REGULATORY HORIZONS COUNCIL

Unlocking the Potential of Robotics and Autonomous Systems (RAS) in Agriculture and Horticulture

RHC Policy Sprint

October 2023

Contents

1. Introduction

The Regulatory Horizons Council (RHC) is an independent expert committee sponsored by the Department of Science, Innovation, and Technology (DSIT) that identifies the implications of technological innovation, and provides government with impartial, expert advice on the regulatory reform required to support its rapid and safe introduction. It has so far published reports on innovations including (but not limited to) drones, artificial intelligence (AI) as a medical device, and genetic technologies.

Agriculture and horticulture[1] are critical industries[2] that are grappling with significant challenges such as labour shortages[3], rising costs of agricultural inputs, low productivity[4], dealing with the impacts of climate change and the need to adopt sustainable practices as the sector moves towards decarbonisation. Robotics and autonomous systems (RAS) have the potential to help to address these challenges and transform the agriculture and horticulture sectors, better aligning them with society's evolving needs. Depending on effectiveness, regulation can be a barrier or an enabler of the adoption of robotics in agriculture and horticulture.

To address these challenges, the Regulatory Horizons Council and the Agri-Tech Sector team in the Department for Environment, Food & Rural Affairs (Defra) collaborated on a policy sprint to help address the regulatory challenges and opportunities surrounding the use of robotics and autonomous systems in agriculture and horticulture. This short project has brought together stakeholders from government departments, academia, research institutions, industry, farmers, and other relevant organisations to collaboratively identify and address regulatory challenges and explore how regulation can enable increased adoption.

Robotics and autonomous systems (RAS) terminology

There is no standard definition of RAS[5] in agriculture and horticulture. In its simplest form, automation is where an operational system performs tasks with little or no human input, often performing dull, dirty, or dangerous tasks previously carried out by humans. Automation in this way can be achieved through purely mechanical components performing low variation tasks at speed, or via computation and robotics enabling

[1] The definitions of Agriculture and Horticulture used in this project are provided in Annex A.
[2] In 2021, the total consumer expenditure on food, drink, and catering reached £240 billion, Defra, 'Food statistics pocketbook' (2023): https://www.gov.uk/government/statistics/food-statistics-pocketbook
[3] From 2000 to 2021, the agriculture sector experienced a significant decline of 23% in the number of employees. Defra, 'Agriculture in the United Kingdom data sets' (2022): https://www.gov.uk/government/statistical-data-sets/agriculture-in-the-united-kingdom
[4] Over the 10-year period leading up to 2020, the average annual growth rate of the food chain was only 0.1. Defra, 'Total Factor Productivity of the United Kingdom Food Chain 2020 – final release' (2023): https://www.gov.uk/government/statistics/food-chain-productivity/total-factor-productivity-of-the-united-kingdom-food-chain-2020-final-release#benchmarking-the-uk-food-chain-against-the-wider-economy
[5] The National Security and Investment Act provides a definition of Advanced Robotics https://www.gov.uk/government/publications/national-security-and-investment-act-guidance-on-notifiable-acquisitions/national-security-and-investment-act-guidance-on-notifiable-acquisitions#advanced-robotics

automation of more varied and complex tasks. Autonomous systems can also use advanced intelligence systems, such as AI. This is often an area where regulatory issues arise, partly based on the very different governance systems that pertain in each area.

In agriculture and horticulture, RAS find applications in various areas, including:

- Precision mapping
- Planting or seeding crops
- Precision applications such as fertilisers or pesticides
- Monitoring weeds, pests, diseases, yields, and soil health
- Data collection
- Harvesting, picking or packing crops

These can be individual or "swarm" systems undertaking single or multiple operations. As well as ground-based systems, drones or other Uncrewed Aerial Vehicles (UAV) can also carry out some similar functions. Robotics also exist in the livestock sector, such as in robotic milking parlours.

There is a sense of urgency in government to provide a clear pathway for the greater adoption of robotics and automation in the agriculture and horticulture sectors. This is showcased by the commitment to a range of significant funding programmes in the sector including:

- £12.5 million in funding allocated for developing cutting-edge innovation in automation and robotics through the Farming Futures Automation and Robotics competition, which is part of the £270 million Farming Innovation Programme (FIP).
- An £80 million investment has been provided as capital-only funds to four Agri-Tech Centres to enhance the capacity in the UK for translating agricultural R&D into commercial applications.
- £6 million allocated to support R&D projects aimed at advancing or developing solutions in service robotics for a more resilient future, including applications in agriculture and food production.[6]
- The Farming Transformation Fund's Improving Farm Productivity grant was active until 2022, providing funding to farmers for the purchase of robotic equipment. It is now operating under the name Farming Investment Fund.[7]

Furthermore, alongside funding programmes, efforts have been made to understand the current obstacles hindering the adoption of RAS, including the Automation in Horticulture Review[8] and the Independent Review of Labour Shortages.[9]

[6] https://apply-for-innovation-funding.service.gov.uk/competition/754/overview
[7] https://www.gov.uk/guidance/farming-investment-fund
[8] https://www.gov.uk/government/publications/defra-led-review-of-automation-in-horticulture/automation-in-horticulture-review
[9] https://www.gov.uk/government/publications/independent-review-into-labour-shortages-in-the-food-supply-chain

The Automation in Horticulture Review identified several key barriers to adoption, including:

- A lack of clarity on how current standards and regulations apply to the next generation of automation in horticultural applications, leading to concerns around health and safety, data ownership and cyber security.
- A lack of knowledge among growers about available and suitable technologies for their operations, along with a broader deficiency in independent information and business support to the sector.
- Difficulty in attracting innovators to develop RAS technologies specific to the agriculture and horticulture sector.
- Difficulty in building confidence in automation adoption among farmers due to sectoral uncertainty, risk-averse mindsets, and the high costs associated with RAS.

Similarly, the Independent Review of Labour Shortages in the Food Supply Chain emphasised that not all businesses have the financial means to invest in RAS, due to the prohibitive costs and financial risks associated with investment.

Building on the insights from these existing initiatives, this policy sprint engaged with regulators to encourage them to adapt regulatory approaches to create a regulatory environment more supportive of robotics and automation.

2. Stakeholder Engagement

This policy sprint project was conducted in three stages and consisted of a series of workshops and meetings with government, industry, regulators, and academia. Annex B contains the methodology for this sprint project.

Stage 1: Evidence and insight gathering (June)

- **Industry Workshop**: The Defra Agri-Tech Sectoral team and the Crop Health and Protection (CHAP) Agri-Tech Centre hosted an industry workshop with **innovators and industry** providing insights and sharing experiences on the regulatory challenges that hinder the adoption of robotics in agriculture and horticulture.

Stage 2: Facilitation (July)

- **Regulatory Workshop:** The RHC conducted an interactive workshop with **regulators, innovators, and industry** to develop solutions for addressing what were determined to be the highest priority regulatory barriers identified in the Stage 1 workshop discussion.

Stage 3: Recommendations (August)

- **Policy Recommendations Formulation**: Insights from the previous workshops were formulated into regulatory policy interventions. The interventions were tested and reviewed with selected regulators to ensure that they aligned with the opinions and feedback gathered from participants. It was not within the reports scope, however, to ensure that all regulators agreed on the proposed policy interventions; the proposals set out in this report are interim proposals from the RHC, that Defra will work with relevant stakeholders to develop further.

The project's primary outputs consist of the workshops and this paper. The workshops fostered discussions, while the paper summarises those discussions and, using ideas generated from the workshop, proposes regulatory policy interventions to overcome barriers to adopting RAS in agriculture and horticulture.

2.1 Industry Workshop

The CHAP Agri-Tech Centre convened a workshop event on behalf of Defra and the RHC on Wednesday 7th June 2023, providing an opportunity for experts to share their thoughts on regulatory barriers and opportunities for the development and application of automation and robotics in agriculture and horticulture.

The workshop addressed several key themes and ideas, including:

- Competitiveness
- Cost and financial considerations
- Liability
- Data ownership

- Compatibility and interoperability

The full responses and analysis of the workshop questions are provided in Annex C. Workshop data was collected via MentiMeter, an online tool that enables participants to share anonymous feedback with workshop facilitators in real time. The main takeaways are outlined below:

2.1.1 Industry Workshop Insights

Supportive regulation:
Participants stressed the need for supportive regulation that fosters innovation in the agri-tech sector. Stakeholders expressed the need for regulation and standards that can adapt to the dynamic nature of robotics and autonomous systems. They desired a regulatory framework that strikes a balance between flexibility and prescription while ensuring freedom to operate within established guidelines.

The various regulatory requirements uncrewed aerial vehicles (UAVs) and autonomous vehicles were discussed; the table below provides a summary:

UAV Spraying	UAV Monitoring	Autonomous Vehicles
• Civil Aviation Authority (CAA) CAP722v9 forbids spraying in open category[10], operational authorisation required. • Health and Safety Executive (HSE) licenses the application method to ensure product effectiveness and prevent harm to the environment.	• CAA CAP722v9 forbids flight beyond visual line of sight (approx. 500m) in open category. • Operational authorisation required beyond that. • Flying at high and low altitude are treated equally. • Clear and scalable legislation for low risk flying in agricultural airspace does not exist.	• Automation is possible within field boundaries, but on-road (even crossing) use is not possible. • ISO18497:2018: Safety for highly automated autonomous machines exists, but not clear if it applies to agricultural applications.

Figure 1. Regulatory obstacles associated with Uncrewed Aerial Vehicles and autonomous vehicles

The point was made that CAA permissions are needed for all but the most basic UAV operations, and HSE approval needed for any spraying operations[11]. This is time consuming

[10] The Open category covers operations that present a low risk to third parties. Operations within this category are conducted within a set of basic and pre-defined limitations and do not require any further authorisation by the CAA.
http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=415
[11] HSE commit to processing applications within 10 days, but that the RHC don't have evidence to confirm whether or not they meet this target https://www.hse.gov.uk/pesticides/using-pesticides/general/aerial-spraying.htm

and costly for farmers, or businesses trying to sell their services to them, harming the prospects for investment in, and adoption of, these technologies.

A participant provided an illustrative example that emphasised the outdated approval process for robotics aids used in pesticide spraying. Currently, the registration process for pesticide spraying centres on their usage with traditional methods like tractor-driven spraying, primarily prioritising the safety of operators and bystanders. This approach overlooks the safety improvements introduced by the advancements of robotic aids to spraying. Additionally, participants posited the existing regulatory requirements for registration do not effectively utilise digital data; instead, they heavily rely on field tests as the primary evaluation method.

Competitiveness:
The potential for drone and automation was seen in field boundaries, but challenges exist in crossing roads and achieving beyond line-of-sight capabilities which need to be addressed if the sector can be internationally competitive.

"The cost of UAV sprayers is approximately £12,000-£15,000 with smaller robots approximately £20,000-£25,000, compared to conventional technology such as tractors which are around £300,000. Without changes to the restrictions on field boundaries usage, farmers are not able to take advantage of the cost savings associated with robotic and autonomous technologies."
Industry workshop participant

The importance of a supportive regulatory environment for investment was stressed, with examples provided of innovators moving geographical location to take advantage of preferential regulatory environments. It was felt that technology leaders and innovators were looking for favourable regulatory environments, and countries with the appropriate regulatory environment could benefit from a first mover advantage, and develop global leadership in UAV production and their safe operation in agriculture.

"Four robotic companies in California have received over $40 million in investment, however, due to a change in California regulation – to a one-person per one-field approach, companies are now moving to Arizona".
Industry workshop participant

Cost and financial considerations:
Stakeholders raised concerns about the costs associated with implementing RAS in agriculture and horticulture. Compliance with regulation was cited as a factor that increases costs and reduces the profitability of investing in RAS. Large-scale agricultural operations may find it easier to absorb the costs associated with implementing RAS due to economies of scale. SMEs, however, may lack the resources and production volumes to take advantage of these economies of scale, which puts them at a disadvantage. Exemptions from certain regulation was cited as a possible method of reducing the costs for SMEs.

In addition, the lack of a secure market for robotics and autonomous systems hinders innovative SMEs from developing agricultural technologies.

Liability:
Liability risk emerged as a critical concern for stakeholders working with robotics and

autonomous systems in agriculture and horticulture. Concerns about liability in case of failure indicate a desire for clear guidelines and accountability. Participants emphasised the need for insurance options to mitigate risks and provide financial stability for operators.

"[A large agricultural machinery supplier] could have put robotics into field 20 years ago. But didn't because they could have been sued. Who is liable? Farmers, operator, software engineer, physical engineer. Insurance needs to cover each of these areas for progress to be made."
Industry workshop participant

"Selective harvesting has the highest Return on Investment (ROI), more than spraying or monitoring. Industry is fine with having supervision for harvesting. But currently there aren't any regulations that clearly tell us how to properly monitor harvesting, without this we can't get insurance."
Industry workshop participant

Data ownership:

A conflict of interest was noted between RAS companies and farmers. RAS companies are motivated to gather and possess data, as it is essential for validating their services. On the other hand, farmers may prefer not to become overly dependent on a single RAS service provider. They have concerns that such reliance could be problematic if the service provider were to fail or if superior technology providers emerged.

The potential risks of relying solely on one RAS service provider are illustrated by the experiences of users in the EdTech solutions sector within schools. In some cases, service providers in the EdTech sector have gone out of business, leaving users with gaps in their services.

Many attendees were concerned by the potential to lose control of their data to a digital service provider, with some also concerned that buyers (supermarkets) might request access to production data and use this when negotiating pricing.

Other participants highlighted the potential advantages of using anonymised open data within the sector as a way to enhance machine learning and automation capabilities.

"Who should control data ownership? A potential quick win here could be open data."
Industry workshop participant

Compatibility and interoperability:

Stakeholders expressed the importance of working across sectors and regulatory regimes and achieving compatibility and interoperability in the field of robotics and autonomous systems. This theme highlights the need for systems that can seamlessly integrate with existing infrastructure, technologies, and practices in other sectors and industries using robotics and autonomous systems.

"Reassurance and guidance is needed for developers of robotics and autonomous systems technologies in agriculture. Currently agri-tech is not the more attractive sector for developers and innovators for this reason."
Industry workshop participant

Creating links between the UK and global regulatory ecosystems would promote innovation and growth and help the UK position itself at the forefront of advancements in robotics and autonomous systems. This significant task would likely require harmonisation of standards, the establishment of common frameworks, and the development of interoperable solutions that can be deployed globally. Such an approach could help to foster a vibrant ecosystem for research, development, and commercialisation, by attracting international investments, talent, and partnerships.

"The UK regulation ecosystem needs to be linked to the global ecosystem; UK is too small to be a market in of itself."
Industry workshop participant

The feasibility of aiming for interoperability for RAS in agriculture was questioned. Although a substantial portion of robotics utilises the standardised open-source 'ROS' (Robot Operating System), the robotics landscape is characterised by a multitude of distinct systems encompassing positioning and navigation, artificial intelligence, sensing, as well as various end-effectors including handling mechanisms, spray guns, and rods, among others. Moreover, addressing the complexities of standardising command, control, and data communication poses additional hurdles. The emergence of a unified standard across these diverse sectors within the short term appears unlikely.

2.2 Regulator Workshop

The RHC convened a workshop event on Wednesday 19th July 2023, providing an opportunity for regulators and industry to discuss and propose policy solutions to regulatory barriers for the development and application of automation and robotics in agriculture and horticulture.

Workshop participants were divided into cross-functional and organisation teams. Each team selected regulatory challenges and outlined various barriers associated with them, before proposing policy solutions, assessing them on an impact/effect matrix and categorising them as quick fixes or longer-term goals.

2.2.1 Regulator Workshop Insights

<u>Funding programmes and regulators:</u>

Funding agencies noted that some funding-recipients are unaware of upcoming regulatory changes, while regulators themselves seem unprepared for certain innovations stemming from funding projects.

"Innovate UK is providing game-changing funding for the sector, but government regulations could curb the potential benefits of this being realised."
Regulator workshop participant

The reluctance of innovators to engage with regulators at an early stage was identified as a significant concern, and efforts are needed to encourage early engagement, acknowledging the limited capacity funding-recipients may have for such activity. It was also noted that funding agencies may not have a mechanism to assess the quality of engagement with regulators by funding recipients. This may suggest funding agencies do not appreciate the importance of high quality regulatory engagement.

"The "In Flight" Project survey by Innovate UK focuses on different forms of monitoring and evaluation for funding recipients but does not attempt to measure engagement with regulators."
Regulator workshop participant

Competing incentives and mindsets:

Innovators noted that understanding the entrepreneurial mindset is crucial, as resource-poor entrepreneurs often face challenges due to insufficient time and funding. The discussion centered around potential regulatory adjustments to support these entrepreneurs without compromising necessary standards.

Furthermore, it is crucial to recognise that innovators often operate within a limited timeframe during which they must generate revenue to sustain their viability. In this context, time holds significant financial implications. In contrast, regulators generally lack incentives for swift responses and typically do not need to prioritise delivering immediate solutions.

Insuring RAS users:

Participants raised the pivotal role insurance availability plays in facilitating the adoption of RAS in agriculture and horticulture. Concerns were raised regarding the absence of a well-defined regulatory framework, which was noted to diminish the pool of insurance providers willing to cover RAS applications. This, in turn, had a detrimental impact on investor confidence. Therefore, the need to establish clear and comprehensive guidelines for insurance pertaining to RAS was deemed an essential matter of concern.

A complex regulatory landscape:

Stakeholders noted regulatory challenges often cut across various regulatory competencies. Both funding agencies and regulators noted the challenge of signposting funding recipients and innovators to the correct regulatory body.

In addition, innovators have observed the complexity and strict regulatory environment in the UK, leading some projects to consider 'regulatory offshoring,' the practice of relocating regulatory compliance activities to other geographic locations that offer a more favorable regulatory environment, making it easier to navigate.

A participant advocated for lessons to be learned from other industries, such as the aviation sector. The Mandatory Occurrence Report (MORs) approach creates a culture of learning from mistakes and can result in improved reliability and reduced liability costs but is predicated on an open and just (no-blame) culture. A no-blame culture provides a culture of psychological safety within which people feel comfortable to report anything, however embarrassing.

2.2.2 Policy solutions

A series of policy solutions collaboratively developed by regulators and industry were put forward during the workshop. These were then assessed by participants using an impact/effort matrix and were categorised as:

- Major Projects - High effort / High impact
- Quick Wins - Low effort / High impact
- Thankless Tasks - High effort / Low impact
- Fill-Ins - Low effort / Low impact

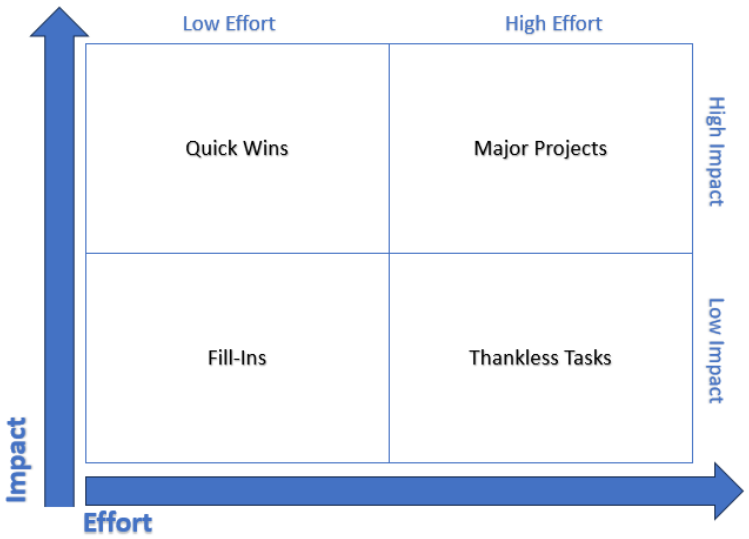

Figure 2. Impact/effort matrix

Use of Data and questions of Data Ownership:

Further leveraging of data should be encouraged to help create more informed regulatory solutions and more efficient farming practices, for example in increasing crop yield. Enhanced data collection enables regulators to streamline regulatory compliance systems. Lessons from the use of RAS, AI in medical devices, and the AI monitoring of animal health provide examples of the benefits of this approach.

Major projects:

- Foster industry-led data standards to enhance trust and provide guidance regarding the responsible use of farming data.
- Designate a data controller to manage sector data, reducing reporting burdens, and integrating data into risk assessment and regulation.

Sandbox Environments and Innovation:

Utilise sandboxing[12] to facilitate collaboration and increase engagement opportunities among stakeholders. Inspiration could be taken from CAA Beyond Visual Line of Sight airspace sandbox trial, which helps to foster innovative developments and raise regulators' awareness of upcoming innovations.

Major projects:

- Working with relevant delivery partners, HSE could conduct RAS in agriculture and horticulture sandboxing initiatives, involving smaller farmers along with a range of other stakeholders, and share valuable knowledge gained with the wider sector.

[12] Regulatory sandboxes are experimental approaches offering supervised real-life or simulated test environments (digital or physical) where innovators can trail new products, services or business models, often under relaxed regulatory requirements, and enhanced supervision from the regulator.

Quick wins:

- Encourage industry members to participate in other sandboxing programmes outsider of the agriculture and horticulture sector.

Promoting dialogue and trust-building between innovators, regulators, and public stakeholders:

The agricultural and horticultural regulatory landscape was described as fragmented, with a noticeable absence of communication between farmers, growers, innovators, and regulators, and public stakeholders such as consumers, local communities, and environmental organisations.

Both innovators and regulators recognised the importance of fostering dialogue and trust-building between themselves. However, it was recognised that merely advocating for increased engagement might not yield significant results and could be an inefficient use of time and resources. Instead, the emphasis was placed on fostering meaningful collaboration, such as through sandboxing initiatives, as a preferred approach over ad-hoc and superficial engagement, such as attending trade fairs.

Thankless tasks:

- Encourage regulators to actively engage and communicate with innovators, potentially through participation in trade fairs.

Major projects:

- Facilitate meaningful engagement between regulators and the farming community to gain insights into day-to-day operations or emerging innovations and technologies, for instance through sandbox initiatives.

In addition, there was an acknowledgement that both regulators and innovators have a role to play in working with public stakeholders in positively shaping public opinion concerning the use of RAS in public spaces. Building positive public trust and understanding in new innovations and technologies can be quite a slow process. On the other hand, loss of trust can be very fast indeed. Regulators and innovators were advised to listen to public concerns and consider if they are legitimate (rather than undue concerns). Although the benefits may only be felt in the medium to longer-term, stakeholders should consider strategies for influencing public thinking, to ensure public opinion to new innovations in RAS do not hold back adoption for undue reasons.

Quick wins:

- Develop strategies for influencing social-cultural thinking, thereby creating broader acceptance and understanding of RAS applications.

Future- proof and proportionate regulations:

Further deployment of adaptable and future-proof regulations via codes of practice, standards and guidance should be encouraged. Leveraging existing legislation and statutory guidance, such as the regulators' code, may provide the necessary flexibility to accommodate innovation, thereby avoiding the need for extensive modifications to legislation.

Major projects:

- Propose a risk-based approach to regulations based on the size, speed, and power of RAS, taking hazard levels into account to ensure targeted and effective oversight.
- A risk-based approach should be supported by clear principles for the deployment of RAS applications in agriculture and horticulture, to provide clarity to farmers on risk assessment and liability. This could take the form of a comprehensive code of practice acting as the fundamental starting point for further RAS regulations. The code should be developed following core cross industry principles and be based on internationally agreed standards.

Funding Agencies' Involvement:

Better dialogue between funding agencies, funding recipients, and regulators needs to take place to anticipate and remove unnecessary barriers to the develop of RAS innovations.

Quick wins:

- Require funding applicants and regulators to clarify their plans for engaging with one another, ensuring either better alignment with existing regulatory requirements or adaptation of existing regulatory requirements. Applicants should be supported to be made more aware of the regulatory environment for future products arising from their research, and where possible tailor their research to fit with regulatory requirements, and where regulatory systems are needlessly problematic, to alert regulators to the problem and seek a solution.

- Proactively involve funding agencies in understanding the regulatory environment before launching competitions. The goal is to prevent situations like the Future Flight Challenge (FFC), where funding was allocated to novel technologies with significant regulatory barriers to market. In this context, the objective is not to discourage funding agencies from approving funding programmes that might be subject to regulations posing challenges to market viability. Instead, the focus is on making regulators aware about potential viable markets that could emerge if the regulatory framework can adapt to upcoming innovations.

3. Regulatory Policy Interventions

What follows is a set of potential regulatory policy interventions that build on the insights shared by innovators and regulators during this policy sprint project. The interventions have been devised to respond to the main regulatory challenges outlined by stakeholders and have been tested for feasibility with regulators and other key government stakeholders. The interventions reflect the views of the RHC, and not necessarily the views of the participants in this project.

These seven interventions make up an integrated set, with sequential implications and interactions that would need to be considered carefully in the event that some are adopted and others not.

Intervention 1. Create a Sectoral Network to facilitate collaboration, set common objectives, and drive performance towards agreed-upon outcomes

A Sectoral Network serves as a solution to address challenges related to information dissemination, sector-specific insights, and issue resolution. Currently, the regulatory landscape governing the use of robotics and autonomous systems in agriculture and horticulture is fragmented, leaving farmers and innovators uncertain about the correct regulatory pathways. The RHC advise the creation of a Sectoral Network to bridge this gap by providing a platform for stakeholders to collaborate effectively and exert influence on regulators to prioritise resolution of crucial matters.

Rationale:

- Overcome regulatory hurdles: The creation of a Sectoral Network for coordination and communication within the RAS sector of agriculture and horticulture is vital to overcome regulatory hurdles, ensure effective collaboration, and expedite the development and deployment of innovative technologies.

- Create shared purposes: A Sectoral Network could unify stakeholders and create shared goals for the sector to work toward. The Network could also promote transparency and facilitate constructive engagement with regulators, ultimately contributing to the growth of the sector.

Recommendations:

1. Effective Coordination: Establish a Sectoral Network with the mandate to coordinate RAS-related activities in agriculture and horticulture. This network should comprise diverse stakeholders, including farmers, technology innovators, regulators, funding agencies, and industry representatives and policy experts such as the National Farmers Union.

2. High Level Oversight: A Sectoral Network should be responsible for: high level oversight; guiding the implementation of the other interventions proposed in this paper; and recommendations made to the sector more broadly such as the Automation in Horticulture Review.

3. Leveraging Existing Expertise: The Sectoral Network should leverage the substantial expertise housed within the AgriTech Centres, namely Agri-EPI, Centre for Innovation Excellence in Livestock (CIEL), CHAP, and AgriMetrics. The merging of the tech centres, and the potential for a creation of a new Agri-Tech Catapult[13] provides a real opportunity to break silos and bring regulators and industry together. The centres could play a vital role in facilitating the Network, and at the very least are likely to be valuable partners in the execution ofits goals.

4. Funding and mitigating dominance: The initial funding of the Sectoral Network could be provided by Defra. The value of the network is ultimately for stakeholders, and therefore over time it would be rational to expect business to fund it. Safeguards within the Sectoral Network structure should be implemented to prevent domination by the largest and most financially capable organisations. A dedicated secretariat can help maintain the network's impartiality and ensure equitable representation. This will also enable the network to influence regulators when necessary.

5. Goal Setting and Identifying Funding: The Sectoral Network should create shared goals for the sector, outline areas for prioritisation, and identify funding streams to resolve specific regulatory challenges. For instance, a network could aid in identifying funding sources. This is particularly useful for facilitating ongoing collaboration between AgriTech Centres and regulators. The project's goal is to establish a pathway and provide guidance for technology companies, helping them navigate existing legislation and demonstrate to insurers that their technology complies with legal and safety standards.

6. Issue Resolution: Empower the Sectoral Network to tackle pressing issues and facilitate efficient communication among stakeholders. One of its primary roles would be to address regulatory uncertainties by clarifying regulatory requirements for RAS applications, such as the use of autonomous vehicles in various agricultural settings.

7. Leveraging Existing Models and Best Practice: Take inspiration from existing models like Local Enterprise Partnerships and Stakeholder Councils, and adapting them to the sectoral context. In addition, best practice should be taken from other sectors such as the construction sector, who are experiencing parallel challenges in relation to the adoption of RAS.

Intervention 2. Establishing Regulatory Sandboxes for Robotics and Autonomous Systems in Agriculture and Horticulture

As the landscape of innovations in robotics and autonomous systems within agriculture and horticulture evolves at a rapid pace, the RHC urges the implementation of specialised regulatory sandboxes dedicated to this sector. Regulatory sandboxes are designed to empower innovators by offering a structured and supportive environment, enabling them to effectively overcome regulatory hurdles and chart a clear course towards commercialisation. In turn, this approach also offers regulators an invaluable opportunity to familiarise

[13] https://www.ukri.org/news/merger-of-agri-tech-centres-paves-way-for-future-ambitions/

themselves with emerging technologies and innovations that have the potential to reshape and dominate the sectors they oversee.

Rationale:

- Agricultural Advancements: Robotics and autonomous systems have the potential to revolutionise agriculture by improving efficiency, sustainability, and productivity. However, navigating complex regulations can hinder the development and adoption of these transformative technologies.

- Innovation Acceleration: Regulatory sandboxes offer a supervised real-life or simulated testing environment where innovators can refine their RAS product and services under relaxed regulatory requirements and enhanced regulatory supervision. This controlled and collaborative space accelerates the pace of innovation for technology developers while allowing regulators to identify potential adaptations needed in the regulatory framework to accommodate innovative technologies.

- Commercialisation Facilitation: By offering a clear path to commercialisation within a regulated framework, these sandboxes help innovators bring their RAS solutions to market more efficiently, reducing time-to-market and associated costs.

Recommendations:

1. Sandbox Creation: Collaboration should take place between Defra, other relevant government agencies, industry stakeholders, and innovators to establish dedicated regulatory sandboxes for RAS in agriculture. These sandboxes should provide a structured environment for testing and validating RAS technologies. Leveraging the existing expertise of the Agri-Tech centres and leading agricultural universities to facilitate initiatives is encouraged. An emphasis should be made to ensure farmers of all size, especially SMEs are able to participate in sandboxes.

2. Sectoral Network Direction: The Sectoral Network should have a role in offering guidance on prioritising new sandbox initiatives that hold the greatest potential and deliver substantial value. Examples of such initiatives could include uncrewed field harvesting robots or vertical farming.

3. Commercialisation Pathways: Simplify the process for innovators to move from the sandbox environment to full-scale commercial deployment. Drawing insights from experiences like that of the Hands Free Hectare project[14], which faced challenges in translating knowledge into commercialisation, it is imperative that a clear pathway exists for innovators from experimentation to commercial success.

4. Knowledge Transfer: Facilitate knowledge transfer from existing sandbox projects, such as the CAA's Beyond Visual Line of Sight airspace sandbox trial[15], by identifying relevant lessons, best practices, and methodologies that can be applied to the agricultural RAS regulatory sandboxes.

[14] https://www.harper-adams.ac.uk/news/203518/the-hands-free-hectare-project
[15] https://www.caa.co.uk/our-work/innovation/beyond-visual-line-of-sight-airspace-sandbox-trial/

Intervention 3. Fostering Industry-Led Data Standards for Data Collection in Agriculture and Horticulture sectors

In recognition of the importance of responsible data collection in the agricultural and horticultural sectors, the RHC suggest the development and adoption of industry-led data standards. These standards are vital to building trust among stakeholders, facilitating interoperability, and providing clear guidance for the ethical and responsible use of farming data.

Rationale:

- Data Trustworthiness: Establishing robust data standards instils trust among farmers, technology providers, and regulatory bodies. Trust in data quality and handling is fundamental for the successful integration of RAS technologies in agriculture and horticulture.

- Interoperability: Industry-driven data standards ensure compatibility and interoperability among various RAS systems, allowing farmers to efficiently collect, manage, and utilise data from diverse sources, ultimately enhancing agricultural productivity.

- Ethical Data Use: By promoting responsible data practices, including data privacy and security, these standards would help safeguard the rights and interests of farmers and stakeholders while preventing data misuse or unauthorised access.

Recommendations:

1. Industry Collaboration: Encourage collaboration among agricultural stakeholders, technology providers, research institutions, and regulatory bodies to collectively establish industry-led data standards for RAS in agriculture and horticulture. Ensure that these standards reflect the evolving needs and priorities of the sector. The industry convening experience held by British Standards Institute (BSI) and displayed in the development of the AI Standards Hub, the Future of Flight Standards Hub, and the Digital Twin Hub, should be used to implement this intervention. As should the expertise held by the Agri-tech centre, Agrimetrics, in relation to processing agrifood data.

2. Data Quality and Integrity: Define clear guidelines and best practices for data quality and integrity, including data collection methods and data validation procedures, to ensure the reliability of data collected.

3. Data Privacy and Security: Develop comprehensive data privacy and security standards and a code that address issues such as data encryption, user access controls, and data anonymisation.

4. Interoperability Framework: Create a framework that promotes interoperability among different RAS systems and data formats. This should include guidelines for data sharing, data exchange protocols, and compatibility with existing farm management software.

Intervention 4: Establishing a Data Controller for Enhanced Data Collection and Management in Agriculture and Horticulture through Robotics and Autonomous Systems

Recognising the pivotal role of data in RAS, the RHC advises the establishment of a data controller to expand and improve trust and volume in data collection by and for robotics and autonomous systems. This approach not only benefits the agricultural and horticultural sectors but also offers substantial advantages to regulatory authorities responsible for overseeing these industries. Existing examples where this independent data control function operates are the Ombudsmen in various consumer sectors: the primary function of the Ombudsmen in financial services, energy, communications, legal, motor, property and other sectors is that of dispute resolution, but they also deliver the function of aggregating data from multiple sources and allowing (appropriately anonymised or aggregated) access to relevant actors. The model therefore provides trustworthy data collection of multiple data sources and appropriate access to relevant stakeholders, whether regulatory or commercial.

Rationale:

- Efficiency and Productivity: The utilisation of RAS for data collection enhances the efficiency and productivity of agricultural and horticultural practices, benefiting both producers and consumers through improved yields, resource conservation, and higher product quality. Regulatory bodies, in turn, benefit from more effective and streamlined monitoring of compliance by farmers. Controllers can also provide aggregated statistics to industry users, identifying new or important issues, as well as detailed feedback to individual companies on their own data and issues.

- Data Management Challenges: With the growth in the volume of agricultural and horticultural data, challenges arise related to data ownership, privacy, security, and equitable access. The appointment of an independent, trusted data controller to oversee data management ensures transparent and compliant data practices, whilst also maintaining relevant commercial confidentiality, thereby facilitating regulators' ability to monitor compliance efficiently.

- Improving Trustworthiness: Data controller should play a role in verifying the quality and reliability of data being generated and applied in the sector. Improved trustworthiness in data may likely follow from where evidence of data validity and reliability is provided.

Recommendations:

1. Independent Data Controller: Establish an independent data controller responsible for overseeing data management in agriculture and horticulture. The data controller should oversee data governance, privacy protection, and conflict resolution among data stakeholders, ultimately ensuring that regulatory authorities can efficiently monitor compliance by farmers. A data controller may be funded via a levy on all actors in a sector, in this case a pay-to-join mechanism may be most appropriate, with the controller operating a not-for profit model to reach incentives to over-charge.

2. Data Collection Expansion: Encourage and incentivise the adoption of RAS technologies for data collection in agriculture and horticulture. This may include subsidies, grants, or tax incentives to promote the deployment of RAS solutions by farmers and growers, providing regulators with richer and more readily accessible data for compliance monitoring.

3. Providing data dispute resolution: In the first instance, the role of a data controller may be to pilot or test the efficacy of the industry-led standards outlined in intervention four. If required, then progressing industry-led standard toward mandatory standards and taking on an ombudsman for data dispute resolution.

Intervention 5. Designation of 'Atypical' Airspace for Expedited BVLOS Approvals in Agriculture and Horticulture Use Cases

In light of the pressing need to expedite Beyond Visual Line of Sight (BVLOS) approvals for agricultural and horticulture applications, the RHC suggest that the Civil Aviation Authority (CAA) undertakes an examination of the feasibility and implications of designating the immediate airspace above specific areas of farmland as 'atypical' airspace.

The utilisation of Beyond Visual Line of Sight uncrewed aerial vehicles (UAV) is a demand that spans multiple sectors. The CAA is seeking to address this demand through a combination of regulatory measures supported by technological safety advancements in UAV. The RHC welcomes the CAA's progress on recommendations outlined in its study of drone regulation[16] and their work to develop a more comprehensive strategy for cross-sectoral UAV. The designation of 'atypical' airspace offers a temporary solution bridging the gap until this strategy is published.

Rationale:

- Agriculture and horticulture is increasingly benefiting from UAV and BVLOS operations to monitor crops, assess field conditions, and more efficient crop spraying mechanisms.

- Customised Solutions: The unique needs of agricultural use cases, such as farmland interspersed with roads and public rights of way, demand a tailored approach to airspace designation that recognises the specific requirements of these applications.

Recommendations

1. Feasibility Study: Initiate a feasibility study to assess the technical, regulatory, and safety aspects of designating 'atypical' airspace above specific agricultural and horticultural areas.

2. Regulatory Framework: Develop a specialised regulatory framework that outlines the criteria and procedures for designating and managing 'atypical' airspace, with a focus on safety, interoperability, and compliance with existing aviation regulations.

[16] https://www.gov.uk/government/publications/regulatory-horizons-council-the-regulation-of-drones

Intervention 6. Funding Agencies' Role in Enhancing Innovation and Regulatory Alignment

To foster innovation and streamline the regulatory process for emerging technologies, the RHC advises the establishment of better communication and collaboration channels among public funding agencies, funding recipients, and regulatory bodies. This will help eliminate unnecessary barriers to innovation and ensure a more seamless transition from research and development to market deployment.

Rationale:

- Innovation-Regulation Interplay: The interplay between innovation funding and regulation necessitates a strategic approach to ensure emerging technologies can thrive within a regulatory framework. There are currently communication gaps among funding agencies, recipients, and regulators unnecessarily impeding innovation.

- Smooth Transition: Enhanced engagement and understanding between funding applicants and regulators could facilitate a smoother transition from research and development phases to market deployment while maintaining proportionate regulatory compliance.

Recommendations:

1. Pre-Competition Regulatory Assessment: Prior to launching funding competitions, funding agencies should proactively involve themselves in understanding the existing regulatory environment. This includes collaborating with regulatory bodies to gain insights into regulatory requirements and potential bottlenecks.

2. Communication with Regulators: Funding agencies should facilitate direct communication between funding recipients and regulatory authorities to promote a mutual understanding of emerging technologies and their potential regulatory implications. Encourage funding applicants to engage with regulators early in the research and development process to address regulatory concerns. In addition, a change to the Innovate UK “In flight” Project Survey could be made to include questions covering the funding recipients’ engagement with regulators. Where regulator resource is limited, applicants could be encouraged to work through third parties, such as regulatory consultants or advisors, to engage with regulators. This approach may be more efficient and contribute to building a common understanding of frequently asked questions put to regulators.

3. Clarify Regulatory Plans: Funding agencies should mandate that funding applicants provide a clear and comprehensive outline of their plans for engaging with regulators, or regulatory consultants and advisors.

Intervention 7. Provide Clarity on the Liability Arrangements governing RAS in Agriculture and Horticulture

Considering the growing demand for the use robotics and autonomous systems in agriculture and horticulture, it is crucial to proactively address concerns by farmers related to liability and insurance. To foster confidence in the use of RAS, the RHC proposes convening roundtable discussions on liability, insurance, and dispute resolution for RAS in agriculture and horticulture.

Rationale:

- Complexity of Liability: The intricate nature of liability in RAS applications, involving multiple stakeholders, presents challenges for innovators, farmers, and insurers. Clarifying liability rules can reduce uncertainty and encourage technology adoption.

- Insurance Uncertainty: The evolving RAS landscape may not align with traditional insurance policies, causing uncertainty for technology providers and farmers. Streamlined insurance procedures can enhance investment confidence.

- Simpler Dispute Resolution: The cost and delay of formal dispute resolution processes raise further barriers for innovators, especially if they are small, and add to the cost of insurance. Developing a tailor-made procedure, as has been done in some other sectors, should reduce costs and delay, and support trust.

Recommendations:

1. Roundtable Discussion: The RHC should convene a roundtable discussion comprising key stakeholders, including technology providers, insurers, legal experts, agricultural associations, and regulatory authorities. This forum should focus on addressing liability, insurance, and dispute resolution process concerns specific to RAS in agriculture and horticulture.

   Roundtable discussions could lead to further actions including:

2. Legal Framework Assessment: Collaborate with legal experts to assess the existing legal framework and identify areas where simplification of liability rules and procedures is feasible. Ensure alignment with evolving technological advancements.

3. Insurance Customisation: Encourage insurers to work closely with RAS technology providers to develop specialised insurance products tailored to the unique needs and risks associated with agricultural and horticultural RAS applications.

4. Dispute Resolution Mechanisms: Establish efficient and accessible dispute resolution mechanisms that can swiftly address liability-related conflicts. This will minimise disruptions and instil trust among stakeholders.

Annex

Annex A – Agriculture and Horticulture Terminology

For Defra, **agriculture** encompasses crop and livestock production and forestry for food. Aquaculture, fisheries, and the production of non-food products produced on a farm are out of scope. The two main areas of agriculture are arable and livestock.

Arable:

- grain crops cultivated for their edible starch grains (wheat, maize, rice, barley, millet).
- pulse crops of the legume family grown for their edible seeds which are high in protein (lentil, beans, peas);
- oil seed crops grown for oil extraction from their seeds (rapeseed, soybean, sunflower).

Livestock:

The production of animals for food and includes cattle, sheep, goats, pigs or poultry, and can include the production of meat, eggs and dairy products.

Horticulture is a subsection of agriculture that includes both edible and ornamental crops and includes:

- bines and vines (e.g hops)
- edible fruits
    - top and orchard fruit (e.g nuts, apples or plums)
    - soft fruit (e.g strawberries)
- vegetables and salads
    - protected vegetables (e.g glasshouses or vertical farms)
    - field vegetables

For the purposes of this study, ornamental horticulture is out of scope (as focus is on food production) but many of the automation and robotics systems for edible horticulture also apply to the ornamental sector too.

Annex B – Methodology

The RHC takes a multidisciplinary and agile approach to developing its recommendations. Acknowledging the existence of recent government initiatives related to RAS, specifically the Automation in Horticulture Review and the Independent Review of Labour Shortages, the RHC made adjustments to its standard process. Instead of the typical deep dive investigation spanning 6-9 months, it opted for a shorter, three-month policy sprint.

The RHC conducted this enquiry by asking the following question, which we developed and sense-checked with stakeholders across industry and in collaboration with the Department for Environment, Food & Rural Affairs.

How can the UK better ensure that regulation can both accelerate the development and adoption of robotics in agriculture and horticulture to address challenges in the sector and support the development and deployment of emerging technologies?

The RHC followed the following process to develop its policy interventions:

1. A **scoping process** to decide the area of focus within robotics and autonomous systems.
2. **Refinement** in collaboration with the Department for Environment, Food & Rural Affairs, the RHC narrowed our focus to the use of robotics and autonomous systems in agriculture and horticulture.
3. **Evidence gathering** through stakeholder engagement with relevant regulators and key parts of industry via workshop discussions. This was supplemented by complementary evidence from published sources.
4. Used key sources on innovation-friendly regulation to help **develop policy interventions**.
5. **Testing findings and policy interventions** – Further stakeholder engagement conducted to test findings and policy interventions, with interventions further developed in an iterative process following input from stakeholders.

The RHC and Defra engaged with the below stakeholders to obtain their views on regulation of robotics and autonomous systems in agriculture and horticulture.

Regulators and standards agencies

- Health and Safety Executive (HSE)
- British Standards Institution (BSI)
- Civil Aviation Authority (CAA)
- Environment Agency (EA)
- National Highways
- Food Safety Agency (FSA)

Government

- Department for Environment, Food and Rural Affairs
- Department for Science, Innovation, and Technology

Innovation and research organisations

- Crop Health & Protection (CHAP)
- Agri-EPI Centre
- The Lincoln Institute of Agri Food Technology
- Innovate UK
- Harper University
- Agriculture and Horticulture Development Board (AHDB)
- Centre for Innovation Excellence in Livestock (CIEL)

Commercial and industry

- Scientific Technologies
- Syngenta
- Cattle Eye
- Michelmores
- PBS International
- Muddy Machines
- Antobot
- Agrivation
- Angus Soft Fruits
- Adrian Scripps

Annex C –Workshop data collected via MentiMeter.

1. What are the top three issues you'd like to see regulation, standards, codes of practice focus on in RAS?

Figure 3. Top three issues participants would like to see regulation, standards, codes of practice focus on in RAS

2. What areas should regulation be focused on in the short term?

Data Ownership and Sharing:

- Data ownership
- Rules of practice for ethical data sharing
- Recommended/default practice for data ownership and sharing
- Data transfer

Standards and Practices:

- Standards
- Values and principles vs regulations
- Standards protection systems
- Investigating the likelihood of having similar legislation in different industries

Safety and Responsible Operation:

- Responsible operator definition
- Safety and adopting codes of practice from other sectors
- Framework for the level of supervision

Freedom to Operate and Flexibility:

- Freedom to operate
- De-risking adoption
- Ensuring freedom to operate while knowing likely future boundaries to build systems around
- Enabling small-scale commercial operations with limitations (e.g., total hectares or total number of robots used)
- Flexibility to change quickly and understanding that technology will be constantly evolving
- Enabling solutions while capturing learnings and sharing to avoid detrimental consequences

Technology-Specific Considerations:

- High TRL (Technology Readiness Level) technologies and beachhead applications
- Agriculture-specific technology

Administrative Efficiency:

- Less red tape

Infrastructure and Methodology:

- Infrastructure modeling methods

International Sales and Market Access:

- Opening markets
- Ensuring no disadvantage internationally
- Overseas sales

3. Where could regulation, standards, codes of practice have the most impact?

Adoption and Use:

- Adoption and use in all agricultural practices
- Adoption and uptake of robotics onto farms
- Adoption of use in commercialization and routine deployment of agri-tech solutions
- Adoption to drive innovation in the sector versus the current large machinery mindset
- Greater interoperability and open platforms for wider application

Data and IP Management:

- Farmer IP/data empowerment and treating farmed data as farmer equity

- Accuracy of infrastructure modelling and growers being able to control and manage their data
- Growers accurately surveying their digital farm and controlling data access
- Data ownership/tradability

Environmental and Safety Considerations:

- Benefits to human and environmental safety
- Environmental benefits, cost benefits, investment risks, and social cohesion risks
- Animal management and welfare
- Soil improvements through less weight trafficking soils
- Shared learning and opportunity for soil improvements

Infrastructure and Technology:

- Infrastructure modelling for growers to follow
- Enabling technology development
- Framework for training to have future generations up to speed when needed
- Standards to aid cross-compatibility
- Quality of product

Market and Competition:

- Sales and commercialization
- Competition and avoiding dominance by one player or technology

Stakeholder Engagement and Practicality:

- Acceptability of technology by stakeholders
- Positive impact from practical regulations tuned to real-world applications and continuously addressing needs and risks
- Ensuring consumer confidence in food production is maintained

Other

- Risk of reduced duplication of similar but different systems

4. What type of regulation would concern you the most?

Restricting Innovation:

- Something that restricts innovation
- Anything that hinders genuine experimentation
- Regulation that stifles adoption

- Measures through another sector that prevents innovation movement into agriculture
- Regulation driven by vested interest
- Prohibited on new ideas

Excessive Prescriptiveness and Rigidity:

- Too prescriptive
- Rigid tick box based regulations
- Overly prescriptive
- Complex and too prescriptive. Burdened by audit and inspections.
- Regulation that focuses on narrowly defined machinery-related challenges that are not contextualized by the broader challenges facing the sector
- Modelling rather than measured regulations

Impact on Autonomous Technologies:

- Supervision of robots too tight to enable small companies to launch innovative solutions
- It would kill us if each robot would have to be supervised in person by one human. One human per 10-20 robots would be okay.
- A one type fits all approach that doesn't recognize the range of autonomous vehicles

Data and Intellectual Property (IP) Regulations:

- Regulation that attempts to define property rights in data
- Trustworthy capture, use, and reuse of data that takes into account the views and rights of stakeholders disjointed approach to different threads of regulations
- Data regulation being too tight
- IP regulation

Compatibility and Contextualization:

- Regulation that's incompatible with current regulation or other standards already part of the supply chain
- Generic non-agriculture focus

Burdensome Requirements:

- Requirement for large-scale trials before commercial operations
- Regulation that adds to end-user workload

Lack of Balance and Consideration:

- Not taking into account benefits, only risks

Other considerations

- National Farmers Union

5. What organisations would be a good "trusted source" of information about regulation, standards, codes of practice?

Government Bodies and Agencies:

- Defra (Department for Environment, Food and Rural Affairs)
- UK Government

Standardisation and Regulation Organisations:

- Health Safety Executive (HSE)
- Chemicals Regulation Division (CRD)
- International Standards Organisation (ISO)
- British Standards Institute (BSI)
- Regulators (unspecified)
- Commercial standards library

Industry and Trade Associations:

- Industry bodies
- Trade body
- Agriculture and Horticulture Development Board (AHDB)
- The Institution of Engineering and Technology (IET)
- Engineering institutions

Research and Development Institutions:

- National Institute of Agricultural Botany
- Innovate UK
- Agri-tech centres
- Agri-EPI Centre
- University research centres

Farms

- On-farm demo
- Other farmers (peer-to-peer knowledge sharing)

Other organisations

- Insurance companies