R&D Management Conference 2024

Theme: ECOSYSTEMS ALLIANCES AND COLLABORATIONS

Track: P43. Digital technologies, ecosystem and industry transformation

TITLE: UAV-Driven Ecosystems for Sustainable Livestock Management in Rural France: A Case Study

AUTHORS : **Despoina Filiou[1]**, Adrien Lebreton[2], Viara Bojkova[3], Aikaterini Kasimati[4] , Nicolas Estelle[2], Kristen Reid[1], Jie Deng[1], Giacomo Carli[1], , Stratos Arampatzis[3]

AFFILITATIONS :

1 The Open University, Business School, UK
2 Institut de l'élevage, (IDELE), France
3 NOOSWARE BV, Netherlands
4 Agricultural University of Athens, Greece

Abstract

The aim of this research is to unpack the main characteristics of an emerging ecosystem for the use of unmanned aerial vehicles (henceforth UAVs or drones) for livestock management in rural France. The ecosystem is initiated through a national policy initiative with the view of enhancing environmental and economic sustainability in agriculture, specifically livestock management. The paper explores the innovation, institutional and knowledge attributes of ecosystems and the role of intermediary organisations in their development through both implementing and informing entrepreneurial policy. The research advances understanding on the role of UAV-driven entrepreneurial ecosystems (EEs) in environmental and economic sustainability of agriculture and rural areas and by highlighting priority areas for potential interventions which could support such early-stage EEs to evolve and flourish.

1. Introduction

The aim of this research is to unpack the main characteristics of an emerging ecosystem for the use of unmanned aerial vehicles (henceforth UAVs or drones) for livestock management in rural France. The ecosystem is initiated through a national policy initiative with the view of enhancing environmental and economic sustainability in agriculture, specifically livestock management. The latter is a key economic activity underpinning economies in certain rural areas, which is experiencing high challenges due its labour-intensive nature, an aging farming population, feelings of social isolation linked to livestock management, which contribute to its unattractiveness to potential new farmers.

The literature on entrepreneurial ecosystems (EE) is burgeoning and the remainder of this work focuses on understanding ecosystem characteristics central for informing future policies in developing both the economic and entrepreneurial potential of rural areas (see Candeias and Sarkar, 2024). The paper unpacks the main characteristics and various interconnected layers of EEs and the processes underpinning their evolution through exploring the interactions across various ecosystem stakeholders. The paper explores the innovation, institutional and knowledge attributes of ecosystems and the role of intermediary organisations in their development through both implementing and informing entrepreneurial policy. As a result, this research aspires to contribute to existing literature in two ways: first, by exploring the role of intermediary organisations in linking top-down with bottom-up approaches to EE policy development, second, by focusing on the characteristics of ecosystems at their early-stage of development, which are aimed at promoting both entrepreneurial opportunities but also broader societal value, such as environmental and economic sustainability of agriculture and rural areas. Because a high number of EEs can linger at an emerging stage, our results can draw important implications for EE policy development by highlighting priority areas for potential interventions which could support early-stage ecosystems to evolve and flourish.

2. Literature Review

The literature on ecosystems is characterised by various contributions which seek to explore how adopting a 'system' or 'group' approach contributes to understanding new ways of organising economic activities. There are various perspectives and points of view on defining ecosystems, with a simple yet comprehensive definition offered in Baldwin et al., (2024) 'in management and economics, the term [ecosystem] is now widely used to denote a network of autonomous economic actors interacting to create value, including a complementary surplus, which is distributed across actors' (p. 1). The 'complementary' surplus value captures the excess that the autonomous actors create through their interaction, which is beyond the aggregate value that each actor creates in isolation.

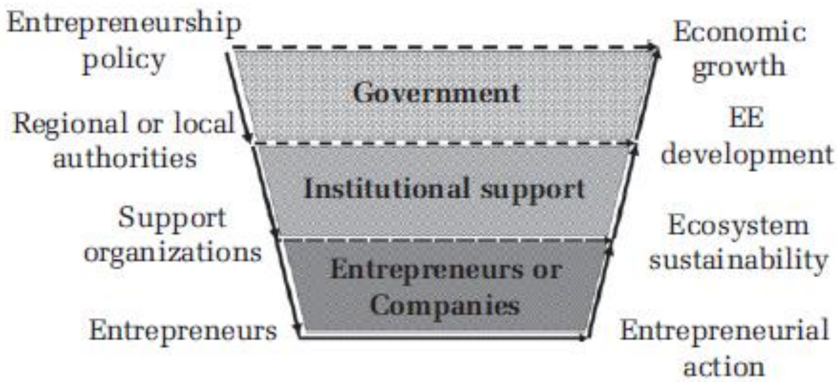
There are various types or attributes of ecosystems, such as innovation, platform and non-platform, entrepreneurial and knowledge ecosystems. A common characteristic is that the actors comprising ecosystems are autonomous, contribute to joint value creation through complementary ways and the products and processes in the ecosystem are modules within a larger technical architecture (e.g. a UAV can form an architecture, with suppliers of components such as cameras and batteries, forming the complementing modules). In platform ecosystems, one or more central hubs (can even be a single business) coordinates interactions among actors, while in non-platform ecosystems such actors coordinate their actions through contracts, alliances, and multilateral agreements. Innovation ecosystems emerge through innovations whose components satisfy the above criteria of modularity and complementarity. What is important here is that a market for this innovation (product or process) might not exist, but innovation ecosystems create value for users, which can benefit from using the innovation and express willingness to invest resources to obtain access. Knowledge ecosystems create aggregate value (and so do EEs) in a region or broadly, by creating and disseminating new ideas which do not necessarily have commercial value (see Table 1 adapted from Baldwin et al., 2024).

Table 1 Comparing Ecosystem Attributes (adapted from Baldwin et al., 2024)

	Innovation ecosystem	Platform ecosystem	Entrepreneurial ecosystem	Knowledge ecosystem
Source of value creation	Focal innovation	Focal platform	Productive entrepreneurship	Novel knowledge
Typical actors	Innovators, Suppliers, Complementors	Platform owner(s), Complementors	Entrepreneurs, Funders, Research Organizations, Accelerators	Universities, research institutes, firms, government agencies
Primary Interaction	Technological and input-output flows	Technological and multi-sided markets	Knowledge and resource flows	Knowledge flows
Link with Innovation studies	Innovation and technological change	Innovation by platform owners, complementors	Innovation clusters and regional ecosystems	University-industry knowledge flows

Ecosystems to support and promote entrepreneurship (EEs) are of specific interest to policy makers due to their potential to boost economic activity, promote economic growth and the vitality of regions where they are situated. Here we draw on some of the latest research on this area (Candeias and Sarkar, 2024) which understands EEs as a community of diverse and interdependent agents operating at multiple, interconnected levels, and whose complex nonlinear interactions within an entrepreneurship conducive environment support self-sustaining and adaptable processes of venture creation, growth, and dissolution over time. Central to this understanding of EEs is their multilayer characteristic and non-static, but evolving nature over time. Figure 1 below shows a multilevel model of EEs with three stacked non-hierarchical layers.

Figure 1 Entrepreneurial Ecosystems: Layers (adapted from Candeias and Sarkar, 2024)



The top layer involves actors, policies and actions of national and supranational organisations relevant to the EE. The middle layer encompasses institutional actors, such as intermediary and support organisations at regional and local level. Their actions and policies are more specifically directed to the local conditions and requirements of an EE. Both the creation, further development and growth of an EE are influenced by the interaction of policies and initiatives at the top two layers. The last layer represents businesses and individual entrepreneurs, which can include both established businesses and new entrepreneurs.

EEs can arise in a 'natural' evolutionary process, germinating from entrepreneurial activity that creates connections across entrepreneurs, supporting organisations and institutions (e.g. funders, business angels); these interactions can create positive feedback loops and amplify entrepreneurship through success of existing ventures which attracts more capital and entrepreneurs. EEs can also be promoted by government initiatives aimed at promoting entrepreneurial activity through altering framework and/or systemic conditions (see

Candeias and Sarkar, 2024). Framework conditions directly impact entrepreneurial activity, such as the creation of infrastructure and institutions, while systemic conditions involve networks of entrepreneurs, finance, talent, knowledge and support services. Supporting the former is linked to top-down policy initiatives, while improving systemic conditions focuses on developing interconnections within actors of the EE through a bottom-up approach that engages intermediary / support organisations and the base layer of EEs.

It is important to note that innovation and platform (non-platform) ecosystems mainly involve interconnections across businesses while knowledge ecosystems can involve actors across all layers of Figure 1. In other ways, ecosystem attributes are overlapping with some actors contributing to value creation on more than one area of Table 1.

3. Methods - Identifying key actors in the ecosystem

3.1. Context of UAV application: Livestock management

Livestock farming systems have progressively intensified, leading to an increasing number of animals per farm. Essentially, a significant part of farmers' work involves the daily task of monitoring animals. Depending on the farm and the season, this can amount to several hours per day. To save time, increase flexibility, and reduce the drudgery of animal monitoring, farmers use new technologies, even milking robots among dairy farmers.

Recently, farmers have begun using drones for monitoring grazing animals. Equipping themselves with second-hand drones, farmers have embraced this general-purpose technology experimenting on their own. In France, currently 8% of ruminant farmers are already using UAVs, and another 20% are considering adoption (IDELE, 2023). However, without training or certification, observed uses have often failed to comply with the regulatory framework or failed to be efficient. Furthermore, UAVs remain a costly investment for economically strained systems. Equipment adoption become highly risky without evidence of their benefits, necessary knowledge, and a proper framework for their use.

The scope of this exploratory UAV application (henceforth case) is to evaluate the risks and the interests to use drones for monitoring cattle and sheep in grassland systems whether drones are piloted by farmers themselves or via a drone service provider. UAVs will be used as an “eye-in-the-sky” supporting farmers and sheepherders with visual information. Indeed, from the drones' images, livestock farmers can collect much information that they are now collecting with a close visual check of the herd – number of animals, position of the animals, access to water, health assessment, and welfare levels. Building on existing and "off-the-shelves" drone technologies, the UAVs will be evaluated in two complementary pilot farms representing 2 species and 2 types of grasslands: the first farm with a beef cattle herd in pastures low-lands, and the second farm with a sheep flock in mountain rangeland. Preliminary results show that UAV use for livestock farming saves farmers numerous trips on foot or, more often, in a pickup truck. This reduction in travel translates into saved time—30% of time saved on the daily routine of 1.5 hours on our pilot cattle farm (preliminary results)—and fuel savings. Drones are not used every day but at best one day out of two, weather permitting. Consequently, with in-person visits occurring every two days, in addition to inputs provided by drones, livestock monitoring is continuous and consistent. Drones, offer more frequent updates on the health and welfare condition of animals, allowing farmers that may lack the time for in-person inspections to react promptly to any issues that may arise.

These findings are preliminary and the application of UAVs for livestock management remains at large at exploratory stages, with the market and purpose-build UAVs yet to be developed. Therefore the focus of this paper is to explore the key actors comprising the EE and to identify their primary needs and interactions. The aim is to understand the key requirements of each stakeholder and how interactions in the EE can fulfil these requirements to advance and develop it further. This case offers a unique opportunity to capture the early stages of an EE and to draw some implications on the requirements and interactions that need to be prioritise and fulfilled for the EE to develop.

The main stakeholders comprising the EE are identified by an intermediary organisation, IDELE, a not-for-profit research organisation which is field-testing UAVs in livestock management in two (Carmejane and Jalogny) pilot farms funded by both national and EU-project funds. In a period of three months IDELE scoped the range of stakeholders. To identify the interactions across the actors of the ecosystem and those with external actors that might influence the EE we pursued as follows. A questionnaire was sent to all stakeholders asking them to identify their requirements and needs for the further development of the ecosystem together with the most important source for fulfilling the respective needs. Stakeholders had to prioritise both their needs and source in terms of importance on a 5-point Likert scale. Finally, representatives from each stakeholder category participated in a focus group session to discuss their needs and vision on developing the EE further.

4. Findings

4.1. Analysis of ecosystem stakeholders and interrelationships

IDELE's experimental field-tests aiming at exploring UAV boundary parameters, such as weather, landscape, UAV flight range (out of line of vision), quality and processing of generated livestock data, livestock-UAV interaction (e.g. welfare impact of UAV noise), impact on neighbouring areas. The overall aim is to evaluate drone solutions for monitoring grazing cattle and sheep systems and ultimately to assess the capabilities of UAVs to improve working conditions by reducing the time requirements due to increasing size of livestock managed per farm. A validation will shape future UAV regulations as currently only UAV flight paths for logistics are licensed in France.

In EE terms, IDELE is an 'intermediary actor' which can inform EEP (entrepreneurial ecosystem policy) from a bottom-up perspective. IDELE identified 13 stakeholders comprising the EE, who belong to one of the following categories: 1) have a direct or indirect **involvement** with livestock management 2) receive direct or indirect **benefits** and 3) possess a significant, legitimate **interest** (e.g. regulators) in livestock management.

The tables and network graph below show the stakeholders, their primary needs or requirements and their interactions, based on simple directional value flows. These capture the early stage of the EE and preliminary results which will be validated and enriched during stakeholder awareness and UAV demonstration events as part of the EE development activities of IDELE. These activities will conclude in 2026, giving the opportunity to capture how the EE will evolve and what policy implications that can be drawn by linking activities with EE evolution. Table 2 shows the stakeholders, their type, and primary requirements.

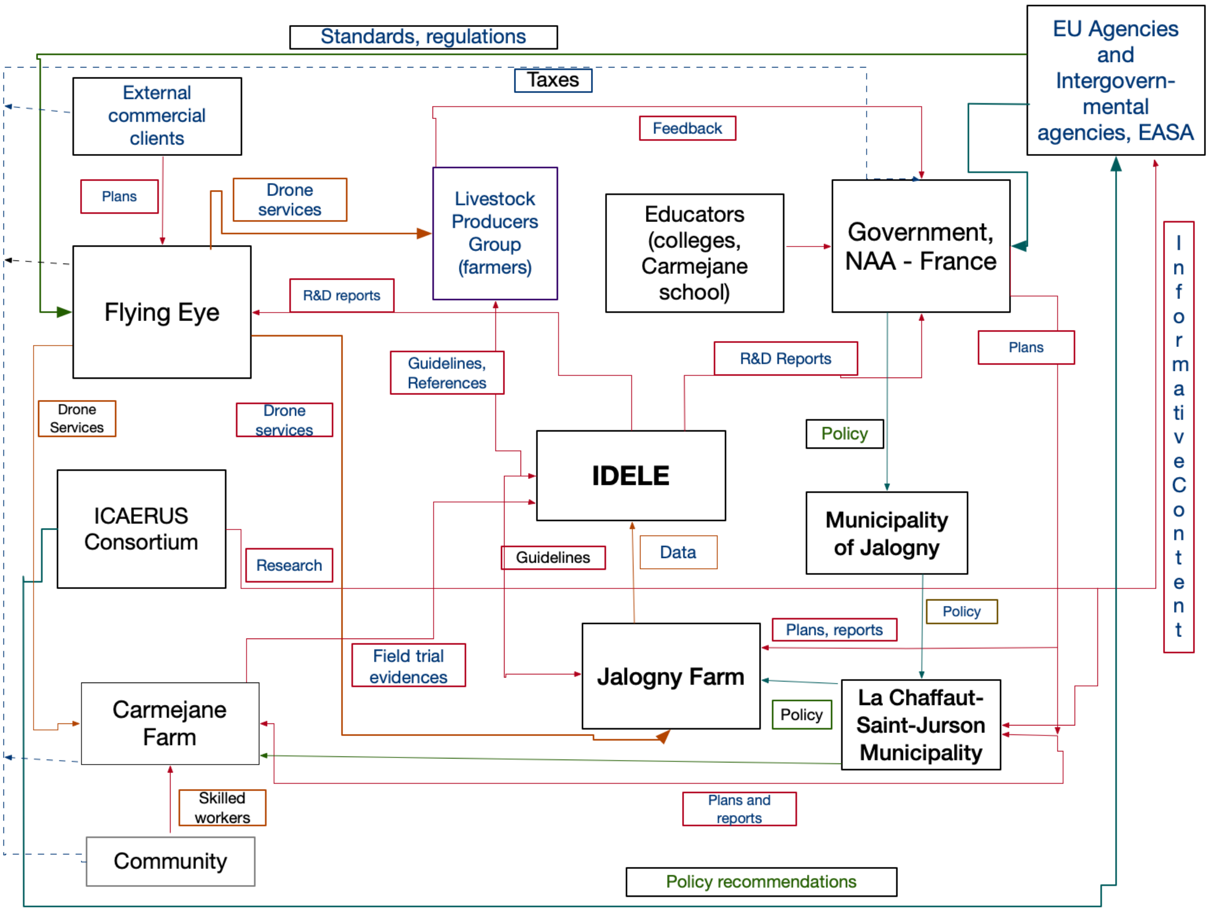
Table 2 Stakeholders, stakeholder type and primary requirements

Stakeholder Name and Type	*Specific Needs and Areas of Interest in order to Achieve their Primary Objective(s)*
UAV organisations -businesses	
1. Flying Eye	Communication with customers – understanding livestock farmer requirements
End-Users (businesses, associations, individuals)	
2. Livestock Farmers / Producer Groups or Associations	User/farmer opinion-feedback
3. Farmers (end-users)	Specific guidelines for safety in UAV use for livestock monitoring
4. Jalogny farm	Skilled workforce in UAV use
5. Carmejane farm	Guidelines on the optimal use of drones in livestock monitoring and its impact on farming in France
Institutional Actors	
6. National Government (France)	Interest in boosting economic and entrepreneurial activities, interest in gathering public opinion from local residents
7. National Aviation Authority (NAA; France)	Consultations with representatives from the UAV hardware industry
8. European Aviation Safety Agency	Community acceptance for safety & environmental protection
9. Municipality of La Chaffaut-Saint-Jurson (Carmejane farm)	No conflict among the inhabitants and visitors of the local community
10. Municipality of Jalogny	Active communication with the local community
11. European Agencies and Inter-governmental Agencies (EASA)	Community acceptance of UAV use for environmental protection & alleviating safety concerns
Education – Knowledge - Research	
12. Local schools - colleges	Available time for education initiatives
13. ICAERUS Consortium (Horizon Europe Funded Partnership)[1]	Generating knowledge about UAV use in agriculture, feeding into activities to increase further UAV awareness, applications & future research
14. IDELE	Plans and reports of progress in projects' participation

1 'Innovation and Capacity building in Agricultural, Environmental and Rural UAV Services' ICAERUS consortium is Funded by the EC under its HORIZON Programme (Contract No: 101060643, HORIZON-CL6-2021-GOVERNANCE-01-21: Potential of drones as multi-purpose vehicle – risks and added values, 2022 – 2026. https://icaerus.eu/)

The Network Graph 1 below shows the central positioning of IDELE and of the two pilot farms. The centrality is based on views from the remaining EE stakeholders when identifying the 'main source' to fulfilling their requirements (e.g. providing the necessary resources, such as equipment, testing grounds, funds) or information (e.g. data, risk assessment, regulation) and knowledge (e.g. reports on cost-benefit analysis, animal welfare and UAV noise).

Network Graph 1: Interactions among the stakeholders comprising the Ecosystem (foundational stage)



Graph note: Blue denotes monetary flows, Red denotes new research/exploratory generated knowledge, Green denotes policy recommendations/implications, Orange denotes information/resource flows linked to UAV technical aspects.

Table 3 details the value flows to and from IDELE as the main stakeholder in the network graph.

Table 3 Value flows to and from IDELE together with respective sources and recipients

Value flows to IDELE and main initial sources (stakeholder)	
Funding	EU; National Government
Cost-sharing	Pilot farms; End users
Research-based evidence and information on UAV efficiency	End Users; EU reports
Skilled workforce	Educators - Colleges
Scientific publications	Ecosystem; Universities
Plans and progress reports	ICAERUS; Ecosystem
New UAV technology and sensors	Ecosystem
Value flows from IDELE and main recipients (stakeholder)	
Outcomes regarding impact of UAV use requirements and labour efficiencies	End users (i.e. farmers)
Exploratory research outcomes and promotional material	End users
Guidelines for promoting drones and reducing ensuing risks	End users; Livestock farmer associations
Demonstration of UAV use on location	End users; Pilot Farms
Drone awareness campaigns	Community; Municipalities

The role of IDELE as EE intermediary organisation becomes evident from Table 3 value flow description and its positioning on Graph 1. IDELE is at the middle layer of Figure 1 (Candeias and Sarkar, 2024) and key stakeholder of the knowledge attribute of the ecosystem as its research on location generates evidence-base knowledge on the benefits and conditions (e.g. identification of a range of flying risks, experimentation with different technologies) for effective and safe UAV use for livestock management. IDELE's pilots generate both visual and thermal data on herd management, including the identification of individual animals within herds, which can feed into the development of state-of-the-art algorithms that can complement the development of purpose-build UAVs for this use. Data collected across the ICAERUS consortium, which will feed into both the training and development of more sophisticated and effective algorithms. In the future, this could potentially facilitate sophisticated analyses of data to enhance animal welfare including early diagnosis of health and nutritional issues.

Table 4 Value flows to and from Flying Eye together with respective sources and recipients

Value flows to Flying Eye and main initial sources (stakeholder)	
Commercial Funding	Commercial clients
Skilled workforce	Educators - Colleges
Science knowledge on UAV technology and ecosystems	IDELE; Universities
Manufacturing business processes	Workforce
Manufacturing components	Suppliers; Ecosystem
Communication with customers	End users (i.e. farmers)
Value flows from Flying Eye and main recipients (stakeholder)	
Production of UAVs	End users; livestock farmer associations
UAV services	Pilot farms; End users
Documented risk assessment	End users; Pilot farms

Flying Eye, established in 2009, is both the French brand and the manufacturer of UAVs for professional use, a distributor of other established international UAV brands, offering a wide range of UAV services. Flying Eye is the only stakeholder representing the 'innovation' attribute of the ecosystem. The UAV market for this use is at exploratory / experimental stage. This is also reflected on the relatively disconnected position of Flying Eye in Graph 1 and their designating 'communication with customers' as their primary need (see Table 2) for developing the EE further.

The regulatory framework shaping the use of UAVs in agriculture is restrictive in comparison to other countries or regions. Technical issues, both in terms of hardware and algorithms for the analysis of UAV-gathered data are still advancing. In technical terms there are trade-offs between size/weight of UAVs and number of components, batteries, flying time and range (which influence flight beyond line of vision).

Overall, the network graph reflects the close interconnections between the institutional and knowledge attributes of the ecosystem and the role of intermediary organisations in advancing knowledge through field research and an evidence-based approach. This knowledge will inform future regulation from the bottom up. The innovation attribute of the ecosystem is the least developed and comprised solely by one firm and its commercial clients external to the EE. The product is generic, while a closer integration of Flying Eye with other stakeholders in the EE can generate the necessary information of the specific needs of livestock farming which can feed into UAV product and component innovations specific to this market/use.

The need to advance understanding on regulations and risk assessment is crucial for the further uptake of UAVs in this sector. Important is also to cover requirements for UAV-trained and skilled staff in the area which can be supported by technical colleges in the area. Some barriers around curriculum flexibility and autonomy of educational institutions need to be overcome.

4.2. Exploring ecosystem needs through stakeholder focus groups

The identification of needs and requirements for the further development of the ecosystem were further explored by focus group discussions which were coordinated by IDELE with representatives of the EE stakeholders, including: sheep farmers, data scientists (linked to development of algorithms), grass and pastoral project managers, specialist on digital solutions for farming, agriculture engineering students. The participants acknowledged the contribution that UAVs can make to alleviating some of the pressures linked to livestock management in challenging landscapes, faced particularly by breeders of an aging population when navigating large farms with high altitudinal differences. Labour substitution is the key desirable UAV service, supporting breeders to manage their time efficiently. Participants deliberated on other highly valuable desirable UAV features. First it is the possibility to monitor 'hidden' physical characteristics of animals (e.g. temperature) that can aid early identification of health issues including breeding, which can in turn facilitate timely interventions, improving livestock monitoring and animal welfare. Second, breeders highlighted the need for multi-purpose use UAVs, that could be used across several complementing activities, such as herd and grazeland monitoring, but also between agricultural and other sectors such as land surveying and damage assessment, contributing to efficient asset use. These needs provide ground for drone manufacturers to modify existing UAVs, by incremental or modular innovations, to satisfy this demand. Connecting the user/demand perspective with the main manufacturer in the EE (Flying Eye or other UAV manufacturers outside the existing EE structure) can develop the innovation attribute of this ecosystem(Baldwin et al., 2024, Moeen et al., 2020).

Discussants were concerned about existing national and EU regulations. Regulation intensifies user uncertainty, particularly because of the lack of exact guidelines on, among others, flight range, height and night-time operation. Developing knowledge and support by intermediary organisations are key to the furtherment of this ecosystem. Some discussants raised concerns about whether UAV use trespasses civilian privacy in communities adjacent to farms. The issue of privacy is highlighted in academic research as a primary concern to citizens, together with security, when assessing the importance of drones (AL-Dosari and Fetais, 2023). Advancements in image recognition technologies, that could discriminate human from animal data and information (e.g. based on temperature) would be a fundamental innovation to furthering UAV-driven ecosystems. This highlights the importance of developing capabilities in complementing technologies, and the role of actors in the broader network of drone suppliers, component manufacturers and software developers for the furtherment of the ecosystem. This echoes earlier comments that the innovation attribute of this ecosystem needs to be developed before greater impact of the UAV use is felt on existing businesses (farmers) and new entrepreneurs in the ecosystem. Participants identified a range of actors-catalysts in developing this ecosystem, primarily by furthering its knowledge attributes. First are agriculture research organisations to provide a convincing case for technology adoption and accumulate knowledge to alleviate existing uncertainty; uncertainty is a core barrier to new technology adoption (Moeen et al., 2020). Second, public agriculture advisory bodies can lead on UAV demonstration events and several rounds of trials on location to support farmers with decision-making. Third, public funding bodies can facilitate farmers gaining access to UAVs. By purchasing UAVs on behalf of farmers at a regional level, funders can assume both the costs and the risks of investing in a relatively new and uncertain technology.

Discussants envisaged that as farmers become more accustomed to the technology, cooperatives can coordinate joint purchase and shared use of UAVs which can contribute to the efficient use of drone assets. Cooperative members share the risks and costs of drone management, such as hiring licensed pilots, storing, and analysing the generated data. Finally, increasing demand of UAV use by breeders can attract new entrepreneurial activity in the EE around 'drones as a service' provision which can complement rather than substitute existing livestock management practices because herd monitoring requires frequent direct breeder involvement.

5. Discussion

This case not only enriches the discourse on technology-driven EEs but also underscores the pivotal role of intermediary organisations in bridging the gap between policy and innovation. Looking ahead, it is clear that the ongoing evolution of UAV-driven ecosystems will depend heavily on collaborative efforts among actors on innovation ecosystems, users, policymakers, and researchers. Such collaboration will ensure that the benefits of UAV technologies are realised widely and equitably, contributing to the overarching goals of sustainable and resilient agricultural practices. This suggests that policy makers can focus on developing the framework conditions of EEs first, providing adequate knowledge and regulations to reduce technological uncertainty, and then proceed to supporting structural EE conditions, by incentivizing and encouraging deeper interactions across innovation, knowledge stakeholders with businesses/users.

This study highlights the significant role played by research institutions and intermediary organisations such as IDELE in fostering the emergence of UAV-driven ecosystems, by spearheading evidence-based research on the benefits of the technology, offering grounds for farmers in investing on its adoption. Intermediary organisations serve as vital links between policy, innovation and practical implementation. Through initiatives like the ICAERUS project, they demonstrate how policy-driven approaches working in harmony with technological advancements support sustainable agriculture. By integrating top-down policy initiatives with bottom-up explorations, such organisations ensure the sustainability of EEs and the fulfillment of broader economic and environmental goals.

The deployment of UAVs in livestock management opens a spectrum of entrepreneurial opportunities that transcend traditional farming methods. This technology allows for the development of new business models, such as drones-as-a-service (DaaS) and cooperative ownership structures, which can significantly reduce barriers to adoption for small-scale farmers. Furthermore, the adaptability of drones for complementary purposes—such as land surveying and damage assessment—illustrates the multipurpose nature of this technology, which can lead to the creation of new market niches and service offerings within rural economies. EEs at early stage primarily aim at enhancing the economic viability, efficiency, attractiveness and quality of life of existing businesses/farmers. New business opportunities opening-up can attract new entrepreneurs in rural areas or can offer complementing economic opportunities for existing farmers. Currently this EE can enhance broader economic, environmental and societal goals by supporting existing business to transition to greener practices.

The introduction of UAVs has shown potential benefits for animal welfare by enabling more consistent and stress-free monitoring of livestock. This technology facilitates early detection of health issues and better management practices without the need for constant human presence, which can reduce stress for both animals and farmers. Additionally, the automation of routine tasks alleviates the labour burden on farmers, contributing to better time management, improving quality of life and reducing feelings of isolation. However, the integration of this technology must be managed carefully to ensure it does not lead to an overwhelming influx of new tools that farmers must learn and maintain.

The integration of UAV technology into rural farming practices has implications that extend beyond immediate agricultural productivity. It poses questions about the socio-economic stability of rural areas, the environmental impact of more efficient farming practices, and the potential for these technologies to reshape rural communities. Future research should focus on longitudinal studies to evaluate the sustained impacts of UAV integration on these communities and ecosystems. Comparative studies across different regions could also offer insights into how localised factors influence the success and adaptability of UAV technologies in agriculture.

References

AL-DOSARI, K. & FETAIS, N. 2023. A New Shift in Implementing Unmanned Aerial Vehicles (UAVs) in the Safety and Security of Smart Cities: A Systematic Literature Review. *Safety,* 9.

BALDWIN, C. Y., BOGERS, M. L. A. M., KAPOOR, R. & WEST, J. 2024. Focusing the ecosystem lens on innovation studies. *Research Policy,* 53**,** 104949.

CANDEIAS, J. C. & SARKAR, S. 2024. Entrepreneurial Ecosystems Policy Formulation: A Conceptual Framework. *Academy of Management Perspectives,* 38**,** 77-105.

IDELE. 2023. *Enquête nationale Sm@rt Elevage sur les taux d'équipements des éleveurs en outils numériques* [Online]. Available: https://idele.fr/smartelevage/publications/detail-article?tx_atolidelecontenus_publicationdetail%5Baction%5D=showArticle&tx_atolidelecontenus_publicationdetail%5Bcontroller%5D=Detail&tx_atolidelecontenus_publicationdetail%5Bpublication%5D=20572&cHash=17327085726c4a4eb9e370769e9899de [Accessed 29 April 2024].

MOEEN, M., AGARWAL, R. & SHAH, K. S. 2020. Building industries by building knowledge: Uncertainty reduction over industry milestones. *Strategy Science,* 5**,** 218-244.