farm assemblage thus incorporates new materiality (a new plant) but also new knowledge - agronomic skills for cultivating an exotic plant. Chania region's agricultural production emphasises tree crops, primarily olive (90%) and citrus (7%), which cover almost 85% of the agricultural land (Hellenic Statistical Authority, 2016). Avocado was introduced to the region in the late 1960s and early 1970s, when the Institute of Olive Tree, Subtropical Plants and Viticulture established an experimental plantation. The first commercial avocado plantations were established in 1974, and a regional project (in the framework of Integrated Mediterranean Programmes) aimed at subsidizing the replacement of (centuries) old, unproductive olive plantations took place from 1985 to 1992, but with limited success, owing largely to the profitability of the established tree crops. This situation changed in 2008 with the collapse in olive oil and orange markets, which coincided with an increase in global demand for avocados. Avocado production was growing rapidly at the time of the study, with the introduction of 80 000 to 100 000 new trees per year. From an assemblage perspective, there was a clear rupture in 2008, caused by a weakening of market codes (i.e. the profitability of production).

In Norway, the case study focused on the implementation of milking robots. This case relates to farm assemblages which are integrating new technologies in the field of robotics and digitisation. There were also changes to how knowledge of animals (and their relations to humans) was generated. The Trøndelag region was chosen because dairy is a primary commodity there, producing 21.1% of all milk in Norway. The region thus had strong market appeal for companies introducing the robots, and was amongst the first in Norway to install the new robotic milking technologies in 2001–2002. At the time of the study, about one third of the almost 1500 dairy farms in Trøndelag (SSB 2021) had installed milking robots. Milking robots increase the efficiency and productivity of dairy farming: cows in a loose housing barn milked by robots are milked more frequently, while requiring less labour. Installation of milking robots can increase the palatability of farming life and was sometimes undertaken to facilitate succession (see also Vik et al., 2019; Hansen 2015; Bear and Holloway 2015). 'Ruptures' in existing assemblages were thus not industry wide, instead tending to reflect the life course of the farm (e. g. when a farmer was approaching retirement and/or a successor introduced), or as means of increasing production efficiency.

In Latvia, the case study focused on the direct marketing of agricultural produce by local farmers. This case relates to territorialisation of new markets into farm assemblages. The Pierīga region was chosen because it is predominantly urban, located near the capital city of Latvia (Rīga), which gives farmers access to a larger pool of customers with higher purchasing power. Direct sales represent an important marketing channel of agricultural products in Latvia, especially for small farmers and small food processors. Like milking robots, there was no single rupture point. Instead, existing farm assemblages gradually deterritorialised through low profitability; integration into different markets was sought as a business opportunity. Ideological changes also deterritorialised farm assemblages, as farmers sought to reach new customers and avoid untrusted middlemen. At times, the deterritorialization took place as a result of a complex, evolving set of factors, both internal and external to the farm (e.g. overproduction on a subsistence farm, loss of paid off-farm job, farm take-over, expressive/outgoing personality traits, restrictive legislation), that opened up spaces of possibility for engaging in individual sales of farm produce. Farm size, as a material characteristic of the land in the farm assemblage, also played an important role. Access to conventional market channels and large retailers can be challenging for small-scale producers because of specific requirements regarding the quality, amount, supplies, etc. as well as their limited bargaining power (Galli et al., 2020).

In France, the case study focused on labour outsourcing. This case related to the inclusion of an external organisation and associated labour as elements in the farm assemblage. As described in other sectors of activities (e.g. Marčeta, 2021), the assemblages may involve new labour practices where workers are dehumanized: commodified and considered as impersonal bodies. Like much of Europe, French farmers have traditionally outsourced some farming operations, such as contract harvesting. However, in the mid-1990s, outsourcing in the agricultural sector began to rapidly increase. Between 2000 and 2016, the number of farms in France making significant use of outsourcing more than doubled, and new forms of labour practices such as posted workers appeared (i.e. employees sent to work in other countries, Nguyen et al., 2019; Depeyrot et al., 2019). Outsourcing to access precision technologies (conservation tillage, crop protection treatments with on-board computerised technologies, etc. (Nguyen et al., 2019) is now common. This coincided with increased employment of workers through another legal entity (foreign or national contractor, specific associations), to perform specific labour-intensive tasks (pruning, grape and fruit harvest, horticulture). A growing number of employees working on farms thus are no longer directly employed by the farm but are employed by a different legal entity. In 80% of cases, these are non-permanent jobs (Depeyrot et al., 2019). More than 190 000 people, or 25% of the total number of precarious workers on French farms, are now employed by legal entities separate from the farm. Similar to the preceding two cases, there was no formal 'rupture' that led to this type innovation.

The cases as a set thus demonstrate the deterritorialising effect of low profitability on farms – weakening the path dependency and pushing farmers to consider other options - but also the important role played by new technologies and the farming household and associated life course issues in deterritorialising existing assemblages. In three of the four cases there was no clear, industry wide rupture event from which to assess assemblage formation. The starting point of the associated assemblages is therefore variable by farm.

5. The intersection of materialities and knowledge in territorialisation processes

The four case studies represent the territorialisation of different types of elements into farm assemblages. The territorialisation processes associated with each innovation demonstrate the interplay between the materiality of the assemblage and the knowledge sources assembled in farmers' microAKIS. A summary of these characteristics can be found in Table 2.

The Greek case study emphasised the integration of a new plant into the farm assemblage, challenging the spaces of possibility for land held in the existing holding.

> "The new [imported] varieties require careful acclimatization … the seedlings react differently in different environments" (Male advisor/hybrid actor, Greece)

The successful introduction of avocado, a subtropical species, involves new materialities as, in the first place, it requires careful selection of the location to establish the plantation: certain types of microclimates, soils, and high-quality irrigation water. Successful establishment also involves specific planting, irrigation, pruning and thinning practices, and protection of bark from sunburn. These plant needs further depend on the cultivar used. To territorialise avocado trees into their farm businesses, farmers built on their own experiential knowledge of citrus production, and attempted to operationalise the scientific knowledge available. However, although there was some scientific knowledge available through retired scientists from the local research institute who had attempted to introduce avocado production to the

Table 2
MicroAKIS and elements of the assemblage by case study.

Case Study	Historicity	Rupture	Key elements of the assemblage	MicroAKIS	Change in microAKIS over time.	Materialities
Greece: New crop – avocado	Avocado unsuccessfully introduced by researchers in the 1960s/1970s and Integrated Mediterranean Programmes 1985–1993	Sectoral level: collapse of olive oil and citrus markets in 2008	Farmer, avocado trees, tree suppliers, formal and informal advisors, land capability, farmers' willingness to experiment	Experienced farmers, retired scientists, agronomist-cultivator, tree suppliers. Organic producers' cooperative.	Farmers who had learned through trial and error became the best sources of advice.	As a species grown in Mexico and South America, the biophysical requirements for successful cultivation in a new climate had to be determined. Experimentation by farmers contributed to environmental degradation in some cases. The slow maturation of avocado trees over 4–7 years distanced suppliers from farmers
Norway: Robotic milkers	Major dairy producing region – concentration of dairy farms and tech suppliers.	Farm level – succession, opportunity for profitability.	Farm household, multiple robots, new buildings, capital to leverage, a supply company, the dairy cooperative, bankers and peer farmers.	Peer farmers, friends, bankers, supply companies New partnerships formed between research and advisory service organisations	Dairy cooperative and tech supplier very important until farmers learned to manage the new system; agricultural advisors could provide assistance once technology well established in the region.	Agricultural advisors could not keep up to date on the changing technologies. Robots often required additional robots and new buildings, and therefore substantial financing Preference for technologies where peer advice was available.
Latvia: Direct marketing	Lengthy history of small-scale production for family and friends.	Farm level –unexpected surplus, growth opportunity, dis-illusion with middlemen, lifecourse changes, job loss	Farm household, location of land, digital technologies, courier services, local market places, local consumers	Other household and family members, acquaintances, local peers, social media, organisers of sales points (markets, etc.), individual consumers	There has been some move from informal/experiential individual learning being gradually supplemented by some institutionalised advice	Internet-based marketing primarily available to those with family members skilled in IT. Proximity to urban areas, and road infrastructure critical to success.
France: Labour outsourcing	Established practice of outsourcing some (e.g. harvesting) activities	Increase of average farm size and substitution of family labour by salaried workers. New farm equipment expensive for a single farm s	Farm household, workers, companies supplying workers. New types of commodification of the labour	Contractors, input suppliers, peers, friends, family, formal farmers' groups	Farmers developed diverse strategies – developing international networks to hire directly, reorganising to avoid hired labour, working with reputable companies. Other work with companies providing working hours at a lowest possible cost.	Some workers seen only as interchangeable bodies. Loss of human interactions. Between family labour and hired labour. Little concern for occupational health of precarious workers.

region in the 1960s and 1970s, much of this production knowledge was gained from their own and other farmers' experimentation:

> "[we] relied on 2–3 agronomists [members of the Organic Producers' Cooperative] who draw much of their knowledge from their experiences as avocado producers". (Male farmer, Greece)

These agronomists (officially public servants or private advisors) supported innovation diffusion amongst its members and others. The lack of available production knowledge made hybrid actors – advisors who were also farmers – the best sources for advice. They also built connections with a research institute in Spain. Greece has very limited state-funded farm advisory services (Koutsouris, 2014). Retired researchers from the institute which had attempted to introduce avocado to the region decades earlier were sought out for their advice; access reflected geographic proximity and personal connections. Both study participants and key informants reported an absence of applied research on avocado and its adaptation to the area (e. g. on new varieties or those suited to the local agroecological conditions; on emerging diseases; on techniques and practices appropriate for the specific conditions of Chania and in view of climate change, etc.). The materialities of avocado production – grown primarily in Mexico and South America – had important implications for access to knowledge: tree salespeople (nurseries) in Greece were disconnected from the tree breeders. The length of time between planting and avocado harvest (4–7 years) also disconnected suppliers from farmers' experiences of production. Territorialising avocados onto citrus farms thus involved the trees, their suppliers, and a cohort of formal and informal advisors, and was heavily reliant on land capability and farmers' willingness to experiment. Successful introduction of avocado has remained challenging with repeated crop failures, and expansion of avocado production has often been onto marginal lands, raising concerns about the adequacy and quality of water resources to support the new trees, particularly as the region struggles to address water resource issues in response to climate change.

The Norwegian case study focused on a new technology. To territorialise milking robots into their assemblages, farmers typically must also undertake (and finance) the building or substantial renovation of a barn, which enabled loose housing for the cows. Installation of a milking robot was therefore part of a major reorganisation of the farm assemblage: combined with new buildings and robots for feeding, activity measuring, cleaning, etc. Territorialising the robots involved accessing knowledge on both the business case to justify the investment, and the effective use of the technology:

> "Tine [*the dairy cooperative]* was important with preparation, DeLaval [*supplier of milking robot]* on running in the milking robot and follow-up afterwards through a service agreement. The phone service was used almost daily in the beginning and then less and less, and now almost nothing because I eventually know most of the problems that arise." (Male farmer, Norway)

This farmer described working with the dairy cooperative – that is, within the spaces of possibility within an existing element of the farm assemblage – and a new entity, the supplier of the milking robots (consistent with Comi, 2020). Dependence on the supplier reduced as his skill level grew, as he personally came to know the technology through working with it.

Consistent with the Greek case, there was a limited role for advisory services in Norway, particularly in the early stages of the innovation. Like many other western European countries, Norway has undergone the process of privatising its formerly publicly-funded agricultural advisory services (Klerkx et al., 2017). Study participants described considerable competition, rather than collaboration, between advisory organisations (i. e. which impact on territorialisation processes), and limited back-office investment. Advisory services therefore had limited 'spaces of possibility' to effectively provide the needed information. At the time of the study, farmer efforts to address gaps in advice were leading to the emergence of new collaborations. In Norway, partnership in research projects/collaboration between research and advisory service organisations, both embedded and non-embedded in the dairy industry, created an opportunity to load the back office. However, this was also dependent on the absorptive capacity of advisory service organisations; that is, the capability to recognize the value of new external knowledge, assimilate it, transform it, and apply it for their business' purposes (Cohen and Levinthal 1990; Zahra and George 2002; Stræte et al., in press).

In Norway, farmers actively chose specific technologies because of the experiential knowledge they could gain from their colleagues:

> "I discussed most with friends, colleagues and my wife before the plans for a milking robot were concretized. I visited other farmers with milking robot to see. Many in the area had DeLaval [*supplier of milking robot]*, and I chose the same type because it is a great advantage to have others in the area who have experience with the same technology and brand." (Male farmer, Norway)

This farmer deliberately chose a robot that allowed him to territorialise experiential knowledge from his peers. External financing is typically required to purchase and install the robot; farmers thus also described how the decision to invest in a robot was strongly influenced by banks, who held decision-making authority over leveraged finance. Territorialising a robot into the farming assemblage thus involved multiple robots, buildings, a supply company, the dairy cooperative, bankers and peer farmers. The farm also had to have sufficient assets to be able to leverage a loan for the new barns as well as robot technologies.

The Latvian case study involved in the integration of new economic entities - new markets - into the farm assemblage. In contrast, commodity markets were well established for the other three cases. Engaging in short food supply chains involved a reorientation of the products produced, but primarily new knowledge and practices associated with marketing and sales. The materialities of this case involved the introduction of digital platforms for direct sales, and novel forms of farmer-consumer interfaces such as direct purchasing groups. Like the Greek study, the geophysical characteristics of the farm holding were important spaces of possibility for the holding, which included the potential to produce marketable crops (e.g. raspberries), but also ease of access to markets.

> "The direct sales expanded with the reconstruction of the nearby highway. The increased flow of cars made us decide that it is worth selling on-farm rather than going somewhere else. […] There was no direct sales here before that since earlier it was hard even for a tractor to drive here." (Male farmer, Latvia)

This farmer described how changes to the spaces of possibility of his farm occurred through infrastructural changes in the locale. The new road became an actant in the farm, making it possible for direct marketing to be undertaken. Other important channels were town and farmers' markets, on-farm sales, farm shops, prearranged delivery to individual clients or client groups in residential and office areas, and online sales. These channels require territorialisation of a number of non-traditional actors into farm assemblages that allow for provision of physical and virtual space for organising sales arrangements.[2] Actors associated with these entities – such as the operators of farm shops and farmers markets – became advisors on what products would sell.

State supported advisory services are widely available in Latvia; these services are seen by the state as a tool to support national agricultural and rural policies. However, Latvian agricultural advisory services (dominated by Latvian Rural Advisory and Training Centre) are primarily oriented towards providing advice on agrotechnical

[2] Several recent papers have outlined how digital technologies are changing the way humans and technologies connect e.g. Fielke et al. 2020; Klerkx, 2021. These dynamics were beyond the scope of this present paper.

production issues in crop farming, livestock farming, forestry, and fisheries, as well on farm economics. When formal advisory organisations assisted farmers who were engaged in direct marketing, it was mainly in matters pertaining to taxes and bookkeeping. Latvian farmers in the case study instead drew on the 'spaces of possibility' of other household members to develop markets and build skills. Internet marketing was facilitated by the improved skills of farmers (both young and old) in the use of mobile applications and social media (often facilitated by younger relatives), easy access to courier services and the growing interest of consumers in local and niche products. Analysis also demonstrated the fluidity between formal and informal networks as experienced peers became advisors. In this case, microAKIS were comprised of a wide range of individuals, including other farm actors (beyond the 'primary farmer', e. g. grandparents, spouses, successors), extended family and acquaintances, local peers, organisers of sales points (e. g. public markets), feedback from clients, professional literature and social media (see also Kilis et al., 2022). MicroAKIS were diffuse and highly variable between farmers, consistent with the historicity of the farm assemblage and the sales opportunities which were opened up through farmers' range of family and informal contacts. As in the other cases, farmers often reported learning through their own experimentation with sales techniques and distribution channels.

The French case focused on integrating new organisations and the labour they provide into the farm assemblage. Both the French and Latvian cases involved integrating elements where the legal footing was uncertain. These issues are outside the remit of traditional advisory services:

> "When we started the unofficial direct sales in the [inner yards of residential areas] in Riga there were quite a few uncertainties if you wanted to make this all legal. The bureaucratic system is quite entangled and there is no one interested in this. If you can do it, do it on your own. If you cannot, you can ask for a consultation where they will tell you to go to another room from where you are sent back to the first one. Thus, you can spend hours in that apparatus. […] next year I will involve a law firm to settle these issues." (Male farmer, Latvia)

> "The technicians from the cooperative are salesmen. They don't give real advice on this [sub contracting and outsourcing]. By talking with neighbours now I found a contractor I can trust." (male farmer, France)

In the Latvian case, the farmer's decision was to enrol a new actor – a law firm – to address the bureaucracy. In France, farmers talked to neighbours to identify a trusted source of advice. The French case draws attention to the materialities of integrating other humans and their skills into the farm assemblage. In some cases, the workers contracted through the companies were essentially considered a substance whose quality was negotiated in relation to the task at hand (evident in statements like "I want Moroccans for pruning" (farmer, male): in French "je veux *du marocain* [substance]" and not "je veux *des marocains* [people]"). In purchasing access to the skills of foreign employees, farmers enrolled a new element – another human – in their farming assemblage, with the associated materialities (e.g. need for food, clothing, healthcare). These needs were ostensibly met by the organisation which employed them, requiring this organisation also be integrated into the farm assemblage. The lack of advice on this topic was acknowledged by key informants from the Chambers of Agriculture. The Chambers of Agriculture, as well as farming organisations, have traditionally been major sources of advice to French farmers. However, since the 1970s, their role has been eroded while that of other organisations, such as farmers' cooperatives, upstream industries, and private traders has grown (Brunier, 2018; Labarthe, 2014; Laurent et al., 2022). The Mutualité sociale agricole (MSA) is also an option; it manages the social insurance of people working in agriculture (family labour and employees). It also provided advisory services regarding occupational health and guidance on the regulatory aspects of employment in agriculture. However, it was also the organisation that controlled employment registrations and adherence to labour regulations. This dual role of advice and control was not conducive to establishing a relationship of trust and farmers were reluctant to discuss their difficulties with this organisation.

The employees territorialised into farm assemblages in France through contractors may bring important knowledge and skills (e.g. of precision technologies, plant cultivation and harvesting), but also have a very limited potential to benefit from advice that would enable them to avoid abuses. In the case study, we did not identify any associations specifically dedicated to this issue. The links between the population of precarious employees in agriculture and the French trade unions also appear to be poorly developed (Magnan, 2022). For employees, information on their rights and on the specific characteristics of the service providers and farms on which they work seems to be transmitted essentially via informal networks, but it was not possible to examine this question in depth. For many farmers, being an 'employer' is a too heavy burden and they prefer to delegate this role to other organisations. In the French case study, regarding labour organisation, two major sources of knowledge were identified during the innovation process: advisors from up-stream industries (e.g. sellers of machineries, of pesticides, contractors) and informal networks (peers, friends, family and networks maintained via the Internet). Formal farmers' groups appear also to be a source of information for some of the interviewees but to a lesser extent. However, there is not a shared pattern of microAKIS that emerged for labour outsourcing, and we could not identify any organisation that has developed a system for evaluating the efficiency of these outsourcing practices, or was a consistently identified source of advice. Similar to the Norwegian case, the complexity of the innovation - the fragmentation of the forms of subcontracting, the types of service providers and the occupational status of workers - makes advice difficult to give.

6. Discussion

In this paper we have presented examples of the utility of assemblage theory for progressing agricultural knowledge systems research at the farm level, through a confrontation of farmers' needs and microAKIS configurations. In this section we first address how the analysis advances understanding of agricultural innovation processes, and associated policy implications, before considering how assemblage theory advances AKIS thinking more broadly.

6.1. Understanding agricultural innovation

Findings support contentions by Cofré-Bravo et al., 2019; Madureira et al., 2022 and Sutherland et al. (2017) that farmers access different sources of knowledge and advice on different topics. Their research focused on the social construction of these networks. In utilising assemblage thinking, the analysis in this paper included material actants, presenting empirical evidence in line with recent calls to include non-human agency in agrarian studies and to acknowledge new farmers' needs (e.g. Contesse et al., 2021; Darnhofer, 2020; Legun and Henry, 2017).

Rethinking of the formation of networks associated with innovations to conceive these as collections of elements with varying spaces of possibility enables us to more actively consider who and what needs to be included in these networks (e.g. back-office, new actors) for an innovation to be successfully territorialised into farm assemblages. Innovation – even technological innovation – does not occur in isolation. Integrating a new element into a farming assemblage almost inevitably involves integrating other elements, both material and human (e.g. new buildings, advisors, peer farmers), which may or may not be located within the 'agricultural sector', and thus a represent a reconfiguration of the farm assemblage. The microAKIS identified primarily involved input suppliers and peer farmers, both of which are often omitted from AKIS assessments (Fieldsend et al., 2021). In a similar vein, NGOs and

controlling agencies had a role to play in the direct marketing and labour outsourcing cases, but are not often considered in analyses of AKIS. Accountancy and legal advice were important to the milking robot and labour outsourcing cases. Banking expertise was of particular importance to the milking robot case; indeed, given the scale of the financial investment required, bankers often held control over whether the innovation could be adopted (or even encouraged expansion to make the investment more profitable). The analysis thus demonstrated the negotiated, relational process which is 'farmer decision-making'. Findings in the Norwegian case in particular were consistent with Comi (2020) construction of the 'distributed farmer' – the decision on whether to integrate a robot was not solely made by a farmer, or the farm household. Instead, decisions were strongly influenced by banks and reflected the perceived spaces of possibility of the holding (e.g sufficient scale to generate profit). Grivins et al. (2021) ably demonstrate that engagement with banks reflects the social history of banking in the agricultural sector, and that banks privilege farming operations which perform in particular ways. Hilkens et al. (2018) found that farmers may actually avoid discussing financial topics with traditional agricultural advisors. As such, banks are pivotal actors for supporting the transformative change required for the agricultural sector to meet, for example, net zero targets, but have had very limited connection to the AKIS literature. Further analysis of banks and other financial actors, following Grivins et al. (2021) and Hilkens et al. (2018) is critically important to understanding agricultural innovation. More globally, our assemblage approach suggests putting greater attention on the new complex relations between labour and capital in agriculture, for both technological and non-technological innovation. This is in line with recent research on outsourcing in agriculture , and on the microAKIS of big corporate farms in Eastern European countries (Konečná and Sutherland, 2022)

The analysis has also demonstrated the importance of 'ruptures' to change in farm business practices. Although it was expected that farm profitability would be an important deterritorialising force, the role of the farm household lifecourse and spaces of possibility of farm household members also emerged as important. This finding is consistent with Sutherland et al.'s (2012), Triggering Change Model. Triggers, or 'ruptures' as they are described in assemblage theory, suggest an important area for intervention; that is, there are some periods in the lifecourse of a farm household where change is more actively considered, and provision of advice or access to other resources is likely to be particularly influential. The Greek case in particular demonstrated that in the absence of a clear driver for change at farm level, a new innovation, however promising, is unlikely to take hold.

The overall impression of innovation, as emergent through applying assemblage theory, is one of process: ongoing movement and development. Farmers attempted, failed, and attempted again. They involved a diverse range of knowledge sources to different degrees over the course of their innovation processes - moving away from initial sources once their own expertise became established, and collaborating with other farmers to meet common knowledge needs. This 'process' approach to innovation undermines a technological determinist perspective (Darnhofer, 2020), instead demonstrating the flexibility and variability in innovation processes, and the opportunities for new practices to emerge.

6.2. Policy implications

As a set, the cases demonstrate that the knowledge needs of contemporary farms far exceed the traditional territory of agricultural advice. At the same time, the capacity of agricultural advisory services to provide even this traditional advice is often weak, and entirely absent in some cases (e.g. Greece). State-funded agricultural advisory services were notably missing from all of the case study cases. Farmers in the study described their microAKIS as primarily comprised of peers, hybrid actors (agronomist-cultivators), regional educational and research institutes, bankers, technology suppliers, and the agronomists from nurseries. Peer farmers played a key role for all of the farmers in the study.

The 'view from the farm' thus sheds new light on the array of issues and actors that should be debated in national level AKIS plans. The broad array of actors identified at micro level is not evident in macro level policies, and could lead to distortion in their implementation. Recent European initiatives have emphasised 'independent' and 'impartial' advice, that is, advice that is not linked to the commercial interests of equipment or farming inputs sellers (see EIP Agri; EU, 2016). The case examples demonstrated the problems with this perspective. First, as Higgins et al. (2017) and Comi, (2020) point out, (some) technologies are designed to build dependence on their suppliers for information and support: this was clearly evident in the Norwegian case, where lack of interoperability and ongoing up-dates in design made it impossible for farm advisory services to keep up (i. e. they are disconnected from the back-office of input suppliers and their own back-offices lack access to up-to-date knowledge), particularly in the early stages of the innovation. Second, consistent with recent research (Labarthe and Laurent, 2013b; Prager et al., 2016; Eastwood et al., 2017) 'independent advisors' are often small businesses or organisations that rarely have the back-office resources to cope with the actual changes of farmers' assemblages and support contemporary production innovations. In the case of avocado, for example, retired scientists were enrolled by farmers to compensate the fact that specialist knowledge on this new materiality was largely lacking. Third, the assemblage perspective reveals that, in complex and uncertain innovation contexts, farmers' choices of advisors might be driven by contingencies and by the materialities of innovation. They build trust relationships with suppliers that can actually support them in mastering these materialities. These suppliers are often not independent. This finding is consistent with Sutherland et al. (2013a, 2013b), who found that farmers' trust in advisors was more reflective of the quality of their ongoing relationship to them, than whether those advisors were funded through public, private, or charitable sources. Finally, the sheer distance between the knowledge of independent advisors and evolving knowledge needs of contemporary farmers suggests that it would be a logistical and economic feat to increase and maintain up-to-date advisory knowledge to address the range of innovations in European agriculture. To meet these needs, new configurations of advice and support need to be developed and considered. As suggested in further studies, a focus on transparency and robustness of evidence provided by the back-office of farm advice could be a key dimension of public investment in and regulation of farm advice (Sutherland and Labarthe, 2022).

The cases presented do affirm the emphasis on peer-to-peer learning embedded in EIP Agri approaches. Pioneering farmers became recognised as experts through their own personal experience of utilising novel technologies or farming practices. Although pioneers typically relied on their own experimentation, these pioneers later became important sources of knowledge in all four of the case studies. However, farmers appeared to have taken up this role themselves, rather than through the facilitation of agricultural advisors (i.e. 'interactive innovation processes'). Farmers' expertise was not in technological developments, but in the practical, day-to-day engagement with the innovation at stake within the farm assemblage. Assemblage theory positions farmers as actants; foregrounding their agency in this study demonstrates the steps they are taking to territorialise new actions, directly – and through farming organisations – to actively co-produce new configurations of advice. The case studies show how farmers proactively look for information sources to draw upon in the process of considering and engaging with an on-farm innovation, and invest in acquiring the necessary skills and knowledge for its deployment. In several cases, farmers themselves were leading the design of new innovation support services (e.g. Greece, Norway) through farmer cooperatives. These new configurations risk marginalisation in AKIS plans which embody infrastructural approaches, emphasising traditional advisory services.

The cases also drew attention to human actors beyond the 'primary

farmer' in knowledge networks. The Latvian case in particular drew attention to the role of extended family members in innovation processes. These individuals were mobilised as both sources of advice (on traditional production approaches and marketing) and as clients. This supports the presence of family-related sources of farmers' knowledge, which complement neighbourhood-related, institution-related, and media-related ones (Wójcik et al., 2019), emphasising the huge role played by family and vicinity in sourcing farming knowledge and micro-social conditioning in shaping this knowledge. The French case drew attention to agricultural employees and their role in on-farm innovation, sometimes acting as sources of new knowledge or access points for new technologies (e. g. through contract farm work). However, the configuration of these employees within farming assemblages is problematic, with limited advice available to these individuals on their own rights, and limited advice for farmers on labour organisation and hired labour management.

All of the cases implicitly or explicitly drew attention to the inequalities in access to advice: in Greece based on geographic proximity to research institutes, in Norway and Latvia by farm size (with larger farms representing a stronger business case to input suppliers, and more important source of attention by advisory services respectively); and in France for employees who were unfamiliar with and not catered for advisory services. By drawing attention to the processes through which farm assemblages come together, these inequalities become more evident (Labarthe et al. 2013a, 2013b).

6.3. A reflection on advancing AKIS thinking

Our research sought to test the utility of assemblage theory for advancing AKIS thinking. In doing so, our research has provided empirical evidence in support of conceptual arguments made by Pigford et al. (2018), and Klerkx and Begemann (2020) on the importance of recognising the role of actors from outside of the agricultural sectors in innovation processes, as well as empirical research at a different spatial scale from Higgins et al. (2018) and Contesse et al. (2021). In addition, all of these researchers have argued for the inclusion of materialities in conceptualisation of innovation and transition in the agricultural sector. As such, assemblage theory can be considered one of a number of approaches for bringing to light the more-than-human agencies involved in what has traditionally been considered 'farmer decision-making'. A particular advantage of assemblage theory is that it offers a set of conceptual terms for analysing innovation processes, particularly historicity and rupture, elements and spaces of possibility, and territorialisation and deterritorialization. Assemblage theory emphasises the process of innovation, and the looseness and flexibility of connections, shifting academic and policy attention beyond the agricultural sector and the 'usual suspects' for advice provision. Applied in relation to AKIS, assemblage thinking highlights the co-constructed nature of farm knowledge and associated farming processes, consistent with recent work on co-learning processes (e.g. Comi, 2020; Ingram et al., 2020). Reciprocally, applying assemblage theory to AKIS develops the role of learning as a territorialising force, a 'glue' which holds assemblages together. It highlights the differing types of expertise lodged in different (i.e. hybrid) actors, suggesting that new, hybrid forms of advice provision require consideration.

There are limitations to the application of assemblage theory, and our research remains exploratory. In particular, the precise mechanisms of change remain vague, attributed by the researchers retrospectively. Identification of which elements to include in the analysis of the assemblage risks becoming 'cherry picking' those elements the researchers find most of interest. Findings may thus become a factor of the methodology, or preconceptions of the researcher. A clear example of this is the centring of farmers (in this paper) as the primary territorialising force for the farm assemblage. Assemblage theory, like other 'more-than-human' approaches, seeks to decentre human agency. Comi's (2020) analysis goes so far as to question whether farmers have substantive agency at all. Our emphasis on farmers is in large part a reflection of the methodological deployment of the microAKIS approach: farmers are positioned as assembling their microAKIS. There is therefore some disconnection between analysing microAKIS and more-than-human approaches, and risk that the agency of farmers is over-estimated in our analysis.

Nevertheless, we see considerable promise in microAKIS as a methodological approach. In focusing on who farmers identify as important sources of information, a wide range of non-traditional actors become visible. Those identified in this present study were clearly aligned with addressing the specific materialities of the innovation. As Darnhofer (2020) points out, much of the farm adaptation literature has emphasised the decision-making process of the farmer, with far less consideration for the material characteristics of the farm and innovation, as well as a range of institutional actors, all of which have agency in the decision-making process. Specifically focusing on one type of actor – in this case farmers – also suggests that there is merit in focusing on other types of actors. Analysis specifically of the networks and approaches of these sources of advice – particularly those which are not professional advisors (e.g. of researchers, input suppliers or bankers) might similarly yield useful insights into innovation processes. In this respect, a critical application of mixed research method (Small, 2011), combining quantitative and qualitative analysis, could allow for more triangulation of data in the empirical exploration of AKIS through assemblage thinking.

7. Conclusion

The current European emphasis on supporting innovation in the agricultural sector through facilitating increased provision of advice and associated research efforts represents an important opportunity for academic research to have a major impact on agricultural sector development. The AgriLink project is a clear example, but research funded by the European Commission is increasingly focusing on the innovation-led perspective, that is, 'multi-actor approaches' aiming at supporting co-design of innovations and networking activities. While valuable, there is a disconnection between these 'process' or soft system approaches and the funding for AKIS, which largely oriented towards maintaining a narrow infrastructure of service provision. This national-level approach lacks precision, in terms of who needs what knowledge. Farmers are confronted with exogenous shocks and triggers (e.g. digitalisation, climate change, migrant workers) that impact the conditions of farming and create the need to territorialise new elements into their farm assemblages, as well as incremental institutional changes that may be invisible from a macro view point but shape individual behaviour (e.g. continuous development of outsourcing). Therefore, we argue that new hybrid models of advice provision require recognition and investigation, and the complexities, nuances and evolution of farmers' microAKIS need to be investigated, before these determinations can be made. To some degree, this type of analysis is already underway in relation to new digital ways of interacting (e.g. Fielke et al., 2020; Klerkx, 2021) but we see considerable scope for considering new interactions with a broader array of actors. Comprehensive studies of these assemblages could reveal new gaps and mechanisms of inequalities between farmers in their access to knowledge, but also highlight some opportunities to break path-dependency and integrate new actors. To do otherwise is to undermine the wide spectrum of both established and newly emerging knowledge sources that support the farm assemblages which enact innovation in European agriculture.

Author statement

We confirm that it is our own original research.

Data availability

Findings reported in this paper can be accessed in further detail on

the project website www.agrilink2020.eu.

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