Farmer Engagement with Citizen Science and Environmental Data Collection

December 2024

Natural England Commissioned Report NECR582

NATURAL ENGLAND

About Natural England

Natural England is here to secure a healthy natural environment for people to enjoy, where wildlife is protected and England's traditional landscapes are safeguarded for future generations.

Further Information

This report can be downloaded from the Natural England Access to Evidence Catalogue. For information on Natural England publications or if you require an alternative format, please contact the Natural England Enquiry Service on 0300 060 3900 or email enquiries@naturalengland.org.uk.

Copyright

Catalogue code: NECR582

Report details

Authors

Eunomia: Isabelle Williamson, Lauren Duffield, Clare Twigger-Ross, Yvonne Rees
Innovation for Agriculture: Holly Shearman, Deborah Crossan, Arran Redman

Natural England Project Manager

Contractor

Keywords

Acknowledgements

Citation

Foreword

Natural England commissioned this research project to gain a deeper understanding of the role and engagement of farmers in citizen science initiatives related to environmental data collection across England. Recognizing the vital role that farmers play in the stewardship of our natural environment, it was essential to explore their attitudes, motivations, and levels of participation in these initiatives. This research will play an important role in understanding farmer participation and engagement with citizen science initiatives, but more widely with data collection, technological tools and data management practices. Helping to understand the gaps and opportunities for improving farmer involvement in these initiatives has the benefit of understanding routes to participating in changing agricultural practices and ultimately advancing towards more evidence-led decision-making. This project was closely aligned with another complementary research project, *Evaluating the current state and potential of citizen science involving farmers, NECR583*, which sought to map and review existing citizen science initiatives that explicitly included farmers. Together, these projects provide a deeper understanding of farmer involvement in environmental research, with the ultimate goal of improving their engagement and participation in citizen science initiatives.

The findings from this research will inform Natural England's strategies for enhancing farmer involvement in citizen science, helping to identify gaps and opportunities for greater participation. By doing so, we aim to foster a more collaborative approach to environmental monitoring and management, where farmers are empowered to contribute to and benefit from evidence-led decision-making.

Natural England commissions a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Executive summary

This project aimed to better understand farmers' awareness and attitudes towards citizen science and environmental data collection, including their motivations and barriers to participation. The project combined a focussed evidence review with primary research with farmers via a survey and interviews. The primary research was designed around the COM-B framework for behaviour change. This framework categorises factors influencing behaviour into: capability; motivation; and opportunity. Understanding the *relative* importance of each category provides insights into the actions needed to enable behaviour change. The research questions derived were:

1. What engagement do farmers currently have in environmental data collection and citizen science? *(existing behaviour)*
2. What opportunities do farmers have to engage in environmental data collection and citizen science? *(existing opportunities)*
3. Do farmers have the knowledge and skills required to engage in environmental data collection and citizen science? *(existing capability)*
4. What motivations and barriers do farmers have to engage in environmental data collection and citizen science? *(existing motivations)*
5. What types of environmental data collection and citizen science could farmers be interested in engaging with? *(future behaviour)*
6. What could encourage or prevent farmer engagement in environmental data collection and citizen science? *(future motivations, capability, opportunities)*

Data were gathered from farmers through an online survey (121 respondents) and 30 minute in-person interviews (15).

Key findings from the primary research clustered by COM-B categories:

Behaviour: 91% of survey respondents and 100% of interviewees already collect environmental data. The most common topics farmers collect data on are related to soil, biodiversity and conservation, or land use. 86% of survey respondents and 93% of interviewees collect data for their own use to help manage their farm.

Capability: 75% of survey respondents who had been part of a specific project said they required knowledge of the topic to participate. 50% of survey respondents and 26% of interviewees reported time as the most significant barrier to environmental data collection and citizen science. This was reported more commonly by female farmers and those in the two 'middle' age cohorts (30-49 and 50-69). 79% of survey respondents use technological equipment to collect data. However, 50% of survey respondents and interviewees collect some data manually.

Opportunity: 60% of survey respondents and 100% of interviewees heard about a data collection project through engagement with other farmers, via farmer groups or clusters. Only 20% of survey respondents heard about projects via digital channels such as email or websites.

Motivation: 62% of survey respondents and 66% of interviewees said they participated in environmental data collection or citizen science to gather useful data for the farm. Other common motives for participation were to learn and develop skills (52% survey respondents) and to access expert advice (48% survey respondents). Interviewees with smaller farm sizes appeared more willing to collect more data compared to farmers with larger farm sizes who were more concerned or undecided.

Summary of recommendations

1. Organisers should consider providing equipment and software to farmers *(capability).* This could include subscription to OS Master app or provision of technology such as drones or sensors.

2. Organisers should offer specific support to tenant farmers *(capability).* This could include contacting or drafting emails to the tenants' landlord to seek their permission to collect data.

3. Organisers should seek to minimise the time required of farmers *(opportunity).* This could include providing a clear and simple methodology for data collection.

4. Organisers should seek opportunities to promote projects more effectively and widely *(opportunity).* The findings from this research found the most effective communication channels to be through farmer cluster groups and networks. Communications should use these networks to promote projects.

5. Organisers should offer meaningful rewards to farmers for their participation *(motivation).* Examples include payment through grants, or provision of free equipment and/or free advice.

6. Organisers should develop trusting relationships with farmers *(motivation)* for example by giving farmers full transparency of the research purpose, process and ultimate use of the data.

7. Organisers should look to empower farmers to participate in the design of environmental research projects *(motivation)*. This could include offering farmers the opportunity to engage in other parts of the research process beyond the data collection itself and in particular, where possible, to co-design the data collection to make it practical for farmers making it easier for them to engage. It is recommended that organisers engage with farm cluster groups as early as possible in the design of the research to encourage this co-design process.

8. Policymakers should review the financial incentives available to farmers for participating in environmental data collection *(opportunity and motivation).* This could include incorporating an incentive or requirement for farmer participation through the use of payments such as the Environmental Land Management Schemes (ELMS).

9. Policymakers should provide training/information for farmers on how and why they might collect environmental data *(motivation).* This could include the production of engaging and accessible online resources on environmental data collection and citizen science, tailored to farmers. As the research has shown that peer-to-peer learning is important, this should engage farm cluster groups and make full use of case-studies/testimonials about the benefits of engaging in citizen science.

10. Policymakers should consider how to reduce the administrative burden of mandatory data collection for farmers *(opportunity and motivation).* This could include reviewing all

mandatory data required of farmers and aiming to synchronise, standardise and simplify processes. In addition, it could be useful for this review to be shared with researchers or policy makers who could benefit from the data being gathered, or are considering collecting similar data, to align requests to farmers.

11. Policymakers should seek opportunities to promote innovation and learning for agri-environment research *(motivation).* This could include funding research into the development and application of technologies, software, and training programs to support farmers to collect data.

12. Policymakers should establish initiatives which encourage members of the public to visit farms for the purpose of environmental data collection and citizen science *(opportunity and motivation).* This could include support to local councils/local community organisations to deliver initiatives which encourage local involvement in farming-related environmental data collection and citizen science.

Overall, the study found two important overarching themes from the recommendations:

- Most of the recommendations fall into the opportunity or motivation category of the COM-B framework. This suggests the key to change will be identifying how to enable opportunities and build the motivation with farmers.

- The process of data collection should shift away from being transactional and more towards being relational, based on quality relationships working together to inform practice.

Contents

1. Introduction

1.1 Background

Agricultural land accounts for 70% of the total area of the UK.[1] As managers and stewards of this land, farmers have an intimate knowledge of our environment and agricultural systems. If more of this knowledge could be captured and shared, farmers could bring valuable insights to policymakers, researchers, and other farmers looking to address issues such as biodiversity loss, climate change, soil degradation, pests and disease, and food security. A key way farmers can achieve this is through observing and recording data about the land they farm. This could include weather forecasts, land mapping, water samples, waste data, or information from Geographical Positioning System (GPS) transmitters attached to wild animals.

While some farmers already collect data on their farm to support on-farm management, there is significant potential for more data to be collected and shared for scientific research.[1] An increasingly adopted method for involving members of the public in scientific research is citizen science.[2] Citizen science can be defined as "a form of research collaboration involving members of the public volunteering in scientific research to address real-world problems".[3] Although citizen science is a long-established practice which has seen a rapid increase in its use and scale over the last two decades, it is not widely adopted in the agriculture sector. [4] [5] Greater uptake could foster increased trust and collaboration between farmers, scientists and policymakers, and empower farmers to collect reliable and meaningful environmental data[2] for their own benefit, as well as to inform national policy and research.

1.2 This study

This research study aimed to better understand farmers' awareness and attitudes towards citizen science and environmental data collection, including their motivations and barriers to participation. With this information, the study aimed to identify how engagement and participation could be improved to enable more meaningful contribution and impact of citizen science to address global issues.

---

[1] Forms of environmental data collection or citizen science which are formally led by research organisations for the purpose of research. This is in comparison to data collected for personal benefit or ad-hoc purposes.

[2] In this study, the term 'environmental data collection' has been interpreted as an umbrella term to encompass different ways data can be collected by farmers (see Figure 1). Three ways were identified which are distinguished by: what the data is used for; whether the data is shared; and whether farmer contribution is voluntary or not. This evidence review focuses on data collected and shared by farmers for the purpose of research. This includes citizen science, which is interpreted more specifically as a form of research collaboration involving members of the public volunteering in scientific research.

1.3 This report

This report represents the primary output to this research, and is structured into the following sections:

- Section 1.**Error! Reference source not found.** provides a background and context to this project and report;
- Section 0 provides a focussed evidence review of environmental data collection and citizen science, including the involvement of farmers in this type of research;
- Section 3 presents the research methodology, including the objectives, framework and limitations;
- Section **Error! Reference source not found.** summarises key findings from the research, including gaps and opportunities for improving farmer involvement;
- Section 5.0 compares findings from the primary research against the evidence review; and
- Section 0 presents recommendations for how farmer engagement and participation can be improved, as well as opportunities for future research.

A section summary box at the start of each section provides a summary of the key points discussed. The Appendix includes the survey and interview questions, and a list of the environmental data collection and citizen science *projects* mentioned by farmers during the primary research.

2. Focussed evidence review

To situate this project within current literature exploring environmental data collection and citizen science involving farmers, we undertook a focussed evidence review to:

- Describe types of environmental data collection projects which involve farmers;

- Introduce citizen science, including its beginnings, core principles and applications;

- Point towards potential changes in environmental data collection as a result of emerging technologies;

- Outline potential limitations and challenges with collecting data through farmers; and

- Explore common enablers and barriers to farmers engaging in environmental data collection and citizen science.

As a focussed evidence review, this section draws on a selected sources to explore the topic area including reviews by academics in journals such as: Center for Advancement of Informal Science Education; Ecology and Society; Land Use Policy; and Experimental Agriculture. The review also used outputs from expert institutions such as the Centre for Ecology & Hydrology (CEH) and UK Environmental Observation Framework, as well as farmer news sites such as Farmers Weekly, and data collection websites such as the Science Museum. Key search strings used included: 'agricultural data collection', 'farmer/farming citizen science'', 'environmental data on farms', and 'farmers collecting data'. While this research is focused on environmental data collection and farmers based in the UK, international sources and project examples have been drawn upon where relevant.

It should be noted that the term 'research' is used throughout this report in a wide sense, recognising that it can include formal scientific research projects as well as more informal data monitoring and recording schemes.

Section summary

- The term 'environmental data collection' can be used as an umbrella term to encompass different ways data can be collected by farmers, according to what the data is used for; whether the data is shared; and whether farmer contribution is voluntary or not. When the research undertaken is for scientific purposes and involves the voluntary participation of farmers, this is understood as a form of citizen science.

- Although a long-established practice, citizen science has seen a rapid increase in its use and scale over the last two decades. This has largely been facilitated by the internet and the increased availability and accessibility of enabling technologies, which have transformed recruitment, data collection, and citizen engagement.

- Citizen science involving farmers is still relatively novel, with no formal definition and projects operating at a small scale. For this research, we have defined farmer citizen science to include the voluntary participation of farmers in scientific research; and data sharing between stakeholders so that farmers may use the data themselves.

- Types of farmer citizen science and data collection projects identified have either been driven by agricultural research goals, involving the monitoring of on-farm activities such as fertiliser use, pest control, land use, crops and yield, or by environmental research goals, which focus on biodiversity, conservation, and sustainable farm practices.

- Technology is expected to revolutionise agriculture and could support greater-buy in and participation of farmers in environmental data collection and citizen science.

- Many scientists have concerns about the robustness of citizen science and highlight the need to acknowledge the potential limitations and pitfalls. Common concerns relate to data quality; participant recruitment; communication; and ethics.

The COM-B model of behaviour change has been used to categorise a range of enablers and barriers to farmer engagement in environmental data collection and citizen science, identified from the literature review. This model has been used to structure the research framework because it is a useful tool to identify the most important influences to individual behaviour, including enablers and barriers to action. This is particularly useful for identifying the most influential ways in which to change behaviour for a specific audience and action.

2.1 Environmental Data Collection

For the purposes of this research, the term 'environmental data collection' has been interpreted as an umbrella term which encompasses three different ways data can be collected by farmers. This is presented through Figure 1 and summarised in the text below. The three ways identified have been distinguished by: 1. what the data is used for; 2. whether farmer contribution is mandatory, and 3. whether the data is shared. While short descriptions of each type of data collection are provided below, this evidence review focuses predominantly on Type 3 - data collected and shared by farmers for research - and more specifically, citizen science.
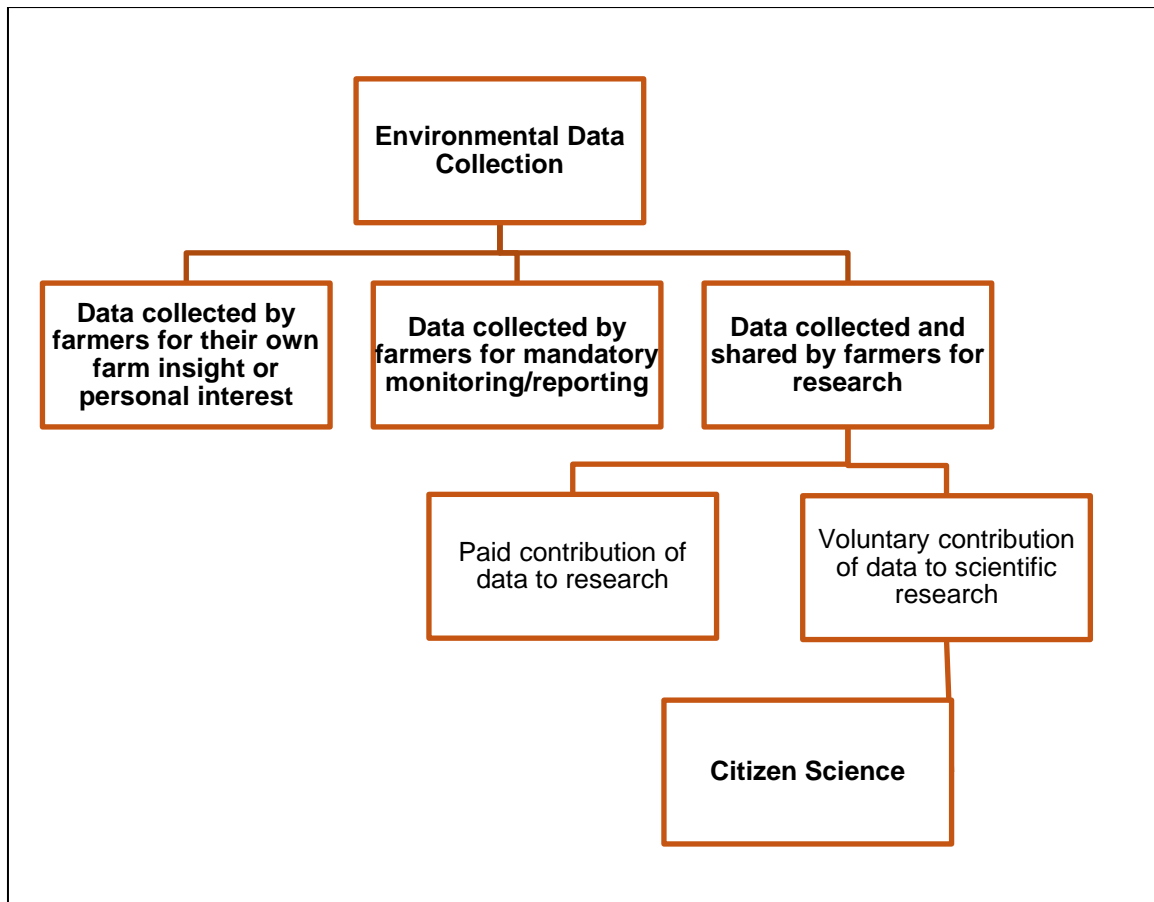
Figure 1: Types of environmental data collection

1. **Data collected by farmers for their own farm insight or personal interest**. Firstly, some farmers collect data to inform their own farm management. This can include data related to soils, animal health, weather, yields, irrigation, fertiliser application, or weather, which can be used to produce outputs such as maps, yield prediction models, satellite imagery or graphs.[6] These insights are used to inform farm practices and potentially improve yields or efficiency. For example, arable farmers use data to monitor fields on a square metre basis, applying nutrients only where necessary and treating disease only in areas that require it, helping to reduce inputs. For livestock farmers, data collected can help identify the quantity and type of feed required for livestock according to their condition or weight, which can contribute to healthier livestock and more efficient use of resources.[7] Increasingly, farmers use data service companies to help them collect, store and analyse the data.

2. **Data collected by farmers for mandatory monitoring / reporting.** Secondly, some famers may be required to submit data to the Government as part of mandatory monitoring or reporting processes. This could include annual census reporting for example.

3. **Data collected and shared by farmers for research**. Thirdly, some farmers collect data for research purposes. This can include scientific research purposes related to agricultural or environmental science, or for commercial research related to the trialling of new crops, technologies or products. The involvement of farmers can be paid or voluntary. When the data collection is for scientific purposes and involves the voluntary participation of farmers, this is a form of **citizen science,** which is explored in more detail in Section 0.

2.2 Citizen Science

Citizen science can be defined as "a form of research collaboration involving members of the public volunteering in scientific research to address real-world problems".[8] The practice is several centuries old, dating back to pre-20th Century in advance of the term 'scientist' being coined in 1833.[9] In 1715, Edmund Halley used the world's first science journal 'Philosophical Transactions' to ask colleagues to help him observe a total solar eclipse, which prompted observers from all over the country. When Charles Darwin was developing the theory of evolution, he sought observations from over 2,000 people.

Although a long-established practice, citizen science has seen a rapid increase in its use and scale over the last two decades. This has largely been facilitated by the internet and the increased availability and accessibility of enabling technologies. It has also been encouraged by a broader recognition of its value to scientific discovery and public engagement with scientific issues.[10] More broadly, growing literacy levels, educational attainment and internet access across the world have also made it possible for more people to contribute to science in meaningful ways without being part of a professional scientific community.[11]

Citizen science is applied to a wide variety of research disciplines, most notably environmental science, physics, healthcare, molecular biology, and natural disasters.[12] Given its varied application, citizen science projects active today are diverse, encompassing a wide range of objectives, scales and designs. This includes differing levels of involvement from citizens, and increasingly, the use of technology. As a result, a wide range of terms have been captured under the citizen science umbrella, including: community science; participatory mapping; participatory science; and local monitoring.[13] To help pin down the key components of a citizen project and ensure research excellence in the field, an international community of citizen science practitioners and researchers have developed **Ten Principles of Citizen Science**, which help define new and existing citizen science initiatives (see Figure 2).[14]

1. Citizen science projects actively **involve citizens in scientific endeavour** that generates new knowledge or understanding.
2. Citizen science projects have a **genuine science outcome**. For example, answering a research question or informing conservation action, management decisions or environmental policy.
3. Both the **professional scientists and the citizen scientists benefit from taking part**. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence.
4. Citizen scientists may **participate in multiple stages** of the scientific process. This may include developing the research question, designing the method, gathering, and analysing data, and communicating the results.
5. Citizen scientists **receive feedback** from the project. For example, how their data are being used and what the research, policy or societal outcomes are.
6. Citizen science is considered a research approach like any other, with **limitations and biases** that should be considered and controlled for.
7. Citizen science project **data and metadata are made publicly available** and where possible, results are published in an open-access format.

8. Citizen scientists are **acknowledged in project results** and publications.

9. Citizen science **programmes are evaluated** for their scientific output, data quality, participant experience and wider societal or policy impact.

10. The leaders of citizen science projects take into consideration **legal and ethical issues** surrounding copyright, intellectual property, data-sharing agreements, confidentiality, attribution**,** and the environmental impact of any activities.

Figure 2: Ten Principles of Citizen Science (Source *Robinson et al, 2020* [14])[Republished under CC BY 4.0]

2.2.1 Types of citizen science

Citizen science projects can involve volunteer members of the public at any stage of the research process. Bonney et al. (2019) help classify projects according to the extent of citizen engagement and the stage at which they participate.[15] This typology classifies projects as: **contributory, collaborative,** or **co-created**. In summary:

- **Contributory** projects are generally designed entirely by scientists, while members of the public primarily contribute data.

- **Collaborative** projects are also generally designed by scientists, but participants are involved in more than one stage of the research process. This could involve helping to refine the project design, analyse data, and disseminate findings.

- **Co-created** projects are designed by scientists and members of the public working together, and for which at least some of the participants are actively involved in most or all aspects of the research process.

Two further categories of project which are less common include:

- **Contractual** projects, where communities ask professional researchers to conduct a specific scientific investigation and report on the results; and

- **Collegial** contributions, where members of the public conduct research independently, with low levels of input from professionals.[16] This has also been termed as 'extreme' citizen science.[17]

While citizen science projects can vary in the extent of citizen participation, according to the Ten Principles of Citizen Science, citizen science projects tend to share an overarching goal to generate new scientific knowledge or understanding. The objectives of doing so can include answering a research question, or informing conservation action, management decisions or policy. Following a review of citizen science directories, Wiggins and Crowston (2011) developed a useful typology of citizen science projects according to different research goals, project scales and level of citizen involvement.[18] The five categories are:

1. **Action**: Projects which encourage citizen intervention in local concerns, using scientific research as a tool to support these agendas. Typically, these are conceived and planned by citizens and involve long-term engagement.

2. **Conservation:** Projects which support natural resource management goals, primarily in ecology, and involve citizens for outreach, education, and data collection. Like Action projects, these are strongly rooted in the geographical place.

3. **Investigation:** Projects which are focused on scientific research goals requiring data collection from the physical environment. These projects can range from regional to international in scope and tend to achieve large scales of participation.

4. **Virtual:** Projects which are ICT-mediated with no physical elements but are directed by scientific research goals.

5. **Education:** Projects which have education and outreach as primary goals. All citizens involved in these projects are education-oriented, with projects orienting upon informal learning resources or formal curricular materials.

2.2.2 The role of technology in citizen science

The increased accessibility and sophistication of technology over the last two decades has had a marked impact on all forms of citizen science.[19] Firstly, with regards to recruitment, many citizen science websites and applications now exist, making it easy to find and access projects for people across the globe.[20] Websites also provide useful information and help manage volunteers through features such as chat systems and forums facilitating real-time communication. Secondly, with regards to data collection, technology has enabled the rapid conversion, communication, and storage of data contributing to increased project efficiency and scalability.[21] Thirdly, technology has also supported improved citizen engagement in projects by making participation easy, quick, interesting and educational.[22] For example, data collection can now be carried out through devices and mobile apps instead of pen and paper. This can include smartwatches which enable participants to collect data automatically during their everyday activities. Finally, technology has also supported the reach of projects and types of data which can be collected. For example, drones and sensors enable the collection of data in difficult to reach environments and locations, while GPS and GIS mapping technologies allow projects to integrate various data layers to support analysis and visualisation.[23]

2.3 Farmer Citizen Science

While citizen science is a well-established form of research, farmers as a targeted group for citizen science projects is very low.[24] In 2018, a search in Scistarter - the largest online portal connecting members of the public to citizen science projects – found that less than 1% of the project contained the tags 'agriculture', 'food' or 'farm'.[25] As an emerging practice, there is no formal definition for farmer citizen science. For this project, we would define it as a minimum to include the voluntary participation of farmers in scientific research; and when data is shared between stakeholders so that farmers may use the data to inform their own business decision-making.[26] We don't include projects where data is collected by volunteers on farmland, with no or little engagement with farmers.

2.3.1 Types of farmer citizen science and data collection projects

The types of farmer citizen science and data collection projects evident so far have either been driven by agricultural research goals, involving the monitoring of on-farm activities such as fertiliser use, pest control, land use, crops and yield, or by environmental research goals, which focus on biodiversity, conservation, and sustainable farm practices. Some common research themes related to farming and land management include:[27]

- **Biodiversity** research. This can relate to species diversity, abundance, distribution, habitats and ecosystem dynamics. This research theme is particularly prevalent amongst citizen science projects and is highly contributory to the field, with citizen science projects related to species monitoring contributing to at least 50% of the total observations to global biodiversity databases.[28]

- **Earth Observation and Geography** research. This can include bottom-up projects involving participant mapping of land use through ground-based observations, as well as projects led by scientists supporting networks of seismographs in regions susceptible to landslides and earthquakes, for example.

- **Climate Change** research. Citizen science is now widely used to investigate climate change mitigation, adaptation, and impacts. This can cover topics related to soil moisture, flood levels, sea ice, snow depth, bird migration, and algae blooms.

In the UK, most farmer citizen science projects are small scale, led by environmental Non-Government Organisations (NGOs) or environmental research agencies.[29] Despite this, there is increasing interest in methods that facilitate engagement with farmers at a larger scale. This has come out of wider recognition that agricultural and environmental fields have not taken full advantage of the tools and knowledge made available through citizen science.[30] With a unique knowledge of local landscapes and farming systems, farmers have a pivotal role in informing how the threats facing the environment and agricultural systems - such as biodiversity loss, climate change, soil degradation, pests and disease, and food security - could be addressed. A greater uptake of projects has the potential to foster greater trust and collaboration between farmers, scientists, and policymakers, and empower farmers to collect real-time environmental data for their own benefit, as well as to inform policy and research. The extent to which this is achieved will largely depend upon how the data is used and the quality of relationships developed between stakeholders.

2.3.2 Use of technology

With regards to technology, artificial intelligence, drones, sensors and genetic engineering are already, and will increasingly play a major role in revolutionising agriculture.[31] At the same time, these technologies are opening up opportunities for farmer citizen science projects given they enable the conversion of data into useable information for both farmers and professionals in real-time. For example, apps such as iNaturalist.org have a variety of algorithms coupled to phone cameras to allow plants, pests, and pathogens to be identified in the field.[32] This approach generates data for scientists and links the result (an identification) with information about its management for farmers. By making the results direct and immediate, this type of

technology could support greater-buy in and participation of farmers in similar environmental data collection projects.[33]

There is now research which suggests that new technologies may facilitate the collection of on-farm data without farmer involvement. This includes autonomous wireless sensors which are currently being designed as a cheaper and less personnel-intensive method to obtain and utilise data relating to food, water and energy systems.[34] The proposed design of these sensors aims to provide real-time data to help stakeholders such as farmers to improve the efficiency of resource management and receive early detection of hazardous events such as floods or drought. Such advancements to environmental data collection may encourage greater participation from farmers, through the ease of involvement and potential personal benefits, or equally, could deter engagement due to concerns over data privacy; lack of digital savviness and internet connection; as well confusion and project fatigue.[35]

Farmer concern and scepticism over data privacy and security has been evidenced as a key barrier to farmers involvement in citizen science and wider forms of data collection. To the extent that Codes of Practice have been established in the US, EU, New Zealand, and Australia to regulate the use of digital agricultural data.[36] Farmer receptiveness to new technologies may influence the extent to which it ends up being integrated into citizen science projects and data collection projects.

2.3.3 Research limitations & challenges of citizen science

With such growth in the number and diversity of citizen science projects, many scientists have concerns about the robustness of the practice and highlight the need to acknowledge the potential limitations and pitfalls during project design, evaluation and reporting. While there are many challenges and limitations which could be explored here, a few common concerns have been identified. These include:

1. **Data Quality**

Some studies evaluating data quality have found volunteer data to be more variable then professionally collected data, which can be due to factors such as lack of training, inadequate skills, low levels of participant involvement, as well as lack of digital connectivity and technological savviness. [37] This can contribute to inaccurate and insufficient data.

2. **Participant Recruitment**

Many projects find it difficult to identify and recruit people that have the appropriate experience and skills to participate. This could include ecological knowledge, technological familiarity, as well as more practical factors such as location and time. Time in particular, is cited as a common barrier for farmers to engage in citizen science projects.

Diversifying recruitment can also be a challenge and if not adequately targeted, can lead to imperfect data. For example, the use of technologies can lead to biased results while creating

barriers that widen the digital divide between those adopting or having the technology, and those avoiding or lacking it.[38]

3. Communication

This can cover a number of issues, including communication between academic and non-academic participants, as well as communicating project results and understanding volunteer knowledge. In addition, there can be tensions between the motivations of participants and organisers[3] in how data is collected, reported, and acted upon at the end of the project, particularly if there is a lack of alignment between community priorities and research agendas.[39]These issues can lead to break down of trust between scientist and volunteer, and subsequently reduce levels of co-operation and engagement in the research.

4. Managing Ethics

Managing non-professional researchers runs the risk of unintentionally exploiting volunteer labour, as well as misusing public data.[40] This can have negative ramifications for the reputation of a research project or organisation and can cultivate a lack of trust among participants and the wider public, which could add to the challenge of recruitment discussed above.

2.3.4 Types of farmer citizen science projects

The list below provides some examples of the types of projects that exist, using the criteria discussed earlier. Some examples have been taken from an international context given the practice is developing more quickly outside of the UK, particularly in developing countries (see the case study example provided in Figure 3.

- **Detection and spread** projects are based on photos of pests, pathogens, pollinators, and other wildlife which are validated by experts. Common examples include plantvillage.org and iNaturalist.org.

- **Pollinator monitoring** projects link land use to pollination services. So far, these projects have focussed on bees and butterflies. A notable example from the US includes the Great Sunflower Project which involves farmers planting a sunflower and tracking the effects of pesticides on pollinators.

- Projects aimed at **preserving agricultural biodiversity** through seed exchanges involve collecting data on variety performance under different environmental conditions and management practices. These projects aim to identify evaluate and distribute seeds to strengthen crop diversity and improve seed innovation to enable adaptation to climatic changes. A notable example includes the Seed Savers Exchange ADAPT program where participants trial varieties from a seed bank and send back feedback on performance.

- Projects gather data related to **plant breeding** (known as participatory plant-breeding - PPB) and **variety selection** (participatory variety selection - PVS) are increasingly being

---

[3] Organisers could include: researchers; non-governmental organisations (NGOs); community groups; private organisations; or government bodies

paired with emerging technologies to engage farmers in crop evaluation through plant phenotyping and ground-truthing remotely sensed data. In certain formats of PVS, farmers come together to observe and rate the varieties on various aspects, such as yield and other characteristics of the final product. Diversity kits involve the distribution of packages with experimental quantities of 2–3 varieties to farmers, to test varieties under their own conditions. These types of projects aim to improve the genetic makeup of crop plants and increase the profitability of crop production, while also building farmer skills in farmer selection and seed production.

- Projects where farmers help **characterise, and map soil properties and health** at large spatial scales involve the collection of soil data via mobile apps. A UK-based example includes the Open-Air Laboratories (OPAL) Soil and Earthworm Survey.

- Projects such as eFARM (a smartphone-based app) help **improve Agricultural Land System (ALS) information** through crowdsourcing to obtain land parcel data and household information. This can be combined with other crowdsourced information from smartphone tools along with socio-economic data from surveys and remotely sensed data. The aim of this program is to improve the sensing, mapping, and modelling of ALS studies to improve understanding of the biophysical and socio-economic environment, for purposes such as land management and policymaking.[41]

Seeds for Needs is a Bioversity International initiative led by CGIAR involving more than 50,000 smallholder farmers.[42] The program started in Ethiopia and is now active in 14 countries across Africa, Asia, and Central and South America.

The program aims to help farmers adapt to the impacts of climate change, in particular the risks of climate variability such as droughts and floods, through the use of agricultural biodiversity. It does this by:

1. Exposing farmers to a portfolio of adapted crop varieties to increase their knowledge about different traits of seeds and suitable conditions for them. This can mean farmers are more able to choose what is appropriate for their conditions and cope with unpredictable weather.
2. Strengthening farmers local seed supply so they have access to a range of seeds that fit changing climatic circumstances.

Since 2011, the initiative has used a crowdsourcing approach whereby each farmer is given three randomly **assigned** varieties out of a broader selection to compare with their own seeds. **The farmers** then carry **out mini trials with** this small selection and evaluate their performance. Feedback is then communicated from farmer to scientist via a mobile app called ClimMob, which merges and analyses field data from many growers. Scientists then make decisions on which varieties to scale up.

Figure 3: Farmer citizen science project example: Seeds for Needs

2.4 Enablers: Farmer Engagement in Environmental Data Collection and Citizen Science

To design a successful methodology for any environmental data collection and citizen science project, it is important to understand the factors that encourage participant engagement to optimise initial buy-in and long-term commitment. In Table 1, the COM-B model of behaviour change[4] has been used to categorise common factors identified in the evidence review that influence behaviour: capability, motivation and opportunity.[43] These three terms are defined as:

- **Capability** – an individual's *psychological* and *physical* ability to participate in an activity. This can include knowledge, physical strength, or skills. Does the person have the skills and knowledge to be able to do the behaviour?

- **Opportunity** – external factors that make a behaviour possible. This can include *physical opportunities* provided by the environment, such as time, location and resource, or *social opportunities*, such as social and cultural norms. Are there opportunities for the person to do the behaviour?

- **Motivation** – *conscious* and *unconscious* cognitive processes that influence decision-making and behaviour. This can include reflective processes such as evaluating previous experiences, as well as desires, impulses, and habits. Does the person want to do the behaviour?

---

[4] A model of behaviour change which categorises common factors that influence behaviour: capability, motivation and opportunity. See Mitchie et al, 2011.

Table 1: Enablers to farmer engagement in environmental data collection and citizen science projects

	Factors Driving Farmer Engagement
Capability	• Technology and remote networks are often a primary characteristic of many projects (see Section 0), therefore familiarity with **digital communication infrastructure** can be a core requirement for participation.[44]
Opportunity	• Most projects are listed online, therefore access to **digital communication infrastructure** can alert farmers of the research opportunity.[45] • Some participation-based agricultural research projects require farmers to be **living within close proximity** to the research facility.[46]
Motivation	Farmers have multiple and diverse motivations to participate in environmental data collection and citizen science projects, which can vary according to factors such as age, gender, education, income, and farm type. Compared to non-agricultural environmental data collection and citizen science projects, farmers have been found to be more motivated to participate based on their perceptions of whether the project results are directly relevant to them and their farm. This compares to projects where participants are science enthusiasts and willing to engage without extrinsic motivation.[47] Some of the most common motivating factors include: • **Personal values**, including self-efficacy and social responsibility to engage with scientific discovery, community participation and local conservation efforts.[48] • **Opportunities for learning**, mentorship, and developing skills. This is particularly relevant for projects involving regular interaction between farmer and expert, whereby farmers can access specialist advice and training which can lead to improved practice and management.[49] • **Inform business decision-making and potentially increase income** through access to expert advice and innovation. Projects might contribute to higher productivity, lower input costs, optimised fertiliser use, or even new income opportunities, providing a financial motive for participation.[50] • **Opportunities for social exchange**, a community interaction and relationship-building. This could be motivating through a sense of enjoyment, feeling part of a community, as well as opportunities for learning and networking.[51] • **Contribution to science**, including the feelings of satisfaction and empowerment associated with sharing knowledge.[52] • **Personal interest or shared goals** in the research topic providing enjoyment, health, and well-being benefits, as well as a sense of impact. For example, farmers with an interest in conservation may be excited by citizen science projects which aim to approach conservation at a landscape-scale through working with specialists and other community members.[53] • **Personal benefits of having data**. In some projects, farmers may be able to use the data they collect for their own benefit. This could include improved management of operations, minimisation of risks, or improved transparency with other actors in the supply chain.[54]

2.5 Barriers: Farmer Engagement in Environmental Data Collection and Citizen Science

The barriers to engaging in environmental data collection and citizen science projects are also vital to understand when designing research methods and recruitment strategies, particularly when projects aim to engage a variety of participant types to gain a representative sample. In Table 2, the COM-B model of behaviour change has been used to categorise common factors which can prevent farmer engagement in environmental data collection and citizen science projects.

Table 2: Barriers to farmer engagement in environmental data collection and citizen science projects

	Factors Preventing Engagement
Capability	• **Lack of knowledge** to engage with the research topic. For example, a farmer may lack the required knowledge of species to be able to identify them.[55] • **Lack of digital confidence** with smartphone technology and agricultural apps which can be overwhelming and daunting for farmers.[56]
Opportunity	• **Lack of time and resource** is frequently cited as a major barrier to farmer participation. This is especially applicable for projects which require regular engagement with an expert. [57] • **Lack of awareness** of the research opportunity. This could be due to a lack of digital technology, membership to a farming group/community, or simply due to rurality.[58] • **Lack of broadband connection** to communicate with experts, which can be particularly common in rural communities.[59]
Motivation	• **Lack of trust around data** privacy and security, leading to reluctance to share data. This is often driven by a lack of trust in the stakeholders with whom the data is shared.[60] • **Lack of enthusiasm** for the research topic.[61] • **Negative previous experience** of similar projects.[62] • **Lack of comfort with the technologies used** in the project. This could be influenced by the user-friendliness, technical complexity and level of input required from the participant.[63] • Perceived **lack of personal benefits**.[64] • The **design of the technology** used in the project, particularly its user-friendliness, technical complexity, level of input required from the participant, and extent of useful features for the participant. [65,66]

3. Research Methodology

This section outlines the research objectives, framework and method.

Section summary

- The COM-B framework for behaviour change was used to design the research objectives and framework**.** This framework looks at three areas that influence behaviour: capability, motivation, and opportunity.

- The six key research questions covered farmers existing and future engagement with environmental data collection and citizen science.

- The primary research included an online survey with 121 respondents, as well as 15 x 30 minute in-person interviews.

- The spread of demographics across survey respondents is considered relatively representative of the UK farming sector, while the spread of interviewee demographics is considered slightly less representative given the skew towards large farms, and farmers who are more engaged in environmental data collection and citizen science.

- The generalisability of the primary research findings are somewhat limited given limitations in the sample:

    o For the survey, although 121 responses were received, the number of respondents for specific questions was variable given the routed design of the questions and some gradual attrition, resulting in a core of ~66 responses and a maximum of 121 responses.

    o For the interviews, the sample is somewhat skewed to farmers on large mixed farms, with a relative lack of livestock and smaller-scale farmers. Furthermore, the sample could be skewed to farmers who are more engaged about environmental data collection and citizen science given the recruitment method.

3.1 Research Objectives

To design the research objectives and framework, we used the COM-B framework for behaviour change. This framework looks at three areas that influence behaviour: capability (psychological and physical capacity to engage in the activity concerned including the necessary knowledge and skills), motivation (goals and conscious decision-making as well as habitual processes, emotions, and analytic processes) and opportunity (all the factors that lie outside the individual that make the behaviour possible or prompt it). The key questions included:

Existing Engagement

1. What level and type of engagement do farmers currently have in environmental data collection and citizen science? **(behaviour)**
2. What opportunities do farmers have to engage in environmental data collection and citizen science? **(opportunities)**
3. Do farmers have the knowledge and skills required to engage in environmental data collection and citizen science? **(capability)**

4. What motivations and barriers do farmers have to engage in environmental data collection and citizen science? **(motivations)**

Future Engagement

5. What types of environmental data collection and citizen science could farmers be interested in engaging with? (**behaviour)**
6. What could encourage or prevent farmer engagement in environmental data collection and citizen science? **(motivations, capability, opportunities)**

3.2 Research Framework

The research framework adopted, including the key question themes associated with the four COM-B categories is provided in **Error! Reference source not found.**.

Table 3: Research framework according to COM-B model

COM-B Category	Factors to Consider	Question themes (and Evidence Source)
1. **Capability**	• Awareness of opportunity • Ability to participate	a) Are farmers aware of any environmental data collection and citizen science methods/projects? (survey) b) Do farmers have the appropriate knowledge, skills and equipment to participate? (survey)
2. **Opportunities**	• External factors which enable the behaviour e.g. education, access,	c) How do farmers hear about environmental data collection and citizen science methods/projects? (survey and interview)
3. **Motivations**	• Attitudes • Personal factors • Social norms • Previous experience	d) Why do farmers choose to participate in environmental data collection and citizen science methods/projects? (survey and interview) e) Why do farmers choose not to participate in environmental data collection and citizen science methods/projects? (survey and interview) f) What types of environmental data collection and citizen science methods/project would be most appealing to farmers? (survey and interview) g) What would encourage or deter farmer engagement in environmental data collection and citizen science methods/project? (survey and interview)
4. **Behaviour**	a) Level and Type of Participation	h) What level & type of engagement do farmers currently have in environmental data collection and citizen science? (survey and interview)

3.3 Research Method

3.3.1 Online Survey

The aim of the online survey was to identify farmers' existing behaviours and attitudes towards environmental data collection and citizen science, as well as attitudes towards future participation. The survey was distributed through Survey Monkey and designed to take around ten minutes. The questions were mainly closed and semi-quantitative for ease of answering and analysis with some open responses to add insight/comment. Participants were provided with an incentive through being included in a draw for Groundswell tickets. The full list of questions can be found in Appendix 1.0.

The link to the online survey was circulated via Innovation for Agriculture (IfA) farmers' networks, events and newsletter distribution list (5,116 recipients), IfA's external contacts including Agriculture and Horticulture Development Board (AHDB), National Farmers Union (NFU) and veterinary practices across the country. The survey was also circulated across social media channels. In total, 121 responses were received over the two-week response window.

3.3.1.1 Survey sample

In total, we received 121 responses to the survey. The demographic split of respondents who answered the demographic questions (i.e. not all respondents) is outlined in Table 4.

When comparing to farmer demographic data from Defra, survey respondents had some similarities with data from Defra's Survey of Agriculture and Horticulture (2023). [67] Defra's statistics show that:

1. **Gender:** 12% of farmers are female and 88% male.
2. **Farm size:** Average farm size is 213 acres
3. **Age:** Those over 55 years old make up 67% of the farming community, with 34 and under forming 6% of the community.
4. **Economic classification:** 72% of farm businesses in England are small or very small in terms of economic classification, and make up 27% of areas farmed.
5. **Farm type:** Defra statistics show that 31% of farms in England are mixed tenure (33,000 farms). [68]

Table 4: Survey respondent characteristics

	Split across respondents
Gender	Male (66% - 43) Female (34% - 21)

Farm Size	100-499 acres (50% - 28) 1000+ acres (21% - 12) 500-999 (13%- 7) <100 (16% - 9)
Owner/Tenant	Landowner (51% - 29) Tenant only (23%) Both (26% - 15)
Age	50-69 years (60% - 39) 30-49 years (23% - 15) 70+, 18-29 (17% - 11)
Number of generations farming	1st or 2nd generation (50% - 27) 3rd or 4th (31% - 17) 5 or 6 (15%)
Involvement in farmer cluster[5]	Not part of a farm cluster (62% - 38) Part of a farm cluster (38% - 23)
Farm Type	Mixed farm (42% - 33) Livestock (40% - 34) Arable (12%) Other (6%)
Number of years farming	31-50 years (44% - 25) 21-30 years (19%) 11-20 years (18%) 51+ years (12%) 0-10 years (7%)

3.3.1.2 Survey farmer profile

To illustrate the most common characteristics from the surveys, we have created a composite profile of the average respondent (see **Error! Reference source not found.**).

---

[5] A farmer cluster is a community of farmers located in the same region who support each other to improve biodiversity and ecological health of their farms.

Farmer 1	
Farm Size	300 acres
Farm Type	Mixed
Age	58 years
Gender	Male
County	West of England
Farm Tenure	Owner
Number of years farming	40 years
Number of generations family has been farming the land	2nd generation
Member of farm cluster group	No

Figure 4: Farmer profile for survey

3.3.2 Interviews

The aim of the interviews was to gain a deeper understanding of the barriers and motivations to farmer engagement in environmental data collection and citizen science. The interviews were 30 minutes in length and designed to be open and conversational. They were tailored based on initial survey responses. The list of interview questions can be found in Appendix 2.

We conducted 15 interviews, coinciding with two 'study tours' run by IfA, which aimed to engage farmers who had previously been difficult to engage, and included many who had never been engaged by IfA before. We also interviewed six farmers online who had indicated that they were happy to be interviewed on the survey. These farmers were selected at random from a range of sectors and regions. These interviews included farmers with horticulture, dairy, arable and beef enterprises. No responses were received from the pig and poultry sector, despite attempts to engage this industry directly through specialist organisations.

3.3.2.1 Interview sample

In total, we undertook 15 interviews. The demographic split of interviewees is outlined below.

The spread of interviewee demographics is considered slightly less representative than the survey, given the smaller sample size. There were a higher percentage of larger farms in this group, though 26% were under 1000 acres. Of those interviewed, 54% were mixed farms.

Table 5: Interviewee characteristics

	Split across respondents
Gender	Male (80% - 12) Female (20% - 3)
Farm Size	1000-1999 aces (40% - 6) 2000+ acres (33% - 5) 100-199 (13%- 2) <50, 500-999 (13%- 2)
Owner/Tenant	Land owner (60% - 9) Tenant only (20% - 3) Both (20% - 3)
Age	30-49 years (54% - 8) 50-69 years (33% - 5) 70+, 18-29 (13% - 2)
Number of generations farming	1st or 2nd generation (40% - 6) 3rd or 4th (33% - 5) 5 or 6 (13.5% - 2) 9 or 10 (13.5% - 2)
Involvement in farmer cluster[6]	Not part of a farm cluster (66% - 10) Part of a farm cluster (34% - 5)
Farm Type	Mixed farm (54% - 8) Arable (33% - 5) Livestock/ Veg only (13% - 2)
Number of years farming	0-20 years (54% - 8) 21-40 years (26% - 4) 40+ years (20% - 3)

---

[6] A farmer cluster is a community of farmers located in the same region who support each other to improve biodiversity and ecological health of their farms.

3.3.2.2. Interview farmer profile

To illustrate the most common characteristics from the interviews, we have created a composite profile of the average interviewee (see Figure 5).

Farmer 1	
Farm Size	1,750 acres
Farm Type	Mixed
Age	40 years
Gender	Male
County	East of England
Farm Tenure	Owner
Number of years farming	16 years
Number of generations family has been farming the land	2nd generation
Member of farm cluster[7] group	No

Figure 5: Farmer profile for interviews

3.4 Research Limitations

The ability to generalise results from these research findings are somewhat limited given the sample sizes for the interviews and survey. Although we had 121 responses in total for the survey, the number of respondents for specific questions was variable given the routed design of the questions. In addition, the survey results saw some gradual attrition as respondents lost interest or ran out of time to complete the survey. This meant that some questions were only answered by a minority of respondents, with a core sample of 66 farmers who answered over 70% of questions. This lack of coverage reduces the generalisability of findings.

---

[7] Farmer Clusters - For farmers, facilitators and advisors

With regards to characteristics of the survey sample, the survey engaged with a range of farmer types, with differences evident across: gender; farm size; age; landholding; number of generations farming; involvement in a farmer cluster; farm type; and number of years farming. The spread of respondents in the survey is considered relatively representative of the UK farming industry, with a larger proportion of male, mixed farmers (livestock and arable), with a farm size between 100-499 acres (UK average farm size ~210 acres). The survey was sent to a wide audience across all sectors and regions (not just farmers who have previously engaged with IfA), however, the reach was biased to farmers who have internet and access to emails. This will have limited reach to those engaging less with these media, such as older respondents or those who are more remote.

With regards to the sample for the interviews, we engaged with 15 farmers. The sample is somewhat skewed to farmers on large mixed farms, with a relative lack of livestock and smaller-scale farmers. In addition, the sample is likely skewed to farmers who are engaged with research and learning, given they were recruited via an IfA study tour. This could suggest that the interview feedback may be more engaged and positive about environmental data collection and citizen science, than what is reflective of farmers views more generally. These limitations are reflected upon throughout.

4. Key Findings

This section summarises the key findings from the survey and interviews according to the six research questions outlined in Section 0. Section summaries are provided for each research question.[8]

4.1 Existing Engagement

4.1.1 What level and type of engagement do farmers currently have in environmental data collection and citizen science?

Section summary

- Nearly all farmers (91% survey respondents (93 farmers), 100% interviewees (15)) participating in this research collect at least some form of environmental data.

- The majority of farmers participating in this research (86% of survey respondents (80 farmers), 93% interviewees (14 farmers)) collect data for their own use to help them manage their farm, or because it is mandatory (75% of survey respondents (79 farmers), 33% interviewees (5 farmers)). A smaller number of farmers said they collected environmental data for a specific research project (28% of survey respondents (26 farmers), 86% interviewees (13 farmers)). A minority of farmers said they collected data for citizen science (23% of survey respondents (18 farmers), 46% interviewees (7 farmers)).

- Over a third of farmers participating in this research collect some form of environmental data on a weekly/daily/constant basis (37% of survey respondents (47 farmers)).

- The most common topics farmers participating in this research collect data on are related to soil (70% survey respondents (65 farmers), 86% interviewees (13 farmers)), biodiversity and conservation (68% survey respondents (63 farmers), 86% interviewees (13 farmers)), or land use (68% survey respondents (58 farmers)).

- **Nearly half of farmers participating in the survey started collecting data in the last ten years (48% survey respondents** (56 farmers)**), and some farmers feel that environmental data collection will become increasingly important going forwards.**

---

[8] As a general rule of thumb, we have specified where findings have originated from farmers participating in the survey or interviews. However, if the findings were from both the survey and interviews, we say "the farmers engaged with".

Level of engagement with environmental data collection

The survey highlighted that **for many farmers, collecting data is important and already an integrated practice on their farm**. This was evidenced by the high proportion of respondents (91% = 93 respondents) who said they collect some form of environmental data. This was also reflected in the interviews, where all 15 interviewees could provide at least three examples of environmental data they collect.

Reasons for engagement with environmental data collection and citizen science[9]

1) Out of the 92 respondents who answered this question, **the most common reason for collecting environmental data, is for personal use**. This was given as a reason by 86% of those who collect data (80 farmers). The majority of respondents who collect data for personal use *and answered* why they collect this data (60 respondents) indicated that they collect this data to help them manage their farm, rather than for personal interest or as a contribution to academic research. This constituted 72% of those who responded to this question (43 respondents),and highlights the perceived importance of data for farm management. Similarly, the most common reason given by interviewees for collecting environmental data was for personal use (given by 14 out of 15 interviewees). However, among the 14 interviewees who collect data for personal use, there was an equal split between those who collect it to help manage their farm (7 interviewees), and those who collect it for personal interest (7 interviewees). Both the survey and interviews highlight that there is a lot of data farmers already **choose to** collect on an informal basis for themselves or the farm, which suggests that it is useful and interesting to them. This could represent opportunities in the future for 1) collecting more data from more farmers who already collect it, and 2) encouraging more farmers to start collecting data.

2) **The second most common reason given by survey respondents for collecting environmental data, is because it is mandatory.** 75% of respondents who collect data (69 farmers) gave this reason. The most common reason for collecting mandatory data was for farm assurance or certification, selected by 38% of respondents who collect mandatory data (16 farmers). Examples provided included Red Tractor reporting, Organic Certification, and for Entry Level Stewardship (ELS), Higher Level Stewardship (HLS), Basic Payment Scheme (BPS), Health and Safety Executive (HSE), and Rural Payments Agency (RPA). Other reasons to collect mandatory data were listed as: to receive payment from agri-environment schemes such as Environmental Land Management Schemes (ELMs), or records for auditing. In comparison with the survey, a minority of interviewees (5) said they collect data because it is mandatory. Those that did collect mandatory data, said they collect it for Defra, ELMS test and trials, or for the Country Land and Business Association (CLA).

3) **A minority of survey respondents indicated that they collect environmental data for specific research projects.** This was indicated by 28% of respondents who collect data (26 farmers). In comparison, the majority of interviewees (13 out of 15) said they collect data for a specific research project. This difference could be due to the sample, whereby farmers willing to sign up to an interview on environmental data collection (requiring more time than a survey), could be more likely to be involved in projects

---

[9] Note that respondents & interviewees could indicate more than one reason.

already. This could also be due to different interpretations of 'research project' between survey respondents and interviewees. Nevertheless, key points of interest include:

    a. Out of the survey respondents indicated they were involved in **research projects which relate to biodiversity and conservation, or soil**, **represented 62%** of those who collect data for a specific project. The remaining respondents were also engaged in projects related to fertiliser, carbon neutral farming, water quality, and nutrient management. This could be due to more research projects related to biodiversity and soil. However, these two topics were also two of the most popular data topics farmers collect data on.

    b. Out of the survey respondents involved in a research project, **50% said the project was led by a specific research organisation**. Examples given included: the Foundations of Innovative Agriculture; Agriculture and Horticulture Development Board (AHDB); Grasscheck GB; ADAS Farming; and Kynetec. Other project organisers listed by respondents included: universities; suppliers; government bodies; manufacturers; Wildlife Trusts; and farmer cluster groups. Interviewees listed similar organisations for research projects they were involved in, and specifically mentioned: water companies such as Thames Water and Southwest Water; manufacturers such as Arla, Oatly and Tesco; councils; farm cluster groups; Wildlife Trusts, universities; and National Institute of Agricultural Botany (NIAB). It is interesting that there is a wide range of organisations collecting data from farmers.

    c. Out of survey respondents involved in a research project, **79% (15 farmers) take part in more than just the data collection process**, and are also part of the project design (58% = 11 respondents); working with other researchers (58% = 11 farmers), and sharing results (63% = 12 farmers). It is interesting that farmers are keen to play a broader role in research projects, beyond the data collection.

For all specific environmental data collection and citizen science projects raised by interviewees and survey respondents, please refer to 0

4) **The least common form of environmental data collection given by survey respondents, was citizen science,** reflecting 23% of total respondents (18 farmers out of 92 respondents). In comparison, nearly half of interviewees (7 out of 15) said they were involved in citizen science, while four said no, and five were unsure. More generally, there was a sense from both the survey and interviews that there is some confusion and different interpretations of the term citizen science.

The reasons farmers are involved in environmental data collection according to the survey and interviews, are presented graphically in Figure 6 and Figure 7.
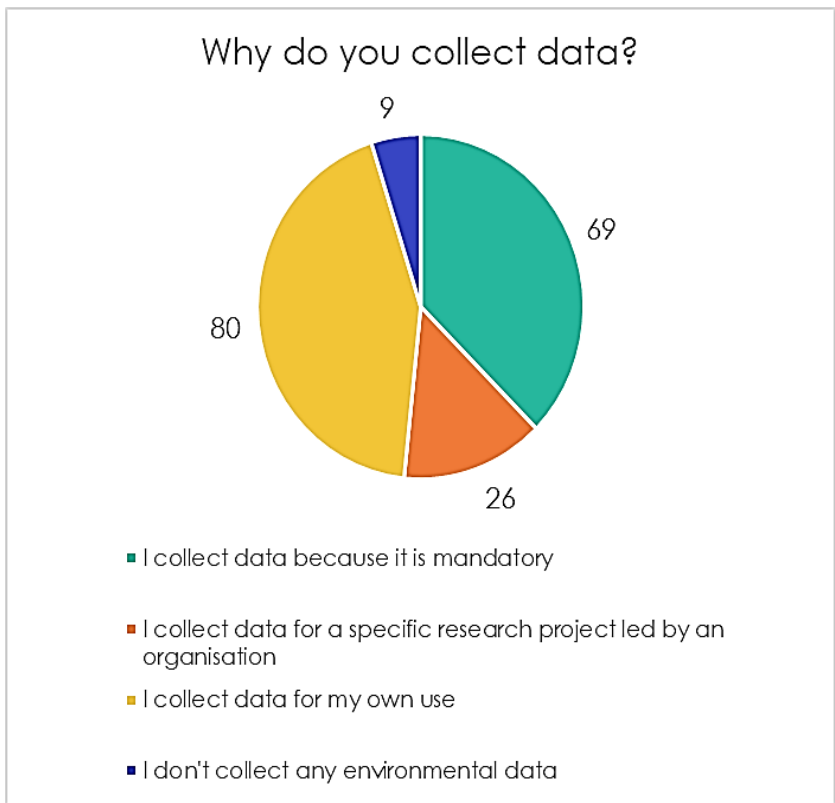
Figure 6: Reasons survey respondents are involved in environmental data collection (n=102)
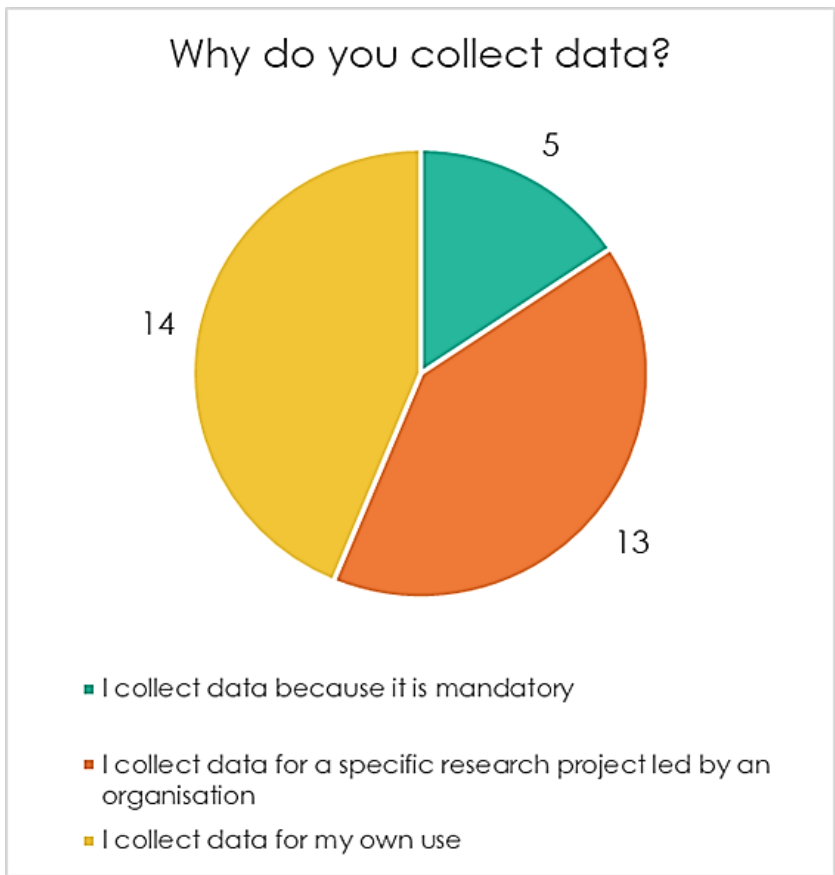

Figure 7: Reasons interviewees are involved in environmental data collection (n = 15)

Types of environmental data already collected

The most common topics survey respondents collect environmental data on are soil or land use. Out of the 93 respondents who answered this question, 70% collect soil data (65 farmers), and 68% collect land use data (63 farmers). These topics were closely followed by biodiversity and conservation, with 63% of respondents (58 farmers). The least common topic (although still given by a high proportion of respondents) is energy & alternative farm fuels, selected by 50% of respondents (46 farmers). The interviews presented similar results, with soil and biodiversity and conservation the joint most common topics, with 13 out of 15 interviewees collecting data on these topics. Interviewees provided examples such as worm counts and soil tests for biology, nutrient levels, and organic matter, as well as wildlife surveys and habitat site monitoring. This suggests that these topics are the most interesting and useful topics to farmers and most likely to garner participation and engagement from farmers.

Other data topics raised by interviewees included:

b) Crops (6 interviewees), including yield and silage;

c) Water quality (3 interviewees);

d) Weather (3 interviewees), including rain gauges and climate monitoring;

e) Fertiliser (2 interviewees), including usage and efficiency;

f) Livestock and animal health (2 interviewees), including liveweight gain, grazing records, and vermin;

g) Carbon (2 interviewees), including sequestration rates and storage;

h) Nutrition (1 interviewee), specifically relating to the nutritional value of food produced on-farm; and

i) Energy (1 interviewee), including Energy Performance Certificate (EPC) monitoring, energy transition surveys, and shifting transport away from fossil fuels.

Table 6**Error! Reference source not found.** breaks down the data topic by purpose of data c ollection, given by 93 survey respondents. For most topics, the reason for environmental data collection is evenly split between personal use and because it is mandatory. However, it is interesting that a higher proportion of survey respondents who collect environmental data for soils or biodiversity, collect it for their own use rather than because it is mandatory. This could suggest that this topic is more important or interesting to farmers on an individual basis and therefore more likely to garner engagement in research; and a topic which farmers have a lot of data on already but is not yet shared.

Table 6: Number of farmers who collect environmental data broken down by data topic (n = 93)

Data Topic	Total for Data Topic	I Collect Data for My Own Use	I Collect Data for a Specific Research Project	I Collect Data Because It Is Mandatory
Other	2	0	0	2
Energy & Alternative Farm Fuels	79	45	6	28
Biodiversity & Conservation	115	61	16	38

Pests & Disease	108	53	8	47
Land Use	128	59	10	59
Fertiliser	121	56	8	57
Soil	138	74	16	48
Crops	131	58	15	58

Frequency of environmental data collected already[10]

Out of the 93 survey respondents who said they collect some form of environmental data, **over a third (37% = 47 farmers) collect data constantly, daily or weekly.** When broken down by reason for data collection, nearly half of respondents (41% = 24 farmers) who collect environmental data *for personal use*, collect it on a very frequent basis, either constantly, daily, or weekly. Similarly, a third of respondents who collect *mandatory data* (15 farmers) collect it on this basis, as well as 37% of respondents (8 farmers) who collect data *for a specific project*. This finding highlights that some farmers are already collecting data very frequently –enough to be part of a routine. This indicates the perceived importance of data to some farmers, and the substantial amount of data already being collected.

History of environmental data collection[11] [12]

Out of the 114 survey respondents who said they collect some form of environmental data, **nearly half (48% respondents) started collecting this data in the last ten years.** When broken down by reason for data collection, the majority of respondents who collect *mandatory data* (45% = 18 farmers) started collecting it in the last ten years**.** Similarly, 42% of respondents (22 farmers) who collect data *for personal use* started collecting in the same time period, as well as 63% of respondents (14 farmers) who collect data *for a specific project*. This could suggest that environmental data collection is becoming increasingly important to farmers.

Time spent on environmental data collection and citizen science projects

This question was only relevant to survey respondents who had collected data as part of a specific research project. Out of those who answered this question, **nearly half (40% = eight farmers) said they spent over 40 hours on the project.** This represented the highest option on the scale provided. This finding demonstrates the significant amount of time required or volunteered by farmers in specific research projects.

---

[10] Note survey respondents could indicate more than one option according to different data collections.

[11] Note that 'constantly' was used by farmers to refer to ongoing live sensors, robots, tags or trackers for data collection, such as robots for milking, or moisture level sensors.

[12] Note survey respondents could indicate more than one option according to different data collections.

4.1.2 What opportunities do farmers have to engage in environmental data collection and citizen science projects?

Section summary

- Most farmers who have been part of a research project (60% survey respondents (21 farmers), 100% interviewees 13 farmers)) heard about the project through engagement with other farmers, such as farmer groups or clusters. A smaller proportion heard about projects via digital channels such as email or websites (20% survey respondents (7 farmers).

Communication about environmental data collection and citizen science projects[13]

This question was only relevant to respondents who had collected data as part of a specific research project. **Most survey respondents who were part of a research project, heard about it through engagement with other farmers**. Out of the 35 respondents who answered this question, 60% (21 farmers) heard about the project through a farmer group or association, or through word of mouth. In comparison, just 20% of respondents (7 farmers) were directly approached via email. The interview findings closely aligned with the survey results. All interviewees who were involved in a research project had also heard about it through engagement with other farmers. This included: a farmer group or association (including the British On-Farm Innovation Network and Camgrain Sustainable Farming Group); word of mouth through a contact on the farm; or the farmer was directly approached via a catchment farming network.

This learning, that informal word of mouth and farmer networking represents an influential communication channel is useful for stakeholders aiming to increase farmer engagement in environmental data collection and citizen science. This could be contributing to a skewing of farmer types contributions to projects, excluding those less connected to farmer networks and cluster groups.

4.1.3 Do farmers have the knowledge and skills required to engage in environmental data collection and citizen science projects?

Section summary

- Most farmers in the survey who had been part of a specific project (75% survey respondents (15 farmers), said they required knowledge of the research topic to participate.

- Nearly half of interviewees (7 farmers) said they rely on skilled labour to collect data for them.

- Most farmers participating in this research use technological equipment to collect environmental data (79% survey respondents (15 farmers), 66% interviewees (10 farmers)). However, half of

---

[13] Note survey respondents could indicate more than one option.

farmers (50% survey respondents (9 farmers), 50% interviewees (7 farmers)) still collect some data manually, with many farmers using a combination of methods.

- A small number of farmers participating in the survey reported requiring written skills to collect environmental data (30% survey respondents (6 farmers)).

Knowledge and skills needed for environmental data collection and citizen science projects

In the survey, this question was only relevant to respondents who had collected data as part of a specific research project. **Three quarters of the 20 respondents (15 farmers) said they needed knowledge of the research topic to participate. An equal number of respondents said they needed technology skills**. In comparison, written communication skills were required by less than half of farmers (6 respondents). The proportion of farmers reporting the need for technology skills could point towards an emerging trend towards more technologically-oriented data collection on farms.

Half of interviewees (7) said they needed interested and skilled people to collect data, including employees, volunteers or experts. This included people who are committed, enthusiastic and able to record good quality data, with knowledge of what they are looking for and how to use equipment. This was also picked up in a free text section of the survey, where a respondent wrote "(I) would welcome it, (citizen science) BUT it needs to be to sufficient standard with skilled volunteers. Sub-standard volunteers with insufficient skills and poor-quality data is a waste of time and resources." Some farmers do not have time to collect data, with some interviewees reporting that they outsource data collection to consultants or students. When doing so, farmers look to select skilled volunteers who they can trust to collect quality data, and require minimal supervision. Six interviewees also said they needed specialist advisors to support them with the data collection and interpretation.

Equipment needed for environmental data collection and citizen science projects

In the survey, this question was only relevant to respondents who had collected data as part of a specific research project, and **the majority of the 19 respondents (79% = 15 farmers), said they use some form of technological equipment to collect environmental data.** This aligns with previous findings where the majority of survey respondents said they felt they needed technology *skills* to participate in projects. Examples of technological equipment provided by respondents included: a mobile; tablet/iPad; an app; drone; camera; sensors; Geographic Positioning System (GPS); Geographic Information System (GIS); automated recording station; or precision farming technology.

A technological requirement of environmental data collection and citizen science projects was also reflected in the interviews. Most interviewees (10) said they needed some form of technological equipment to collect environmental data, such as tags, remote sensors, yield monitors, cameras, apps (such as iRecord), drones, combine equipment, and automated monitoring systems. In addition, four interviewees said they needed software to support them

with mapping, atomisation, and data organisation and storage. A further two interviewees said they needed paid subscriptions such as Greenlight Growers or yield mapping software.

Despite a focus on equipment and technology, **nearly 50% of survey respondents (9 farmers) and 50% of interviewees (7), said that they still collect some data manually,** through pen and paper, counting, and walking around the farm. Interestingly, the majority of interviewees who collect data manually, also collect data using technology. This suggests that while technology is increasingly playing a role in environmental data collection and on-farm activities, many farmers still use a combination of methods to collect data.

Overall – Knowledge, skills and equipment

This survey question asked respondents who had collected data as part of a specific research project, what knowledge, skills *and* equipment they needed, and gave respondents a list of nine options. Nearly half of respondents (45% = nine farmers) ticked all the knowledge, skills and equipment options**,** which included: knowledge of the research topic; technology skills; numerical skills; spoken communication skills; written communication skills; internet connection; and physical equipment. This is a relatively high percentage of farmers requiring skills, knowledge and equipment to participate in research projects of this type. This could present a barrier to some farmers looking to participate in environmental data collection or citizen science projects.

4.1.4 What motivations and challenges do farmers have to get involved in environmental data collection and citizen science projects?

Section summary

- For farmers participating in this research, the most common motive to engage in environmental data collection or citizen science, is to gather useful data for the farm (62% survey respondents (13 farmers), 66% interviewees (10 farmers)). The second most common motives are to learn and develop skills (52% survey respondents (11 farmers)), and to access expert advice (48% survey respondents (10 farmers)).

- Farmers participating in this research are also motivated to collect environmental data or participate in citizen science for non-financial reasons. Some farmers said they were motivated if it helped protect the environment, supported the community, or related to a personal interest.

- For farmers participating in this research, the most significant barrier to engaging with environmental data collection and citizen science, is a lack of time (experienced as a challenge by 50% survey respondent**s** involved in a specific project (7 farmers), and the most common challenge cited by interviewees (4 farmers)).

Motivations for involvement in environmental data collection and citizen science projects

Survey respondents who collected data as part of a *specific research project* were asked what their main reasons were for taking part. **Out of the 19 respondents, most said they were motivated to participate in order to gather useful data for their farm**. This was applicable to 62% of respondents (13 farmers) who selected this motive in one of their top three choices out

of a list of eight provided (see Figure 8). The second and third most common motivations were to learn and develop skills (selected by 52% of respondents in their top three = 11 farmers) and to access expert advice (selected by 48% of respondents in their top three =10 farmers). These results suggest that engaging farmers in environmental data collection or citizen science is likely to be most appealing if it offers commercial value. This could be through providing data insights or knowledge of new management practices which could help improve farm efficiency or profitability.

In comparison, **respondents were least motivated to participate in environmental data collection/citizen science in order to engage with the local community.** 10% of respondents (2 farmers) selected this motive in one of their top three choices out of 8.

The full list of motives and their relative importance to farmers is presented in Figure 8.

Reason for participation	% of participants who ranked this in their top three reasons
1. To gather useful data for the farm	62% (n = 13)
2. To learn and develop skills	52% (n= 11)
3. To access expert advice	48% (n = 10)
4. To contribute to scientific research	43% (n = 9)
5. To protect the environment	33% (n = 7)
6. To support business-decision making and farm income	33% (n = 7)
7. For personal enjoyment	19% (n = 4)
8. To engage with the local community	10% (n = 2)

Figure 8: Farmer motivation to participate according to the survey (n = 21)

Similarly, the majority of interviewees (10) said they collect data to gather useful information for the farm, predominantly to support business decision-making and farm income. More specifically, interviewees said that data was useful as it helps them to: identify hotspot areas with high/low levels of wildlife; monitor the effects of a new management or production practice; improve knowledge and a sense of control over farm operations and performance; and to make business assessments, plans and decisions. Out of the ten interviewees, six specifically mentioned that they collect environmental data in order to have a baseline. This was regarded as important because it helps farmers to: prepare for the future when suppliers and markets may need this baseline data; prepare for involvement with green finance[14] options; "provide confidence on how well agricultural activities have been completed" and "communicate a story around nature friendly farming". The importance of this motivation was also highlighted when interviewees who had been part of a research project were asked how it had been useful to them. Five interviewees said that the project had helped them understand a baseline which would help evidence improvement and inform decision-making. It is clear that a primary motivation for farmers engaging with environmental data collection is to have a more detailed insight into farm operations and measure the impact of management changes.

---

[14] According to the World Economic Forum, green finance is any structured financial activity that's been created to ensure a better environmental outcome. What is green finance and why is it important? | World Economic Forum (weforum.org)

Three of the interviewees said that they collect environmental data for personal enjoyment or curiosity. This was more important to interviewees than respondents to the survey, however this could be due to the nature of the stakeholder engagement. Interviewees said they said they were motivated by: a personal "fascination for carbon footprinting"; a passion to protect the environment and "do the right thing" – including the ability to be able to evidence positive impact and "tell a story"; a desire to continue a legacy of conservation on the farm; and an appetite to stay involved and up to date with universities and their research. This finding could suggest that for some farmers, financial incentive is not the only motivation and personal interest in and passion for the environment can also play a part.

Two interviewees demonstrated an interest in collecting environmental data in order to learn, network and contribute to innovation. One interviewee said that "networking is key, and we to try to share as much data as we can. What we do is quite complex. We have a lot of contacts on different areas and try to work together to be able to move forward and keep up." When interviewees who had been part of a specific research project were asked how it had been useful to them, three said that it had developed their knowledge and skills on new techniques and research. Several interviewees said they valued free access to consultants and advisors and highlighted this as a key reason for participating in the project again.

Other reported motives to collect environmental data raised included:

- To adapt to pressure from supply chains to track data on climate change, welfare and good practice (1 interviewee);
- To comply with funding requirements of ELMS (1 interviewee); and
- To comply with government regulations (1 interviewee).

Overall, it is clear that farmer motivations to participate in environmental data collection are varied and personal. However, a majority of farmers are motivated by the prospect of using data to improve the farm business.

Challenges with environmental data collection and citizen science projects

Survey respondents who collected data as part of a specific research project were asked if they had experienced any challenges with the project. Over two thirds of the 20 respondents (70% = 14 farmers) said they had experienced a challenge, and 30% said they had not experienced a challenge. **The most common challenge, experienced by half of those who gave a challenge (7), was too much time required of them.** Interestingly, this was indicated by the respondents who said they had spent over 40 hours on their project, previously in the survey. Not one respondent who had spent less than 40 hours on a project noted time as a challenge. A second challenge given by 43% respondents (6 farmers) was a lack of guidance and support.

In the interviews, time was also a challenge farmers experienced with research projects and citizen science (4 interviewees). One of the interviewees said that more time was needed because the project had been poorly organised. Other challenges with projects included:

- Difficulty in following protocols and procedures, which can be complex and impractical (1 interviewee);

- Difficulty in turning the data into meaningful results for the farm (1 interviewee);

- Receiving negative comments from neighbours as a result of enabling public access to their land (1 interviewee);

- Challenges in understanding the data topic (1 interviewee);

- Lack of trust in the reliability and validity of the data collected (1 interviewee); and

- A higher availability of projects to participate in the South of England, being more sporadic and difficult to access in the North (1 interviewee).

These challenges present important findings for those designing research projects, suggesting that in order to engage farmers effectively and encourage their continued participation, projects should limit the time asked from farmers (keeping this to below 40hours). This should include designing data collection processes so that they are easy and efficient. In addition, project organisers should provide sufficient support to farmers, which might include upskilling support on how to apply data usefully for the farm, as well as information on the research topic.

Despite these challenges, 11 interviewees said that the project in question had been useful to them, with only one interviewee saying that it hadn't been because it confirmed what they already knew. Furthermore, **all nine interviewees said they would participate in the same project again**, with an additional two interviewees saying they would so long as they had trust in the project organisers and felt the data would be useful to them. In addition, when interviewees were asked why they had stopped collecting data, the reasons provided were not due to challenges with the project, but practical reasons such as: the project had stopped; data collection had been automated; and the data was no longer needed or relevant to the farm. This indicates there is significant potential for more farmers to be involved in research projects and citizen science.

4.2 Future Engagement

4.2.1 What types of environmental data collection and citizen science could farmers be interested in engaging with?

Section summary

- The majority of interviewees participating in this research already share data they collect, **when it is not already collected for a specific project** (60% interviewees (9 farmers)). Predominantly, this is with other farmers and people they trust for the purpose of knowledge sharing.

- The majority of farmers participating in this research who already collect environmental data indicated they would be willing to share it (80% survey respondents (44 farmers)), with a further 14% (8 farmers) if certain conditions were met. This included factors such as: a reward; a simple process for data submission; and trust in the end user.

- The most common forms of environmental data farmers already collect which they would be willing to share, were related to biodiversity (45% survey respondents (25 farmers)) and soil (25% respondents (14 farmers)).

- The majority of farmers participating in this research are most interested in collecting data on biodiversity and conservation (94% survey respondents (57 farmers), 40% interviewees (6 farmers)), or soil (89% survey respondents (54 farmers), 40% interviewees (6 farmers)).

- The majority of farmers participating in this research would be willing to participate in citizen science in the future, particularly projects on data topics that interest them (66% survey respondents (49 farmers)). However, some farmers were unsure, or felt they could not trust citizen science (22% survey respondents (16 farmers)).

- The majority of interviewed farmers said they would prefer to collect environmental data as part of a paid research project (50% interviewees (7 farmers)), rather than doing this as citizen science (14% interviewees (2 farmers)) because of the financial incentive.

- There is some scepticism and differing understandings among farmers participating in this study about the term 'citizen science', and interviews demonstrated that some data collected on farms is not recorded.

- The majority of survey respondents are interested to participate in the design of the research project as well as the data collection process itself (62% survey respondents (38 farmers)).

Environmental data already collected which could be shared

In the survey, **the most common forms of environmental data farmers already collect which they would be willing to share, were related to biodiversity (selected by 45% of respondents = 25 farmers) and soil (selected by 25% of respondents = 14 farmers)**. Other shareable topics included: water quality; hedgerows; trees and grass; crops/land use; livestock numbers; and carbon. This corroborates findings in Section 4.1.1 on what environmental data farmers already collect, which indicates that farmers would be most willing to share data that they already collect, rather than on new topics to them.

Willingness to share existing environmental data

Nearly 80% of the 56 survey respondents who already collect environmental data (44 farmers) indicated that they would be willing to share existing environmental data. A further 14% of respondents (8 farmers) said that they would be willing to share their data *if certain conditions were met,* leading to a total of 94% of respondents. This included payment and a simple process for sharing data. One farmer expressed that they already "give far too much data away for free", and another two farmers expressed how they feel "over-burdened with compulsory data requirements which feel meaningless and are difficult and time-consuming to collect and share". One farmer specifically said "Do NOT make anything else compulsory for farmers, too much emphasis is made on paperwork!" and another farmer echoed this by saying "There are more and more pressures and requirements being put onto farmers with data and information requests which are often duplicated between differing organisations so another one isn't particularly welcome, would be useful if organisations could collaborate on their requirements and requests".

The high percentage of survey respondents (94%) willing to share data they already collect, representing potential for future research . This is especially relevant when considering the amount of data that is already collected by farmers, identified in Section 4.1.1. However, farmers have clearly communicated that their willingness to share data is dependent on: 1) a reward for sharing data; 2) an easy process for sharing data; and 3) trusting the end user. This resonates with time as a key barrier to engagement for farmers identified in Section 4.1.4 and highlights that organisers of environmental data collection/citizen science need to minimise time required of farmers.

Farmers also expressed that information requested needs to be better streamlined, coordinated and formalised to improve overall efficiency for farmers. This would require an improved understanding of what environmental data farmers already collect and share. One survey respondent suggested that improved information management systems could help encourage farmers to share more data, saying that "In order for it to be effective, data collection and management needs to be underpinned by effective requirements analysis, planning and information management".

In the interviews, nine **out of 15 farmers said they share their data already**, when it is not already collected for a specific project. Interviewees said this is typically with other farmers and like-minded people that they trust, for the benefit of knowledge sharing. One interviewee said "There are benefits from sharing agricultural data with other farmers as group discussions, looking at margins and comparing with others is useful to the farming business.". This indicates that there are already knowledge sharing activities associated with environmental data among farming networks and communities. Tapping into farmer networks could be an effective way to gather data. However, this finding also reinforces the importance of trust to data sharing effectively engaging.

Interviewees were also asked about their peers: "To what extent do you think other farmers would or wouldn't be willing to share data?". In response, interviewees indicated that the

majority of farmers would be willing to share their data with projects and people they trust, and this is an increasing trend across the sector. However, some farmers will be more difficult to encourage than others. three interviewees felt that most farmers would be willing to share their data "if the request came with good reasoning", and four indicated that there would be a mix of those who would be willing and unwilling. One interviewee said that "It very much depends on the individual and comes down to the personality of the farmer", and another said that among some farmers, there is "definitely still a mindset of 'my data, why share?'". This suggests that willingness to share data is likely to be personal, meaning strategies to engage farmers in environmental data collection and citizen science projects will need to consider factors that influence farmer trust, and avoid a 'one-size-fits-all' approach in communication to engage a diverse range of audiences.

The interviews highlighted that a lot of data is already collected on farms, and while some of this is collected and formally recorded, **a lot of data remains unrecorded even though it may be contributing to knowledge and informs practice.** This was indicated by one interviewee who said that "I don't always record all the information I collect in a data system, I just sort of have a look and see how many worms I've got and think "well, that's good amount of worms" but I don't necessarily write it all down". Another interviewee felt that useful environmental information is collected by farmers off the farm, and used an example of conversations about water quality and litter at their local paddle boarding club. They said that "conversations are constantly happening in communities which would be useful data but is never recorded". This was also indicated by a survey respondent, who shared that "I find it hard to differentiate in the question the difference between 'collecting data' and the knowledge I just have in my head about my farm. It may not be written down but I do have the knowledge". Accordingly, interviewees felt that while there is a lot of environmental data already collected, and a general willingness to share data with trusted end users, processes for data collection and sharing need to become more formalised, structured and joined up to facilitate action. Interestingly, interviewees with smaller farm sizes generally appeared more willing to collect more environmental data, whereas farmers with larger farm sizes came across as more concerned or undecided in their responses.

In summary, farmers collect a lot of environmental data which is not always recorded and there is some confusion over what counts as data. It was also interesting that interviewees with smaller farm sizes appeared more willing to collect more environmental data.

Willingness to participate in citizen science

Amongst the 74 survey respondents who were asked if they already take part in citizen science, a third (24 farmers) said they already do. In response to a follow-on question: 'In future, would you be willing to take part in citizen science?', **two thirds of the respondents (49 farmers) said they would be willing to take part in citizen science in future.** The minority of respondents who said they would not be willing to participate (12%), expressed that they did not trust citizen science, and felt that the Government should not interfere with farmers. Another interesting finding was that 22% of respondents (16 farmers) said they were unsure if they would be willing to take part in citizen science in the future. This was partially borne out of some

confusion about what citizen science is, identified in a free text section where a respondent wrote "What is the background to the creation of citizen science and why is it needed?".

When interviewees were asked the same question, nearly half (7 out of 15) said they were already involved in a citizen science project. A further five said they were unsure, again reflecting a knowledge gap among farmers regarding what citizen science is, with one interviewee saying "The term was new to me until now". **When asked how they would be most interested in collecting environmental data in future**, **only two interviewees out of 14 said they would do this as citizen science.** In comparison, seven interviewees said they would collect data as part of a paid research project, one said they would collect data independently, and four said they would participate in a combination of types. Interestingly, interviewees who were part of a farm cluster group showed a general preference towards projects led by farm cluster groups, and groups such as IfA. One interviewee said "Farm clusters, I think are probably one of the best things", and "I would say is better taken by farmers when it comes from an established group, organization, probably a better word, but not from government, or, you know, higher up organization.". Overall, this suggests that some farmers are already participating in citizen science and would be willing to in future, however, their preference would be to participate in a paid research project. The difference in findings between the survey and interviews could be because interviewees were given the choice between different forms of data collection, whereas survey respondents were simply asked a closed yes/no question with regards to citizen science specifically.

The main reason interviewees said they would prefer to participate in a paid research project, is because of the financial incentive. One interviewee expressed that "Data should be paid for – Data has a value and is unique to me and my farm". In addition, interviewees felt that paid research projects were likely to be of a higher quality in terms of organisation and methodological rigour, and could result in expert advice and guidance. In comparison, interviewees were attracted to citizen science because:

- It can be more suitable for collecting certain types of data, such as data on wildlife;
- It is more likely to bring people and the environment together and build a sense of community.
- It can involve sharing the workload of data collection with public volunteers (Note this was listed by farmers as an attraction however this review does not consider this as *farmer* citizen science. This indicates mixed understandings of the term citizen science);
- It opens the farm up to the community to give them an "opportunity to explore the farm and engage with wildlife"; and
- It builds awareness and skills among the community to future environmental change.

Interviewees who said they would opt for a combination of citizen science and paid research projects, said that their involvement depends on the project requirements and outcomes, but also, by participating in a mix of the two, farmers can end up collecting a more diverse set of data, and "get a better range and understanding of what's actually happening on the farm".

Interesting topics for environmental data collection and citizen science

In the survey, **the most interesting environmental data topics to the 61 respondents were biodiversity and conservation, and soil.** This was reflected through 94% of respondents (57 farmers) who said they were either 'very interested' or 'interested' in biodiversity and conservation, and 89% of respondents (54 farmers) who were 'very interested' or 'interested' in soil. These preferences correlate with the data already collected by farmers, as well as existing data which farmers are most willing to share – with biodiversity and soil being the most popular in both cases (Section 4.1.1). These preferences were mirrored by interviewees, with the most popular topics for data collection being soil (6 interviewees) and biodiversity and conservation (6 interviewees). These topics were closely followed by water and air quality (5 interviewees), carbon sequestration (2 interviewees), livestock and crops (2 interviewees), and pollinators (2 interviewees).

In the survey, **the least interesting data topic was fertiliser,** with 25% of respondents (14 farmers) saying they were either 'disinterested' or 'Not interested at all'. In the interviews, fertiliser, disease, weather, and nutrient quality of food were topics which were raised (by one interviewee each), but nevertheless still a topic of interest for some farmers.

Farmers' role in citizen science

In the survey, respondents were given seven roles in citizen science to rank according to which interested them the most (see Table 7**Error! Reference source not found.**). **The majority of t he 60 respondents indicated that they were most interested in being part of the design of the research project**, with 62% of respondents (38 farmers) ranking this in one of their top three roles. This was closely followed by data collection, and data analysis. In comparison, **respondents were least interested in being part of recruitment,** where just 20% of respondents (12 farmers) selected this in one of their top three choices. It is interesting to find that a majority of farmers are most interested in being involved in the design of the research project – more so than collecting the data itself. This is an interesting finding for organisers of environmental data and citizen science projects, and could be a way to engage more farmers in future.

Table 7: Role in Citizen Science (n = 60)

Role in Citizen Science	% of participants who ranked this in their top three reasons
1. Involvement in the design of the research project and questions	62% (n = 37)
2. Collection of data	55% (n = 33)
3. Analysis of data	52% (n = 31)

4. Sharing results	43% (n = 26)
5. Development of materials or resources	37% (n = 22)
6. Presentation of data	32% (n = 19)
7. Recruitment of participants	20% (n = 12)

4.2.2 What could encourage or prevent farmer engagement in environmental data collection and citizen science?

<div>

Section summary

- The majority of farmers participating in this research would be most encouraged to participate in environmental data collection/citizen science by commercial incentives, including: access to expert advice (52% survey respondents (35 farmers), 26% interviewees (4 farmers)); financial reward (60% interviewees (9 farmers)); or gathering useful data for the farm (45% survey respondents (30 farmers), 20% interviewees (3 farmers)).

- The majority of farmers participating in this research consider time as the most significant barrier to engaging in environmental data collection/citizen science (63% survey respondents (39 farmers), 33% interviewees (5 farmers)).

- Several interviewees cited a lack of trust in sharing their data as a barrier to participation (53% interviewees (8 farmers)). These farmers expressed concern over the end use of data as well as the end user, with a general scepticism towards data collected by the private sector for commercial reasons, or by the government which could escalate into further data requests or penalties. **Females were more likely to be worried about sharing data than males.**

- The majority of interviewees generally perceive technology as a facilitator to environmental data collection, predominantly due to the time savings (66% interviewees (10 farmers). Furthermore, only 2% of survey respondents (2 farmers) highlighted technology as a barrier to data collection. However, some farmers said that this can vary according to whether the farmer is: open to using the technology; given training on how to use it; and provided the technology for free. Female farmers and older farmers were more likely to report a lack of skills and knowledge or problems with the technology as a barrier to engaging.

- Female farmers were more likely to cite a lack of time for data collection and citizen science, with their male counterparts more likely to experience problems with communicating with organisers.

- Males were very motivated by a potential benefit to the business that data collection could bring.

- The oldest and youngest cohorts were less likely to cite a lack of time as a barrier.

</div>

Enablers to encourage engagement in environmental data collection and citizen science

In the survey, respondents were given a choice of 15 enablers to engage in environmental data collection or citizen science. Respondents were asked to tick the top 3. **Out of the 67 farmers who responded to this question, over half (35 farmers) were motivated most by access to expert advice. This was closely followed by gathering useful data for their farm (45% - 30 farmers), and protecting the environment (43% - 29 farmers). The least influential were participation in case studies (13% - nine farmers) and engaging with the local community (18% - 12 farmers).**

This suggests that farmers are most likely to engage in environmental data collection or citizen science, if it is useful for the farm business. This directly aligns with the findings in Section 4.1.1, which found that the most common reason for farmers' existing engagement with

environmental data collection and citizen science, is to help manage their farm. Secondly, it aligns with findings in Section 4.1.4, which found that farmers are most motivated to participate in future, by the prospect of gathering useful data for the farm, learning and developing skills, and accessing expert advice.

Interviewees were also asked about what would encourage them to engage more in environmental data collection or citizen science. **The most consistent motive was financial reward (9 farmers)**. Interviewees suggested this could be through the form of grants, equipment, or tax breaks. Other incentives interviewees raised included:

1) **Opportunity to learn** (4 interviewees) to "feed back to the farm and improve business efficiency and resilience". This could also help farmers "adapt to change", and "understand potential improvements". This also aligns with the business reward theme.

2) **Good relationships with coordinators** (3 interviewees). This was perceived as an incentive because less time is required to prepare, supervise or fill out forms such as risk assessments, and the process is trusted by farmers. This aligns with time as a barrier to farmers as outlined in Section 4.1.4. Interestingly, interviewees who felt particularly encouraged by effective coordination, leadership and trust in project organisers, were part of a farm cluster group. This could be because they appreciate coordination, leadership, and trust provided through their cluster group. The importance of good relationships with other researchers in the project was also brought up by some survey respondents, with one respondent saying face to face consultation with researchers and experts would be a motive for engagement.

3) **The right thing to do for the environment, community, and the farm** (3 Interviewees). This aligns with findings from the survey, whereby 43% of survey respondents selected 'protecting the environment' in one of their top three incentives to engage in environmental data collection and citizen science. This also aligns with reasons given by interviewees on why they would participate in citizen science (Section 4.2.1), where community and environmental impact came out as an incentive to participation. Interestingly, interviewees who were most encouraged by a feeling of doing the right thing and contributing back to the community, tended to be the older interviewees. One of the oldest interviewees said that they would be encouraged "As long as the results feed back to the people, community and farm. For the good of the community and the country". In comparison, younger interviewees tended to be more motivated by commercial incentives, with the youngest saying "Farming is always about justifying what you're doing. Because we're always spending money at the end of the day. And we're all here to make a bit of money".

4) **A clear protocol and methodology** (2 interviewees) for data collection to support understanding of what data is required and how it will be. One interviewee said "Where there's a reasonable sort of structure for what to put the data into and of an understanding of what we're looking for, and what that's feeding into, the level of detail required, it's been quite straightforward". This aligns with findings from Section 4.1.4 which found that a challenge to involvement is complex and time-consuming procedures.

5) **Helps to maintain a commercial relationship** (1 interviewee), such as with a seed company. Again, this aligns with the business reward theme.

6) **Offers the potential to network and meet new people** (1 interviewee). *Again, this aligns with the business reward theme.*

7) **Data is already being collected on the farm** (1 interviewee). Again, this aligns with time as a barrier to farmers.

8) **Software provided for free** (1 interviewee)**,** such as subscriptions to OS Master App or Land App. In particular, the interviewee said that "If there was a tool to combine all of the data collected for the farming business and keep all the data in one place that would be very useful". Again, this aligns with the business reward and upskilling themes.

Overall, the findings in this section highlight that farmers are most likely to engage in environmental data collection and citizen science if their participation offers them something useful in return.

Barriers which could prevent engagement with environmental data collection and citizen science

In the survey, **the most common barrier to engaging in environmental data collection and citizen science is a lack of time to participate**, indicated by 63% of the 62 respondents (39 farmers). Other significant barriers were not knowing any projects (selected by 35% of respondents = 22 farmers), and a lack of interest for the research topic (selected by 29% of respondents = 18 farmers). Farmers' lack of time has consistently emerged as a barrier to engagement. A key takeaway for organisers of environmental data collection/citizen science.

Interviewees were also asked what would prevent them from engaging in environmental data collection and citizen science. **The most consistently referenced barrier (by eight interviewees), was a lack of trust in sharing data, with concern about how it might be used.** This reflects the motivation aspect of the COM-B framework. Interviewees explained that their willingness to participate in data collection and sharing is significantly influenced by *who* is collecting the data and *what* the data will be used for.

There was a general scepticism for data collected for commercial reasons or "private capital generating", but also a fear of the consequences of government-led data collection where data sharing could escalate to unwanted attention, potential sanctions, or mandatory data collection in future. One interviewee said: "we've got the Environment Agency funding our cluster group and our projects to build ponds in the landscape. But as I've given them information they're now sending me text messages saying we're going to turn up and start regulating all your chemicals and look into chemical stores and they're sort of police". The same interviewee expressed "the fear with a lot of this is you start something that's a voluntary thing, like counting how many birds you've got, and then you've got an SSSI restriction on your farm". A different interviewee echoed similar feelings by saying "I've been asked to get involved in a benchmarking project for the government. It's Defra. I'm very nervous about doing that because they want to dig right the way into our financials and I am nervous of that." Interestingly, younger interviewees were most concerned about this issue, showing greater scepticism and fear than older interviewees, who were more concerned about time and resource to participate.

This finding aligns with Section 4.2.1, which found that although the majority of interviewees said they would be willing to share data, this was dependent on who with and for what purpose. Fundamentally, trust in who data is shared with, is important to farmer engagement with environmental data collection and citizen science, and will act as a barrier to recruitment unless this trust is developed. Further research on determinants of farmer trust in different stakeholders would be an interesting avenue to explore in future, with several farmers highlighting that farmers' willingness to share data is likely to be highly variable. It was interesting that younger farmers were more concerned about this issue, which could be due to greater familiarity or awareness of the varying ways in which data can be used, or due to negative previous experiences.

A second barrier raised by interviewees was a lack of time to participate in data collection (5 interviewees). This correlates with the survey which also found time to be the most significant barrier to engagement. This also aligns with findings in 0, which identified that some farmers already engaged in environmental data collection or citizen science are finding time commitment a challenge. These findings demonstrate the need for projects to minimise the amount of time required from farmers.

Other barriers raised by interviewees included:

1) **Complexity of the data collection process** (3 interviewees) including reporting requirements and forms. This aligns with the finding that a clear protocol and methodology for data collection could act as an incentive to action.

2) **Insufficient reward for time** (2 interviewees). This aligns with the finding that farmers are most likely to be incentivised to engage with environmental data collection and citizen science if it provides them with something useful in return.

3) **Feeling that the data collection is not important, impactful or usable** (2 interviewees). One interviewee expressed that they would be less inclined to participate if the data is going to "disappear into a rabbit hole where you're not going to find it again…compared to consistent year-on-year data collections when there's value because it's interrogable, usable with other data, and it sort of starts to form a richer picture of what's going on". This aligns with previous findings that farmers are incentivised to engage if data collection provides the opportunity to learn, or it feels like the right thing to do for the environment, community, and farm.

4) **Lack permission to participate** (1 interviewee) because the farmer is a tenant and needs authorisation from their landlord. This is a structural barrier to farmers' engaging with environmental data collection and citizen science.

5) **Lack the required equipment** (1 interviewee) because it is too expensive. aligns with findings from Section 4.1.3, which found that most farmers require some form of equipment to participate in environmental data collection or citizen science projects.

The least significant barrier indicated by survey respondents was a lack of familiarity with technology. This was selected by 2% of respondents (2 farmers). This is somewhat unsurprising given the findings in Section 4.1.3, which identified that 80% of farmers surveyed said they use some form of technological equipment to collect environmental data. Farmers' ability to using technology for environmental data collection was also identified in the interviews,

where **the majority of interviewees (7) felt that technology was an enabler of engagement, with a further three saying that it was an enabler *if* certain conditions were met.** Only one interviewee felt that technology was a hinderance to participation. The interviewees who felt that technology is a enabler , said this was because it improves the efficiency and ease of data collection, freeing up farmers' time. An example given was that technology can monitor data automatically on a constant basis, which means the data collection takes them no time. One interviewee was very positive and expressed that "Technology is wonderful, it speeds life up significantly and you can achieve so much more with the time we are given". Another interviewee raised that "Labour problems are so significant that technology is one of the only ways that we can solve this problem". This aligns with the findings in Section 4.1.3 which found that some farmers rely on other people to collect data because of limited time.

The three interviewees who perceived technology as an enabler *if certain conditions* were met, said that technology can be a "massive enabler" so long as farmers are: open to using the technology; given training; and given funding to pay for it. One interviewee also highlighted the importance of farmers' belief and trust in the technology to record information reliably. The interviewee used the example of an app having structural issues with data presentation, which made it "clunky and painful". In addition, an interviewee raised that openness to technology can vary according to age, with many farmers unaware of the full benefits.

The one interviewee who felt that technology could be more of a hinderance rather than an enabler, indicated that some farmers who are frightened or sceptical of technology can have a misperception of where data ends up and how it is used, which can deter some farmers from sharing their data. This links to the finding that a farmer's potential willingness to engage can be influenced by trust in the user of information. The interviewee said that "a lot of tech comes from the private sector and commercial market" and was sceptical of how it is or might be used in future. The interviewee also said that technology is not always suitable for certain types of data collection, giving the example of finding signal in a field for a technology which requires an internet connection.

These findings suggest that most farmers do not find technology a barrier to engagement with environmental data collection and citizen science, and in fact more of an enabler because of the time savings it can provide. However, this is reliant on the farmer being able to use the technology. (see Section 0).

4.2.3 Age and gender analysis

Analysis was conducted on the survey data to see if there were differences between the age and gender categories and answers to some of the questions. A full breakdown of this analysis is provided in Appendix 4. Headline results show;

- **Motivations of farmers:** Of the few responses for this question (20 of those who provided their age and gender data), there were no differences between male and female respondents. Those aged 30-49 were more motivated by protecting the

environment than those aged 50-69, and those aged 50-69 were more motivated by accessing expert advice and engaging with the local community than those aged 30-49.

- **Challenges:** For this question, only 20 responses were collected for those who provided age and gender data. Those in the 30-49 category were less likely to experience challenges overall, but more likely to experience a lack of time and support compared to those aged 50-69. 50-69 year olds reported more challenges in using equipment, communicating with organisers and a lack of knowledge or skills compared to 30-49 year olds. Males were less likely to report challenges, but only males reported challenges in communication with organisers. More females than males reported challenges in a lack of skills and knowledge and a lack of time.

- **Willingness to participate:** Of those providing age and gender data, 65 answered this question. 30-49 year olds were most likely to answer "yes" to participating in citizen science in future, with 18-29 year olds most likely to answer "no". Males were marginally more likely to answer "yes" compared to females (and females marginally more likely to answer "unsure".

- **Topics of interest:** There were 58 responses to this question from those providing their age and gender data. There were only minor differences between age categories, with the exception of energy and alternative farm fuels, where those in the 70+ age category were less likely than 18-29 year olds and 50-69 year olds to select this topic as interesting. There were no notable differences between genders.

- **Interests in aspects of citizen science:** There were 55 responses to this question. For age, the most pronounced difference was in the "involvement in the design of the research project and/or questions" where those in the 70+ age category were more interested in this aspect compared to other age categories, and "collection of data" which those in the 70+ age category were less interested in this aspect compared to other age categories. There were no notable differences between genders.

- **Aspects that would encourage farmers:** There were 65 responses to this question. There were a range of differences in responses between each age category, with the most pronounced differences in the aspects "Improve farmer participation in agricultural planning and policy" and "Payment or free products" with 18–29 year olds more likely to be encouraged by these than other age categories. Similarly, 18–29 year olds were encouraged by "personal enjoyment" (as well as those in the 70+ age category) and "getting access to expert advice". Between the genders, males were encouraged more than females by most aspects, with the exception of "learning and developing skills", "improving farmer participation in agricultural planning and policy" and "opportunities to pilot new technology". The most marked difference between the two genders was "supporting business decision making and farm income", with males much more likely to be encouraged by this.

- **Barriers to engagement:** There were 61 responses to this question. Two key barriers to engagement for 18-29 year olds were identified; "Not interested in the research topic" and "Not aware of any projects". "Don't have the time" was a widely reported barrier for all respondents, but this was more of a barrier for those in the 30-49 and 50-69 age brackets. Those aged 70+ were more likely to consider a "lack of required knowledge and/or skills to participate" as a barrier, that they were not comfortable around the technology, and were most likely to report having had negative experiences with citizen science before. 70+ year olds were also least likely to report not being interested in the research topic. The genders had very few differences in what they considered a barrier

to engagement, with the exception that females were more likely to be unwilling to share the data.

5. Discussion

This section compares the findings from the primary research with the evidence review. Section summaries are provided according to each sub-section.

5.1 Comparison against Evidence Review

The key findings from the survey and interviews (referred to in the below as the primary research), can be compared against the evidence review presented in Section 0.[15] These are summarised through four key questions below which signify the areas of most overlap.

It should be noted that the evidence review was focussed in nature, and only reviewed a selected number of papers.   Whilst it provides a useful comparison for the research, it cannot be considered comprehensive.

5.1.1 What is farming-related environmental data collection and citizen science?

Section summary

- There is a lack of clarity and differing understandings of the term 'farmer citizen science' between the scientific community and farmers. For example, some farmers perceived data collected by volunteers on their farmland as citizen science, whereas the evidence review suggested that farmer citizen science should only include projects where data is collected by the farmer themselves.

- Most farmers participating in this research collect environmental data for themselves, to benefit their farm. This is contrary to the evidence review which found that most data collected on farms is for a specific research organisation.

- Both the evidence review and primary research found biodiversity to be a common topic which farmers collect data on.

Definition of the term 'farmer citizen science'

The evidence review found that citizen science projects which involve farmers are still relatively novel, with no formal definition of farmer citizen science.[69] The newness of farmer citizen

---

[15] We have specified where findings have originated from farmers whether they participated in the survey or interviews. However, if the findings were from both the survey and interviews, we say "the farmers engaged with".

science was also evident in the primary research where only a minority of farmers saw themselves as engaged in citizen science, with some unsure of what the term actually meant, and what data counts as citizen science. The undefined nature of the term was further highlighted through the differing interpretations of citizen science between the scientific community (outlined in the evidence review[70] and the farming community (outlined in the primary research). For example, some farmers perceived data collected by volunteers on their farmland as citizen science, whereas the evidence review suggested that farmer citizen science should only include projects where data is collected by the farmer themselves.

Types of farming-related environmental data collection and citizen science

The evidence review found that environmental data collection on farms is predominantly driven by agricultural research or environmental research goals.[71] The primary research partially supported this finding, with some farmers conducting environmental data collection on behalf of private, public and charitable organisations researching agricultural practices and environmental indicators, through for example, pollinator monitoring. However, the primary research also found that a lot of environmental data is collected because it is mandatory, often for the government, for accessing funding, or complying with regulations. Overall, however, the majority of farmers in the primary research collected environmental data for themselves, rather than a research organisation, for the purpose of managing and improving their farm operations.

With regards to the types of data collected on farms, the evidence review found biodiversity to be a common topic,[72,73] also reflected in the primary research as the joint most common topic. The evidence review also found earth observation, geography, and climate change as common research topics.[74] While some farmers in this study listed data which could fit into these categories, particularly in relation to soil and land use, farmers were more focused on data relating to specific agricultural or conservation practices, rather than broader geography, topography and climate.

5.1.2 What role does technology play in environmental data collection and citizen science?

Section summary

- Both the evidence review and primary research found that: technology is generally a facilitator to farmers collecting environmental data; but, there are still farmers who have concerns about technology and require support (financial and practical) and reassurance in using it.

- While the evidence review found that technology has had a marked impact on recruitment for environmental data collection and citizen science projects, the primary research found that most farmers hear about projects through word of mouth rather than digital channels.

Technology as an enabler to farmer engagement

The evidence review found that increased accessibility and sophistication of technology over the last two decades has had a marked impact on environmental data collection and citizen science.[75] This has been through increasing efficiency and scalability of data collection and sharing.[76,77,78] This finding was supported by the primary research, which found the majority of farmers use some form of technology to collect environmental data. In addition, these farmers felt that technology generally facilitated data collection through making the process easier and quicker. Despite this, some farmers said they still use a pen and paper to record data, and both the evidence review and primary research found that the impact of technology will be highly dependent on its application to farming and how farmers engage with it. For example, farmers in the primary research said they would be more (or only) likely to engage with technology if it is: paid for; they are provided with appropriate training on how to use it; and they trust the end user of information. These concerns were also identified in the evidence review, particularly farmers' concern over data privacy and security.[79] Codes of Practice have been established in the US, EU, New Zealand, and Australia to regulate the use of digital agricultural data.

Interestingly in the evidence review, some literature pointed towards the emergence of autonomous technologies such as wireless sensors, which reduce the time required of farmers to collect data.[80] In the primary research, one farmer was using this type of technology: remote sensing. Given that time was highlighted as a major barrier to farmers engaging with environmental data collection and citizen science, further research could explore the potential uses of autonomous technology, including its practicality and cost, and trust farmers have in using it.

Technology for recruitment

The evidence review also found that technology has supported recruitment for environmental data collection and citizen science projects more generally, as a result of increased reach through websites and apps.[81] This was less apparent from the primary research as the majority of farmers said they had heard about environmental data collection and citizen science projects through word of mouth, such as farmer cluster groups, with no farmers saying they had identified the opportunity through a website.

5.1.3 What could encourage or prevent farmers from engaging with environmental data collection and citizen science?

Section summary

- Both the evidence review and primary research found significant potential for greater involvement of farmers in environmental data collection and citizen science, based on the amount of data already collected by farmers, and general willingness for sharing data. However, both the evidence review and primary research found that the potential to engage more farmers is dependent on the quality of relationships developed, with a particular emphasis on trust in how the data is used.

1) Both the evidence review and primary research found that most projects require certain skills and knowledge from farmers, but the primary research found that these rarely act as barriers to engagement.

2) The primary research found the *cost* of technological equipment to be a more significant barrier to engagement than the knowledge of how to use it, and that generally, technology is a enabler of engagement.

3) The evidence review found that most environmental data/citizen science projects are listed online, but the primary research found that most farmers hear about projects through word of mouth.

4) Both the evidence review and primary research found a lack of time (and resource) to be the most significant barrier to engagement, and anything that minimises time required of farmers will tend to act as an enabler to engagement.

5) Both the evidence review and primary research found that farmers have multiple and diverse motivations to engage with environmental data collection and citizen science, but the commercial incentives to the farm/farmer tend to be the most common and influential.

6) The primary research found that farmers can be motivated by the prospect of positive relationships with project coordinators, and access to skilled volunteers.

7) Both the evidence review and primary research found a lack of trust in the end user and ultimate use of information can act as significant barriers to engagement.

8) Overall, the evidence review and primary research found the greatest enablers s to farmer engagement lie with farmers' motivations, and the greatest barriers to farmer engagement lie with farmers' motivations and opportunity.

The opportunity to engage farmers

The evidence review suggested that agricultural and environmental fields have not taken full advantage of the tools and knowledge made available through citizen science, given farmers' unique knowledge of local landscapes and farming systems.[82] It suggested that greater involvement of farmers in environmental data collection and citizen science could benefit farmers' knowledge as well as informing policy and research.[83,84,85]

The primary research also found significant potential for engaging more farmers in environmental data collection and citizen science, firstly due to the amount of environmental data already collected by farmers, and secondly due to a general willingness among farmers to share data. The opportunity to increase trust between farmers, scientists and policymakers was certainly apparent, with many farmers suggesting their willingness to share data is dependent on trust in the end user. This suggests that the potential to engage more farmers in data collection, will largely depend upon the quality of relationships developed with researchers – and specifically the trust between farmer and researcher.

Enablers of engagement

With regards to a farmers' **capability** to engage in environmental data collection and citizen science, the evidence review found that farmers' familiarity with technology and digital communication infrastructure is a common requirement for participation.[86,87] This was supported by the primary research, where 75% of survey respondents said they needed technological skills to participate in their project. Furthermore, most interviewees said they

needed some form of technological equipment, software or subscription to collect their data. Despite a focus on equipment and technology, nearly 50% of survey respondents and 50% of interviewees said that they still collect some data manually e.g. using pen and paper. This suggests that farmers still use mixed methods for data collection, either depending on the data type, or due to a personal preference or project requirement.

With regards to a farmers' **opportunity** to engage in environmental data collection and citizen science, the evidence review found that access to digital communication infrastructure can be an enabler to participation, given that most data collection opportunities are listed online.[88] The primary research did not support this, instead finding that most farmers hear about projects through farmer cluster groups and networks. The evidence review alternatively found that other factors, such as living in close proximity to the project supports engagement.[89]

With regards to farmers' **motivations** to engage in environmental data collection and citizen science, the evidence review found that farmers have multiple and diverse motivations. However, it also found that compared to non-agricultural environmental data collection and citizen science, farmers are typically more motivated to participate based on their perceptions of whether the project results are directly relevant to them and their farm. This was strongly supported by the primary research. Although the farmers we engaged with were motivated by a variety of factors, an overarching theme was that most farmers are motivated by the direct benefits to them and their farm. Both the evidence review and primary research found that these motivations can be driven by the potential to: learn and develop skills; inform business decision-making and potentially increase income; and have useful data for the farm. Despite this, a minority of farmers in the primary research expressed non-commercial motivations (although these were often listed *in addition* to their commercial motivations). These included: personal interest in the topic; personal values around the environment, community and farm; the opportunity to contribute to innovation in the sector; and collaborating with the community.

A motivation to farmer engagement identified in the interviews but not in the evidence review, included positive relationships with project coordinators, and access to volunteers who could collect data independently, without supervision and to a high standard. This was motivating because it minimises time required from the farmer. In addition, the interviews found that farmers would be incentivised if they have a clear protocol and methodology for data collection, because it minimises confusion and wasted time.

Barriers to engagement

With regards to a farmers' **capability** to engage with environmental data collection and citizen science, the evidence review found a lack of knowledge in the research topic can prevent farmer engagement. This was identified in the primary research as a common requirement of projects, with 75% of survey respondents saying they needed knowledge of the research topic to participate, however, this was not highlighted as a barrier to engagement. As a common requirement of projects though, this could present a barrier to other farmer types not represented in this study.

The evidence review found that a lack of digital confidence with smartphone technology and agricultural apps can act as both an enabler and barrier to farmer engagement with environmental data collection and citizen science. Although the majority of farmers participating in this research identified technological confidence as a requirement to data collection, it was not highlighted as a barrier to engagement. While a small minority of farmers raised some limitations associated with the use of technology, the majority of interviewees felt that technology was an enabler to their engagement, and familiarity with technology was ranked the least significant barrier by survey respondents. In contrast, the cost of technological equipment was seen as a more significant barrier to engagement than the knowledge of how to use it. In addition, although identified in the evidence review as a potential barrier, communications infrastructure such as internet access and broadband signal were not raised by farmers as barriers. This may be due to the sample engaged with in this study, who, being recruited via IfA's network, may be more likely to have internet connection given their association with the network.

A barrier raised in the primary research but not in the evidence review, was lack of permission to participate because the farmer is a tenant and needs authorisation from a landlord to engage with projects. This could be acting as a structural barrier for many tenant farmers (whether in reality or a perceived barrier) but is not reflected as strongly in this study due to the sample being skewed towards landowners.

With regards to a farmers' **opportunity** to engage with environmental data collection and citizen science, the evidence review found a lack of time and resource to be a major barrier.[90] This was strongly supported by the primary research. Lack of time was the most referenced barrier to engagement by both survey respondents and interviewees. Some farmers raised difficulties in accessing skilled resource to collect data for them, including willing volunteers.

With regards to farmers' **motivations** to engage with environmental data collection and citizen science, the evidence review found that a lack of trust around data privacy can contribute to farmers' reluctance to share data.[91] This was strongly supported by the primary research, which found that trust in the end user and ultimate use of the data, was a significant barrier to farmer participation. The primary research also found that farmers can be put off by a fear of the consequences of the research project. This was found in the interviews, with farmers expressing concern about the consequences of government-led data collection, where data sharing could escalate to: unwanted attention into farm operations and financial information; potential sanctions for the farm; or the risk of mandatory data collection in future. These issues surrounding trust in data use and user, were highlighted mostly by interviewees, potentially due to greater opportunity to expand on feelings and concerns.

In addition, the evidence review found that a lack of enthusiasm for the research topic can deter farmer engagement.[92] This was supported by the survey, which identified lack of interest as one of the top three barriers to farmer engagement in environmental data collection and citizen science. The most interesting topics identified by farmers were related to soil, biodiversity and conservation, with the least interesting featuring fertiliser and disease.

The evidence review also suggested that negative previous experience of environmental data collection or citizen science projects could act as a barrier to future engagement.[93] In the survey, over two thirds of respondents said they had experienced a challenge with their project, with the most common being time. Although time was raised frequently throughout the survey as a barrier to engagement, nearly 80% still said at the end of the survey, that they would be willing to share their data, and two thirds said they would be willing to participate in citizen science in future. Similarly in the interviews, although nearly all interviewees (12 out of 15) gave a challenge for their project, 11 out of the 12 said that the project had still been useful to them, with only one interviewee saying that it hadn't been because it confirmed what they already knew. Furthermore, all nine interviewees who were asked if they would participate in the same project again, said they would. In sum, this suggests that challenges experienced by farmers in the past, have not been significant enough to prevent future participation, marking this as a relatively minor barrier in this study.

Finally, the evidence review found that a perceived lack of personal benefits can act as a barrier to engagement in environmental data collection and citizen science.[94,95] This was echoed in the primary research as both a facilitator and barrier to engagement, with farmers more motivated to participate based on their perceptions of whether the project results are directly relevant to them, and deterred by opportunities which offer insufficient reward for the time, or which don't feel important, impactful or usable to them personally.

5.2 Age and Gender

As age and gender was not examined in the evidence review, a small review of evidence is provided here, and some discussion of how the results of the study may relate to this evidence review. It should be noted that the sample size for the questions was relatively small, especially for motivations and challenges with 20 farmers answering each of these two questions.

Age

There is little research on farmer age and how this might influence attitudes and opinions; a lot of research focuses on the mental and physical wellbeing of farmers. For example, a study by the Royal Agricultural Benevolent Institution (RABI) in 2021 found that there was poorer mental health amongst farmers aged 25-64, which improved after the age of 64 (cited as due to being "over working age"; presumed to mean farmers aged 65 and over begin to reduce or stop being involved in farm operations).[96] While difficult to tie mental health to the results obtained in this study, the fact that farmers appear to be less involved in farm operations over the age of 65 may have an influence on some of the answers given. For example, both the youngest and oldest cohorts in this study cited "personal enjoyment" as an encouraging factor, and less likely to say that they didn't have the time to participate than other age groups. This could be attributed to the idea that those aged 65+ are less involved in farm operations, giving them more time and 'headspace' to enjoy the data collection activities. The RABI study also found marginally better mental health in their younger cohort aged 16-24, which may be associated

with less responsibility on the farm (aligning with the lowest age cohort of this study being less likely to say a lack of time to participate was a barrier).

The oldest cohort of this study were more likely than others to state that they were interested in being involved in the design of the research project and/or questions; this could be due to having more 'free time' to pursue an interest in citizen science combined with the increased knowledge and confidence gained from working in the sector for longer (as the youngest cohort did not show the same interest).

In terms of the topics of interest, there were few differences, but the fact that the oldest cohort showed the least interest in energy and alternative farm fuels may be linked to their knowledge and expertise gained over the years not aligning with this 'newer' technology. This is similar to the challenges reported in the older of the two cohorts that answered; with 50-69 year olds reporting more challenges relating to a lack of knowledge or skills and using equipment. The RABI study reported that farmers tend to have more physical ailments than the general population, with this increasing in age; depending on the equipment required for data collection, older cohorts may experience physical difficulties in using the equipment too.

Of the small number of farmers that answered the question on motivations, there were two cohorts (aged 30-49 and 50-69). The older cohort were more motivated by accessing expert advice and engaging with the local community; this is perhaps linked to younger farmers having spent less time interacting with the community, and therefore less interested in community engagement. Older farmers are likely to have knowledge gaps in the more recent technological and conceptual advancements in the industry (in part as more time is likely to have elapsed since beginning their farming career and they therefore could be in a routine of doing things a certain way without the need to explore other options).

Gender

In terms of challenges, males were more likely to report problems in communicating with the organisers of citizen science, and females a lack of skills and knowledge and a lack of time. A 2014 survey of 2,000 farmers reported that women took on a wider breadth of farm duties than their male counterparts, including administrative and domestic duties, with men more focused on the 'field operations'.[97] Women are also more likely to have secondary jobs to support family income and have higher qualifications (e.g. a degree), with men having more practical or vocational qualifications. This is congruent with the findings of males potentially struggling with communicating with organisers. This may be due to men spending less time spent on administrative duties, or potentially lower computer literacy due to a more practical background. Similarly, women may not have had the time to learn the skills and knowledge required for tasks assigned for citizen science, or may have expertise in other areas due to time spent in higher education or completing other work. A study of women in farming and the agriculture sector in Scotland in 2017 also found that women were more likely to cite a lack of time due to the juggling of family responsibilities, farm work, housework, off-farm employment and volunteer work.[98] Additionally, the study found that women faced more barriers in accessing practical and vocational qualifications, which may explain the challenge of lack of skills and knowledge.

Although this study was for Scottish women, there are many cultural and administrative similarities with that of the rest of the UK.

More females answered "unsure" to being willing to participate in citizen science in future. This may also be explained by the challenges relating to lack of skills, knowledge and time, which could be said to be a bigger challenge than problems with communication that the males experienced.

In terms of aspects encouraging farmers to participate, females were more likely to answer "learning and developing skills", which ties with the lack of skills and knowledge answers given to the question on challenges, and shows a willingness of female farmers to learn these skills. Females were also more likely to be encouraged by improving farmer participation in agricultural planning and policy; perhaps due to the more administrative role that women play in farming, and the higher educational attainment (which may provide them with more awareness of the governance practices surrounding agriculture, and how much influence farmers can have, e.g. when engaging as stakeholders in policy formation). The largest difference between the genders was in "supporting business decision making and farm income", where males were much more likely to be encouraged. The aforementioned 2014 survey found that 51% of the males surveyed considered themselves 'final decision makers' on the farm, compared to 10% of females; 58% of females surveyed felt they were able to influence decisions, and 32% felt they had no influence on the decisions made on the farm.[99] This was cited to be due, in part, to the successional nature of farm ownership, where parents are much more likely to hand farm ownership over to sons rather than daughters. This may explain the result that males were more likely to be encouraged by data that supports business decision making and farm income, as they are much more likely to be making business decisions on the farm than women.

Finally, there were few differences between genders in terms of barriers to engagement with citizen science; with females being less willing to share the data as the most marked difference. It is unclear why this is the case, as there are likely complex reasons to a farmer's unwillingness to share data. However, it could relate to the decision-making aspect mentioned above; if women are less likely to have a decision-making role, or are less likely to be a 'final decision maker', then they may view data as not 'theirs' to give away, but an asset to the farm. As women are more likely to perform administrative roles and also have attained a higher educational level, perhaps women are more aware of the value of data and therefore less likely to share it. The RABI (2021) study of Welsh and English farmers found that women also had higher levels of depression and anxiety than men.[100] This higher anxiety especially might explain the reluctance of sharing data, due to worries and fears of how data could potentially be used to discredit a farm.

6. Recommendations

This final section of the report presents a list of recommendations for effective collaboration with farmers around environmental data collection and citizen science.

These recommendations are split according to two audiences: organisers of environmental data collection and citizen science; and policymakers. It is anticipated that the recommendations developed for organisers of environmental data collection and citizen science, may prove useful for the sister research project being carried out by UK CEH. The section also points towards opportunities for future research. The recommendations presented are formed by the analysis within the report, rather than directly from stakeholders themselves.

An overarching theme of the research is that the process of data collection should shift away from being transactional and more towards being relational, whereby quality relationships are built between farmers and researchers, working together to inform practice. This should involve treating farmers as equals and experts in the research process.

Should the recommendations be fully implemented, this would address issues relating to differences in age and gender by, for example, increasing accessibility to engage with environmental data collection and citizen science.

Section summary

- Most of the recommendations provided fall into the opportunity or motivation category of the COM-B framework, with the capability category representing the least significant category (albeit still relevant). Organisers of environmental data collection and citizen science should therefore aim to address limitations to a farmers' opportunity and motive to engagement.

- *Organisers of environmental data collection and citizen science* should focus on: minimising time required of farmers; and rewarding farmers for their time (financial or non-financial).

- *Policymakers* should focus on: reviewing the financial incentives to farmers for participating in environmental data collection; educating farmers on how and why they might collect environmental data; reducing the administrative burden of mandatory data collection; and promoting innovation and learning.

- Organisers, policymakers and farmers should look to make the process of data collection more relational rather than transactional, where quality relationships are built between farmers and researchers, working together to inform practice.

- Opportunities for taking this research further could look to explore topics such as: determinants of farmer trust in the context of data and citizen science; using technology to engage farmers in data collection; how to effectively collate and use data already collected by farmers; engaging members of the public in farming citizen science; and techniques used in other countries to engage farmers in data. While there is already literature and research on some of these topics, it may not be specific to environmental data collection and citizen science so may cross over and provide important findings. These could therefore present interesting follow-ons from this research.

6.1 Recommendations for Organisers of Environmental Data Collection and Citizen Science

This section provides a list of recommendations for how organisers of environmental data collection and citizen science could improve farmer engagement. These organisers could include: researchers; non-governmental organisations (NGOs); community groups; private organisations; or government bodies. The recommendations have been grouped into seven themes across the three elements of the COM-B framework:

1. **Organisers should consider providing equipment to farmers and overcome knowledge/skills gaps (capability).**

   a) Organisers should look to ensure that farmers have the appropriate equipment to undertake data collection. It is recommended that equipment is provided free of cost and that farmers are provided with training on how to use the equipment, especially where technology is involved.

   b) Organisers should provide relevant and timely support to farmers throughout the data collection process, including the provision of information on the research topic.

   c) Organisers should look to address knowledge gaps and different interpretations of the terms 'data' and 'citizen science' in order to promote best practice in the sector and encourage wider uptake.

   d) Organisers should consider the age and gender of farmers when addressing knowledge and skill gaps, recognising the barriers that some cohorts face in this area. This could be as simple as providing detailed and comprehensive instructions (in video and written form) to aid learning.

2. **Organisers should offer support to tenant farmers to participate in environmental data collection and citizen science projects (capability).**

   a) Organisers should offer support to tenant farmers who may require permission from their landlord to participate. This could be provided through drafting letters or speaking to landlords on tenants' behalf.

3. **Organisers should seek to minimise the time required of farmers in environmental data collection and citizen science projects (opportunity).**

   a) Organisers should seek to minimise the time required of farmers in data collection. The survey undertaken in this research study found that farmer engagement dropped after a threshold of more than or equal to 40hrs for a given project. Where applicable, minimising the time required of farmers could involve integrating technology to increase efficiency.

   b) Organisers should provide a clear and simple methodology for data collection. This should avoid complex forms and reporting requirements.

   c) Organisers could look to encourage members of the public onto farms to collect data on behalf of farmers. Several farmers participating in this study expressed that they would be willing to have people collect data on the farm if the data was returned. Where

environmental data collection/citizen science projects involve members of the public visiting farms, project organisers should ensure that volunteers and researchers are fully briefed so they are able to undertake the data collection with minimal guidance and supervision of the farmer.

4. **Organisers should look to promote environmental data collection and citizen science projects more effectively and widely (opportunity).**

   a) Organisers could promote projects more through farmer cluster groups and networks. The primary research in this study found that these were the most likely communication channel farmers had heard about these project types, and the most trusted organisers of projects.

   b) Organisers should adopt a clear and engaging communication strategy which is appropriate for a farmer audience. This should include clear communication of the direct benefits to the farmer as well as the project methodology and final outcomes. Specifically, this should include transparency of who the data is shared with and for what purpose. Any promotion of projects should also clearly explain key terms such as 'data' and 'citizen science' to overcome any knowledge gaps.

   c) While cluster groups are recommended as a way to increase recruitment, organisers should look at how promotion of projects can capture farmers who are not part of cluster groups and networks, potentially in more remote locations, in order to recruit a balance of farmer types with differing attitudes and characteristics.

5. **Organisers should offer meaningful rewards to farmers for their participation in environmental data collection (motivation).**

   a) Organisers should offer a meaningful reward to farmers for their time spent on non-voluntary forms of environmental data collection. Rewards raised by farmers engaged with in this study include:

      i. Payment through grants, subsidies, tax breaks or agri-environment payments;

      ii. Free equipment, including technological equipment, as well as digital tools such as software or paid subscriptions; and

      iii. Useful services for the farm, such as:

         i. Free expert advice from an agronomist, ecologist or consultant;

         ii. Free access to data and monitoring systems for the farm, including support on how to interpret and apply the data usefully;

         iii. Free labour where members of the public are collecting data on-site;

      iv. Shared open access to agricultural data across England;

      v. Opportunities to network or develop commercial relationships; and

      vi. Formal training from an agricultural advisor or specialist.

6. **Organisers should seek to develop trusting relationships with farmers in environmental data collection and citizen science projects (motivation).**

   a) Organisers should aim to give farmers full transparency of the research purpose, process and ultimate use of the data.

   b) Organisers should aim to communicate regularly with farmers in a friendly manner, and engage face to face where possible.

   c) Where environmental data collection/citizen science projects involve members of the public visiting farms, project organisers should ensure that volunteers and researchers are fully briefed on safety and security procedures on site, such as wearing bags over shoes to prevent contamination. This is important to developing respect and trust between farmers and members of the public.

   d) Organisers should send the outputs directly to participating farmers, and make research outputs open-source where possible so that all farmers can benefit from the data and insights.

7. **Organisers should look to empower farmers to participate in the design of in environmental data collection and citizen science projects (motivation).**

   a) Organisers of environmental data collection/citizen science projects should offer farmers the opportunity to engage in other parts of the research process, specifically the design of the research project as well as the data collection itself. This was highlighted in the primary research as something that farmers were particularly keen to be involved with.

   b) It is recommended that organisers engage with farm cluster groups as early as possible in the design of the research to encourage co-design.

6.2 Recommendations for Policymakers

Some of the recommendations presented above will be relevant to the government department or arms-length bodies who organise environmental data collection and citizen science with farmers. However, this section provides a list of recommendations which are more specific to policymakers thinking strategically about engaging farmers in citizen science. The recommendations have been grouped into five themes across key elements of the COM-B framework:

8. **Policymakers should review the financial incentives available to farmers for participating in environmental data collection (opportunity and motivation).**

   a) Policymakers could incorporate an incentive or requirement for farmer participation in environmental data collection projects, through the use of agri-environment payments such as the Environmental Land Management Schemes (ELMS).

   b) Policymakers could use agri-environment payments to fund or subsidise technologies which support farmers to collect data. This could include physical equipment such as monitoring systems, or digital tools such as software or subscriptions.

c) Policymakers could incorporate an incentive into agri-environment payments which funds advisory support to farmers on how to collect data (including the use of technological tools to do so), and importantly, how to interpret the data so that it can be usefully applied to the farm.

9. **Policymakers should provide training/information for farmers on how and why they might collect environmental data (motivation).**

a) Policymakers could provide facilitation funding for farm cluster groups, local advisors, and councils who can: promote opportunities for farmers to get involved with environmental data collection and citizen science; talk through and demonstrate data collection methods; organise free training days, farm visits and talks on the topic; and even organise data collection projects themselves.

b) Policymakers could produce engaging and accessible online resources on environmental data collection and citizen science, which is specifically tailored to farmers. As the research has shown that peer-to-peer learning is important, this should engage farm cluster groups and make full use of case-studies/testimonials about the benefits of engaging in citizen science. Paper copies could be distributed via farmer cluster groups and networks, as well as organisers of projects.

c) Policymakers could look to engage with educational institutions encouraging them to incorporate data modules onto curriculums in agricultural schools and colleges in order to train prospective farmers on how to collect environmental data and teach how it can be useful for the farm as well as the environment. This should include training on the use of technological equipment and digital tools.

10. **Policymakers should consider how to reduce the administrative burden of mandatory data collection for farmers (opportunity and motivation).**

a) Policymakers could review all mandatory data required of farmers from the government and aim to synchronise, standardise and simplify some of the processes. This could involve: minimising duplication; merging data requests; aligning timelines of data requests; and standardising the requirements of different requests. It could also involve the development of an online database or platform which streamlines government data requests into one place.

b) Policymakers could explore ways to reduce the amount of paperwork associated with data collection and sharing.

11. **Policymakers should seek to promote innovation and learning for agri-environment research (motivation).**

a) Policymakers could fund research into the development and application of technologies, software, and training programs which can support farmers to collect data.

b) Policymakers could look to make more agricultural data open source so that all farmers can learn and benefit from it. This may also help develop trust between farmers and the government. Policymakers could also encourage or require research organisations to make agri-environmental data available to farmers.

12. **Policymakers should establish initiatives which encourage members of the public to visit farms for the purpose of environmental data collection (opportunity and motivation).**

a) Policymakers could support local councils/local community organisations to deliver community initiatives which encourage local involvement in farming-related

environmental data collection and citizen science. This could include engagement with local schools and colleges, as well as community groups such as ramblers associations. While providing a source of free labour to farmers, community involvement could deliver wider benefits, such as introducing younger generations to farming, encouraging exercise, education, and time spent in nature.

6.3 Reflections according to COM-B

The above recommendations have all been categorised according to COM-B. It is apparent that most recommendations fall into either the opportunity or motivation categories, with the capability category reflecting less prominently. This suggests that organisers of environmental data collection and citizen science should aim to target actions which either support a farmers' **opportunity or motivation in order to encourage their engagement. This includes: factors that lie outside the individual that make the behaviour possible or prompt it (in this study - time being the most significant)**; as well as **goals, decision-making, habits and emotions**. In comparison, addressing a farmers' **capability** to engage (concerning their **psychological and physical capacity to engage - including the necessary knowledge and skills),** is likely to be less influential for enabling behaviour change according to the research undertaken in this study (albeit still important). Factors such as minimising the time required of farmers in data collection (opportunity), and rewarding farmers for their time through a financial or non-financial incentive, are instead likely to be more influential in changing behaviours and should therefore be prioritised by actors looking to encourage engagement.

6.4 Recommendations for Future Work and Research

This study has provided initial insight into farmers' existing engagement with environmental data collection and citizen science, as well as their potential engagement in the future. Useful findings and recommendations have been drawn from this research, however it has also raised questions which could be pursued through further research. While there is already literature and research on some of the key topics outlined below, it may not be specific to environmental data collection and farmer citizen science, and yet may cross over and provide important findings and recommendations. The five topic areas for potential further work are summarised below, alongside some key research questions:

1) **What influences farmers' trust in sharing data?** There is a wealth of literature on the important of trust in farming, and how to build and maintain it, and it would be interesting to combine this with the findings from this research. This could help research organisations understand how to develop trusting relationships with farmers for the specific purpose of encouraging greater participation in environmental data collection and citizen science. Questions which could be explored include:

   a. What are the factors which influence farmers' trust in an *organisation* for the purposes of data sharing?

   b. What purposes are farmers most interested to share their data for?

c. What strategies can support the development of trusting relationships between farmers and research organisations to encourage data sharing?

d. To what extent do farmers trust new technologies to support data collection? Would farmers trust autonomous technology to collect data?

e. What types of agreements around data use need to be in place to support farmers' trust in environmental data collection projects?

2) **What data is already collected by farmers and what organisations are requesting this?** Although this was partially identified through the survey, a more focused exploration involving a larger sample of farmers, as well as engagement with research organisations, could help identify crossovers in data requests, as well as existing banks of data which could be tapped into. Questions which could be explored include:

a. What types of data do farmers already collect? Who is this for? What format is this in?

b. How could data already collected by farmers be useful to wider audiences? How could this data be collected and shared most effectively?

c. Does farmers' data tell the whole story? What is currently not captured by environmental data collection and citizen science?

3) **What are other countries doing to improve farmer engagement in environmental data collection and citizen science?** This could explore practical strategies to improve farmer participation in environmental data collection and citizen science projects, to build on the recommendations from this study. Questions which could be explored include:

a. What are other countries outside of England doing to engage farmers in environmental data collection and citizen science?

b. How can organisers of environmental data collection and citizen science projects better promote projects to capture a wider range of farmers?

c. What level of financial reward do farmers expect for their time collecting and sharing data?

d. What types of environmental data do farmers consider to be most useful to them? Why?

4) **Is there a broader opportunity to engage public audiences in environmental data collection and citizen science?** This could explore the benefits of educating members of the public on food and farming in England, and encouraging them to engage with farming through collecting on-farm data. Questions which could be explored include:

a. Would farmers be willing to have members of the public collect data on their farm and share it?

b. How can public audiences be encouraged to participate in environmental data collection and citizen science?

5) **How could technology be used more effectively to engage farmers in environmental data collection and citizen science?** This could look into existing and emerging technologies, as well as a deeper exploration of farmers attitudes towards technology. This could help identify how technology could be used on a wider scale to increase farmer participation and enable more data sharing. Questions which could be explored include:

a. What types of technology are farmers most interested in using to collect environmental data, and why?

b. What would encourage different types of farmers to use technology to collect environmental data?

6) **What are the current understandings and motivations of government departments and arms-length bodies on using environmental data collection and citizen science?**
This could look into the potential awareness and motivations of government to collect more data from members of the public (not only farmers) in order to support environmental research and action. Questions which could be explored include:

a. How does the government and arms-length bodies currently use citizen science? How is it used for environmental research?

b. Why is the government and arms-length bodies interested in citizen science?

c. How could citizen science be used more across government and arms-length bodies?

Appendix

Survey Questions

Participant Information

What is this survey for?

This survey is being conducted by Eunomia Research and Consulting and Innovation for Agriculture for Natural England who want to understand farmer attitudes and behaviours towards environmental data collection and citizen science. The survey will take approximately 15 minutes and if you participate, you will be included in a draw for Groundswell tickets.

What will you need to do?

The first half of the survey is about environmental data collection, and the second half is specifically about citizen science. Before you start, please read the following information.

Things to know

- The survey is voluntary. You can stop at any point and come back to it later (your progress will be saved). Results from partially completed surveys will still be recorded.
- You can withdraw your data up to two weeks after taking part by contacting us using the details below and providing your unique participant code (see below).
- All participant input will be anonymous. Information on how your data will be handled is provided in this Privacy Notice and you can view Survey Monkey's privacy policy here.
- The outputs of the research will contribute to a report for Natural England.

Thank you for reading this information, if you are happy to take part in this survey, please click to give your consent in the box below.

Before you start, please put in a 5-digit number or memorable word in this box which will become your unique ID in case you want to withdraw your data from the project at any point.

1. We are interested in any data about the environment on your farm, for example, on your crops, pests or diseases, applications of fertiliser and pesticides, how you use your land, the condition of soil, or water or nature, or the energy you use. We'd also like to hear about why you collect this information. We have provided some example types of information below. **Please tick the boxes which apply to you**.

2.

Reason for collecting data	I collect data because it is mandatory (e.g. Certification body, Red Tractor, Organic, etc)	I collect data for a specific research project led by an organisation	I collect data for my own use
Project topic			
Crops			
Soil			
Fertiliser			
Land Use			
Pests & Disease			
Biodiversity & Conservation			
Energy & alternative farm fuels			
Other (please specify)			

If you do not collect any environmental data please go to Question 13.

3. If you answered 'because it is mandatory':
    a) please provide any detail on the data required from you, and the purpose for which it is collected:
    b) How often do you collect this data?
    c) When did you start collecting this data?

4. If you answered 'I collect data for a specific project':
    a) please provide any detail about the project, for example: Project name, who was running the project and a short description of what data you collect:
    b) How often do you collect this data?
    c) When did you start collecting this data?
5. If you answered 'I collect data for my own use':
    a) why do you collect this data?
    • To help me manage the farm
    • For my personal interest
    • Other (please specify)

    b) How often do you collect this data?
    c) When did you start collecting this data?

If you collect data for a specific project, we'd like to get your feedback on how these worked to understand how to design projects better in the future. Please answer the following questions (Q5-12). If you have been part of <u>more than one</u> data collection project before, please answer the questions <u>twice:</u> your first responses about the <u>best project</u> you have been part of i.e., it was useful and easy to be part of, and your second responses about the <u>worst project</u> you have been part of i.e., it was not useful and difficult to be part of.

6. How did you hear about the project you collect data for? Please tick all that apply
   - Word of mouth
   - Website
   - Directly approached via phone/email
   - Newsletter
   - Farmer Group or Association
   - Similar projects
   - Other (please specify)

7. As well as collecting the data what, if any, has your involvement in the project been? Please tick all that apply
   - Involvement in the design of the research project and questions
   - Developing materials or resources
   - Recruiting participants
   - Collecting data
   - Working with others who collect data
   - Analysing data
   - Presenting data
   - Sharing results
   - None of the above

8. What knowledge, skills and equipment did you need to collect the data? Please tick up to 3 main skills/equipment
   - Knowledge of the research topic
   - Technology skills e.g. ability to use computer/mobile phone apps
   - Numerical skills
   - Spoken communication skills
   - Written communication skills
   - Internet connection
   - Physical equipment e.g. mobile phone/computer
   - Other – please specify

9. How did you collect this data? Please tick all that apply
   - Pen & Paper
   - Mobile phone
   - Tablet/iPad
   - Using a specific app
   - Drone
   - Camera
   - Sensors
   - Global Positioning System (GPS)
   - Geographical Information Systems (GIS)

- Automated recording stations
- Precision farming technology
- Other (please specify)

10. What were your main reasons for taking part in the project? Please tick up to 3 main reasons (ranking 1-3 in order of preference).

- To learn and develop skills
- To access expert advice
- To engage with the local community
- To contribute to scientific research
- For personal enjoyment
- To gather useful data for the farm
- To protect the environment
- To support business-decision making and farm income
- Other (please specify)

11. Have you experienced any of the following challenges with the project you have been part of? Please tick up to 3 main challenges (ranking 1-3 in order of significance).
- Too much time required
- Lack of guidance and support
- Difficulties in communication with organisers
- Difficulties in using the technology or equipment
- Difficulties in reporting the data
- Lack of required skills or knowledge
- Lack of relevance to me
- It was not of interest to me
- Other (please specify)
- I didn't experience any challenges

12. How much time was required of you over the project?
- Less than four hours
- Between four and ten hours
- Between 11 and 25 hours
- Between 26 and 40 hours
- Over 40 hours

13. How clear is it how the data will be used ?

- 1 Very clear
- 2 Clear
- 3 Unclear
- 4 Very unclear
- 5 I wasn't given any information about how the data would be used

Please could you elaborate on your answer….FREE TEXT

1. **Thinking towards the future, is there information about your farm that you already collect, or could quite easily collect, that you think could be useful in understanding the state of nature/biodiversity or the environment on your farm? If yes please use the space below to provide details.**

So far, we have been asking about your involvement in environmental data collection from a broad perspective, including data collection for specific projects, your own farm insight, or for mandatory monitoring purposes. In this section, we will be focusing specifically on data collection as part of Citizen Science* projects.

Citizen Science is activity that involves volunteer members of the public in scientific research, reporting or monitoring. It usually involves collecting data (in the case of farms, this could be about fertiliser use, pest control, land use, crops and yield, or data on biodiversity, e.g. birds, butterflies or pollinators). By our definition, **farmer citizen science** differs from other forms of farm monitoring because (i) the monitoring is voluntary (rather than a minimum level of monitoring that is mandated), and (ii) the data are shared with others (rather than being kept private, e.g. commercial sensitive data).

2. According to the above definition, do you already take part in citizen science?
   - Yes - this refers to my answer in Question 2
   - Yes - this is in addition to my answer in Question 2
   - No
   - Unsure

3. In future would you be willing to take part in citizen science?

   - Yes / No / Not sure
   - **IF no go to Q17**

4. **If yes**, which project topics would interest you the most? Please score the below topics on a scale of 1-5 (scale provided in table).

Project Topic	How interested would you be in this topic? 1 = not at all interested 2 = not interested 3 = neither interested or not interested 4 = interested 5 = very interested
Crops	
Soil	
Fertiliser	
Land Use	

Pests & Disease	
Biodiversity & Conservation	
Energy & alternative farm fuels	
Other (please specify)	

5. What aspect of citizen science interests you the most (ranking 1-3 in order of preference)?

- Involvement in the design of the research project and questions
- Development of materials or resources
- Recruitment of participants
- Collection of data
- Analysis of data
- Presentation of data
- Sharing results

6. [This question follows Q16 and also those **who said No to Q14**] What would **encourage** you to take part in a citizen science project in the future? Please tick up to 3 main reasons (ranking 1-3 in order of importance).

- Learning and developing skills
- Getting access to expert advice
- Engaging with the local community
- Contributing to scientific research
- Personal enjoyment
- Gathering useful data for the farm
- Protecting the environment
- Supporting business-decision making and farm income
- Participation in case studies
- Improve farmer participation in agricultural planning and policy
- Payment or free products
- Opportunity to pilot new technology
- Compare my farm with others
- Other (please specify)

7. What would **prevent** you from taking part in a citizen science project in the future? Please tick up to 3 main reasons (ranking 1-3 in order of: main barrier, significant barrier, bit of a barrier).

- Don't have the time
- Not interested in the research topic
- Not aware of any projects
- Don't feel comfortable around the technology
- Don't want to share my data
- Fear the consequences of the research program

- Have had negative experiences with citizen science before
- Insufficient personal benefits from the project
- Lack the required knowledge and skills to participate

8. Is there anything else you would like to say about citizen science and your involvement in it?
    - Free text

We have a few questions about you so we can see if there are any trends in behaviour according to farm/farmer characteristics. If you would prefer not to provide these details, please feel free to skip this section.

9. Gender
    - Male
    - Female
    - Prefer not to say
10. Age
    - 18 – 29
    - 30 – 49
    - 50 – 69
    - 70 +
11. Farm size (acres)
12. Farm Type/Produce:
13. County:
14. Owner/tenant: owner/tenant/mixed
15. Number of years farming:
16. Number of generations your family have farmed the land:
17. Do you think a family member would take on running the farm if you needed to permanently stop? yes/no
18. Member of a farm cluster group: yes/no
19. If you would like to be included in the draw for Groundswell tickets, please provide an email or phone number.
20. If you are happy to be contacted further for a short interview, please tick the box below.

If you want any other information about our privacy policy or have any further queries or complaints, you can email us at dataprotection@eunomia.co.uk or write to us at Eunomia Research & Consulting Limited, 37 Queen Square, Bristol, United Kingdom, BS1 4QS.

Interview Questions

Introductions

Intro

Thank you for joining us today. My name is _____ and I am part of the Innovation for Agriculture Team working on behalf of Natural England. This interview is part of an evidence gathering exercise to understand farmer attitudes and behaviours towards environmental data collection and citizen science. I'm joined by _____ who will be taking some notes from our conversation.

Just a few things to note before we start:

- This interview is voluntary and there is no need to answer every question.

- All your input during the interview will be treated as anonymous.

- We will send you our notes from the interview in due course for you to check our interpretations.

- We would really appreciate you being open and honest here, there is no right or wrong answer.

- The outputs of our research activities will contribute to a report for Natural England.

- We expect this interview to take around 30 minutes.

Just before we start, I'll take a minute to outline what we'll be covering and what we mean by the terms environmental data collection and citizen science. Throughout, we ask about your involvement in either: environmental data collection, which includes data *or information* for specific projects, your own farm insight, or for mandatory monitoring, **as well as** farming-related citizen science, which involves public volunteers in scientific research, reporting or monitoring. It usually involves collecting data or information (in the case of farms, this could be about fertiliser use, pest control, land use, crops and yield, or data on biodiversity, e.g. birds, butterflies or pollinators). By our definition, **citizen science** differs from other forms of data collection because (i) the monitoring is voluntary and (ii) the data is shared with others.

Based on this, in this interview we will discuss:

• Your participation in environmental data collection and citizen science

• Your attitudes towards environmental data collection and citizen science

Personal Information

1. Persons Name:

2. Gender:

3. Age:

4. Farm Size (acres):

5. Farm Type/Produce:

6. County:

7. Owner/tenant:

8. Number of years farming:

9. Number of generations your family have farmed the land:

10. Member of a farm cluster group:

Questions

1. Could you tell me about the environmental data you collect on your farm? **OR,** any data you used to collect, if you don't collect any anymore? *[Interviewer to ensure farmer gives all examples they can think of]*

2. Why do you collect this data?

   If the farmer collects (or collected) data for a specific project, ask the following:

   a) How did you hear about the project?

       a. Is it a citizen science project? i.e. is voluntary and information is shared

   b) How have you found the project?

       i.   Is it useful to you?

       ii.   Have you experienced any challenges?

   c) Do you trust how your data is used in the project?

   d) Would you participate in the same project again?

   If they have not said they collect it for a project, or if they collect other data as well as that for a project, ask the following:

   a) Do you share your data?

       i. If yes, with whom?

       ii. If not, would you ever consider sharing it? E.g., other farmers/cluster group, a research organisation, the Government, or suppliers / private companies? Yes/No

      iii. Why or why not

If using a historic example of data collection, ask the following:

3. Why did you stop collecting this data?

4. To what extent do you think other farmers would or wouldn't be willing to share similar data? Why or why not? Under what conditions?

5. How do you collect the data?

    a. What do you need to collect it?

        i. in terms of equipment?

        ii. in terms of skills/knowledge?

    a. Would you consider collecting more environmental data? What type(s) of data would you be most interested in collecting? (have examples as prompts) Why?

    b. Would you be most interested in doing this:

        i. Independently;

        ii. As citizen science (i.e. where you share your data voluntarily); or

        iii. As part of a paid research project

    c. Why?

6. What would encourage you to do this? Why?

7. What would prevent you? Why?

8. To what extent do you think that technology helps or hinders farmers to participate in data collection and citizen science, What do you think are good ways of getting farmers involved with environmental data collection or citizen science projects?

9. Thinking towards the future, is there data or information about your farm that you already collect, or could quite easily collect, that you think could be useful in understanding the state of nature/biodiversity or the environment on your farm?

Wrapping Up

10. Is there anything else you would like to tell us about your views on or experiences with environmental data collection or citizen science?

That's everything I was hoping to ask. It has been a pleasure to speak with you, thank you so much for your time.

Environmental data collection and citizen science projects

This section provides a list of the environmental data collection and citizen science projects raised by survey respondents and interviewees.

Projects raised by survey respondents:

- Foundations of Regenerative Agriculture (FAI) – grass and soils analysis.
- British On-Farm Innovation Network (BOFIN) - slugs and beetle activity.
- Smartsheep project - grass growth.
- FAI - Floral Margins and Insects.
- Agricultural & Horticultural Development Board (AHDB) - soil biology and health.
- ADAS - mob grazing study.
- Grasscheck GB.
- Kynetec - British Survey of Fertiliser practice.
- Farm cluster group projects.
- ADAS – Yield Enhancement Network project.
- Organic Research Centre – wheat data.
- Innovate UK - biodiversity monitoring.
- Arla Regenerative Dairy - pilot farm data.
- Innovative Farmers – field lab data.
- Cambridge Farm survey.
- Wiltshire Wildlife Trust - nature recovery project.
- Arla - climate check for milk buyer sustainability incentive scheme.

Projects raised by interviewees:

- National Institute of Agriculture Marketing (NIAM) and AHDB - soil health and grazing impacts.
- RSPB - bird survey.
- Game & Wildlife Conservancy Trust - Big Farmland Bird Count.
- BOFIN - slug counting.
- Anglian Water and Essex County Council - nitrogen use efficiency.
- Oatly and Farming and Wildlife Advisory Group (FWAG) - yield mapping and soil mapping.
- Tesco milk monitoring programme - welfare and environmental data.
- ADAS Learn project - tramline trials of nitrogen rates.
- Bat survey property work for planners/developers.

- Royal Society for the Protection of Birds (RSPB) - Big Garden Birdwatch.

- Thames Water - catchment sensitive work.

- Devon Wildlife Trust - wildlife data and soil sampling.

- Southwest Water - water quality data.

- Wending Beck Environment Project (WBEP) – habitat creation, nature restoration and regenerative farming.

- Defra - ELMS test and trial.

- Arla - milk monitoring.

- Community of practice citizen science project – a group of farmers who volunteer to look at subjects together.

- Defra – Biodiversity Net Gain (BNG) pilot.

- Protected Site Surveys.

- Energy transition survey.

- University projects.

- Energy Performance Certificate (EPC) monitoring.

Detailed Age and Gender Analysis

The following section provides more detailed commentary on those survey questions where age and gender were taken into account when analysing answers.

Motivations of Farmers

The motivations of farmers were compared by age category and gender to see if there was any difference between the average scores. A difference was seen as noteworthy if it was greater than or equal to one. For this question, the sample size is particularly small; as only 65 and 64 farmers providing their age and gender respectively, and only 20 farmers completed the question relating to motivations for participating in citizen science.

There was a small degree of difference between the 30-49 and 50-69 age categories; the former appear more motivated by protecting the environment, and the latter in accessing expert advice and engaging with the local community.

Between males and females, none of the differences in the average score were greater than or equal to one.

Challenges

The challenges reported by farmers were compared by age category and gender. Sample sizes for this question were again small. Differences were considered noteworthy if there was more than a 5% difference between each category.

The 30-49 age category were more likely than 50-69 year olds to not experience any challenges, but where they faced challenges, this was more likely to be due to a lack of time and support compared to the 50-69 age category. Those in the 50-69 age category experienced more difficulties in communicating with organisers, using technology or equipment and having a lack of required skills or knowledge compared to 30-49 age category.

A much higher proportion of males reported not experiencing any challenges. However, only males reported experiencing difficulties in communication with organisers. Females reported difficulties in using the technology or equipment (no males reported this) and also experienced more challenges than males in a lack of required skills or knowledge, and that too much time was required.

Willingness to Participate

The willingness of farmers to participate in citizen science in future was compared by age category and gender. Differences were considered noteworthy if there was more than a 5% difference between each category.

30 to 49 year olds were most likely to answer "Yes" to participate in citizen science in the future, with 18-29 year olds being most likely to answer "No" compared to the other age categories. The two older age categories were more likely to answer "Unsure".

Males were more likely to answer "Yes" than females to participating in citizen science in the future, with females more likely to answer "Unsure" than males.

Topics of Interest

The topics of interest, including crops, soil, fertiliser, lands use, pests & disease, biodiversity & conservation, and energy & alternative farm fuels, were against age category and gender. Each answer was given a score (Very interested = 4, Interested = 3, Neither interested nor disinterested = 2, Disinterested = 1, Not interested at all = 0). Scores were averaged across each category. Where a score of ≥1 was seen, this was considered noteworthy.

Overall there was not much difference between age categories per topic, with the exception of energy and alternative farm fuels, where those in the 70+ age category were less likely than 18-29 year olds and 50-69 year olds to select this topic as interesting.

For gender, both male and female had similar average scores for each topic.

Interest in aspects of citizen science

The most pronounced difference was in the "involvement in the design of the research project and/or questions" where those in the 70+ age category were more interested in this aspect compared to other age categories, and "collection of data" which those in the 70+ age category were less interested in this aspect compared to other age categories.

For gender, both male and female had similar average scores for each aspect of citizen science.

Aspects that would encourage farmers

Aspects of citizen science that would encourage farmers to participate have been compared by age category and gender. Differences of 5% or more were considered noteworthy.

The most pronounced differences in the aspects "Improve farmer participation in agricultural planning and policy" and "Payment or free products" with 18–29 year olds more likely to be encouraged by these than other age categories. Similarly, 18–29 year olds were encouraged by "personal enjoyment" (as well as those in the 70+ age category) and "getting access to expert advice". "Engaging with the local community" and "Opportunities to pilot new technologies" were the least encouraging aspects of citizen science for 18–29 year olds.

30-49 year olds and 50-69 year olds followed similar patterns to one another, although the former was more encouraged by "learning and developing skills", "getting access to expert advice" and "opportunities to pilot new technologies".

70+ year olds gave generally lower scores than their younger counterparts, but "Learning and developing skills", "Personal enjoyment" and "Improving farmer participation in agricultural planning and policy" were aspects that this cohort scored more highly. **Error! Reference source not found.** shows that males were more encouraged by most aspects compared to females, with "Getting access to expert advice" being their most encouraging aspect. Females gave higher ratings for "Learning and developing skills", "Improving farmer participation in agricultural planning and policy" and "Opportunities to pilot new technology" compared to males. The most marked difference between the two genders was "Supporting business decision making and farm income.

Barriers to Engagement

Aspects of citizen science that would encourage farmers to participate have been compared by age category and gender. Where any differences of 5% or more this was considered noteworthy.

The two key barriers to engagement for 18-29 year olds were "Not interested in the research topic" and "Not aware of any projects". 18-20 year olds were also more likely to state "Insufficient personal benefits from the project" as a barrier.

"Don't have the time" was a key barrier for all respondents, but this was more of a barrier for those in the 30-49 and 50-69 age brackets. Of the age categories, those aged 70+ were more likely to consider a "lack of required knowledge and/or skills to participate" as a barrier, and that they were not comfortable around the technology. Those aged 70+ were most likely to report having had negative experiences with citizen science before, but less likely to report a fear of consequences or an unwillingness to sharing data (the latter barrier only a small number of 50-69 year olds gave this answer). 70+ year olds were least likely to report not being interested in the research topic.

Males and females had very few differences in what they considered a barrier to engagement, with the exception that females were more likely to be unwilling to share the data.

List of acronyms

AHDB Agriculture and Horticulture Development Board

ALS   Agricultural Land System

BPS   Basic Payment Scheme

ELS   Entry Level Stewardship

ELMS Environmental Land Management Schemes

HLS   Higher Level Stewardship

HSE   Health and Safety Executive

NIAB National Institute of Agricultural Botany

NGO Non-Governmental Organisation

OPAL Open Air Laboratories

PPB   Participatory Plant-Breeding

PVS   Participatory Variety Selection

RPA   Rural Payments Agency

Glossary

Citizen Science: A form of research collaboration involving members of the public volunteering in scientific research to address real-world problems.

COM-B model: A model of behaviour change which categorises common factors that influence behaviour: capability, motivation and opportunity. This was considered useful to identify the relative importance of determinants of behaviour, and accordingly, how changes to these determinants can encourage behaviour change.

Environmental Data Collection: A term which can be used as an umbrella term to encompass different ways data can be collected by farmers (see Figure 1). In this study, three ways were identified which are distinguished by: what the data is used for; whether the data is shared; and whether farmer contribution is voluntary or not. This evidence review focuses predominantly on data collected and shared by farmers for the purpose of research.

Environmental data collection/citizen science projects: Forms of environmental data collection or citizen science which are formally led by research organisations for the purpose of research. This is in comparison to data collected for personal benefit or ad-hoc purposes.

Farmer Citizen Science: Citizen science which specifically involves the voluntary participation of farmers in scientific research. Note that some of the farmers engaged with in this study perceived this as members of the public collecting environmental data on farms, on behalf of farmers.

References

[1] GOV.UK (2023) Agricultural Land Use in United Kingdom on 1 June 2023. https://www.gov.uk/government/statistics/agricultural-land-use-in-the-united-kingdom/agricultural-land-use-in-united-kingdom-at-1-june-2023

[2] Wiggins, A., Crowston, K., 2011. From Conservation to Crowdsourcing: A Typology of Citizen Science, in: 2011 44th Hawaii International Conference on System Sciences. Presented at the 2011 44th Hawaii International Conference on System Sciences (HICSS 2011), IEEE, Kauai, HI, pp. 1–10. https://doi.org/10.1109/HICSS.2011.207

[3] Wiggins, A., Crowston, K., 2011. From Conservation to Crowdsourcing: A Typology of Citizen Science, in: 2011 44th Hawaii International Conference on System Sciences. Presented at the 2011 44th Hawaii International Conference on System Sciences (HICSS 2011), IEEE, Kauai, HI, pp. 1–10. https://doi.org/10.1109/HICSS.2011.207

[4] Tweddle, J.C, Lucy Robinson, Michael J.O. Pocock, and Helen E. Roy. "Guide to Citizen Science: Developing, Implementing, and Evaluating Citizen Science to Study Biodiversity and the Environment in the UK." Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF, 2012.

[5] Beza, E., Steinke, J., Van Etten, J., Reidsma, P., Fadda, C., Mittra, S., Mathur, P., Kooistra, L., 2017. What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers. PLoS ONE 12, e0175700. https://doi.org/10.1371/journal.pone.0175700

[6] Mark, Oliver. "How collected data could benefit your farm". February 27 2014, Farmers Weekly. How collected data could benefit your farm - Farmers Weekly (fwi.co.uk) Accessed: 29th September

[7] UK Environmental Observation Framework. Farmers, citizen science & environmental monitoring symposium, Webinar, UKEOF Citizen Science Working Group. 13th January 2023.

[8] See Wiggins and Crowston, 2.

[9] Highfield, Roger. "Three Centuries of Citizen Science", March 6, 2015. https://blog.sciencemuseum.org.uk/three-centuries-of-citizen-science/

[10] See Tweddle *et al.*, 4.

[11] Beza, E., Steinke, J., Van Etten, J., Reidsma, P., Fadda, C., Mittra, S., Mathur, P., Kooistra, L., 2017. What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers. PLoS ONE 12, e0175700. https://doi.org/10.1371/journal.pone.0175700

[12] Reynolds, Christian, Libby Oakden, Sarah Elizabeth West, and Rachel Pateman. "Citizen Science and Food: A Review." Food Standards Agency, 2021.

[13] See Reynolds et al, 12.

[14] Robinson, Lucy Danielle, Jade Lauren Cawthray, Sarah Elizabeth West, et al. "Ten Principles of Citizen Science." In *Citizen Science: Innovation in Open Science, Society, and Policy*, edited by S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, and A. Bonn, 1–23:2020. London: UCL Press.

[15] Bonney, Rick, Heidi Ballard, Rebecca Jordan, Ellen McCallie, Tina Phillips, Jennifer Shirk, and Candie C. Wilderman. "Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education." A CAISE Inquiry Group Report. Center for Advancement of Informal Science Education (CAISE), Washington, D.C., USA, 2009.

[16] Shirk, Jennifer L., Heidi L. Ballard, Candie C. Wilderman, Tina Phillips, Andrea Wiggins, Rebecca Jordan, Ellen McCallie, et al. "Public Participation in Scientific Research: A Framework for Deliberate Design." *Ecology and Society* 17, no. 2 (2012).

[17] Haklay, Muki. "Conference Presentation." "Knowledge for Change: A Decade of Citizen Science (2020-2030) in Support of the SDGs," Berlin, October 14, 2020.

[18] See Wiggins and Crowston, 2.

[19] Mourad, Khaldoon A., Seyyed Hasan Hosseini, and Helen Avery. "The Role of Citizen Science in Sustainable Agriculture" Sustainability 12, no. 24(10375): 2020.

[20] van de Gevel, Jeske, Jacob van Etten, and Christian S. Deterding. "Citizen science breathes new life into participatory agricultural research." A review. *Agron. Sustain. Dev.* 40(35): 2020.

[21] Ryan, S.F., Adamson, N.L., Aktipis, A., Andersen, L.K., Austin, R., Barnes, L., Beasley, M.R., Bedell, K.D., Briggs, S., Chapman, B., Cooper, C.B., Corn, J.O., Creamer, N.G., Delborne, J.A., Domenico, P., Driscoll, E., Goodwin, J., Hjarding, A., Hulbert, J.M., Isard, S., Just, M.G., Kar Gupta, K., López-Uribe, M.M., O'Sullivan, J., Landis, E.A., Madden, A.A., McKenney, E.A., Nichols, L.M., Reading, B.J., Russell, S., Sengupta, N., Shapiro, L.R., Shell, L.K., Sheard, J.K., Shoemaker, D.D., Sorger, D.M., Starling, C., Thakur, S., Vatsavai, R.R., Weinstein, M., Winfrey, P., Dunn, R.R., 2018. The role of citizen science in addressing grand challenges in food and agriculture research. Proc. R. Soc. B. 285, 20181977. https://doi.org/10.1098/rspb.2018.1977

[22] See Mourad et al, 19.

[23] Mazumdar, S.; Ceccaroni, L.; Piera, J.; Hölker, F.; Berre, A.; Arlinghaus, R.; Bowser, A. "Citizen Science technologies and new opportunities for participation". In Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. Citizen Science: Innovation in Open Science, Society and Policy. UCL Press, London. 2018.

[24] Beza, E., Steinke, J., Van Etten, J., Reidsma, P., Fadda, C., Mittra, S., Mathur, P., Kooistra, L., 2017. What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers. PLoS ONE 12, e0175700. https://doi.org/10.1371/journal.pone.0175700

[25] Ebitu, Larmbert, Helen Avery, Khaldoon A. Mourad, and Joshua Enyetu. "Citizen Science for Sustainable Agriculture – A Systematic Literature Review." *Land Use Policy,* 103 (105326): 2023.

[26] See UK Environmental Observation Framework, 7.

[27] See Reynolds et al, 12.

[28] See Reynolds et al, 12.

[29] Alblas, E., and Josephine van Zeben. "Public Participation for a Greener Europe: The Potential of Farmers in Biodiversity Monitoring." *Land Use Policy* 127 (2023): 106577.

[30] See Mourad et al, 19.

[31] Van Etten, Jacobm Eskender Beza, Lluís Calderer, Kees van Duijvendijk, Carlo Fadda, Basazen Fantahun, Yosef Gebrehawaryat Kidane, Jeske van de Gevel, Arnab Gupta, Dejene Kassahun Mengistu. "First Experiences with a Novel Farmer Citizen Science Approach: Crowdsourcing Participatory Variety Selection through On-Farm Triadic Comparisons of Technologies." *Experimental Agriculture 55*, no. S1 (2016): 275-296.

[32] A Community for Naturalists · iNaturalist. Accessed: 7th September 2023.

[33] See Mourad et al, 19.

[34] Dong, Ziqian, Sarah Meyland, and Muhammet Karaomeroglu. "A case study of an autonomous wireless sensor network system for environmental data collection." Environ. Prog. Sustainable Energy, 37(2018): 180-188.

[35] Roy, H.E., Pocock, M.J.O., Preston, C.D., Roy, D.B., Savage, J., Tweddle, J.C. & Robinson, L.D, 'Understanding Citizen Science & Environmental Monitoring.', Final Report on behalf of UK-EOF, NERC Centre for Ecology & Hydrology and Natural History Museum. 2012

[36] Zhang, Airong, Richard C. Heath, Katie McRobert, Rick S. Llewellyn, Jay Sanderson, Leanne Wiseman, and Rohan Rainbow. "Who will benefit from big data? Farmers' perspective on willingness to share farm data." *Journal of Rural Studies* (2021).

[37] Aceves-Bueno, E., Adeleye, A.S., Feraud, M., Huang, Y., Tao, M., Yang, Y., Anderson, S.E., 2017. The Accuracy of Citizen Science Data: A Quantitative Review. Bulletin Ecologic Soc America 98, 278–290. https://doi.org/10.1002/bes2.1336

[38] University of Reading. "Ten Challenges and Barriers to Public Engagement and Citizen Science". January 16, 2019. https://research.reading.ac.uk/openupsci/2019/01/16/challenges-and-barriers-to-public-engagement-and-citizen-science/ Accessed 20th September 2023.

[39] Baard, P. and Per Sandin. "Principlism and citizen science: the possibilities and limitations of principlism for guiding responsible citizen science conduct. Research Ethics, 18, no 4. (2022) 304-318.

[40] See Baard and Per Sandin, 39.

[41] Yu, Qiangyi, Yun Shi, Huajun Tang, Peng Yang, Ankun Xie, Bin Liu, and Wenbin Wu. "eFarm: A Tool for Better Observing Agricultural Land Systems." *Sensors 17*, no. 3(2017): 453.

[42] Seeds for Needs: citizen science and crowdsourcing – CGIAR. Accessed 12th September 2023.

[43] Michie, Susan, Marieke M. van Stralen, and Robert West. "The Behaviour Change Wheel: A New Method for Characterising and Designing Behaviour Change Interventions." *Implement Science 6* (2011): 42.

[44] See Alblas and van Zeben, 29.

[45] See Alblas and van Zeben, 29.

[46] See Beza et al, 24.

[47] See Mourad et al, 19.

[48] See Mourad et al, 19.

[49] See van Etten, Jacob et al, 31.

[50] See Beza et al, 24.

[51] See Mourad et al, 19.

[52] Frensley, Troy & Crall, Alycia & Stern, Marc & Jordan, Rebecca & Gray, Steven & Prysby, Michelle & Greg, Newman & Hmelo-Silver, Cindy & Mellor, David & Huang, Joey. "Bridging the Benefits of Online and Community Supported Citizen Science: A Case Study on Motivation and Retention with Conservation-Oriented Volunteers. Citizen Science Theory and Practice". 2017. 2. 1-14.

[53] Friedman, Suzy. "A farmer's perspective: 4 reasons why collecting data is important." *Environmental Defense Fund.* 2015. Accessed via: A farmer's perspective: 4 reasons why collecting data is important | Growing Returns (edf.org)

[54] See Friedman, 53.

[55] See Alblas and van Zeben, 29.

[56] See Friedman, 53.

[57] See UK Environmental Observation Framework. 7.

[58] See UK Environmental Observation Framework, 7.

[59] Kenny, Ursula and Aine Regan. "Co-designing a smartphone app for and with farmers: Empathising with end-users values and needs." *Journal of Rural Studies*, 82(2021): 148-160.

[60] See Zhang et al, 36.

[61] See UK Environmental Observation Framework, 7.

[62] See UK Environmental Observation Framework, 7.

[63] See Kenny and Regan, 59.

[64] Walker, David W, and Magdelena Smigaj, Masakazu Tani. "The benefits and negative impacts of citizen science applications to water as experienced by participants and communities." *WIREs Water.* 2921; 8:e1488.

[65] See van de Gevel, van Etten, and Deterding, 20.

[66] See Kenny and Regan, 59.

[67] Defra National Statistics – Agricultural Workforce in England at 1 June 2023 (2023) https://www.gov.uk/government/statistics/agricultural-workforce-in-england-at-1-june/agricultural-workforce-in-england-at-1-june-2023

[68] See Defra, 67.

[69] See Beza et al, 24.

[70] See UK Environmental Observation Framework. 7.

[71] See Reynolds et al, 12.

[72] See Reynolds et al, 12.

[73] See Alblas and van Zeben, 29.

[74] See Reynolds et al, 12.

[75] See Mourad et al, 19.

[76] See van de Gevel et al, 20.

[77] See Ryan et al, 21.

[78] See Mourad et al, 19.

[79] See Zhang et al, 36.

[80] See Dong et al, 34.

[81] See van de Gevel et al, 20.

[82] See Mourad et al, 19.

[83] See Mourad et al, 19.

[84] See Ryan et al, 21.

[85] See Ebitu et al, 25.

[86] See Alblas and van Zeben, 29.

[87] See Mazumdar et al, 23.

[88] See Alblas and van Zeben, 29.

[89] See Beza et al, 24.

[90] See Friedman, 53.

[91] See Zhang et al, 36.

[92] See UK Environmental Observation Framework. 12.

[93] See UK Environmental Observation Framework. 12.

[94] See Walker et al, 64.

[95] See University of Reading, 38.

[96] Royal Agricultural Benevolent Institution (RABI), (2021) The Big Farming Survey https://rabi.org.uk/wp-content/uploads/2021/10/RABI-Big-Farming-Survey-FINAL-single-pages-No-embargo-APP-min.pdf

[97] Farmers Weekly (2014) New survey shows changing role of women on farms https://www.fwi.co.uk/farm-life/new-survey-shows-changing-role-of-women-on-farms

[98] Scottish Government (2017) Women in Farming and the Agricultural Sector https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2017/06/women-farming-agriculture-sector/documents/00521489-pdf/00521489-pdf/govscot%3Adocument/00521489.pdf

[99] See Farmers Weekly, 97.

[100] See RABI, 96.