Use of antimicrobials in animal health on the island of Ireland:

Knowledge, attitudes and behaviour

safefood

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Date: September 2021

Foreword and acknowledgements

The content of this report is informed by the work carried out in the ***safe*****food**-funded research project on the use of antimicrobials – agents that can kill microorganisms – in animal health on the island of Ireland. The research was conducted by

- Dr Áine Regan, Alison Burrell and Dr Edgar Garcia Manzanilla (Teagasc)
- Dr Claire McKernan, Dr Tony Benson, Sarah Farrell (Ph.D.) and Professor Moira Dean (Queen's University Belfast)
- Hannah Martin and Dr Conor McAloon (University College Dublin)

The project team would like to gratefully acknowledge the significant contribution made by the stakeholder advisory board during this project, as well as all the farmers, veterinarians and stakeholders who gave their time to participate in the research activities and consultations throughout the project.

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Executive summary

Aims

This research project aimed to provide a holistic (complete, integrated) insight into identifying and understanding the behaviours of farmers and veterinarians with respect to the use of antimicrobials – treatments that can kill disease-causing microorganisms – within different livestock industries.

Researchers used an “interdisciplinary” and “multi-actor” approach – combining many disciplines, or branches of research and learning, and involving many different individuals and organisations, or “actors” – to gain detailed, valuable information.

The project was conducted with a view to enhancing our current understanding of behavioural patterns (both use, and the wide range of factors influencing use, of antimicrobials) amongst farmers and veterinarians on the island of Ireland and to recommend “interventions” (strategies) that can help to support good practices amongst these actors, with respect to animal health.

Objectives

The specific objectives of this research project were to

- Determine the
    - Current practices in the use of antimicrobials in meat and dairy producing animals on the island of Ireland
    - Alternatives to using antimicrobials in animal health, for example improvements in biosecurity (prevention of infection and further spread of disease), use of vaccines and so on
- Assess attitudes towards
    - Antimicrobial usage
    - The problem of antimicrobial resistance (the overuse or misuse of antimicrobials, causing reduced effectiveness of the treatment in animals and humans and contaminating the environment)
    - Use of alternatives to antimicrobials amongst farmers and prescribing veterinarians

- Identify behavioural drivers and barriers and facilitators to the
  - Responsible use of antimicrobials
  - Use of alternatives to antimicrobials in meat and dairy producing animals
- Develop behaviour-change interventions for overcoming identified barriers and leveraging (making best use of) identified opportunities to promote and facilitate responsible use of antimicrobials in meat and dairy producing animals

Final outcomes

Measuring antimicrobial usage at farm level

The research project produced the first review of veterinary antimicrobial use in all livestock sectors in Ireland, providing an overview of all data currently available and identifying important knowledge gaps. Unfortunately, data from NI is aggregated with data from Great Britain and published as for the UK as a whole, and so data for NI could not be included in this part of the project.

The project launched an antibiotic use calculator for dairy herds for use in Ireland, during World Antimicrobial Awareness Week 2020. The calculator aims to help farmers "self-monitor" their use of antibiotics (treatments that can kill specific bacteria), acting as a tool to support behaviour change. Our partners in the desk-based study to determine current usage of antimicrobials and alternatives in animals adapted the University of Nottingham Dairy Antimicrobial Usage Calculator for use in an Irish setting. The tool is available as a Microsoft® Excel® document and is publicly available to download for free in the antimicrobial resistance section of the "Teagasc" website. (Teagasc is the state agency providing research, advice and education in agriculture, horticulture, food and rural development in Ireland.) A press release was issued by Teagasc announcing the launch of the tool to the farming community. The impact of this tool is to allow farmers and veterinarians to self-monitor their antibiotic use, observe trends, set goals, monitor progress and take action. This tool empowers farmers and veterinarians to make "bottom-up" change at the individual farm level to tackle overuse or misuse of antibiotics, rather than responding to a "top-down" requirement from governments and public authorities, such as the introduction of new legislation or imposing penalties for noncompliance with regulations.

Understanding knowledge, attitudes and behaviour

This project is the first study to apply the theoretical "COM-B Model" and the "Behaviour Change Wheel" to the study of antimicrobial use in the farming sector on the island of Ireland, advancing the application of this theoretical framework to new areas. (The COM-B Model suggests that 3 factors, **C**apability, **O**pportunity and **M**otivation, affect **B**ehaviour and that inducing a change in behaviour requires modifying at least one of these factors. The Behaviour Change Wheel provides a systematic way of identifying appropriate intervention functions to effect behaviour change.

Insights produced by the project and distributed widely to stakeholders (the people affected or involved) have highlighted the behavioural impact at an individual and interpersonal level of the new regulations being introduced in 2022 (see point 5 on page 8) and the challenges that farmers and animal health professionals will require support with. Through ongoing stakeholder engagement and empirical (that is, practical rather than theoretical) research, it has become clear that providing expertise in behaviour change can help to navigate the new measures required to reduce the risk of antimicrobial resistance at policy, community, interpersonal and individual level.

The project has also developed a new self-report antimicrobial usage measure, which measures farmers' antimicrobial usage behavioural patterns, and piloted it (trialled it) in a national survey providing data for testing of the validity and reliability of this new measuring scale.

Codesigning behaviour-change interventions

The research project has developed a range of behaviour-change interventions that will be publicly available, offering stakeholders a behavioural lens through which to consider the challenges of antimicrobial resistance and antimicrobial use on the island of Ireland. The report outlines 7 ideas that can be taken, adapted and put into practice by the "agrifood" (food farming) community to support good animal health practices and responsible antimicrobial use on farms.

The project has also developed a specialised training programme for animal health professionals, such as veterinarians and farm advisors. The course is designed to train animal health professionals in the practice of "motivational interviewing" – a collaborative communication approach developed by psychologists and used extensively in human health settings, which draws on individuals' inner motivation to change rather than responses to external pressures. The Motivational Interviewing training programme will be delivered to the first group of veterinarians in 2022 as part of the follow-on project researching antimicrobial usage on farms. The provision of technical animal health advice and information using specialised communication strategies can improve awareness and understanding of antimicrobial resistance and influence motivations to reduce antimicrobial usage in the farming community.

Key recommendations

1. Communicate to research funding bodies the need for further research in veterinary use of antimicrobials. Further data collection at farm level is required to give an overview of antimicrobial use in each livestock sector on the island of Ireland, particularly in Northern Ireland.
2. Establish a “research call” (a request for further study) to focus on data collection relating to antimicrobial usage in the less-intensive livestock industries, such as the sheep and beef sectors, where data is seriously lacking. In the short term, small surveillance studies would be beneficial to build on knowledge of antimicrobial use in these sectors while national monitoring systems are being developed for all food-producing animals.
3. Provide workshops for farmers and veterinarians, focusing on reducing their antimicrobial use in specific areas. Strategies to reduce antimicrobial usage and encourage “prudent” (wise and appropriate) use will have a greater impact if they are focused on “hot spots”, or particularly problematic areas of use, including specific behaviours, patterns of use and high usage farms.
4. Increase accessibility of herd-health recording software for farmers in all livestock sectors. A move to electronic recording of antimicrobial usage data would streamline data collation (collection and organisation) and ensure that valuable information recorded on paper is not lost at both veterinary practice and farm level.
5. It is important that the views of farmers and veterinarians are heard and understood. New animal health legislation is set to be introduced in 2022 as part of the European Commission’s “Farm to Fork Strategy” that will require a change in how antibiotics are used in some areas of agriculture. This can only be achieved through understanding farmers’ and veterinarians’ needs and helping them to address any necessary changes at farm level.
6. The agrifood community should recognise the varied levels of preparedness across farmers and veterinarians to navigate the incoming regulations and identify resources that will support them through this major transition.

7. Research fieldwork is an opportunity to hear from farmers and veterinarians on the ground about their experiences of using antibiotics and the challenges they face in making changes to farm practices. With a better understanding of these lived experiences, targeted supports can be developed that are practical, relevant and useful. Continued research is required to monitor farmers' and veterinarians' coping strategies and responses to regulatory changes in the coming years.
8. Reducing antimicrobial use in agriculture requires a focus on human behaviour, and specifically on human behaviour change. Widespread and long-lasting behaviour change will only come about when we address the many individual, interpersonal, organisational, financial and social factors shaping antimicrobial use on farms.
9. From a behavioural science perspective, to bring about long-lasting behaviour change, instead of a purely restrictive approach (simply limiting antimicrobial usage), it is necessary to enable farmers to adopt new approaches to farm management, which will inevitably have knock-on effects for the overall sustainability of Irish agriculture.
10. The research community can play a leadership role in bringing together different actors (farmers, veterinarians, policy-makers, scientists, regulators, and so on, both academic and non-academic) to address antimicrobial usage. Having formalised mechanisms in place to bring different individuals, groups and organisations together in a "multi-actor" approach is required; with this specific goal in mind, we highlight the need for a formalised, thematic network building on the work of past and current research projects, which have acted as individual means for bringing agrifood actors together to date.
11. There is a need to trial and evaluate the impacts of behavior-change interventions to explore the extent of behavior change that can be brought about. The next step for these methods and interventions is to carry out field trials and controlled interventions to explore the level of impact they can achieve in the applied setting. Where possible, pilot interventions should take a "nested community of practice", multi-actor approach to their implementation, which means sharing findings and information in an organised flow within and between the stakeholder individuals and groups.

1 Introduction and background

Antimicrobial resistance

Antimicrobials are considered one of the greatest medical innovations of the twentieth century. Since the discovery of penicillin in 1928 by Alexander Fleming, antibiotics have saved countless lives, extending life expectancy by 20 years, making them an indispensable medical resource. However, imprudent (unwise or irresponsible) antimicrobial usage ("AMU") is accelerating the development of antimicrobial resistance ("AMR") and reducing treatment efficiency, so endangering the future of animal and human medical treatment (World Health Organization [WHO], 2011; WHO, 2015a). Identified as a major twenty-first century global health challenge (WHO, 2015a), AMR poses a major public health threat (Speksnijer and colleagues, 2015) and is contributing to huge social and economic costs (Chan and colleagues, 2012). Typically, "imprudent" AMU refers to the overuse and misuse of antimicrobials in agricultural and healthcare settings and environmental contamination, making AMR worse (WHO, 2015a).

The seriousness of the consequences of AMR is demonstrated in many international reports, stating that if efforts are not made to address this problem serious health implications such as increased death rate, people dying earlier and prolonged illnesses are inevitable (O'Neil, 2016; WHO, 2015a). In response to these reports, several frameworks have been developed, such as the "One Health Action Plan" and the "Global Action Plan" (WHO, 2015a), recommending a "multidisciplinary" approach – involving many branches of research and education – to tackle the challenge of AMR. Since the COVID-19 pandemic, AMR is resonating with the public more than ever as people become increasingly aware of the impact that public health threats can have on society (Regan and colleagues, 2021). The management of the COVID-19 pandemic also highlights the role of collective responsibility and actions in responding to "One Health" emergencies. ("One Health" is an approach that recognises the health of people is closely linked to the health of animals and our shared environment.)

Antimicrobial use in farming

Antimicrobial-resistant bacteria can be transmitted between animals and humans through the "food chain" (the life journey of food from producer to consumer), direct contact and the environment, resulting in a significant loss of effectiveness of vital medication used to treat illness. The food-producing animal industry has been identified as an area in which antibiotics need to be used more prudently. Antibiotics are a critical tool for preserving the health and welfare of sick animals. However, they are often used as a means of preventing disease without clinical signs of disease being detected ("prophylactic use") or given to the entire herd when only a proportion show clinical signs of disease ("metaphylactic use"). This leads to excessive use of antibiotics within the industry, potentially increasing levels of AMR. The WHO has identified a list of antibiotics that are considered "highest-priority, critically important antimicrobials" (HP-CIAs) to human health. The development of bacteria resistant to HP-CIAs would result in a severe loss in effectiveness of antibiotics for currently treatable diseases and so cause a serious public health risk and increased death rates. Despite this, HP-CIAs are still frequently used to both prevent and treat disease among livestock.

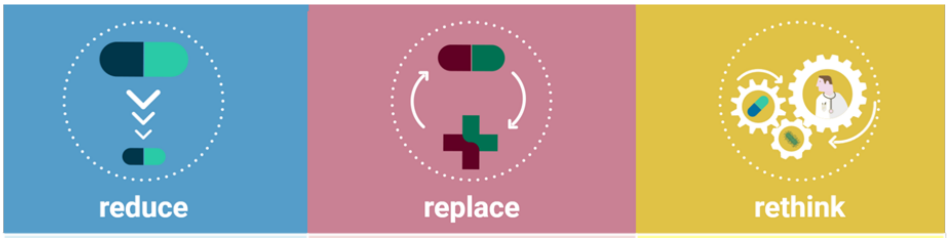
Antimicrobial resistance is an issue of key strategic concern on the island of Ireland (IOI). In November 2017, the Department of Agriculture, Food and the Marine in Ireland (DAFM) released Ireland's National Action Plan on Antimicrobial Resistance 2017–2020 (iNAP). The plan outlines the action taken by many stakeholders in the animal health sector in recent years to reduce AMU but also highlights that significant quantities of antibiotics are still in use and calls for further work to increase awareness amongst stakeholders. The action plan to support the United Kingdom (UK) 2013–2018 5-Year Antimicrobial Resistance Strategy also outlines a number of urgent actions needed at veterinarian, or "vet", and farm level to reduce AMU, highlighting the key role that social research will play in determining best strategies to achieve this.

Common agricultural practices such as using antimicrobials for growth promotion or prophylaxis (disease prevention), or the use of HP-CIAs that are primarily reserved for human treatment, are considered "imprudent" AMU (European Medicines Agency [EMA] and European Food Safety Authority [EFSA], 2017; O'Neill 2014; WHO, 2017). In 2006, the European Union (EU) approved regulations banning the use of antimicrobials for growth promotion. As part of "One Health" efforts to address the global challenge of AMR, further legislative and policy changes are being introduced at European and national level, centred on agricultural antibiotic use. The European Commission's (EC) "Farm to Fork Strategy" (EC, 2020) has set a 2030 target of reducing sales of antimicrobials for farmed animals and in aquaculture (freshwater and sea plants and animals cultivated for human consumption) by half. The EU will introduce new regulations in 2022 on veterinary medicinal products and medicated feed.

Responsible antimicrobial use

Adopting a "proactive" approach (that is, *causing* change rather than *reacting to* change) in addressing imprudent use of antimicrobials on farms, there has been an emphasis on encouraging "responsible AMU" in the farming sector. There are many different elements in this approach; it does not involve any one single behaviour or practice. One way to think about responsible AMU is the "Reduce, Replace, Rethink" approach proposed by the EFSA and EMA (2017), who jointly reviewed measures taken in the EU to reduce the need for and use of antimicrobials in food-producing animals. The measures listed in Figure 1 outline actions that can be taken at different levels, by different actors (farmers, vets, policy-makers, scientists, regulators and so on); such actions require both individual behaviour change and whole system changes.

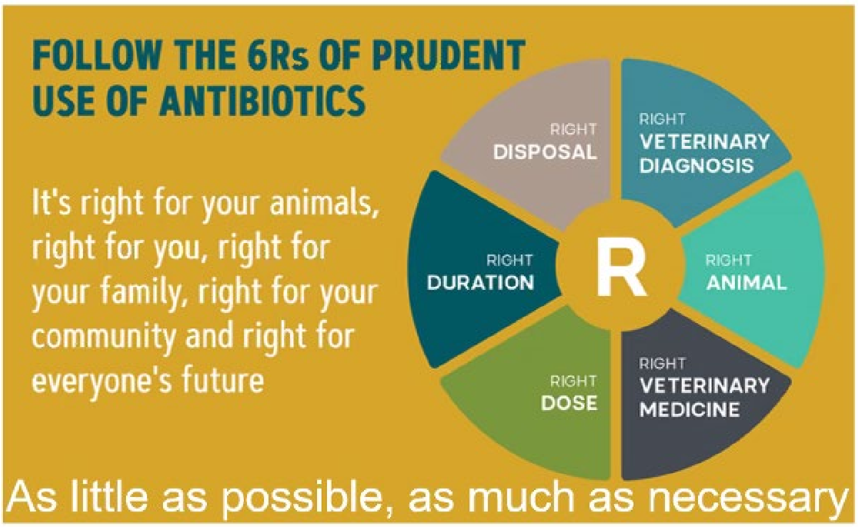
Figure 1. Measures to reduce the need for and use of antimicrobials in farming. *(Source: European Food Safety Authority and European Medicines Agency, 2017.)*



...the use of antimicrobials	...antimicrobials with alternative treatments	...the livestock production system
✓ Set targets for reducing the use of CIAs	✓ Consider alternatives to antimicrobials	✓ Improve prevention and control of diseases
✓ Increase responsibility of veterinarians	✓ Research new alternatives	✓ Consider alternative farming systems
✓ Use antimicrobials only when needed	✓ Develop a clear EU legal framework for alternatives	✓ Education and awareness of AMR

Taking a more specific look at the behaviours and practices that farmers and vets can engage in, responsible AMU can be defined through the "6 Rs approach" to using antimicrobials, as set out in the iNAP-led "Code of Good Practice Regarding the Responsible Prescribing and Use of Antibiotics in Farm Animals" (DAFM, 2019). In agriculture, the "6 Rs approach" outlines the guiding principles for prescribing and using antibiotics at farm level (Figure 2) as: **R**ight veterinary diagnosis, **R**ight animal, **R**ight veterinary medicine, **R**ight dose, **R**ight duration and **R**ight disposal, and a reminder to use "as little as possible, as much as necessary".

Figure 2. The "6 Rs" of prudent use of antibiotics. *(Source: Ireland Department of Agriculture, Food and the Marine, 2017.)*



Additional to the "6 Rs", there is also a focus on changing the conditions so that less bacterial infections occur and the need for antimicrobials is reduced. Treating the cause rather than the problem involves prioritising many different behaviours in areas such as infection control, biosecurity, vaccination, nutrition, hygiene, farm health plans, diagnostics, the best possible livestock housing, transport management and so on. Adopting new approaches to using antimicrobials, and adopting new animal health management practices, will require significant behaviour change for many vets and farmers.

Understanding antimicrobial use on farms

Antimicrobials have been used in farming for decades, leaving habitual behavioural patterns that are socially and culturally ingrained. The surveillance (observation and recording) of AMU in animal health plays a major role in dealing with the growing issue of resistance. A key objective of the WHO Global Action Plan on AMR focuses on strengthening knowledge of AMR and AMU through surveillance (Masterton, 2008). Reliable data on the quantities of antimicrobials used are needed to measure current usage, observe trends over time and to monitor the response to any interventions to reduce use (European Centre for Disease Prevention and Control, 2017). Within the EU, the EMA promotes the prudent use of antimicrobials in humans and animals, and the collection and reporting of AMU data, in the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project (EMA 2018). Member States are encouraged to record and report usage data in both human and animal health so that the impact of policy change may be monitored. The ESVAC project, initiated by the EMA in 2010, collects information on how antimicrobial medicines are used in animals across the EU. Additionally, new EU Veterinary Medicinal Products Regulations (EU Regulation [EU] 2019/6) will make it a requirement for antimicrobial prescription data on all food-producing animals to be collected in a national antimicrobial consumption database from January 2027 (EU, 2019).

Currently, on the IOI national-level AMU data are gathered from the sales of veterinary antimicrobials by the Health Products Regulatory Authority (HPRA) in Ireland (HPRA, 2019) and the Veterinary Medicines Directorate (VMD) in Northern Ireland (NI) (VMD, 2019). This provides information on the classes of antimicrobials and the pharmaceutical forms (tablets taken by mouth, injections and so on) sold but cannot explain how much antimicrobials are given to each species; nor does it tell us anything about farmers' behaviours in relation to AMU, for example manner of purchase, administration route (how the antimicrobial is given to the animal), recording, and storage and disposal practices. The monitoring of AMU is an integral part of "antimicrobial stewardship" (responsible usage). Access to AMU data will be essential to develop strategies to reduce AMU and lessen the threat of AMR to society. More work is needed to explore the knowledge gaps with respect to surveillance and data collection of AMU at farm level.

In recent years there has also been increased interest in understanding AMU in agriculture and, more specifically, understanding key stakeholders' (farmers' and vets') knowledge, attitudes, perceptions and behaviours in relation to antimicrobials and AMR to determine what influences decision-making and current AMU behaviours (McKernan and colleagues, 2021, under review). Changing behaviour has been identified as a crucial component by the WHO and the EU to support responsible AMU (EC, 2017; WHO, 2017).

A review completed by McKernan and colleagues (2021) found huge variability in relation to knowledge, attitudes, perceptions and behaviours of AMU and AMR; because of this, decision-making in relation to AMU is complex, involving many factors, with variable attitudes apparent between countries and even between different industry sectors. Therefore, an initial assessment of the stance (the viewpoint or position) of a sector or country is essential to establish current attitudes. An approach of this nature will identify specific priority areas and gaps in knowledge and skills for farmers and vets that are required to make changes and tailor intervention design. Strategies should encourage incremental behaviour change (made in small steps) so that farmers and vets feel capable, supported and empowered to implement antimicrobial stewardship strategies. Strategies should not have any bad effects on production but should increase profits and maintain and improve animal welfare, so helping farmers and vets to make the necessary behaviour changes and to maintain these behaviours in the long term.

"Top-down" and "bottom-up" behaviour change

Figure 3. The "social ecological" approach, which goes beyond examining change from a purely regulatory, "top-down" perspective.

Public policy around farming practices and expected behaviour changes often come in a "top-down" manner from governments and public authorities, such as the introduction of new legislation or imposing penalties for noncompliance with regulations. This approach to behaviour change can result in improvements to farm practices and animal welfare such as the successful ban on battery cage egg production at EU level (Morgans and colleagues, 2021). However, the "top-down" approach to change in agricultural practices can, at times, result in unintended consequences; for example, a disconnection from what is considered "good farm practice" (Escobar and Demeritt, 2017) or a change in antibiotic use rather than a reduction (Bager and colleagues, 2016).

New regulations are being introduced in 2022 at EU level that will change how antibiotics can be used on farms. Adopting a "social ecological" approach (Figure 3), which includes both "top-down" and "bottom-up" interventions, will help with meaningful, sustainable behaviour change. Together with the necessary changes at public policy level, this approach involves targeting an individual's own knowledge, attitudes and skills within their environment including family, social network, organisations, communities and wider society (Eldredge and colleagues, 2016). Adopting this approach to understanding and, where necessary, improving antibiotic use on farms can address social "norms" (that is, behaviours considered normal and acceptable) within agriculture, increase knowledge of AMR and improve motivation to make these sustainable, meaningful changes to farm practice.

The "COM-B Model" and the "Behaviour Change Wheel"

Strategies that are designed along with behaviour-change frameworks have notable success in many health-related behaviours such as addiction, smoking and physical activity, amongst others, based on behaviour-change models (for example the Theory of Planned Behaviour, Practice-Based Coaching and the COM-B Model). To structure the overall investigation of the issue of AMU on farms on the IOI and development of intervention recommendations, the COM-B Model, Behaviour Change Wheel and Theoretical Domains Framework were used (Cane and colleagues, 2012; Michie and colleagues, 2011). This is a "behavioural science" approach, which tries to understand behaviours in terms of an individual's capability, opportunity and motivation to carry out that behaviour. It aims to support those in policy making and intervention design, and practitioners, to gain a deeper understanding of how to help people change behavioural patterns through evidence-based methods. It explores how different factors impact on a person's behaviour. In this model, "**C**apability", "**O**pportunity" and

"**M**otivation" interact to generate "**B**ehaviour". Within each component, it is possible to identify and explore the role and linkages of various psychological and social constructs in determining behaviour. These are shown in Table 1.

Table 1: COM-B Model components and corresponding Theoretical Domains Framework constructs for understanding determinants of behaviour used in a study of knowledge, attitude and behaviour relating to the use of antimicrobials and alternatives in animal health on the island of Ireland

COM-B Model component	Theoretical Domains Framework constructs
Physical capability	Physical skills
Psychological capability	Knowledge
	Cognitive and interpersonal skills
	Memory, attention and decision processes
	Behavioural regulation
Reflective motivation	Professional or social role and identity
	Beliefs and capabilities
	Optimism
	Beliefs about capabilities
	Optimism
	Beliefs about consequences
	Intentions
	Goals
Automatic motivation	Reinforcement
	Emotion
Physical opportunity	Environmental context and resources
Social opportunity	Social influences

Figure 4 The Behaviour Change Wheel

Behaviour Change Wheel aims to understand the behaviour that needs to be changed, identify what intervention options are possible and clarify what content and implementation options for that intervention have been successful when rolled out. This model provides a user-friendly and evidence-based approach to help with intervention design (Figure 4). The starting point for developing interventions using the Behaviour Change Wheel approach is the behavioural analysis carried out using the COM-B Model. Once we understand the range of factors that may be preventing a behaviour or practice from changing, we can then tackle those factors through targeted interventions. Based on the insights from the behavioural analysis, a range of targeted interventions can then be chosen. Evidence suggests interventions that combine restrictive *and* enabling measures (for example education and training, restructuring the environment, communications and messaging, incentives and intervention targeting) are more successful than restrictive, legislative measures alone. This is because restrictive measures may not be targeting those factors that are likely to bring about *motivation* to change one's behaviour. For example, new legislation may mean that a farmer *knows* they have to change their behaviour ("capability") but they may not see the need or value to them personally of changing their behaviour ("motivation").

Behaviour-change technique taxonomy

Behaviour-change techniques are the measurable, reproducible, "active ingredients" of behaviour-change interventions. An in-depth "synthesis" (an exercise in combining) of relevant published literature (articles and research papers) was conducted at University College London to produce a "taxonomy" – a naming and classification system – of 93 behaviour-change techniques. The taxonomy aims to provide behavioural scientists with a shared language of intervention components to support behaviour change and ensure that successful interventions, regardless of length or intensity, can be reproduced in other situations (Michie and colleagues, 2013). Even a short conversation between a professional and client could contain several successfully delivered behaviour-change techniques. This would be considered a "low-intensity" behaviour-change intervention to increase an individual's motivation, help them to get started with a new change or find ways of maintaining these new changes (National Institute for Health and Care Excellence, 2014).

An example of a behaviour-change technique is "self-monitoring". Self-monitoring is a very common technique used to promote positive behavioural changes. For example, individuals who are motivated to increase their physical activity may monitor their steps per day. Depending on the context and, most importantly, on the client, behaviour-change techniques will be used to suit where the client is in their journey towards making changes to their AMU.

A "multi-actor" approach to behaviour change

Interventions aimed at behaviour change at farm level have best success when they follow a "multi-actor" approach and use "codesign" and "participatory" principles; that is, when the people who must *make* the changes are involved in the process of *designing* the intervention or the new procedures. Employing a participatory approach to codesign intervention options enhances their suitability and effectiveness in practice (Macken-Walsh, 2019). The codesign approach facilitates end-users to have an input into the design of policies, technologies and strategies. There are many examples outlining the advantages and success of implementing a multi-actor, codesign approach for improved farming practices, particularly where animal health is concerned (Penry and colleagues, 2011; Roche, 2013; Van Dijk and colleagues, 2016).

In line with the social ecological approach, the research project has employed a multi-actor stakeholder approach throughout. From the initial project planning stage to a needs analysis and through to the development of intervention recommendations, stakeholder engagement has been a core activity of the project. This interdisciplinary project – combining many disciplines, or branches of research and learning – aimed to blend scientific literature with practical, local knowledge through the ongoing input of a vast variety of stakeholders such as veterinary practitioners, farmers from various food-producing sectors, knowledge-transfer specialists, farm advisors, academics, industry representatives, those contributing to policy and people working for animal health organisations.

2 Aims and objectives

Aims

By implementing an interdisciplinary and multi-actor approach, the research project aimed to provide a holistic (complete, integrated) insight into identifying and understanding the behaviours of farmers and vets with respect to the use of antimicrobials within different livestock industries.

By integrating behavioural and social science perspectives with those of veterinary and animal health, the project aimed to develop practice-ready, evidence-based interventions aimed at ensuring responsible use of antimicrobials at farm level.

This project was conducted with a view to enhancing our current understanding of behavioural patterns related to AMU amongst farmers and vets on the IOI and to recommend interventions that can help to support good practices amongst these actors with respect to animal health.

Objectives

The specific objectives of this research project were to

- Determine the
  - Current practices in the use of antimicrobials in meat and dairy producing animals on the IOI
  - Alternatives to using antimicrobials in animal health nationally and internationally, for example improvements in biosecurity, use of vaccines and so on
- Assess attitudes towards
  - Antimicrobial usage
  - The problem of antimicrobial resistance
  - Use of alternatives to antimicrobials amongst farmers and prescribing veterinarians
- Identify behavioural drivers and barriers and facilitators to
  - Responsible use of antimicrobials

    - Use of alternatives to antimicrobials in meat and dairy producing animals
- Develop behaviour-change interventions for overcoming identified barriers and leveraging (making best use of) identified opportunities to promote and facilitate responsible use of antimicrobials in meat and dairy producing animals.

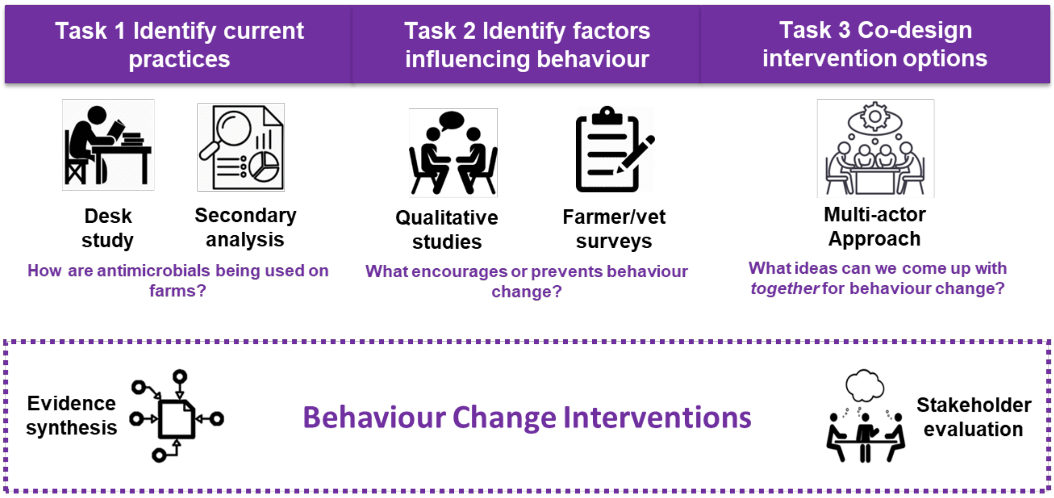
3 Project tasks: materials, methods and results

The work plan for the research project is outlined in Figure 5. It is defined by an interdisciplinary and multi-actor approach to understanding farmers' and vets' behaviour.

- An in-depth desk study will determine behavioural patterns on the IOI regarding farm-level AMU and use of alternatives to antimicrobials.
- The COM-B Model will be used to assess the great variety of behavioural influences on AMU, as well as the barriers that may be preventing responsible use and facilitators to responsible antimicrobial stewardship.
- Through stakeholder engagement exercises, the multi-actor approach will help inform intervention development.

The combination of these approaches will ensure a holistic, systematic and "bottom-up" approach to intervention design.

Figure 5. Work plan for the research project on knowledge, attitudes and behaviour relating to the use of antimicrobials and alternatives in animal health on the island of Ireland



3.1 Task 1: Desk-based study to determine current usage of antimicrobials and alternatives in animal health on the island of Ireland

3.1.1 Task 1 objectives

The objectives of Task 1 were modified based on the data available. Three main objectives were finally identified, which were to

- Undertake an in-depth review to identify and collate (collect and organise) the current data available on on-farm practices in relation to the use of antimicrobials on the IOI.
- Collate data on alternatives to using antimicrobials in animal (for example improvements in biosecurity, the use of vaccines and so on) nationally and internationally, with a focus on "hot spots", or particularly problematic areas of antimicrobial use, within each livestock sector.
- Carry out a literature review of the methods used internationally to capture data on farm-level use of antimicrobials.

The planned secondary analyses of available data on on-farm practices in relation to the use of antimicrobials, and of available data on the use of alternatives to using antimicrobials in animal health, was explored. However, these analyses were excluded as an objective due to a lack of suitable data to study.

3.1.2 Task 1 materials and methods

a) In-depth review of current data on on-farm practices relating to use of antimicrobials and alternatives on the island of Ireland

The first objective of Task 1 was to undertake an in-depth review to identify and collate the current data available on on-farm practices in relation to the use of antimicrobials on the IOI. We initially carried out a systematic review of AMU in farm animals on the IOI using online scientific databases including CAB Direct and PubMed® to find relevant peer-reviewed articles (articles that have been checked by suitably qualified people). Data was not available separately for NI as it is included in UK data, so the search proceeded using the data available for Ireland.

Figure 6 shows the systematic search and selection process used and the number ("n") of articles resulting from each search. The criteria for selecting an article based on the title was the inclusion of these phrases, or ideas related to them:

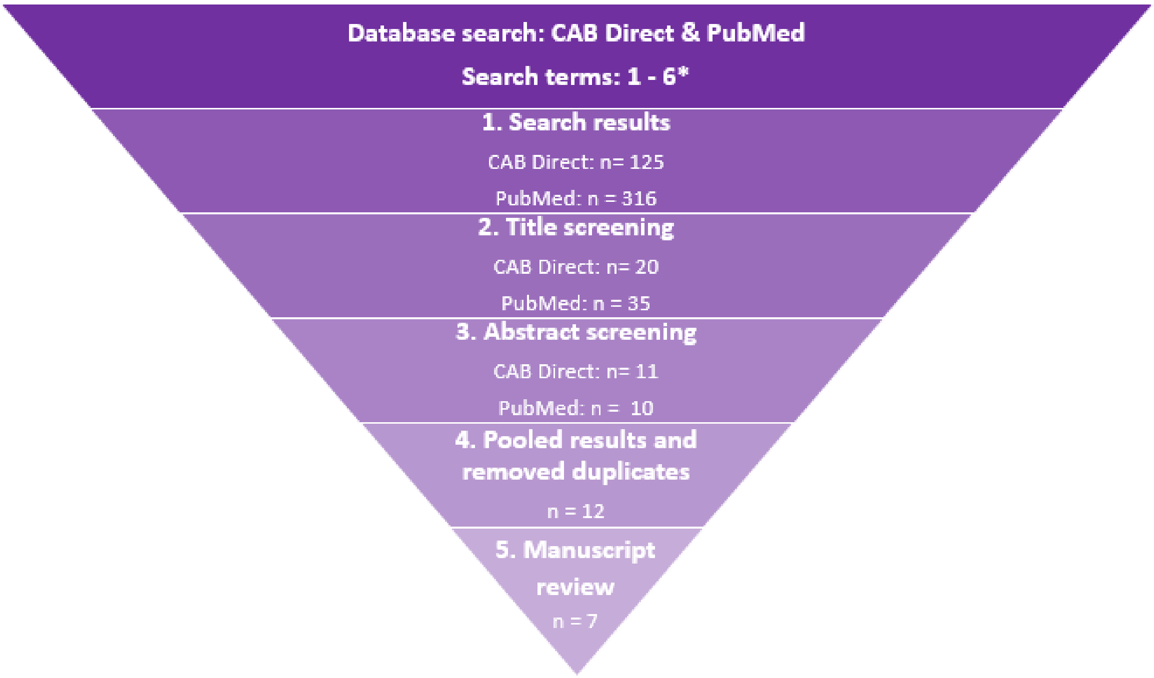
- Antibiotic use or therapy

- Antimicrobial use or therapy
- In-feed medication

Articles with relevant titles were exported from the databases and their abstracts – short summaries of the articles' contents – were screened (checked for relevance and suitability for inclusion in the study). Potentially eligible full-text articles were then reviewed and irrelevant articles were excluded. Inclusion criteria required that the articles dealt with one of these categories of information:

- Quantifying (measuring or calculating) AMU
- Describing antimicrobial usage patterns
- Collection of antimicrobial usage data

Figure 6. The systematic search and selection process for articles for inclusion in a review of current data on on-farm practices relating to use of antimicrobials on the island of Ireland.



* Search terms 1 to 6:

1. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Animal Production
2. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Pig OR Swine
3. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Poultry OR Broiler OR Chicken OR Layer

4. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Dairy OR Cattle OR Calf
5. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Beef
6. (((Antimicrobial) OR Antibiotic) AND Ireland) AND Sheep

In addition to reviewing published research, a search was conducted to identify ongoing research projects around AMU in animal production within Ireland. Searches were conducted in each of the research databases of the 2 main agriculture funding bodies in Ireland, which are Teagasc (the state agency providing research, advice and education in agriculture, horticulture, food and rural development) and the Department of Agriculture, Food and the Marine (DAFM). In livestock sectors where published data were not available and on-going research projects were not identified, discussions were had with stakeholders in the relevant industries, mainly vets with expertise in these livestock sectors. Reports on the sales of veterinary antimicrobials were also reviewed to give an overview of total veterinary AMU in Ireland and gain an insight into the types of antimicrobials used in terms of the class of antimicrobial used and in which pharmaceutical forms – for example oral (by mouth), injectable, intramammary (infused into the mammary gland) and so on.

b) Collation of data on alternatives to using antimicrobials in animal health on the island of Ireland and internationally

The second objective of Task 1 was to collate data on alternatives to using antimicrobials in animal health (for example improvements in biosecurity, use of vaccines and so on) both nationally and internationally, with a focus on "hot spots" (particularly problematic areas of antimicrobial use) within each livestock sector. Information from the review of current data on on-farm practices relating to the use of antimicrobials on the IOI was used to inform this second objective and provide a basis for the selection of "hot spot" areas of AMU to focus on for targeted reduction strategies. Where no published data was available, discussions were had with industry experts to gain insight on the "hot spot" areas of use within their livestock sectors.

The "hot spot" areas identified within each livestock sector are outlined in Table 2.

Table 2: "Hot spots", or particularly problematic areas of antimicrobial use, within livestock sectors on the island of Ireland

Livestock sector	"Hot spot" problem area of antimicrobial use
Pigs	In-feed medication for weaners. ("Weaners" are piglets that are no longer suckling from their mother.)
Poultry	Young chick diseases
Dairy	Mastitis control and prevention. ("Mastitis" is a disease or inflammation in a cow's mammary gland – its udder.)
Beef	Bovine Respiratory Disease (BRD)
	Oral antimicrobial use in calves
Sheep	Young lamb diseases

Once the "hot spot" areas of use had been identified within each livestock sector, a similar method of search and selection as used for the in-depth review of current data on on-farm practices relating to use of antimicrobials on the IOI was carried out using relevant search terms in the online databases CAB Direct and PubMed®. The "grey" literature (that is, from nonacademic publishers) was also explored, including articles from industry bodies such as Teagasc. For each "hot spot" area of use, 2 targeted reduction strategies were explored.

In addition to each livestock sector, alternative options to AMU were explored for vets, as these actors play an essential role in the reduction of AMU. While farmers are most often the end-users of antimicrobial products, they would not have access to these products without a prescription from a vet. Ultimately, the responsible use of antimicrobials begins with the prescribing veterinarian.

c) Literature review of methods used internationally to capture data on farm-level use of antimicrobials and alternatives in animal health

The third objective of Task 1 was to carry out a literature review on the methods used internationally to capture data on farm-level use of antimicrobials. Similar search and selection methods as used in the in-depth review of current data on on-farm practices relating to use of antimicrobials on the IOI, and in the study to collate data on alternatives to using antimicrobials in animal health both nationally and internationally, were used to source articles for the literature review for this third objective, using online scientific databases. Lists of references to other publications used or mentioned in the sourced articles were also screened for additional relevant material. Further articles were collected through what could be called an “organic search” – for example those recommended by colleagues, and those sourced by searching the websites and social media pages of organisations known to be actively working on the collection of AMU data, such as the “AACTING” network and project. (AACTING is short for the “Network on quantification of veterinary Antimicrobial usage at herd level and Analysis, CommunicaTion and benchmarkING to improve responsible usage”.)

For this literature review we explored various topics including the roles of the vet and the farmer in monitoring AMU in various international monitoring systems, the methods used to monitor AMU in these systems, and the different methods used in research trials.

3.1.3 Task 1 results

Task 1 results: a) In-depth review of current data on on-farm practices relating to use of antimicrobials and alternatives in animal health on the island of Ireland

The first objective of Task 1 was to undertake an in-depth review to identify and collate the current data available on on-farm practices in relation to the use of antimicrobials on the IOI. Unfortunately, it was not possible to include information on the use of antimicrobials on farms in NI as data from NI is added together with data from Great Britain and published for the UK as a whole. Further research in NI will be required to provide an overview of veterinary AMU on the whole IOI. Thus, this first objective focused on the use of antimicrobials on farms in Ireland, through looking at sales data, published data and ongoing research.

Table 3 shows the amount of veterinary antimicrobials sold in Ireland (in tonnes) for the years 2014 to 2019. Sales remained at a steady 100 tonnes per year between 2015 and 2018, with a drop to 88.8 tonnes sold in 2019. The sales of the critically important antimicrobials (CIAs), including third- and fourth-generation cephalosporins, and fluoroquinolones and macrolides, were also reduced in 2019.

Table 3: Sales (in tonnes) of veterinary antimicrobials in Ireland, including third- and fourth-generation cephalosporins, and fluoroquinolones and macrolides, for the years 2014 to 2019

Year	2014	2015	2016	2017	2018	2019
Total sales (tonnes) for all classes of antimicrobials	89.4	96.9	103.4	99.7	99.4	88.8
Third- and fourth-generation cephalosporins	0.24	0.22	0.25	0.30	0.33	0.21
Fluoroquinolones	0.69	0.79	0.94	0.85	0.84	0.74
Macrolides	6.26	5.58	6.58	7.17	7.07	5.60

(Source: Adapted from Martin and colleagues, 2020.)

Figure 7 shows the breakdown of sales of veterinary antimicrobials in terms of the pharmaceutical forms sold. Over two-thirds of antimicrobials sold are administered orally, with the remainder made up of injectable and intramammary products

Figure 7. A percentage breakdown of the pharmaceutical forms of the veterinary antimicrobials sold in Ireland in 2019. *(Source: Health Products Regulatory Authority, 2020.)*

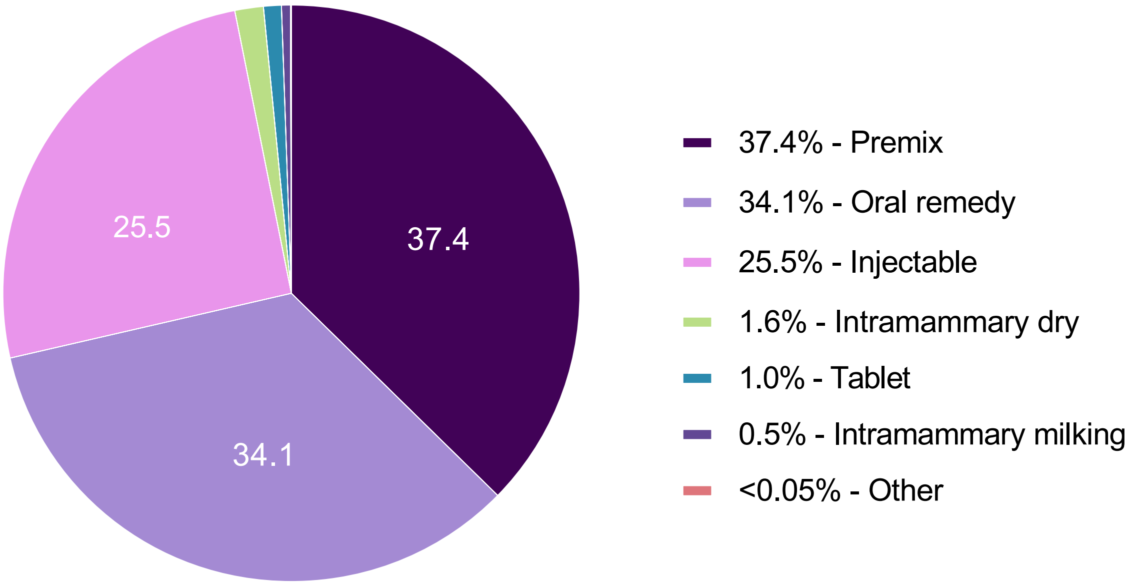
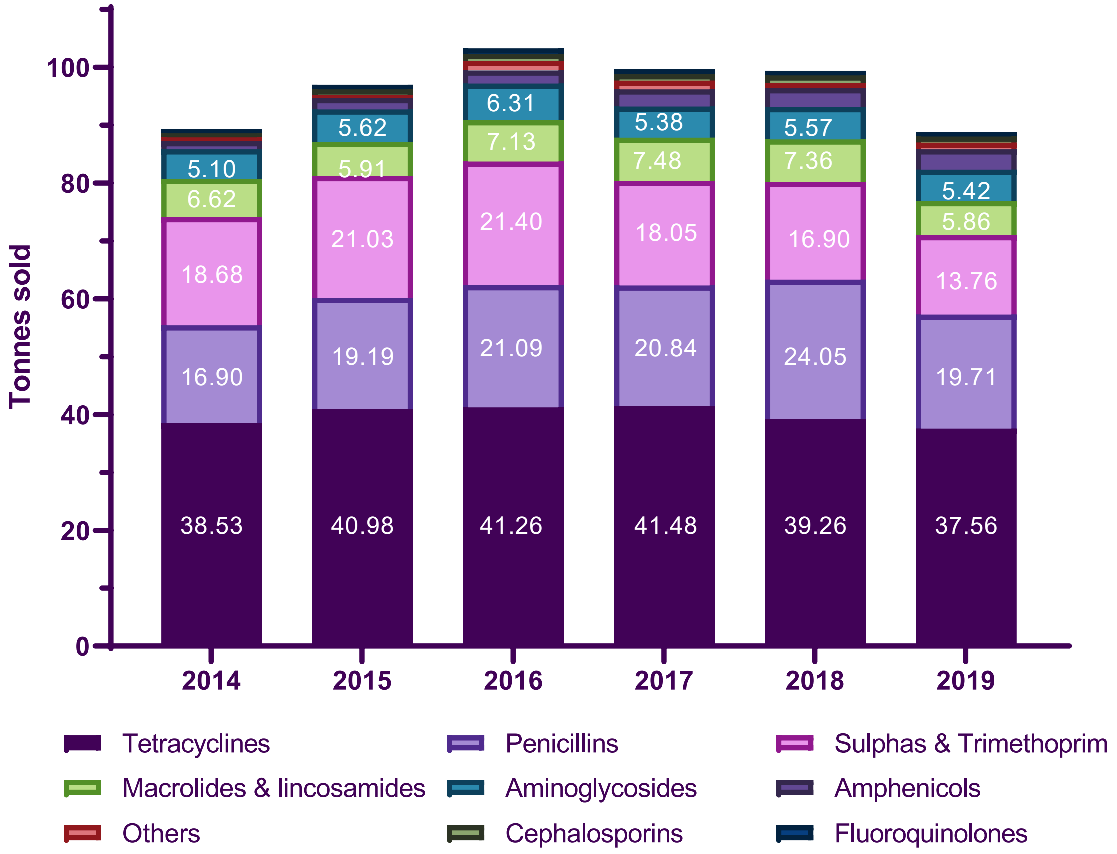


Figure 8 shows the distribution of sales of veterinary antimicrobials in Ireland between 2014 and 2019, broken down by antimicrobial class. In 2019 the reduction in overall sales is reflected in a reduction in the most popular antimicrobial drug classes – tetracyclines, penicillins, sulphas and trimethoprim – as well as in macrolides and lincosamides.

Figure 8. The distribution of sales (in tonnes) of veterinary antimicrobials supplied from 2014 to 2019 in Ireland, by class of antimicrobial. *(Source: Adapted from Martin and colleagues, 2020.)*



Within each livestock sector the availability of AMU data varied greatly. Table 4 provides a breakdown of the data available for each sector. The "intensive" livestock sectors of pig farming and poultry farming had comprehensive farm-level data available; however, data was lacking in other sectors. ("Intensive" farming means a system where the livestock is kept indoors, fed concentrated food and given medicine to prevent disease outbreaks in the closed environment.)

Table 4: Data available on antimicrobial use in each livestock farming sector in Ireland

Livestock sector	Data available on antimicrobial use
Pigs	Farm-level data collected and published*
Poultry	Farm-level data collected, unpublished
Dairy	Sales data on intramammary use published No farm-level data available
Beef	Farm-level data on calves published No farm-level data available on breeding stock or finishing stock. ("Finishing" stock are animals being fed energy-rich food to add muscle and fat before slaughter.)
Sheep	No farm-level data available

* Pig data was unpublished at the time of writing but has since been published.

Task 1 results: b) Collation of data on alternatives to using antimicrobials in animal health on the island of Ireland and internationally

The second objective of Task 1 was to collate data on alternatives to using antimicrobials in animal health nationally and internationally (for example improvements in biosecurity, use of vaccines and so on). Specific case studies identified as "hot spot" areas of AMU and the reasons for including each case study for behaviour-change interventions were included. The reasons for inclusion vary to an extent; however, the trend across each sector is that the preventive use of antimicrobials is the most common behaviour that could be targeted for change.

Table 5: "Hot spot" areas of antimicrobial use in animals on the island of Ireland and the targeted strategy for reduction of use

Livestock sector	**"Hot spot" area of problem antimicrobial use**	**Targeted strategy for reduction of use**
Pigs	In-feed medication for weaners	Biosecurity improvements Official mandatory (compulsory, or required) interventions
Poultry	Young chick diseases	Biosecurity improvements
Dairy	Mastitis control and prevention	Selective Dry Cow Therapy – Milk recording Reduce use of critically important antimicrobials
Beef	Bovine Respiratory Disease (BRD) Dairy calf-to-beef systems (wherein male calves bred from dairy cows are reared for breeding or slaughter for beef): Oral antimicrobial use in calves	Reduce stress during weaning Vaccination Anti-inflammatory use Faecal sample testing
Sheep	Young lamb diseases	Prebirth and lambing management Increased labour during lambing

For each “hot spot” area, 2 options for alternatives to AMU were explored, except for the poultry sector. One example of a “hot spot” area of AMU and an alternative option is the use of oral antimicrobials in calves to treat diarrhoea (called “scour”) and the introduction of routine faecal sample testing. Farmers could test faecal samples using a scour test to identify the type of diarrhoea they are dealing with. The most common causal agents of calf diarrhoea on the IOI are *Cryptosporidium* and Rotavirus (All-island Disease Surveillance Report [AIDSR], 2016) neither of which are susceptible to (responsive to) antimicrobial treatment. Oral antimicrobial tablets and powders will only have an effect on bacterial cases of diarrhoea. However, the 2 most common bacterial agents that cause diarrhoea in calves on the IOI, *Escherichia coli* and *Salmonella*, had a relatively low frequency in comparison to others in faecal samples sent to the DAFM and the Agri-Food and Biosciences Institute laboratories (AIDSR, 2016). Where farms have a persistent problem with calf scour, encouraging farmers to test faecal samples for the causal agents of diarrhoea in their calves may have a positive effect on the use of antimicrobials. If samples are identified as nonbacterial, the use of antimicrobials can be removed as a treatment option.

Vets are a trusted source of advice to farmers. In a study looking at the factors affecting dairy farmers’ attitudes towards AMU in cattle in England and Wales, vets were found to be the most influential source farmers used to make decisions on controlling disease in their herds (Jones and colleagues, 2015). Almost 70 per cent of farmers in this study believed that their vet would approve of them reducing their AMU. In a similar study on Dutch farmers, almost all farmers (97.8 per cent) indicated that they valued the opinion of the vet when deciding to treat animals with antimicrobials, with 86 per cent of farmers indicating that the vet can best judge whether their animals required antimicrobial treatment (Kramer and colleagues, 2017). Considering the influence that vets have on farmers, it is likely that interventions targeted at vets would have an influence on farmers’ behaviour also, as the advice is passed on to them. Therefore, alternative options for vets to reduce AMU were explored and include

- Herd-health planning
    - A significant reduction in AMU on farms could be made possible through higher emphasis on preventive measures and herd-health planning wherein the veterinarian plays an advisory role.
- Antimicrobial Susceptibility Testing (AST)
    - AST is used to determine which antimicrobials a particular bacteria or fungus are susceptible to. Vets can use AST to help them decide which antimicrobial is

appropriate to use before any treatment is given or to determine the correct antimicrobial to use after a previous treatment has failed.

- "Benchmarking" and a "One Farm, One Vet" policy
    - Benchmarking systems allow farmers and vets to compare the quantities of antimicrobials used and prescribed by their peers (that is, other farmers and vets in their sector), while also allowing for identification and monitoring of high-level users and prescribers. To allow for vets to be benchmarked, the Netherlands operate a "One Farm, One Vet" policy, meaning they are required to hold contracts with their clients stating they are the designated prescribing vet for that farm (Netherlands Veterinary Medicines Institute, 2019).

Task 1 results: c) Literature review of methods used internationally to capture data on farm-level use of antimicrobials and alternatives in animal health

The third objective of Task 1 was to carry out a literature review on the methods used internationally to capture data on farm level use of antimicrobials. For this literature review we explored various topics including the roles of the vet and the farmer in monitoring AMU in various international monitoring systems, the methods used to monitor AMU in these systems, and the different methods used in research trials.

Much of the information on methods used internationally to capture AMU data included in this review was collated by the AACTING consortium. Established in 2017, The AACTING consortium is an international network of professionals involved in the quantification of veterinary antimicrobials at herd level. It has collated information on the AMU monitoring systems currently in place in 15 European countries and Canada, available at their website (aacting.org).

International antimicrobial use monitoring systems

Several AMU monitoring systems exist internationally, which may utilise sales data, prescription data or farm-level usage data. The longest-running AMU monitoring systems include the Swedish Board of Agriculture and the Danish "VetStat" database, established in 1971 and 2000, respectively. Since 2010 there has been a rapid increase in the number of monitoring systems available and the expansion of existing systems to include additional species. As of March 2020, 38 active farm-level AMU monitoring systems from 16 countries were identified. Descriptions of the various systems can be found on the AACTING website (aacting.org).

There are several differences between the various monitoring systems available internationally, including their level of coverage, the method of data collection and the requirement for participation. Systems may be "full coverage", aiming to include all farms in a certain livestock sector; "partial coverage", targeting a substantial part of a sector; or surveys of a sample of farms, which target a small representative sample of a sector. Currently, comparable numbers of full coverage, partial coverage and surveys of sample farms exist. Surveys are often used as pilot studies in the development of monitoring systems, to collect detailed data, inform decisions and test options for improving monitoring systems.

The method of data collection varies among systems and can be automatic, where data are delivered in a digital format through software, or manual, which requires data to be actively provided such as by entering it into a web application, using invoices or hand-written prescriptions or treatment records. Where surveys of sample farms are used to gather AMU data, several collection methods may be used.

The role of veterinarians and farmers in monitoring antimicrobial use internationally

Internationally the responsibility of recording AMU is placed primarily on the vet prescribing the medicine. Of the 38 existing AMU data collection systems identified by the AACTING consortium, 29 involve the input of data from the vet, illustrating the importance of the vet's role in capturing AMU data.

The farmer and farm staff have an extremely important role in the monitoring of AMU. Many monitoring systems available require the involvement of farmers, such as the "AMU Pig Database" in Ireland and the "eMedicines Book" in NI, and, internationally, systems such as "GVET" in France. The obvious advantage of monitoring AMU at farm level is farmers or farm staff will know exactly how the antimicrobials are being used on their farm. As the end-users of the product, the farmer will know if antimicrobials prescribed have actually been used and to who (what weight group, age group and individual animal) it has been administered. However, while there are major benefits to obtaining farm-level AMU data, there are several barriers to obtaining data from farmers. In many countries, including Ireland, there is no quick and easy way for farmers to record their AMU. Often manual input is involved, which is time-consuming, and many older farmers may not be skilled or experienced in the use of technology. Additionally, the accurate monitoring of AMU requires commitment of all farm staff and currently, on the IOI, there is no real incentive for farmers to record AMU in a digital format; and a lack of knowledge about the threat of AMR may result in farmers not being as willing to participate in AMU monitoring.

Research trials of antimicrobial usage monitoring systems

In addition to national monitoring systems, antimicrobial surveillance studies have been used in many countries to record and quantify AMU across a range of livestock species. Various methods of data collection have been used in research trials to accurately estimate the on-farm usage of antimicrobials. Although the more accurate methods may not be scalable or suitable for national-level data collection, they can still provide ideas for collection.

One of the most reliable methods used in research trials is the inventory, or cataloguing, of empty drug containers. In this method, farmers are asked to dispose of all empty medicine packages into designated bins on their farm for a study period, usually 12 months. The contents of the bins are collected and examined at regular intervals. While the inventory of empty drug containers has been considered one of the most reliable sources of AMU data collection, the information provided by this method is "quantitative" (meaning it is a system that measures or counts the amount, or quantity, being assessed). It does not provide "qualitative" details (that, is not directly countable or quantifiable details) such as information on the reason or need for use, particularly concerning the use of "systemic" treatments (injectable treatments that enter the bloodstream and may have more than one indication for use), highlighting the importance of obtaining data from treatment records.

In many research trials examining farm-level AMU, extracting prescription data or farm treatment records from software is common. The ability to download the required data for analysis simplifies the process where it is available; however, not all farms or veterinary practices will have access to this type of software. To make this type of data collection scalable, monetary investment may be needed in some agricultural sectors, particularly in traditionally low-income sectors such as the sheep sector.

3.1.4 Task 1 deliverables and outputs

The outcomes for the project "deliverables" (the specific work produced, or delivered, that enabled the objectives to be met) for Task 1 (the desk-based study to determine current usage of antimicrobials and alternatives in animal health on the IOI) are shown in Table 6.

Table 6: Deliverable outcomes from Task 1, a desk-based study to determine current usage of antimicrobials and alternatives in animal health on the island of Ireland

Task 1 deliverables	Task 1 outcomes
1. Collation of current data available on the use of antimicrobials in animal health on the island of Ireland	Done
2. Collation of data available on the alternatives to using antimicrobials in animal health on the island of Ireland and internationally	Done
3. Report on farm-level antimicrobial usage on the island of Ireland	Done

There have been several opportunities to showcase and promote the valuable work undertaken within Task 1 of this project, which are shown in Table 7.

Table 7: Promotional or "outreach" activities showcasing outputs from Task 1, a desk-based study to determine current usage of antimicrobials and alternatives in animal health on the island of Ireland

Outreach activity	Audience and description of activity	Title	Date
Media outreach	A 2-minute video shown at an international "webinar" (an online seminar) hosted by VirtualVet.eu to mark World Antimicrobial Awareness Week 2020	How much antibiotics are used to treat animals in Ireland?	18–24 November 2020
Media outreach	Press release to coincide with World Antimicrobial Awareness Week 2020	Antimicrobials – Handle with Care	18 November 2020

Dairy stakeholder presentation	Chief Executive of the Dairy Council for Northern Ireland Dr Mike Johnston requested a presentation of the research completed by the ***safe*food** antimicrobial usage project. This provided a platform to share the purpose of the research and make contacts with key stakeholders in Northern Ireland: Lakeland Dairies Dale Farm dairy cooperative Glanbia	Use of antimicrobials in animal health on the island of Ireland: Knowledge, attitudes and behaviour	18 May 2021
Technology available to the public	A Dairy Antibiotic Usage Calculator was adapted and made publicly available for download online at https://www.teagasc.ie/animals/amr/prudent-use/	Dairy Antibiotic Usage Calculator	November 2020
Journal article	*Irish Veterinary Journal*, Volume 73, article 11, available online at https://doi.org/10.1186/s13620-020-00165-z	Current antimicrobial use in farm animals in Ireland (Martin and colleagues, 2020)	26 June 2020

3.2 Task 2: Behavioural analysis to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to use of alternatives in animal health on the island of Ireland

3.2.1 Task 2 objectives

This study employed the theory-based psychological model the COM-B Model (Michie and colleagues, 2011) to carry out a behavioural analysis of farmers' and vets' attitudes to AMR and the use of antimicrobials and alternatives to their use. It was anticipated that the findings obtained would identify factors that contribute to stakeholders' awareness, attitudes and perceptions towards antimicrobials and how these impact on current behaviours, enabling recommendations to be made to promote sustained behaviour change to encourage responsible AMU on farms. The objectives of Task 2 were to

- Determine current behaviours and attitudes to AMU and the use of alternatives amongst dairy and meat-producing farmers on the IOI
- Determine current behaviours and attitudes to AMU and the use of alternatives amongst vets on the IOI
- Investigate drivers, barriers and facilitators to prudent AMU on farms

3.2.2 Task 2 materials and methods

a) Critical literature review

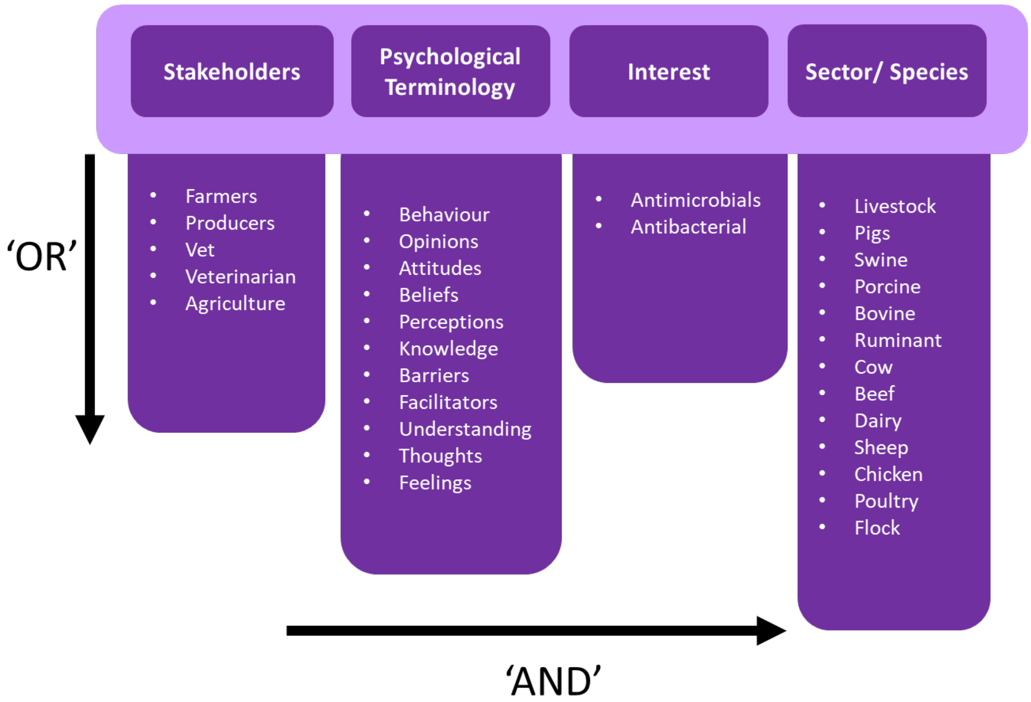
A critical review of relevant articles was conducted. This type of review closely examines and evaluates the strengths and weaknesses of themes, methods and outcomes in an article to assess its value to the current study.

Search strategy

The critical literature review was completed in a structured approach in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines involving a key number of steps.[18] Articles exploring farmers' and vet's knowledge, attitudes and perceptions of antimicrobials and AMR were sourced. Initially, search terms were generated to cover the scope of the research aims; that is, to assess attitudes to antimicrobials and AMR and identify drivers, barriers and facilitators to the use of alternatives in animal health on the IOI. To ensure that all the relevant search terminology had been sourced a second researcher (Dr Tony Benson) reviewed the search terms, identifying 3 additional terms. The search term strategy and search words used are shown in

Figure 9. In September 2020 a comprehensive and systematic search of the keywords catalogue was conducted across 4 electronic databases: MEDLINE®, PyscINFO®, Scopus® and Web of Science®.

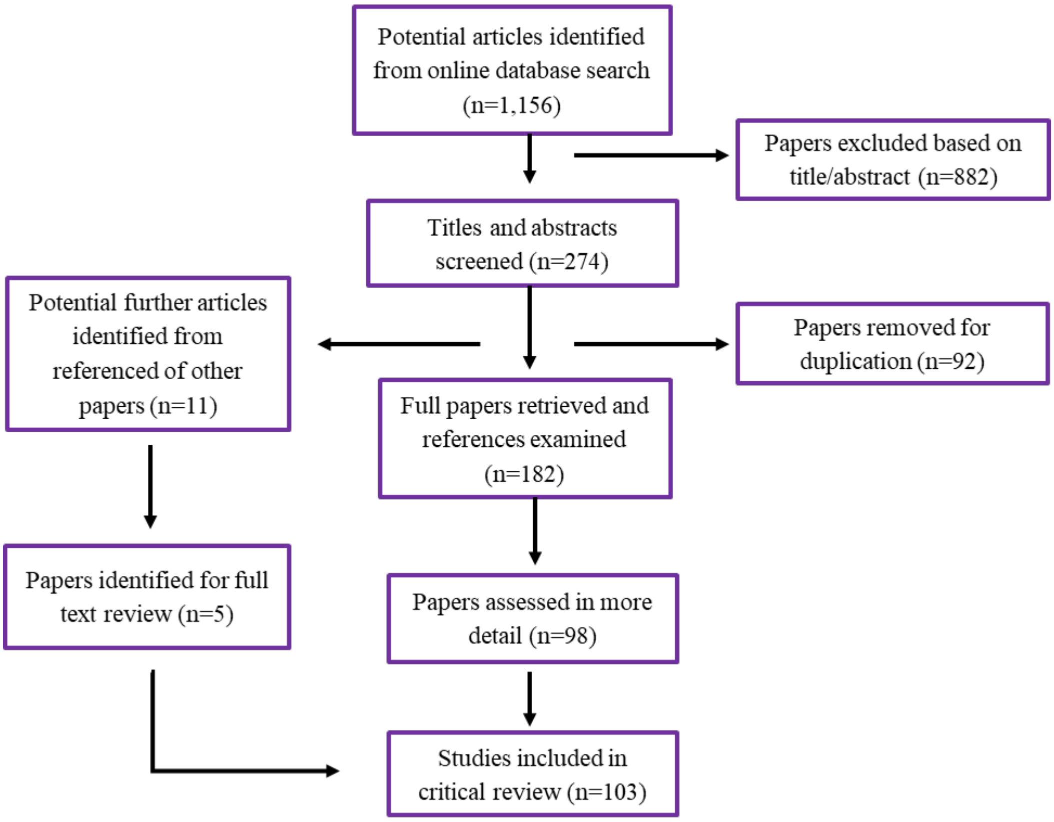
Figure 9. The search term strategy used for a critical literature review conducted to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland.



Article screening

Initially, 1,156 papers were identified from the database searches. One researcher (Dr Claire McKernan) independently screened the article titles and abstracts. Duplicated articles were crosschecked and removed. Subsequently, 274 relevant articles were sourced based on the title and abstract. Based on the eligibility criteria (provided below) a total of 98 papers were identified from the database searches. An additional 5 articles were identified from manually searching the lists of references to other publications used or mentioned in the sourced papers for key articles of interest. As a result of this approach a total of 103 papers were sourced for full text review (Figure 10).

Figure 10. Flow diagram illustrating the assessment and selection of articles for review in a study to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland.



Eligibility criteria

- To be eligible for inclusion in the critical literature review, articles had to meet the following criteria.
- Stakeholders: Veterinarian (vet), farmer or both
- Sectors: Ruminant (dairy or beef), porcine (pigs), poultry, sheep
- Study design: Qualitative and quantitative approaches, including interviews, focus groups and questionnaires, or a mix of these methods
- Outcomes: Reports on themes and areas of interest in relation to the knowledge, perceptions, attitudes and behaviour surrounding antimicrobials
- Language: Published in English
- Date: Studies completed and published at any time
- Location: Studies published in any location or region

Data extraction, synthesis and inductive thematic analysis

All articles were analysed, and data was extracted on

- Country of study
- Stakeholder
- Sector
- Study design
- Sample size
- Strengths
- Limitations
- Key results
- Outcomes

Extracted data was thematically coded inductively in accordance with Braun and Clarke's protocol (a set of rules) (Braun and Clarke, 2006). To analyse the different studies, pieces of information are given codes to help researchers look for any patterns, links or similarities. "Thematic inductive analysis" is a way of coding information that does not try to make the data fit into an existing theme or a pattern that might be created or driven by a researcher's own ideas and assumptions.

Findings from the eligible articles were coded for information relevant to the research aims. Subsequently, all articles in relation to famers' and vets' knowledge, attitudes and perceptions of antimicrobials and AMR were coded. From the generated codes, 5 key themes were constructed and are described in the results for Task 2. To ensure the reliability of sample (the selection of articles being analysed) half of the papers that were independently reviewed were crosschecked and verified by a second researcher (Dr Tony Benson). A further 10 per cent were reviewed by a third researcher (Professor Moira Dean) to ensure consistency in the data extraction approach.

b) Qualitative secondary analysis

A secondary analysis of qualitative data was conducted. Qualitative secondary analysis means analysing data originally collected in other studies, and possibly for a different purpose, to find answers to a new question or area of research.

Qualitative datasets

A secondary qualitative analysis was carried out on existing datasets made available from our research project partners:

- Selected Dry Cow Therapy (SDCT) Targeted Advisory Service on Animal Health Consult, from University College Dublin (UCD) – 22 interviews with dairy farmers
- Behaviours around AMU in the pig sector in the UK, from Queen's University Belfast (QUB) – 10 interviews with pig farmers
- Johne's disease and disease prevention, from Teagasc – 13 interviews with mixed farmers
- Behaviours surrounding animal death, from Teagasc and UCD – 3 focus groups and 4 interviews with mixed farmers

Thematic analysis

A thematic analysis was carried out (Braun and Clarke, 2006). All data were coded and similar codes were then merged together to form themes. The themes were named and descriptions developed for each theme.

c) Farmer survey

A survey involving 392 respondents (male and female, aged between 20 and 83) from the IOI was conducted between February and May 2021. To ensure a broad and representative sample, or group of participants, the survey was available on various platforms, including an online survey, a telephone survey (where the researcher would take the participant through the survey verbally) and a postal version (where the survey was sent out to participants).

Participant recruitment

To satisfy the objectives of Task 2 the participants in the farmer survey had to identify either the beef, dairy, pig or sheep sector as their main enterprise. Recruitment of participants was facilitated through several agricultural organisations including Teagasc, Animal Health Ireland (AHI), the Ulster Farmers' Union, and the Department of Agriculture, Environment and Rural Affairs in Northern Ireland (DAERA).

Data collection

On average, the survey lasted 15 minutes. The data was collected using survey software SurveyMonkey®. If participants opted to complete the survey by telephone or post, the responses were inputted into SurveyMonkey® and were labelled accordingly to differentiate these responses from online responses.

At the beginning of the survey a participant information sheet was provided and it was explained to respondents that there were "*No right or wrong answers*" and that their answers would be treated confidentially. The study was approved by the Faculty of Medicine, Health and Life Sciences Research Ethics Committee at QUB and consent was obtained from each respondent (Ethics code: MHLS 20_123). The study was conducted in accordance with the guidelines given in the Declaration of Helsinki.

Survey questionnaire design

Following the critical literature review and qualitative secondary data analysis of datasets (McKernan and colleagues, 2021, under review), questionnaire "items" (for example specific questions, or statements for measuring levels of agreement or disagreement against) were drawn up. The items were developed and adapted from previous validated measures to assess factors previously found to influence behaviours surrounding AMU, drawing on guidelines for constructing a questionnaire based on the theory of the COM-B Model (Michie, 2011).

The questionnaire contained "closed-ended" questions (which can only be answered "yes" or "no" or by marking a single point on a scale measuring a level of agreement) and underwent extensive piloting and "face validation" (which tries to assess whether the questionnaire would be likely to meet the researchers' aims). Face validation involved a group of 6 experts in the area to ensure that items measuring "responsible antibiotic use" were both suitable and relevant. The second round of piloting was completed with a group of 9 farmers and involved "cognitive interviewing". Cognitive interviewing involves the end-users "thinking aloud" as they read items and choose responses to the proposed scale with a researcher. This identifies any possible misinterpretations of items and ensures the measure is appropriate for the target population (the desired audience or respondents), understood as intended by researchers, and helps to reflect participants' experiences. This process aims to reduce "cognitive burden" on participants (the amount of mental energy or memory recall required) and allow researchers insight into the mental process involved in providing answers to items.

To test the face validity of the farmer survey questionnaire items and ensure the items were relevant to farmers across different sectors, a convenience sample of 9 people from the target population was recruited to take part in cognitive interviews, which took place either online through Microsoft® Teams or by telephone. ("Convenience sampling" means the researchers selected easily or quickly accessible participants.) These interviews captured how the participant has interpreted and answered each question and identified the source of any problems in the questions or the survey design. As a result, changes were made to the final structure of the questionnaire.

Piloting the farmers' survey was rigorous and comprehensive. This approach enabled improved survey design, satisfying the "deliverables" of the project (that is, the specific work produced, or delivered, that enabled the objectives to be met) for Task 2, exploring attitudes and identifying drivers, barriers and facilitators to the use of antimicrobials and alternatives in animal health on the IOI.

At the outset, we sought to measure responsible AMU behaviours, intentions for AMU, perceived blame and contribution to AMR, "objective knowledge" (how much a person actually knows), AMR and "One Health" awareness, and "declarative knowledge" (knowing what needs to be done).

Following this, participants were provided with an explanation of AMR before completing items measuring

- Level of concern
- Perceived risk
- Professional identity
- Professional responsibility
- Emotions
- Self-efficacy (a person's belief in their ability to act, and achieve an objective)
- Extrinsic motivation (motivation to act due to external pressures, for example regulations)
- Goals and plans

Survey questionnaire measures

Following an extensive review of the relevant literature, items were developed to measure factors previously found to influence behaviours and perceptions around AMU and AMR. These items were then organised into the relevant constructs of the COM-B Model: capability, opportunity, motivation and behaviour. These were included alongside other relevant sociodemographic items (that is, information such as age, education, income, marital status and so on) and further farm details (farming sector, herd size and so on) to form the study questionnaire. (The farmer survey is in Appendix 1 and participants' characteristics are in Appendix 3.)

The COM-B Model is a theoretical framework that identifies what needs to change for a behaviour-change intervention to be effective. The Theoretical Domains Framework (TDF) is an overarching theoretical framework comprised of 14 domains, integrating constructs from multiple theories relating to health behaviour change (Cane and colleagues, 2012). To make survey design stronger and more thorough, the TDF was mapped on the COM-B Model.

Behaviour

A gap in literature was identified when developing the questionnaire. Although there are means of measuring quantities of antimicrobials used through monitoring methods, it was highlighted that a self-report measure to gather data on farmers' behaviour relating to AMU (for example use as a prophylaxis, if accurately recorded, and if completing the prescription) would contribute significantly to research in the area of AMU in animal health. The research team therefore put together a protocol based on the guidelines of Boatang and colleagues (2018) to validate the self-report measure of "behaviour" (the "B" in the COM-B Model).

Experts in the relevant area were consulted to generate a full picture of the behavioural patterns associated with AMU during a "brainstorming" exercise (an intensive meeting to stimulate discussion and ideas). An initial list of potential questionnaire items along with sector-specific vignettes (imagined scenarios or examples of likely situations) were generated and presented to stakeholders for a content analysis of the items. These items have now been updated and reduced to ensure the "behaviour" measure is concise, appropriate, understandable and relevant to the Irish food-producing sectors.

To capture current AMU behaviours, participants responded to 14 items to measure current practices at farm level. The purpose of this project was to encourage responsible AMU in a farm setting; therefore, these items were designed to complement the "6 Rs" of antimicrobial stewardship developed by iNAP (2018). Items were scored on a 5-point Likert-type scale for frequency where 1 means "*Never*" and 5 means "*Always*". Due to the sensitivity of some of these items, participants were made aware that "*All answers are completely anonymous and will only be used to gain an overall picture, rather than to measure antibiotic use on* *individual farms*". Additionally, due to the sensitive nature of these questions, 2 more options were added to the 5-point scale including "*I don't know*" and "*Prefer not to say*".

Negatively worded items were reverse scored. ("Reverse scoring" is a way of crosschecking results to make sure they are valid and questions are answered honestly by, for example, using positive wording for low-scoring items and negative wording for high-scoring items.) The mean, or average, of all summed items was used to provide a total "Responsible antimicrobial behaviour" score, ranging from 14 to 70, with a higher score representing better or more responsible practices. To generate the scale, responses "*I don't know*" and "*Prefer not to say*" were recoded as "*Missing data*". (There were 18 such responses.)

To measure the consistency of recording AMU, participants were asked, "*When do you record your antibiotic usage?*" Participants selected from the options "*Immediately after I use the antibiotic*", "*Weekly*", "*Monthly*", "*Quarterly*" "*Before an inspection*" or "*Never*". These will be measured descriptively and reported as percentages.

Capability

"Capability" is defined as an individual's psychological and physical capacity to engage in the behaviour concerned.

"Subjective knowledge" (that is, "knowledge" based on a person's own beliefs or opinions rather than on facts) was measured using 3 items adapted from Moorman and colleagues (2004). Participants rated their self-perceived knowledge on statements such as "*Compared to the average farmer, I know a lot about antibiotics*". Items were reported on a scale of 1 ("*Strongly disagree*") to 5 ("*Strongly agree*"). Items were summed to create a total "subjective knowledge" score ranging from 3 to 15, with a higher score indicating greater subjective knowledge.

To measure participant knowledge, 7 items were adapted from Moreno and colleagues (2014) and Kramer and colleagues (2017). To measure "objective" (fact-based) or "declarative" knowledge, participants were asked, "*To the best of your knowledge, do you think these statements are true or false?*" and answers were measured on a dichotomous scale (a 2-point scale), "*True*" or "*False*". In addition to the dichotomous scale, after each item participants were asked, "*How sure are you that the answer you gave is correct?*" and answers were measured on a confidence scale ranging from "*Very unsure*" to "*Very sure*", to eliminate guessing.

Participants' "objective knowledge" score was calculated from the number of correct answers provided in addition to "confidence in answer provided", ranging from 0 to 5, with a higher score indicating greater objective knowledge. For example: incorrect answer = 0; correct answer + very uncertain = 1; correct answer + quite uncertain = 2; correct answer + slightly uncertain = 3; correct answer + slightly uncertain = 4; correct answer + very uncertain = 5. Due to this scoring system, responses could range from 0 to 35, with a higher score correlated to higher objective knowledge responses.

Six items were designed to ascertain the "level of awareness of the topics of AMR and 'One Health'", adapted from Cotta and colleagues (2014). Participants were asked questions such as "*I am aware of the links between animal health practices and human health*". Responses were scored on a on a dichotomous scale, "*Yes*" or "*No*". The additional option of "*I don't know*" to the dichotomous scale was included for 2 of the items: "*Antibiotic resistance is a problem in my country and worldwide*" and "*Antibiotic resistance is an issue that could affect me or my family*".

Motivation

"Motivation" involves all the brain processes that energise (or activate) and direct behaviour. It includes "reflective motivation", such as conscious decision-making and looking back on earlier actions or decisions, as well as "automatic motivation", such as habits or immediate emotional responses.

To measure participants' "intention to change AMU behaviours" on the farm, 6 items were adapted from Prochaska and DiClemente's "Cycle of Change Model" (1986). This approach aims to capture the participants' readiness to change on-farm behaviours in relation to AMU. Participants are asked to "*Choose a box that best represents your farm practices in relation to antibiotics used on your farm*." Items included "*I know that I should change how I use antibiotics, but I am not ready to make changes*". These will be measured descriptively and reported as percentages.

Within the "beliefs about consequences" part of the farmer survey, 3 questions were asked. The first question measured "perceived sector blame for contribution towards AMR". Four items were adapted from Echeverria and colleagues (2004), scored on a 5-point Likert scale of agreement ranging from 1 ("*Strongly disagree*") to 5 ("*Strongly agree*"). The items included "*I believe antibiotics are used too much in agriculture / medicine / my sector / other sectors*".

Scores could range from 4 to 20, with a higher score indicating higher perceived sector blame. Before the next 2 questions, an explanation of AMR was provided. Thereafter, 3 items were included to assess the "level of concern of AMR in relation to" "*Your animals' health / human health / you and your family's health*", adapted from Cotta and colleagues (2014). Items were scored on a 5-point Likert scale from 1 ("*Not at all concerned*") to 5 ("*Extremely concerned*"). Scores could therefore range from 3 to 15, with a higher score indicating higher level of concern for AMR. "Perceived risk" was measured using 4 items adapted from Collineau and colleagues (2015), such as "*The risks to the average person / farm animal / my animals / my family and me of antibiotic resistance are …*". Items were scored on a 5-point Likert scale from 1 ("*Very low*") to 5 ("*Very high*"). Scores could therefore range from 3 to 15, with a higher score indicating higher perceived risk for AMR.

The "professional identity" of a "good farmer" was measured using 3 items generated from the critical literature review. In this instance professional identity measured if a farmer is "data-driven", informed by science and is open to change, assessing if the farmer is progressive or reluctant to change on a 5-point Likert scale from 1 ("*Strongly disagree*") to 5 ("*Strongly agree*").

"Perceived professional responsibility" was assessed by asking participants, "*How much responsibility do you believe lies with each of the following groups to take action to reduce the risk of antibiotic resistance for humans and animals?*" Twelve stakeholder groups were included, adapted from Kramer and colleagues, (2017). Participants scored each stakeholder from 1 ("*Not at all responsible*") to 5 ("*Extremely responsible*").

Before "self-efficacy" was measured, participants were provided a vignette describing positive changes towards responsible AMU: "*John is a farmer who has recently made changes to how he uses antibiotics. He made a plan to manage his herd's health and prevent disease occurring. He now no longer uses antibiotics with his whole herd to prevent disease breaking out ('blanket use') and where possible only gives antibiotics to the animals who show clinical signs of disease.*" Self-efficacy, emotions and reinforcement were anchored on this vignette. "Self-efficacy" was measured using 3 items adapted from Schwarzer and Renner (2009), such as "*I am confident that I could make similar changes to John on my farm*" and were scored from 1 ("*Strongly disagree*") to 5 ("*Strongly agree*"). Items were summed to create a total "self-efficacy" score ranging from 3 to 15, with a higher score indicating greater self-efficacy to make changes on the farm.

To understand "emotions" around changing farm practices similar to those described in the vignette above, participants were asked, "*If you had to stop blanket use of antibiotics, and make the same changes as John on your farm, how do you think it would make you feel?*" Answers were measured on 3 semantic differential scales, which ask participants to select certain words to rate a statement or product, in this case "*Dissatisfied*" or "*S*atisfied", "*Foolish*" or "*W*ise" and "*Worried*" or "*Calm*"). Items were summed to create a total "emotion" score ranging from 3 to 15, with a higher score indicating positive emotions to make changes on the farm.

Opportunity

"Opportunity" is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it (for example physical and environmental infrastructure, and social relationships).

The literature review identified vets and farm advisors as key influencers and considered them as credible sources of information. To capture a holistic understanding of "what participants use their vets and farm advisors for", participants were asked, *"What services do you avail of from your vet, or farm advisor? (Tick as many as applicable)*" as 2 separate questions. For vets, participants were provided with 11 services commonly associated with the vet, such as "*To prescribe medication to treat animals*" and "*Laboratory testing to diagnose disease*". If participants indicated that they had a farm advisor, participants were provided with 7 items to cover common services provided by farm advisors, such as "*To get nutrition advice*" and "*To make herd-health plans*". Within both questions, the items "*To get advice on reducing antimicrobial use*" and "*To plan vaccine programmes*" were included. In this format, these items capture if the participant has made goals and plans for AMU at farm level and are measured in the "motivation" construct of the COM-B Model. These items allow for an exploration of the organisational culture within AMU in agricultural settings. These items will be reported descriptively as percentages.

As mentioned earlier, measuring "reinforcement" is anchored into the vignette describing making on-farm changes centred on responsible AMU. Therefore, to assess the perceived effectiveness of 7 extrinsic reinforcements adapted from Habing and colleagues (2016) to encourage similar on-farm changes centred around responsible AMU, for example "*Subsidised vaccination programmes*", the items were scored on a 5-point Likert scale from 1 ("*Not at all helpful*") to 5 ("*Very helpful*").

"Social support" is measured using 9 items adapted from Kramer and colleagues (2017) and Visschers and colleagues (2015), which identify different support groups such as "*Own judgement*", "*Another farmer*" or "*Another vet for a second opinion*". Participants were asked, "*When an animal is sick, how often do you consult the following for advice …?*" and were scored on a frequency scale where 1 means "*Never*" and 5 means "*Always*", to assess which groups participants consider a trustworthy source of social support. This scale will measure the frequency with which participants consult each of these groups, to identify key groups as a source of trust and competence in diagnostic judgement. Scored items were summed and could range from 9 to 45, with a higher score indicating increased reliance on social support.

The literature review identified that "peer support" is considered a credible source of information. Six items were included to obtain an indication of the type and level of support received from other farmers, such as "*To get advice on herd health management*" and "*To get advice on reducing antibiotic use*". Answers were scored on a frequency scale where 1 means "*Never*" and 5 means "*Always*". Items were summed and could range from 6 to 30, with a higher score indicating increased reliance on peer support.

To measure "social pressure" of groups to reduce AMU, 4 items were adapted from Francis and colleagues (2004) and Jones and colleagues (2015). Items included "*I feel under pressure from my vet/ my farm advisor/ consumers/ department of agriculture (DAERA/DAFM) to reduce the antibiotics used on my farm.*" Items were scored on a 5-point Likert agreement scale from 1 ("*Strongly agree*") to 5 ("*Strongly disagree*").

To assess the "access to resources" such as training and education surrounding AMR, 3 items were designed: "*Have you ever learned about antibiotic resistance during formal training?*", "*Have you ever been to an online or in-person event (for example webinar, conference, farm walk) where antibiotic resistance on farms was discussed?*" and "*Are you currently a member of a farm advisor-led or facilitated discussion group?*" and scored on a dichotomous scale, "*Yes*" or "*No*". These items should provide a sense of how much the topic of AMR is discussed and will be reported as percentages.

To identify "possible worthwhile channels for information", participants are asked, "*Have you ever looked for information on antibiotic resistance from …? (Please select as many as applicable)*" and were provided with 8 common platforms to select. This approach will enable the identification of preferred channels of information, as participants have utilised these methods previously. Results of these items will be reported descriptively as percentages.

Sociodemographic and farm characteristics

Standard sociodemographic data was collected including age, gender, marital status, highest level of agricultural education, farm location (which county) and annual income. In addition to the standard sociodemographic data, information detailing specific farm characteristics was included, such as type of farm employment, farm personnel structure, herd or flock size (number of stock), years' experience and if a succession plan was in place. Participants were asked to indicate what agricultural sector they worked in and filled in their current herd or flock size. Where a participant indicated that their enterprise was "*Mixed or combination*" farmers were asked to provide numbers of stock in their farms for all sectors and then asked to select a dominant sector within their enterprise and instructed to "*Please keep this sector in mind when answering the remaining questions*".

Data analysis

All data were analysed using IBM® SPSS® Statistics version 26.0 for Windows (International Business Machines Corporation [IBM], Armonk, New York, United States of America), with a p-value (p) equal to or less than 0.05 considered to be significant. ("P" is a measure of the probability that a finding is true, even if it seems unlikely, rather than occurring by chance or accident.) Descriptive statistics (mean values [M] and standard deviations [SD] – variations from the average or common values) were used to explore the data. Analysis of Variance (ANOVAs) with Bonferroni post-hoc tests were used to assess differences between and within sociodemographic parameters (age, years' experience, education, sector, farm size) and psychological measures (social and peer support). Using Pearson's correlations, the strength of the relationships among the psychological variables (the "r" value) such as subjective knowledge and objective knowledge, and emotions and self-efficacy, were explored. Cronbach's alphas (the "α" value, a measure of how closely related a set of items are as a group) were used to assess internal reliability of the scales. Missing data was handled using listwise deletion (where a whole list of data is excluded if any single value is missing) as the missing values were scattered randomly through the dataset.

A "hierarchical regression model" was used to understand the relative contribution of "predictor" ("independent variable") factors, including constructs of the COM-B Model (capability, opportunity and motivation) in relation to responsible AMU behaviour (the "dependant variable"). For regression analyses, multicollinearity (where several independent variables in a model are correlated) was assessed using the variance inflation factor (how much a variable is influenced by its correlation with other factors) and by examining the tolerance statistic (the calculated expected level of variation). These were below the suggested critical values of 10 for variance inflation factor (Myers, 1990) and above 0.2 for tolerance (Menard, 2002), indicating that the level of multicollinearity was acceptable. In addition, the autocorrelation (a measure of similarities between a variable's current value and its value in the past) between the measures of the predictor variables was assessed in the analysis with the Durbin–Watson test and found to be acceptable at a value of 2.08.

d) Vet online survey and interviews

To reduce the burden on participants and maximise data collection a mixed-method approach was designed. Initially, participants were asked to complete a short online survey, followed by a short telephone interview. On average the online survey lasted 15 minutes, and the follow-up interviews ranged from 10 to 120 minutes.

Participant recruitment

To satisfy the objectives of Task 2, the participants in the vet survey and interviews must dedicate most of their time (more than 40 per cent) practising veterinary medicine on farm animals.

Purposive (that is, deliberately selective) and convenience sampling was used for recruitment. Recruitment was facilitated through veterinary organisations (Veterinary Northern Ireland, or "VetNI", and Veterinary Health Ireland).

Data collection

The data for the online survey was collected using survey software SurveyMonkey® and the telephone interviews were recorded using an audio device. Interviews were chosen as the method of data collection as it would allow for maximum individual clarity on this sensitive topic, because participants within a focus group can be influenced by other participants.

Participants were provided with an information sheet explaining to that there were "*No right or wrong answers*" and that their answers would be treated confidentially. The study was conducted in accordance with General Data Protection Regulations and was approved by the Faculty of Medicine, Health and Life Sciences Research Ethics Committee and consent was obtained from each respondent (Ethics code: MHLS 20_123).

Forty-two respondents completed the online survey and, of these, 28 respondents completed the follow-up telephone interview between February and June 2021.

Online survey measures

Closed-ended questions

"Capability" is defined as an individual's psychological and physical capacity to engage in the behaviour concerned. To measure participants' "knowledge" 7 items were adapted from Moreno and colleagues (2014) and Kramer and colleagues (2017). The participants were asked, "*To the best of your knowledge, do you think these statements are true or false?*" and answers were measured on a dichotomous scale of "*True*" or "*False*". In addition to the dichotomous scale, after each item participants were asked, "*How sure are you that the answer you gave is correct?*" and answers were measured on a 5-point Linkert confidence scale where "*Very unsure*" and "*Very sure*", to eliminate guessing. Participants' objective knowledge score was recoded into a new variable for objective knowledge items; combining responses from the dichotomous "yes/no" scale and confidence scale. For example: incorrect answer = 0; correct answer + very uncertain = 1; correct answer + quite uncertain = 2; correct answer + slightly uncertain = 3; correct answer + slightly uncertain = 4; correct answer + very uncertain = 5. The recoded individual objective knowledge variables based on the correct answer and confidence in answer provided ranged from 0 to 5, with a higher score indicating greater objective knowledge. Due to this scoring system, for scaled objective knowledge scores for 7 items, subsequent scores could range from 0 to 35, with a higher score indicating higher objective knowledge.

To measure "procedural knowledge" (knowing how to perform a particular task) 7 items were developed centred around the "6 Rs" of responsible AMU (iNAP, 2018). Items included "*I am able to identify the correct antibiotic for an infection*" and "*I am able to calculate and administer the correct duration the antibiotics are used for*". Items were scored on a scale from 1 ("*Unskilled*") to 7 ("*Highly skilled*"). Summed scores ranged from 7 to 49, with a higher score indicating a greater procedural knowledge in relation to responsible AMU.

"Intentions towards AMU" was measured using 3 items adapted from Francis and colleagues (2004), such as "*I intend to … Encourage the implementation of alternative methods to using antibiotics e.g., use of vaccines*". Items were scored from 1 ("*Strongly disagree*") to 7 ("*Strongly agree*"). Items were summed and ranged from 4 to 28, where a higher scored indicated a higher intention to implement responsible AMU practices.

Two items were included to assess the "level of concern of AMR" in relation to "*Animals' health/ human health*", adapted from Cotta and colleagues (2014). Items were scored on a 7-

point Likert scale from 1 ("*Not at all concerned*") to 7 ("*Extremely concerned*"). Scores could therefore range from 2 to 14, with a higher score indicating higher level of concern for AMR.

To measure "reinforcement of strategies that would encourage good AMU", 13 items were adapted from Kramer and colleagues (2017) and Visschers and colleagues (2015), such as "*Provide financial incentives or grants to support the use of alternatives to antibiotics*" and "*Assign one contracted vet to a farm*". The items were scored on a 7-point Likert scale from 1 ("*Not at all helpful*") to 7 ("*Very helpful*").

Open-ended questions

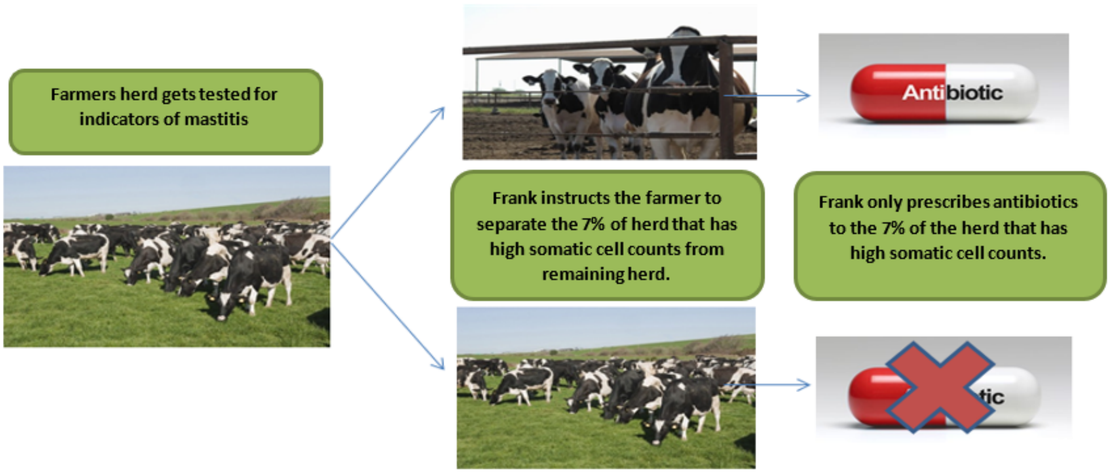
To obtain a greater depth of the "benefits of the proposed strategies", participants were asked 2 open-ended questions: "*What strategy do you feel would be the **most** effective in encouraging good antimicrobial practice? And why*?" and "*What strategy do you feel would be the **least** effective in encouraging good antimicrobial practice? And why*?" This approach will enable participants to tap into various domains within "motivation", such as belief about capabilities, beliefs about consequences, and emotions in relation to perceived effectiveness of strategy. In addition, this question could provoke the participant to delve into the domains of "opportunity", such as resources identifying very clearly the perceived barriers and facilitators of these strategies. This will be analysed thematically using NVivo® and coded and organised in relation to the constructs of the COM-B Model.

A literature review completed by Martin and colleagues (2020) identified specific common diseases where antimicrobials are relied on, for example blanket dry cow therapy in the dairy sector. To examine the participants' perceptions towards "responsible AMU on farms", 4 sector-specific vignettes were designed for the beef, dairy, pig and sheep sectors. (See Figure 11 for an example of selective dry cow therapy.)

Figure 11: An example of a vignette used to describe responsible antimicrobial usage on the farm in a behavioural analysis study to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland.

Dairy

Frank is a vet and his client is a dairy farmer getting ready to dry off his herd. Together with his client, they discuss the latest milk recordings for the herd. Only 7% of cows have high cell counts. Frank decides to prescribe the high cell count cows with dry cow antibiotic tubes but does not give antibiotic treatment to the remaining herd.



As many vets practice in a mixture of practices, participants were able to see the vignettes for all sectors.

Five open-ended questions followed, relating to the vignettes depicting responsible AMU. The first 3 questions included "*What are your views of these treatment plans*?", "*What would make you encourage a farmer to go down this treatment route?*" and "*What, if anything, would stop you from going down this treatment route?*" Framing the questions in this way will enable the author to identify facilitators and barriers to antimicrobial stewardship strategies. Additionally, the item *"What alternative treatment plans would you consider? And why?*" encourages the participant to discuss goals, plans and intentions with antimicrobial stewardship practices, within the "motivation" construct of the COM-B Model. Finally, participants were asked, *"How do you feel about suggesting treatment options to farmers that do not involve antibiotics?*". These questions were designed to elicit vets' perceptions towards responsible AMU practices, identifying the barriers and motivators for implementing such an approach, their own insights into alternative treatment plans they would consider, and communicating with farmers, as this stakeholder relationship is fundamentally important in creating and implementing strategies to reduce AMU in animals.

Sociodemographic and veterinary characteristics

Standard sociodemographic data was collected including age, gender and practice location (which county). In addition to the standard sociodemographic data, information detailing specific veterinary characteristics were included, such as role within practice, contract details (full-time or part-time), number of vets within the practice, years' experience, and in which sectors the participant practices veterinary medicine.

Interview questioning guide design and procedure

Based upon a review of previous literature (McKernan and colleagues, 2021, under review), the research team developed a semi-structured interview questioning guide consisting of open-ended questions. To facilitate a deeper understanding of vets' narratives, questions were classified and related to the constructs of the COM-B Model framework: capability, opportunity, motivation and behaviour.

The interview guide was piloted for clarity, comprehension reliability and timing with 4 individuals and refined before implementation. Questions were designed to elicit participants' perceptions regarding AMU and AMR to identify the motivators and barriers to encouraging responsible AMU, and obtain a better understanding of factors including perceived consequences of reduced AMU, sense of professional responsibility and influence of social relationships.

The interviews were led by 1 of 2 experienced interviewers (Dr Claire McKernan and Sarah Farrell) who had completed courses on qualitative data collection. Prompts were used, if necessary, to encourage elaboration, and to facilitate and redirect discussion.

Data analysis

Audio recordings were professionally transcribed word for word, checked for precision (Dr Claire McKernan and SF) and imported to qualitative data analysis programme NVivo® 10 (QSR International Pty Ltd, Victoria, Australia). Initially, to achieve data "immersion" (full familiarity with the information), transcripts were read repeatedly to generate general ideas on interesting aspects of the data. Two reviewers (SF and Dr Claire McKernan) independently coded 3 randomly selected transcripts and discussed coding to verify the validity and reliability of the data. After this, inductive thematic analysis was completed in accordance with Braun and Clarke's protocol (2006) to identify themes from the data set. Awareness, perceptions of reduced AMU, perceived professional responsibility, access to resources and impact of social relationships were coded systematically. Codes were then grouped into themes identifying overlap and commonalities and, where necessary, themes were refined to ensure distinctions between themes (that is, collapsed or divided), for example if specific codes could be combined/collapsed to an overall subtheme. Similarly to identify if the separation of themes is necessary, where a difference of codes within that theme is evident after reviewing exercises with the research team. For example, education sources were coded individually initially, then after reviewing codes and themes these codes were combined /collapsed into an overall education sub theme withing facilitators. At this stage transcripts were re-read to ensure no data has been overlooked at earlier stages of coding. The themes were reviewed and checked by a third researcher (Dr Tony Benson) with no refinements necessary.

To ensure observer reliability, discussions between 4 members of the research team experienced in qualitative data analysis (Dr Tony Benson, a psychologist; Professor Moira Dean, a consumer psychologist; Dr Claire McKernan, a natural scientist with social science training and experience and SF and Dr Edgar Garcia Manzanilla in social sciences) reached a consensus (Professor Moira Dean, Dr Tony Benson, SF and Dr Claire McKernan). Themes were defined and relationships between themes were formed, and appropriate quotes were extracted to illustrate views from each theme. Finally, transcripts were read a final time to ensure the themes represented the data set and appropriate quotations were selected for to exemplify each theme. Reviewers (Dr Claire McKernan and SF) agreed that data saturation has occurred (that is, no new information could be found in or derived from the data) as no new codes emerged from the final 10 interviews.

Similar to the interview data, open-ended responses collected from the online survey were analysed thematically in accordance with Braun and Clarke's protocol (2006). In addition, to complement the interview data, descriptive statistics were obtained on the close-ended questions from the survey using IBM® SPSS® Statistics version 26.0 for Windows (International Business Machines [IBM] Corporation, Armonk, New York, United States of America).

3.2.3 Task 2 results

Task 2 results: a) Critical literature review and qualitative secondary analysis

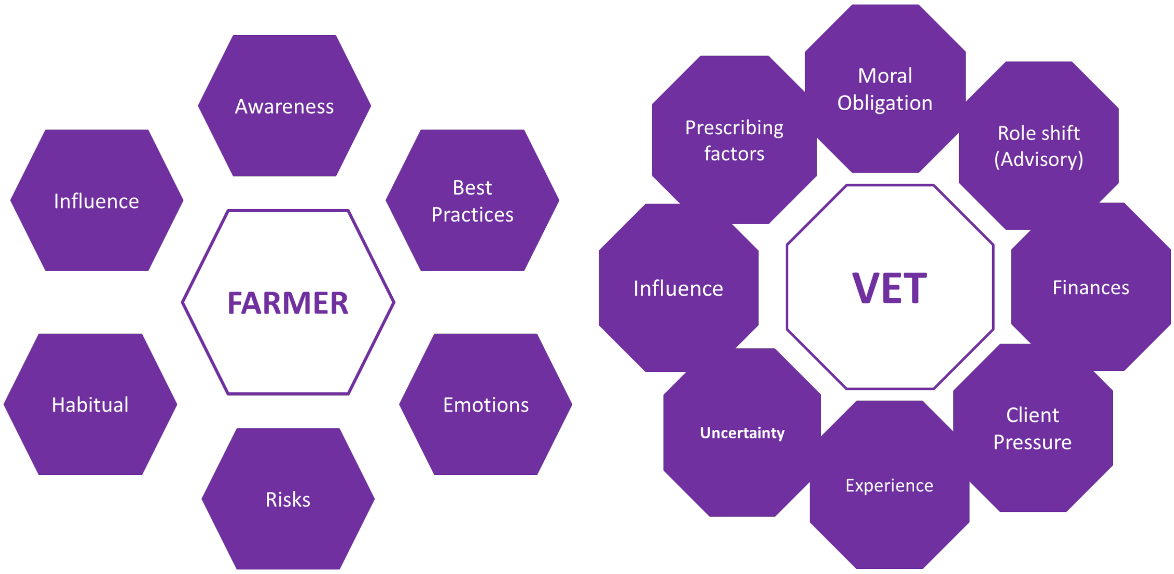
The findings from the literature review and the qualitative analysis provided insights for the themes to be then explored in the farmer and vet surveys. Key themes were identified relating to

- Knowledge and awareness of antimicrobials
- Attitudes towards antimicrobials
- Influential relationships
- Resources
- Factors that influence AMU

These themes were further broken down into subthemes of importance for farmer behaviour and vet behaviour (Figure 12).

The findings identified that the factors influencing behaviour with farmers and vets in relation to AMU are multifaceted and complex. As discussed, farmers' and vets' decision-making is based on a delicate balance of knowledge, finances, productivity, animal welfare, attitudes such as "optimism bias" (the difference between a person's expectations and what actually happens), perception towards disease risk and strategies, concern for AMR, access to resources and people's habits. Moreover, it is evident both farmers' and vets' motivation and justifications to make decisions on AMU and antimicrobial stewardship strategies is based on a continuous personal evaluation of these factors. Addressing any one of these aspects discussed for intervention design alone is not enough to encourage behaviour change. A full review of these findings is available in the critical review paper (McKernan and colleagues, 2021, under review).

Figure 12: Key themes of importance in exploring farmer and vet antimicrobial use practices.



Task 2 results b) Farmer survey

Participant characteristics

A total of 454 participants took part in the farmer survey exploring attitudes and identifying drivers, barriers and facilitators to the use of antimicrobials and alternatives in animal health on the IOI. During the data "cleaning" process, partially completed responses were removed (n = 62). The final sample included 392 participants, predominantly male (88 per cent) and equally represented across NI (46 per cent) and Ireland (54 per cent). Age ranged from 20 to 83, with a mean age of 45.6 years (SD = 13.22 years). The majority of participants had obtained a Certificate in Agriculture (a Level 6 qualification commonly known in Ireland as the "Green Cert") or equivalent in agricultural education (70 per cent) and were married (75 per cent). A complete overview of sociodemographic characteristics of the sample is in Appendix 3. Statistical analysis was run to ensure that the different sample collection methods (online, telephone and postal) did not influence survey responses.

Measures

Cronbach's alphas were used to assess internal reliability of the psychological scales measured in the farmer survey. A Cronbach's alpha value greater than 0.7 is considered satisfactory. A value of 0.6 or higher shows acceptable reliability (Fornell and Larcker, 1981). A

Cronbach's alpha of 0.6 to 0.7 has been shown to be acceptable in nonclinical samples (Hair and colleagues, 1998; Bland and Altman, 1997; Rattray and Jones, 2007). Table 8 contains more information on scaled items measured in the farmer survey.

Table 8: Descriptives of psychological scales and Cronbach's alphas used to measure attitudes and identify drivers, barriers and facilitators to the use of antimicrobials and alternatives in animal health on the IOI, in a survey of 392 farmers

Variable (descriptive of psychological scale)	Number of items on scale	Possible range of score	Mean score, and standard deviation (SD)	Number of participant farmers	Cronbach's alpha (α)
Behaviour	-	-	-	-	-
Engagement in responsible antimicrobial use	12	14–70	59.28 (5.34)	374	0.65
Capability	-	-	-	-	-
Subjective knowledge	4	4–20	15.83 (2.09)	392	0.70
Objective knowledge	7	0–35	25.59 (6.41)	392	0.718
Motivation	-	-	-	-	-
Perceived blame	4	4–20	13.90 (3.02)	392	0.81
Level of concern	3	3–15	10.69 (2.88)	392	0.89
Perceived risk	4	4–20	11.61 (3.19)	392	0.89
Professional identity	3	3–15	12.53 (1.90)	392	0.85

Professional responsibility	12	12–60	4.96 (7.87)	392	0.89
Emotions	3	3–15	12.17 (2.73)	392	0.86
Self-efficacy	3	3–15	11.88 (2.34)	392	0.88
Opportunity	-	-	-	-	-
Reinforcement	7	7–35	25.38 (5.51)	392	0.79
Social support	9	9–45	23.69 (4.55)	392	0.644
Peer support	6	6–30	15.03 (4.71)	392	0.895
Social pressure	5	5–25	13.58 (3.55)	392	0.77

Capability

Participants believed they had a relatively good knowledge of responsible AMU, with a mean score of 15.83 (range between 4 and 20); this was complemented with the relatively high objective (actual) knowledge score reported in this survey, with a mean score of 25.59 (range between 0 and 35). Furthermore, the majority of participants declared that they are aware of the consequences of AMR (more than 87%) and the concept of "One Health" (more than 70%). Pearson's correlations found that objective knowledge is significantly correlated with subjective knowledge ($r = -0.272$; p =** , where correlation is significant at <0.01 level).

Motivation

Participants were concerned about the impacts of AMR, with a mean score of 10.69 (range 3 to 15), and the perceived risk of AMR was substantial, with a mean score of 11.61 (range 4 to 20). The level of concern score for "*My family and me*" was highest in terms of concern regarding AMR (M = 3.70, SD = 1.06), in comparison to perceived risk of AMR to "*My family and me*", where likelihood for AMR is considered low (M = 2.83, SD = 0.10).

In descending order, participants believed antibiotics were used too much in human medicine (M = 3.66, SD = 0.90), in other agricultural sectors (M = 3.59, SD = 0.87) and in their own sector (M = 3.23, SD = 1.02).

When participants were asked to identify groups that were responsible to "*Take action*" to reduce the risk of AMR, participants scored 8 groups as "*Very responsible or responsible*": "*Farmers in my sector*" (M = 4.17, SD = 0.81), "*Farmers in other sectors*" (M = 4.22, SD = 0.80), "*Government departments*" (M = 4.24, SD = 0.92), "*Medical doctors*" (M = 4.24, SD = 1.00), "*Vets*" (M = 4.35, SD = 0.084), "*Scientists*" (M = 4.27, SD = 0.90), "*Pharmaceutical companies*" (M = 4.43, SD = 0.83) and "*Public organisations, e.g. NHS*" (the UK National Health Service) (M = 4.26, SD = 0.89).

Generally, participants had positive attitudes ("emotions") towards changing antibiotic usage practices, with a mean score of 12.17 (range between 3 and 15) and believed that they would be able to make changes on the farm ("self-efficacy"), with a mean score of 11.88 (range between 3 and 15). Pearson's correlation found a strong significant relationship between self-efficacy and emotion (r = 0.569, p =** where correlation is significant at <0.01 level).

Over 64 per cent of participants reported that they had successfully made changes to AMU or had started to make changes to how they used antibiotics on their farm, while 20 per cent (n = 75) reported that they have no intentions to change AMU.

Table 9: Results of questionnaire items relating to "motivation" that were scored on a 5-point Likert-type scale used to measure attitudes and identify drivers, barriers and facilitators in the use of antimicrobials and alternatives in animal health on the IOI, in a survey of 392 farmers

Variable (farmer survey questionnaire item)	**Mean score, and standard deviation (SD)**	**Scale range**
Farmer behaviour (14 items measured)	-	Never (1) – Always (5)
I follow the dosage instructions given by the vet when using an antibiotic	4.86 (0.43)	
I follow the instructions given by the vet on how to administer an antibiotic	4.89 (0.31)	

I follow the instructions for storing antibiotics safely (for example, refrigeration)	4.64 (0.64)	
I store antibiotics in a secure location such as a locked fridge or medicine cabinet	4.35 (1.00)	
I follow the instructions for disposing of antibiotics safely once they are expired or empty	4.15 (1.08)	
I record the antibiotic usage on my farm	4.59 (0.68)	
If the animal looks better, I stop the antibiotic before the end of the prescription	1.99 (1.13)	
I give the full course of antibiotics as written in the prescription	4.49 (0.71)	
I keep a stock of antibiotics on my farm to treat common diseases	3.56 (1.29)	
Giving antibiotics to animals to prevent disease ("*blanket use*") is part of my animal health management routine	1.96 (1.24)	
If an animal gets sick, I give antibiotics to the whole group to prevent the spread of disease	1.58 (.083)	
I share antibiotics with other farmers if they are stuck	1.38 (0.72)	
I get the antibiotics I use on my farm directly from a vet	4.84 (0.60)	
When animals get sick, I use antibiotics before consulting a vet	2.86 (0.98)	
Perceived blame (4 items measured)		Strongly disagree (1) –
I believe antibiotics are used too much in agriculture	3.42 (0.99)	
I believe antibiotics are used too much in human medicine	3.66 (0.90)	

I believe antibiotics are used too much in my sector	3.23 (1.02)	Strongly agree (5)
I believe antibiotics are used too much in other sectors	3.59 (0.87)	
Level of concern (3 items measured)		Not at all concerned (1) – Extremely concerned (5)
How concerned are you about antibiotic resistance for your animals' health?	3.44 (1.00)	
How concerned are you about antibiotic resistance for human health?	3.54 (1.11)	
How concerned are you about antibiotic resistance for you and your family's health?	3.70 (1.06)	
Perceived risk (4 items measured)		Very low (1) – Very high (5)
The risks to the average person of antibiotic resistance are ...	3.06 (0.87)	
The risks to the average farm animal of antibiotic resistance are ...	3.12 (0.89)	
The risks to my animals of antibiotic resistance are ...	2.61 (0.98)	
The risks to my family and me of antibiotic resistance are...	2.83 (0.10)	
Professional identity (3 items measured)		Strongly disagree (1) – Strongly agree (5)
A good farmer is progressive in using new farming approaches and strategies	4.09 (0.79)	
A good farmer makes decisions based on evidence and data	4.29 (0.65)	
A good farmer keeps up to date with the latest scientific advice and recommended practices	4.15 (0.73)	
Professional responsibility (12 items measured)		

Food consumers	2.89 (1.13)	Not at all responsible (1) – Extremely responsible (5)
Food processors / manufacturers	3.67 (1.06)	
Restaurants / fast food chains / caterers	3.00 (1.20)	
Farmers in my sector	4.17 (0.81)	
Farmers in other sectors	4.22 (0.80)	
Retailers	3.21 (1.17)	
Government departments (including DAFM, DAERA)	4.24 (0.92)	
Medical doctors	4.24 (1.00)	
Veterinarians	4.35 (0.84)	
Scientists	4.27 (0.90)	
Pharmaceutical companies	4.43 (0.83)	
Public organisations (for example, NHS in the UK, Health Service Executive [HSE] in Ireland, WHO)	4.26 (0.89)	
Emotions (3 items measured) *If you had to stop blanket use of antibiotics, and make the same changes as John on your farm, how do you think it would make you feel?*		Dissatisfied/ Foolish / Worried (1) – Satisfied / Wise / Calm (5)
Dissatisfied / Satisfied	4.19 (0.90)	
Foolish / Wise	4.24 (0.93)	
Worried / Calm	3.74 (1.15)	
Self-efficacy (3 items measured)		

If I had to stop the blanket use of antibiotics, I am confident that I can make changes similar to John on my farm	3.98 (0.90)	Strongly disagree (1) – Strongly agree (5)
If I had to stop the blanket use of antibiotics, I am confident that I would know what to do	3.87 (0.89)	
I If I had to stop the blanket use of antibiotics, I believe I have the ability to make changes similar to John	4.02 (0.81)	
Reinforcement (7 items measured)		Not at all helpful (1) – Extremely helpful (5)
New government financial grants to support antibiotic reduction on farms	3.62 (1.24)	
Subsidised vaccination programmes	4.09 (0.99)	
Publish national averages for antibiotic use across sectors	3.27 (1.23)	
New policies and regulations to restrict antibiotic use on farms	2.79 (1.27)	
Consumers paying more for produce coming from farms that have proven responsible antibiotic use	3.98 (1.12)	
A quality assurance scheme that would include using a new label or logo to alert consumers to produce coming from farms that have proven responsible antibiotic use	3.43 (1.35)	
A farmer receiving a financial bonus from the processor for taking action to reduce their antibiotic use on the farm	4.19 (1.05)	

Opportunity

When participants were asked what would help to make changes on the farm, subsidised vaccination programmes (M = 4.09, SD = 0.99) and farmers receiving a financial bonus from the processor for taking action to reduce their antibiotic use on the farm (M = 4.19, SD = 1.05) were considered the most helpful. The introduction of new policies and regulations to restrict AMU was considered unhelpful (M = 2.79, SD = 1.23).

In terms of services that farmers made use of from veterinarians, 96 per cent of participants used vets to prescribe medication to treat animals. In close succession, 78 per cent of respondents used advice on herd-health management and 73 per cent used vets for laboratory testing, with over 60 per cent of participants seeking vets to make herd-health plans and launch vaccination programmes.

In terms of Farm Advisory Services that farmers made use of, discussion groups, nutrition advice and herd-health management were the top services frequently sought of farm advisors. Discussion groups were the most common source of information (33 per cent). Interestingly, after discussion groups the most common selection was "*None of the above*"; this may suggest that other channels, such as word of mouth, tacit (implied and unspoken) knowledge and personal experiences with practices, may be important for farmers.

Over 70 per cent of participants have been to an event where antibiotic resistance on farms was discussed and have learned about AMR. A one-way ANOVA showed that the effect of years' experience on social support was significant: the "F-value" F (2, 239) = 14.61, p = below 0.000. ANOVA uses the F-test statistic as a ratio of the between group and within group variances. To determine whether the variability between group means is significantly different. If that ratio is sufficiently large, you can conclude that not all the means are equal.

Post-hoc analyses using Bonferroni criteria for significance indicates that the mean score for younger farmers with fewer than 20 years' experience (M = 25.00, SD = 4.44) was significantly different to the farmers with more than 31 years' experience (M = 22.25, SD = 4.54). However, the middle group, with 21 to 30 years' experience, did not significantly differ from the younger or older group of farmers (M = 24.10, SD = 4.11).

Similarly, a one-way ANOVA showed that effect of years' experience on peer support was significant: F (2, 389) 9.47, p less than 0.000. Post-hoc analyses using Bonferroni criteria for significance indicates that the mean score for younger farmers with fewer than 20 years' experience (M = 15.93, SD = 4.49) was significantly different to the farmers with more than 31 years' experience (M = 13.76, SD = 4.07). However, the middle group, with 21 to 30 years' experience, did not significantly differ from the younger or older group of farmers (M = 15.70, SD = 4.07).

Behaviour

Overall, the responsible AMU score is quite high, with a mean score of 59.28 (range between 14 and 70). The majority of participants (53 per cent) indicated that they record their AMU immediately after usage. Moreover, the majority of participants have indicated that they have made changes that reflect responsible AMU on the farm, and this correlated with the intentions reported in the "motivation" section of the survey.

Hierarchical multiple regression analysis

Table 10 summarises the results of a hierarchical multiple regression analysis predicting the relationship between sociodemographic characteristics in addition to psychological constructs of the COM-B Model including capability, opportunity and motivation in relation to responsible AMU behaviour (the "dependent variable" factor). The baseline model included sociodemographic factors, which accounted for 4 per cent of the variance in responsible behaviour scores, with a significant contribution (p less than 0.01). The addition of "capability" variables to the model explained a further 2 per cent of the variance, with a significant contribution (p less than 0.01). The addition of "motivation" variables to the model explained a further 7 per cent, with a significant contribution (p less than 0.001). In the final model additional variables related to "opportunity" were added and this accounted for 13 per cent of the variance in responsible AMU behaviour. The variables contributing most significantly to explain the variance in the final model include "years' experience", "farm size", "subjective knowledge" and "emotions".

Table 10: Hierarchical multiple regression predicting responsible antimicrobial usage behaviour in a study to assess knowledge, attitudes and behaviour in relation to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland

Variables	Model 1 (Sociodemographic)	Model 2 (Capability)			Model 3 (Motivation)		Model 4 (Opportunity)	
	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Education level	-0.325 (0.616)	-0.28	-0.475 (0.612)	-0.040	-0.479 (0.599)	-0.041	-0.470 (0.599)	-0.040
Years' experience	0.064 (0.021)	0.161**	0.062 (0.020)	0.157**	0.052 (0.020)	0.132*	0.047 (0.021)	0.119*
Farm size	-0.718 (0.268)	-0.135**	-0.635 (0.267)	-0.120*	-0.540 (0.259)	-0.102*	-0.477 (0.262)	-0.090
Sector (dairy against non-dairy)	-0.278 (0.543)	-0.26	-0.284 (0.537)	-0.026	0.112 (0.531)	0.0102	0.067 (0.537)	0.006
Subjective knowledge			0.355 (0.134)	0.139**	0.261 (0.133)	0.102	0.265 (0.133)	0.103*
Objective knowledge			0.043 (0.044)	0.052	-0.016 (0.045)	-0.020	-0.018 (0.045)	-0.021
Level of concern					0.178 (0.111)	0.096	0.194 (0.111)	0.105
Perceived risk					-0.043 (0.096)	-0.026	-0.023 (0.096)	-0.014

Professional identity					0.044 (0.155)	0.016	0.077 (0.157)	0.027
Professional responsibility					0.049 (0.037)	0.073	0.061 (0.037)	0.091
Emotions					0.334 (0.120)	0.168**	0.360 (0.124)	0.181**
Self-efficacy					0.194 (0.139)	0.086	0.213 (0.139)	0.094
Reinforcement							-0.057 (0.056)	-0.059
Social support							0.019 (0.072)	0.017
Peer support							-0.098 (0.069)	-0.087
Social pressure							-0.061 (0.078)	-0.041
F	4.995**	5.230**			5.140***		1.360	
Adjusted R^2	0.040**	0.061**			0.129***		0.132	

* P<0.05, ** P<0.01, *** P<0.001.
B: Unstandardised Coefficients

SE: Unstandardised Coefficients Standard Error
β: Standardized Coefficients Beta
F test: assess the null hypothesis that the change in R^2 is 0
Adjusted R^2 explains the variation in the dependant variable as accounted for by the independent variables and adjusted for the quantity of the independent variables in the model.

Task 2 results: c) Vet online survey and interviews

Online survey (quantitative data)

Participants had comprehensive procedural knowledge and considered themselves as "skilled" in relation to responsible AMU, with mean scores for individual items ranging from 5.87 to 6.64 on a scale of possible scores ranging from 1 to 7. The majority of vets reported an intention to use antibiotics responsibly within their practice (M = 6.47, SD = 0.57), and intended to encourage the implementation of alternative methods such as vaccines (M = 6.65, SD = 0.64). Vets were highly concerned about AMR for humans (M = 6.06, SD = 1.31) and animals (M = 5.66, SD = 1.36). Helpful measures included tailored herd-health plans and routine veterinary visits (M = 6.47, SD = 0.89), improved diagnostic and susceptibility testing procedures (M = 6.29, SD = 0.99) and the provision of financial incentives to support the use of alternatives to antibiotics, such as vaccines and anti-inflammatories (M = 6.12, SD = 1.27). Uncoupling veterinary prescribing from the sale of antibiotics was not considered helpful (M = 1.78, SD = 1.49).

Table 11: Results of questionnaire items that were scored on a 7-point Likert-type scale used to measure knowledge, attitudes and behaviour and identify drivers, barriers and facilitators in relation to use of antimicrobials and alternatives in animal health on the IOI, in a survey of 42 veterinarians

Variable (vet online survey questionnaire item)	Mean score, and standard deviation (SD)	Scale range
Procedural knowledge (9 items measured)		
I am able to identify the correct antibiotic for an infection	5.95 (0.99)	

I am able to calculate the correct dose of antibiotics for animals	6.64 (0.60)	Unskilled (1) – Highly skilled (7)
I am able to calculate and administer the correct duration the antibiotics are used for	6.37 (1.08)	
I am able to record relevant antibiotic usage information for each farm within my practice	5.87 (1.57)	
I am able to monitor and record antibiotic use within my practice	5.81 (1.48)	
I am able to comply to antibiotic protocols when treating animals	6.27 (1.00)	
I am able to educate farmers about the use of alternative therapies to treat common diseases on their farm (for example vaccines, anti-inflammatories)	6.27 (1.05)	
Intentions (4 items measured) I intend to …		Strongly disagree (1) – Strongly agree (5)
… Reduce antibiotic use in my practice	5.96 (1.21)	
… Use antibiotics responsibly in my practice	6.73 (0.57)	
… Adhere to antibiotic selection protocols and recommendations before prescribing antibiotics (for example, susceptibility and diagnostic testing)	5.58 (1.22)	
… Encourage the implementation of alternative methods to using antibiotics (for example, use of vaccines)	6.65 (0.64)	
Level of concern (3 items measured) How concerned are you about antimicrobial resistance for …		Not at all concerned

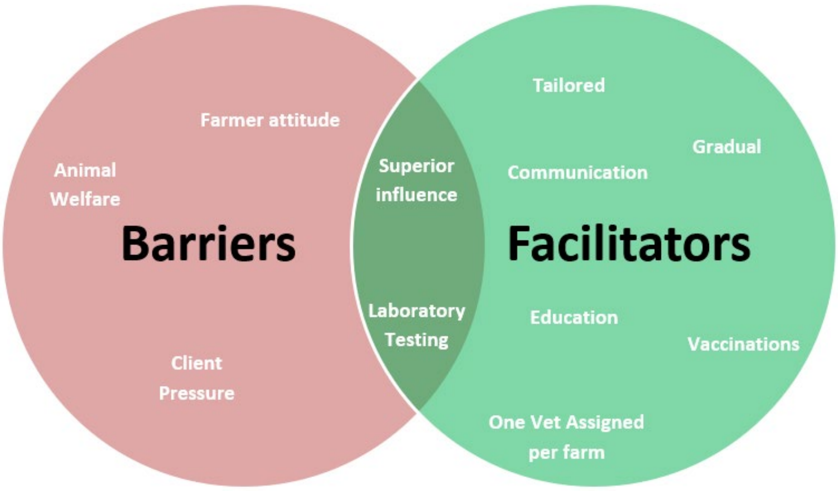
… Humans	6.06 (1.31)	(1) – Extremely concerned (5)
… Animals	5.66 (1.36)	
Reinforcement (13 items measured)		Not at all helpful (1) - Extremely helpful (7)
Put in place new policies and regulations to restrict antibiotic use	5.45 (1.67)	
Implement legal action should policies and legislation not be adhered to	4.81 (2.22)	
Provide financial incentives or grants to support the use of alternatives to antibiotics	6.12 (1.27)	
Change current procedure where veterinarians profit from antibiotic use	1.78 (1.49)	
Provide educational training programs for all farmers on antibiotics and preventing infectious disease	5.90 (1.35)	
Provision of tailored herd-health plans and routine visits for clients	6.47 (0.89)	
Assign one contracted vet to a farm	5.23 (2.09)	
Publish antibiotic usage data on each farm 3 times a year	4.83 (1.96)	
Improve diagnostic and susceptibility testing procedures	6.29 (0.99)	
Provide training and support to improve communication skills of vet	5.69 (1.55)	
Compulsory continuing professional development for veterinarians on antimicrobial use	4.61 (2.03)	

Mandatory antibiotic use recording for farms	4.76 (1.49)	
Mandatory antibiotic prescribing recording for veterinary practices	5.45 (1.80)	

Interviews (qualitative data)

On analysing the transcripts no differences in responses from vets from different specialties (dairy, beef, pig, sheep) was observed. Therefore, the themes extracted from the dataset represents the views and opinion of vets in relation to reducing AMU on the whole. Several themes emerged from the dataset, including perceptions towards AMR in addition to interacting barriers and facilitators considered for responsible AMU. Five barriers emerged from the vet interview dataset, 2 of which overlapped into facilitators. In addition, 6 more facilitators were identified to enable responsible AMU (Figure 13).

Figure 13: A figure to show the subthemes of barriers and facilitators to the responsible use of antimicrobials and alternatives in animal health on the island of Ireland, revealed in interviews with 28 veterinarians.



Perceptions towards antimicrobial resistance.

i) Professional responsibility

During the interviews, it was evident that all participants had a good knowledge and awareness of the consequences of AMR. Vets discussed AMR as a drawback of AMU in agricultural and clinical settings, with the potential to reduce treatment efficiency and increase mortality rates in both humans and animals. Responses also highlighted that vets considered the consequences of AMR to be very serious, with vets believing that it was their professional responsibility to ensure antimicrobials are used responsibly. Furthermore, vets demonstrated commitment to changing practices on farms to alleviate AMU and advocated strategies to reduce AMU on farms.

Participant 2.27.7.20: "I would say my duty is reducing antimicrobial usage. Theoretically that would reduce resistance ... So personally, I would see my responsibility. I would see that a poor vet would use high levels of medication."

Interestingly, while vets unanimously championed strategies to reduce AMU, a cohort of participants believed a generational divide existed within the profession in relation to AMU: younger vets believe they use antibiotics more responsibly and are more receptive and proactive in implementing antimicrobial stewardship approaches to reduce AMU in comparison to more experienced vets. Younger vets frequently cited that this was due to the focus of AMR in their curriculum during their years at university.

Participant D65G: "I actually think that this is an issue that will sort itself out as the older generation of veterinarians retire and the younger ones come in because, in my experience, younger vets are much more careful with their use of antimicrobials than older veterinarians."

However, while the vets demonstrated commitment to improving AMU on farms, they also acknowledged that some vets within the profession to do not hold the same values and attitudes towards AMU, suggesting that they are unwilling to change prescribing practices.

ii) Sectoral responsibility

While vets recognised the medical profession (both veterinary and human) as prescribers, they considered their professional role as "gatekeepers" governing antimicrobial prescription. Unanimously, vets considered that every individual using and prescribing antimicrobial treatment is responsible for AMR, thus it is a shared responsibility. Vets credited prescribers (vets and doctors) for overprescribing and end-users (farmers and patients) for not using antimicrobials correctly, contributing to AMR.

L30G: "Everybody that's involved, anywhere along the line of either prescribing antibiotics or given antibiotics, or if a person is taking them as well."

Barriers to reducing antimicrobial usage

i) Animal welfare

Vets identified a range of benefits and risks with reducing antibiotic usage on farms. Typically, they believed that improving farm management practices would improve overall herd health, thus reducing the need for antimicrobial treatment improving animal welfare. However, vets also believed that an abrupt stop in the use of antimicrobials on farms that are not ready for change will significantly compromise animal welfare and productivity.

Participant H59H: "It depends on the situation, like; so if you're reducing them because you have improved your management and don't need them anymore, that is great. If you're reducing them because you have been told that you have to, and nothing else has changed and you were quite reliant on them in the first place, then I think people are going to find themselves in a bit of trouble."

Furthermore, vets believed that the current regulations around antimicrobials were already stringent and are concerned that the introduction of new legislation to further restrict AMU would obstruct their ability to treat animals and consequently compromise animal welfare.

ii) Farmer attitude and readiness

Vets acknowledged that reliance on antimicrobials persists within farmers. Vets discussed that, historically, antibiotics were a convenient resource, with farmers preferring the assurance that prescribing antimicrobials provided them. Moreover, vets also discussed that farmers did not believe that reduced AMU was feasible on their farm.

Furthermore, vets acknowledged that farmers' attitude towards stewardship strategies is important before implementing strategies to reduce AMU. Vets believe that if a farmer is not invested in the changes themselves, or feels pushed to make certain changes, it could have significant repercussions such as animal fatalities. A negative experience of this nature would hinder farmers' confidence and trust in stewardship strategies in the future. Additionally, this negative experience has the opportunity to "spread" through the farming community, intensifying scepticism and uncertainty of these strategies.

H59H: "And not only in hypothetical terms, but if that happens, word spreads, everybody hears about that. And people will lose confidence in reducing antimicrobial use on their farm. Yeah, and the next farm could be perfect, it could be an excellent candidate to SDCT (selective dry cow therapy). But if they don't have faith in it, they are not going to try it!"

iii) Client pressure

The majority of vets felt pressure from clients to prescribe antimicrobials. Vets frequently experienced pressure to prescribe specific treatment plans to satisfy client expectations and preferences. For example, vets discussed that farmers feel more assured if an antibiotic was prescribed, and that farmers request a specific antibiotic treatment because it worked previously.

Interestingly, in addition to experiencing client pressure, the majority of vets indicated that many farmers “shop around” for antimicrobials: if a farmer does not receive the antibiotic that they desire, they will go to another practice. This in turn fuels the vet’s pressure to prescribe, as there is a potential loss of clients and revenue for their business. Vets acknowledged that farmers’ ability to “shop around”, coupled with client pressure for antimicrobials, intensifies competitiveness between practices. Thus, vets prescribed to keep their clients satisfied and maintain their relationships and reduce the risk of clients going to a competitors’ practice.

> P15P: “We have had farmers coming in asking for some of the drugs we’ve talked about and have said, ‘Sorry, we can’t really use them anymore’, and they say, ‘Okay, that’s fine’, and then you’re out on farm a while later and you find bottles supplied by someone else.”

iv) Superior influence amongst vets

Younger vets frequently discussed that more experienced vets influenced their treatment plans in a negative manner, and on occasion vets felt pressured to follow treatment plans that were against their own judgement and with which they were not comfortable.

Younger vets also cited that with increased experience outside of university, younger vets gain the confidence and trust with both veterinary colleagues and farmers and thus do not succumb to the pressure of their seniors. Moreover, younger vets indicated that the “type of boss you have” and how the “boss” (the leading practice vet) portrays you (the junior vet) to clients is a fundamentally important factor in relation to client trust.

L25S: "And I suppose, at the start, I was probably pressured into it but now – I don't know, I don't see the benefit of that … I used to worry, but not anymore. I just, you know, I just do my own thing now but, like, that takes time, you know; you know, when you do a bit of experience and confidence, it's easier to make your own decisions. But definitely, at the start, when you have just graduated – if your boss is saying all every cow needs, you know, it's very hard to break away from that, like, you know. It just depends what type of boss you have."

While some vets felt the pressure to prescribe certain treatment plans from superiors, many others had a positive experience with their superiors. Vets in these circumstances felt supported and able to discuss issues with colleagues openly to make an informed decision about a treatment plan.

Interestingly, while occasionally vets discussed superior influence as a key barrier of responsible AMU, a cohort of vets have also discussed a significant shift within veterinary practices, where younger vets have demonstrated to more experienced vets that the reliance on antimicrobials is not essential, and now more experienced vets look to the younger vets for advice on preventative management practices.

v) Laboratory testing

Laboratory testing is considered a good resource to assist vets in their clinical diagnosis. Susceptibility and diagnostic testing facilitate vets to be able to make an informed decision about treatments plans. However, there are conflicting views about the accessibility of these services to vets, with some vets considering the access to be satisfactory and others believing the access is poor.

While vets consider the information provided by laboratory testing as valuable, they also feel that laboratory testing is often impractical due to the time taken to get test results back.

Vets discussed that delayed results are a significant barrier that could prolong animal suffering. Additionally, vets feel that the delayed treatment time, coupled with the additional cost, can make it difficult to persuade farmers to avail of this service.

Facilitators to reducing antimicrobial usage

i) Gradual change

As discussed earlier, while many vets desired reduced AMU on farms, they worried that farmers not taking the proper measure in place beforehand would significantly compromise animal welfare. Therefore, the majority of vets suggested that reducing AMU on farms should be incremental.

Taking a gradual and careful approach is beneficial for both farmers and vets. Such an approach proves to the farmer that the changes on farm are effective and feasible, thus providing the farmer more confidence in progressing further, implementing additional and perhaps more complex strategies. The benefit to this approach is two-fold: focused on maintaining animal welfare while improving overall herd health and reducing reliance on antimicrobials, and, at the same time, improving farm productivity and profitability. Moreover, a gradual approach is beneficial for a vet as they are able to monitor effectiveness in a controlled manner; therefore, should a disease outbreak occur, they would be able to control and manage it promptly.

531720: "Yeah, they might be inclined to pick up the phone to you the next time, saying, 'Well, you said *do this* and we're not going down that line again'. So, it's just a matter of, again, just trying to prove to them that they don't need it, and to do it nice and gradual, and see that approach to it. And also, then, if there is a problem, that hopefully they can get in quite quickly and straighten it out rather than have a massive problem with it … And building up that relationship, and going in with the vaccine, and pushing that into things –

I think there is certainly … We give them a chance, and they start to see the benefits of it, and obviously that will encourage them then to do a bit more and a bit more."

ii) Communication

Vets reported that communication with farmers is a vital component to encourage changes on farms to reduce reliance on AMU. Vets believe that facilitating open discussion with farmers has benefits as it can create a joint venture, eliciting feeling of investment in both farmer and vet. In addition, it instils farmers with confidence in their abilities to successfully implement antimicrobial stewardship strategies, encouraging them to adopt more. Promotion of open communication amongst peers (other farmers) is beneficial as "hearsay" about strategies employed on farm is a significant influencer on whether other farmers will incorporate strategies into their own farm.

227720: "Usually the farms coming from a reducing medication usage and going antibiotic-free, many farmers are very positive about that. As soon as there's talk about going antibiotic-free, if they think that that's your aim and it's possible then they're very positive about it."

iii) Tailored approach

Many vets acknowledged every farm is individual, recognising that a treatment plan could be successful on one farm but may be unsuccessful on another. Subsequently, the majority of vets indicated that having previous experience on a farm and access to farm history records is an important factor when it comes to both treatment choice and promotion of antimicrobial stewardships.

With all the factors reported taken into account, including farm individuality and communication, vets believed that a "tailored" approach would be most effective to encourage better farm management practices, such as mandatory "herd-health visits". A tailored approach would combine an individual approach suitable for a farmer's capabilities and in relation to the farmer's attitude and the facilities available, strengthened with communication from vets to discuss and agree on goals and plans.

T87l: "But I definitely think opening the communication between farmers and vets is important: we make plans *together*, we can talk things through *together*."

iv) Assign one vet to a farm

As discussed earlier, vets frequently cited a farmer's ability to "shop around" for antibiotics from numerous practices as a significant barrier when it comes to using antimicrobials responsibly. Therefore, it is unsurprising that vets believed that assigning one vet to a farm and incorporating a consultation-based approach as described (a "tailored approach") would significantly improve farm management practices, thus alleviating reliance on AMU. Vets believed that assigning one vet to a farm will promote communication, reduce competition among practices and so on.

65820: "But I think, realistically, on that, that you have to have, I would say, a legislative structure that puts into a position that effectively at any one time a farmer has one nominated vet ... I don't know what is going on, sometimes. I don't know what medicines the farmer is using or what he has tried."

v) Education

Education was commonly suggested as a means to improve responsible AMU for both vets and farmers. While vets acknowledged that the concept of AMR is complex and multifaceted, they believe that providing information to a farmer in a relatable manner using various different platforms such as informal presentations from veterinarians, formal training and education from farms already demonstrating responsible antimicrobial use would prove effective at increasing awareness of the consequences of continuous, imprudent AMU.

vi) Vaccinations

Vaccinations are considered one of the most effective interventions by vets. Vets have discussed this as a positive alternative to substitute the reliance on antimicrobials to reduce disease incidence, thus alleviating reliance on antibiotics to treat common diseases. Moreover, vets also acknowledge that, should an animal get a disease, it is easier to treat as they have not previously relied on antibiotics. Vets sought for the development of vaccinations to help tackle the occurrence of common diseases on farms.

P15P: "We are big believers in vaccinations, here. We just done a tally and we have about 22,000 dairy cows in our practice, and we have sold 23,000 of a particular vaccine in the last year ... New vaccines that come out, the company vets will come around and do presentations to our farm team and explain the uses and protocols, etcetera."

3.2.4 Task 2 deliverables and outputs

The outcomes for the project "deliverables" (the specific work produced, or delivered, that enabled the objectives to be met) for Task 2 are shown in Table 12.

Table 12: Deliverable outcomes from Task 2, a behavioural analysis to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland

Task 2 deliverables	Task 2 outcomes

1. Critical literature review of behavioural research and interventions aimed at antimicrobial usage in animal health	Done
2. Qualitative secondary analysis of data on behaviours around antimicrobial usage in animal health	Done
3. Questionnaire development (Survey of farmers and veterinarians: Testing models of behaviour)	Done
4. Survey recruitment, data collection and analysis	Done
5. Refinement of “COM-B” behavioural models	Done

In addition to satisfying the deliverable outcomes of the project, there have been several opportunities to showcase and promote the valuable work undertaken within Task 2 of this project (Table 13).

Table 13: Promotional or “outreach” activities showcasing outputs from Task 2, a behavioural analysis to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to the use of alternatives in animal health on the island of Ireland

Outreach activity	Audience and description of activity	Title	Date
Media outreach	A 2-minute video shown at an international “webinar” (an online seminar) hosted by Virtual Vet.eu to mark World Antimicrobial Awareness Week 2020	Understanding attitudes and behaviours towards antimicrobials in agriculture	18–24 November 2020

Conference	Information poster at the 74th Association for Veterinary Teaching and Research Work (AVTRW) Conference	Use of antimicrobials in animal health on the island of Ireland: Knowledge, attitudes and behaviour	14–15 September 2020
Media outreach	Article in Agriland.ie ("Ireland's biggest farming news portal") to recruit survey respondents	Cross-border project to investigate Irish farmer attitudes towards antibiotics (Rachel Martin, 2021)	22 April 2021
Dairy stakeholder presentation	Chief Executive of the Dairy Council for Northern Ireland Dr Mike Johnston requested a presentation of the research completed by the ***safe*****food** antimicrobial usage project. This provided a platform to share the purpose of the research and make contacts with key stakeholder in Northern Ireland:	Use of antimicrobials in animal health on the island of Ireland:	18 May 2021

	Lakeland Dairies Dale Farm dairy cooperative Glanbia	knowledge, attitudes, and behaviour	
Conference	Presentation at the 75th Association for Veterinary Teaching and Research Work (AVTRW) Conference	Factors influencing responsible antimicrobial usage on farms	2–3 September 2021
Journal article	Article in the *Journal of Antimicrobial Chemotherapy: Antimicrobial Resistance,* Volume 3, article 4: dlab178. Available online at https://irishvetjournal.biomedcentral.com/articles/10.1186/s13620-020-00165-z	Antimicrobial use in agriculture: Critical review of the factors influencing behaviour (McKernan and colleagues, 2021)	30 November 2021

3.3 Task 3: Codesign of behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use

3.3.1 Task 3 objectives

For an intervention to be successful, it is critical to understand what components of the situation require change and what factors are shaping the behaviour. The current task aimed to build on the insights from Tasks 1 and 2 to codesign behaviour-change interventions for supporting good animal health practices and encouraging responsible AMU on farms.

The specific objectives of this task were to

- Gain insights from participatory stakeholder engagement processes to develop practice-ready strategies and tools for the responsible use of antimicrobials at farm level
- Synthesise the evidence to design behaviour-change interventions aimed at raising awareness and improving practices in relation to the use of antimicrobials in animal health
- Test acceptability and feasibility of behaviour-change interventions with end-users through multi-actor participatory engagement

3.3.2 Task 3 materials and methods

a) Stakeholder mapping participatory workshop

Workshop design

In March 2019, at the outset of the project, a participatory workshop was carried out with the research team and stakeholder advisory board. The aim of the participatory workshop was to identify all relevant actors with an interest and stake in AMU and AMR on the IOI and create a visual "stakeholder map". This served as a starting-point activity for identifying all relevant stakeholders who could then be contacted for engagement at appropriate points throughout the project.

Participants

Workshop participants (n = 12) included government representatives, microbiologists, animal health scientists, behavioural scientists and veterinary and farmer representatives.

Activities

Workshop participants took part in 3 linked activities:

- Stakeholder identification
- Group participatory sort
- Stakeholder matrix development

Working in 2 groups, participants engaged in a stakeholder identification "brainstorming" exercise. They were tasked with identifying all relevant stakeholders on the IOI who would have an interest in AMU and AMR in farming. They were provided with a collection of picture cuttings that could be used to prompt ideas and wider thinking and asked to write down a single stakeholder on a single Post-it® note and attach all notes to a single sheet of A0 paper. Participants were encouraged to be as thorough as possible in identifying stakeholders.

Next, a "group participatory sort" was carried out whereby both groups called out the stakeholders they had identified and, collectively, the 2 groups sorted the stakeholders into categories, providing names for each category. The end output was a list of stakeholder categories posted to a large sheet on a noticeboard.

Finally, participants engaged in populating a "stakeholder matrix". They were presented with a topic banner: "*Identifying solutions to try and reduce antimicrobial use for animal health management.*" The stakeholder categories (developed in the group participatory sort) were placed on the left-hand column of a matrix (labelled "*Who*") and participants were then invited to brainstorm "*Why*" for each row – what types of knowledge, resources or access might each stakeholder category bring to identifying solutions.

b) Stakeholder engagement

At the outset of the project, it was envisioned that stakeholder engagement would take place through a series of participatory workshops. However, with the emergence of the COVID-19 pandemic, holding face-to-face workshops was no longer feasible. Instead, one-to-one phone calls, smaller online meetings and interactive, online software were used to target relevant experts for specific aspects of the intervention codesign process. This flexible approach avoided online meeting "fatigue" and was deemed more appropriate for this form of codesign that requires deliberative, reflective and open engagement. It also took into account the shift in timing of the intervention development stage of the project, which fell in spring –

the busiest time of the year for farmers and vets. By providing a more flexible schedule, with one-to-one interactions, busy participants were able to find a time suitable to take part.

c) Codesigning behaviour-change interventions: Stakeholder consults

Synthesis of evidence to design behaviour-change interventions

Desk-based work synthesised the insights from Task 1 around the identification of AMU "hotspot" areas for behaviour change in the farming sector and from Task 2 relating to the developed COM-B models and their application to the Behaviour Change Wheel. Additional to this, a literature review of existing behaviour-change interventions in the human and animal fields of AMU and AMR was carried out.

Collectively, these insights were collated and used to develop a starting set of possible behaviour-change recommendations, interventions and tools that could be applied in policy and practice to reduce the misuse and overuse of antimicrobials in the livestock industries. These insights and starting ideas were used as prompts for further discussion in a series of stakeholder consults and key informant interviews with a range of stakeholders to further discuss, elaborate and refine potential behaviour-change ideas.

Participant recruitment

Through all stages of the project, efforts were made to adhere to the European Commission's guidelines on Public Engagement in Responsible Research and Innovation (European Commission, 2021). The recruitment of stakeholders aimed to be as inclusive as possible in respect to stakeholder type, gender and region to achieve diverse and "reflexive" thinking (being aware of one's own impartiality and assumptions when questioning or researching a topic) throughout the development of behaviour-change recommendations.

In line with the concept of "gendered innovations" (intending to overcome gender bias in research, with the aim of adding insight and new knowledge) particular emphasis was placed on ensuring inclusion of all genders in the intervention development process. "Purposive sampling" (deliberate and subjective) strategies were used to select key stakeholders for one-to-one interviews to discuss and codesign behaviour-change recommendations.

Stakeholder consults

All stakeholder consults were held through one-to-one or small group meetings by telephone or through ZOOM™ (Zoom Video Conferencing Incorporated, San Jose, California, United States of America). An unstructured approach was used for the consults, where ideas were exchanged and free dialogue took place to support idea creation and "bottom-up" feedback from the participants.

d) Refining behaviour-change interventions and testing acceptability and feasibility: Online, interactive exercise

Online, interactive exercise design

Following the evidence synthesis and the stakeholder consults, 7 behaviour-change interventions were developed and further elaborated. An online, interactive exercise was then carried out with a range of stakeholders to receive feedback and evaluation for further refinement. This exercise aimed to act as a user-driven sense-check to ensure that any planned interventions meet the "APEASE" criteria: **A**cceptability, **P**racticability, **E**ffectiveness, **A**ffordability, **S**ide-effects and **E**quity (fairness). The aim of the online, interactive exercise was to carry out a multi-actor "APEASE" assessment of general concepts for possible behaviour-change interventions for supporting responsible antibiotic use in farming.

Participant recruitment

The recruitment of stakeholders aimed to be as inclusive as possible in respect to stakeholder type, gender and region to achieve diverse and reflexive thinking throughout the development of behaviour-change recommendations. In line with the concept of "gendered innovations", particular emphasis was placed on ensuring inclusion of all genders in the intervention development process. Purposive sampling strategies were used to select key stakeholders to participate in the online exercise to evaluate and refine the behaviour-change recommendations.

Online, interactive exercise

Survey software platform SurveyMonkey® was used for the online, interactive exercise. Video software was integrated into the platform to make the online exercise an interactive experience for the participant, mimicking a dialogue between the research team and the stakeholder. When participants initially entered the survey, they were provided with an information sheet and asked to provide informed consent before continuing to the "welcome" page. Participants were then asked to enter some brief sociodemographic and background information.

A short video was then presented by the research team in the "welcome" page, giving the participants the background to the project and the intervention development process. Next, the participant was taken through a series of 7 video clips, 1 video clip per behaviour-change intervention idea. Each video lasted around 4 minutes and involved a researcher presenting the background and basics of the behaviour-change intervention idea. After each video, the participant was asked to provide their quantitative and qualitative feedback on that idea. The questions were asked in such a way so as to draw out feedback according to the "APEASE" criteria (Table 14).

The anonymous and individual nature of the online exercise supported honest and open evaluations of the recommendations and increased the number of stakeholders able to provide feedback. The nature of the exercise provided the opportunity for more in-depth, honest and open feedback, avoidance of online meeting "fatigue", and facilitated participants to complete the exercise at a time that suited the individual. Table 14: Open-ended questions asked in a multi-actor, online, interactive exercise to evaluate behaviour-change intervention ideas to promote and facilitate good animal health practices and responsible antimicrobial use, according to "APEASE" criteria

"APEASE" criteria	Open-ended question
Acceptability	How do you think this intervention would be received by others?
Practicability	What would need to happen in order for this intervention to work in Ireland / Northern Ireland?
Effectiveness	How effective do you think this intervention would be in the real world?
Affordability	What economic factors or costs, if any, would need to be considered in running an intervention like this?
Side-effects and Equity	What, if any, unexpected side-effects or spill-over effects could arise from this intervention? Think about both good and bad unintended outcomes that could occur.

3.3.3 Task 3 results

a) Stakeholder mapping participatory workshop

Stakeholder maps (Figure 14) were produced from the outputs of the participatory exercise identifying *who* the stakeholders are and *why* engagement with these stakeholders is important. These maps highlight the many different types of expertise, knowledge and perspectives relevant to the ***safe*food** project.

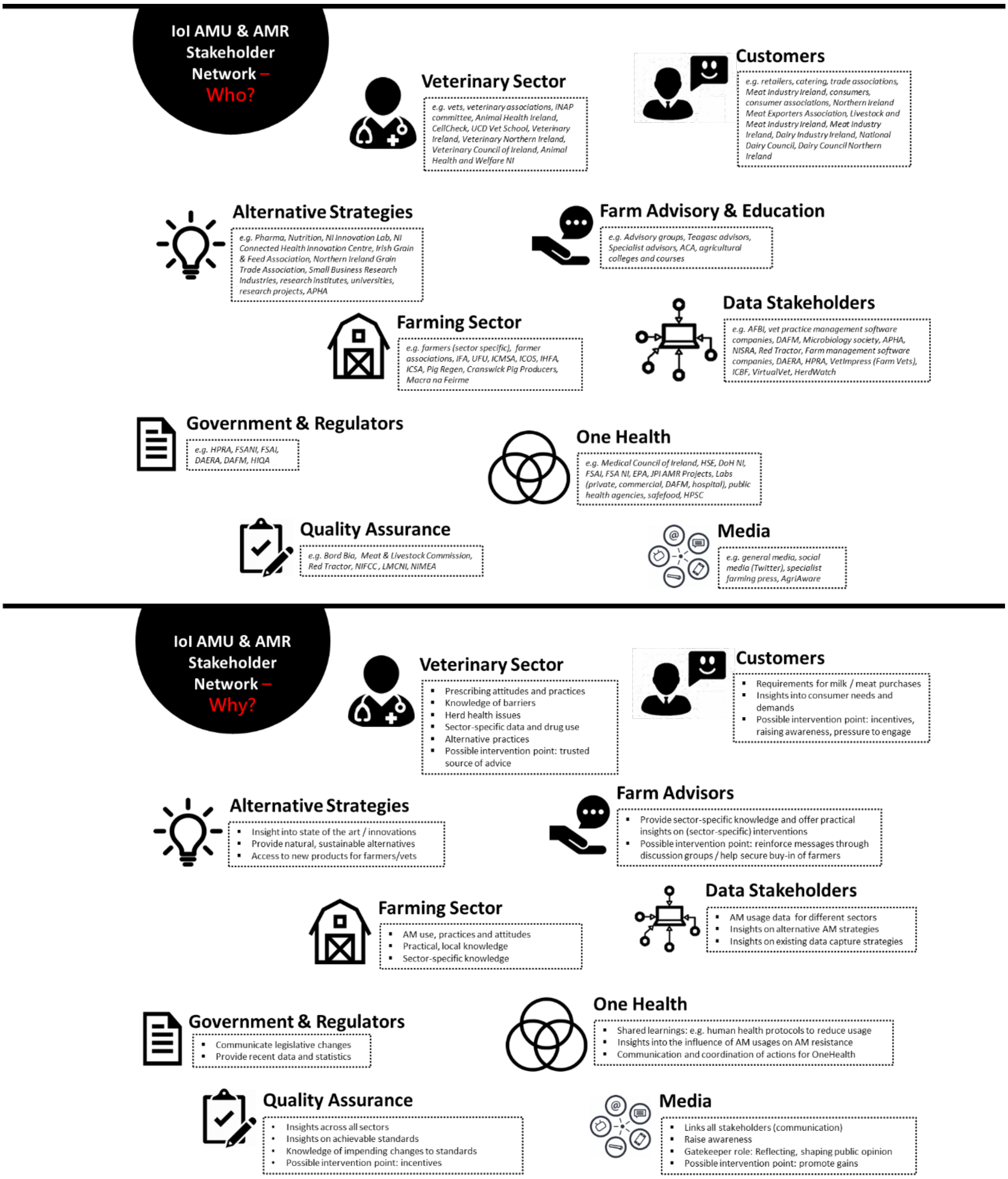


Figure 14: Stakeholder maps produced through participatory workshops, identifying relevant stakeholders interested in antimicrobial use (AMU) and AMR (antimicrobial resistance) on the island of Ireland.

b) Codesign of behaviour-change interventions

Synthesis of evidence to design behaviour-change interventions

Insights from Task 1 and Task 2 were collated along with those from a literature review carried out as part of Task 3. The literature review explored literature on current strategies, nationally and internationally, employed to reduce AMU and behaviour-change interventions that target the factors identified as influencing AMU behaviour in Task 2.

Limited research was found in the area of animal health AMU and behaviour change. This literature review highlighted a considerable lack of reported interventions to reduce AMU and AMR in animal health using a behavioural science approach. Although a considerable amount of literature was identified as part of Task 2 to identify key factors that influence AMU behaviours, taking the next step towards the development of an intervention using a behavioural science approach and behaviour-change techniques is quite novel to animal health.

An intervention development plan was formed with guidance from the Behaviour Change Wheel guide to intervention development. Task 3 took an inductive approach to intervention recommendation design, drawing on the stakeholder consults carried out. It also looked outside the discipline of animal health to find behaviour-change techniques that have a strong evidence base in changing the behaviours highlighted in Task 1 (such as monitoring of AMU and preventative use of AMU) and the driving factors highlighted in Task 2 (such as social support, self-belief in capabilities and knowledge) that influence farmers' and vets' prescribing and using of antimicrobials.

Based on the findings from Task 1 and 2, key actors identified to most significantly change AMU on farms included

- Farmers
- Veterinarians
- Farm advisors

It was decided that the target population for future intervention recommendations will be *farmers*, with *veterinarians* and *farm advisors* as key agents to deliver behaviour-change techniques (such as goal-setting and self-monitoring of behaviours).

Stakeholder engagement

In total, 70 stakeholders from a wide and diverse range of knowledge and expertise (Figure 15) provided formal input during the planning, development and evaluation of the intervention recommendations (Table 15). The gender breakdown was 43 males and 27 females, with representation from the farming community, veterinary sector, farm advisory and education, research and education, government and regulators and industry.

Given that intervention development was particularly focused on interventions with farmers, vets and farm advisors, stakeholder engagement was particularly concentrated on categories representative of these actors (Figure 15). Some stakeholders engaged with the project at different points throughout the project, resulting in a total number of 89 stakeholder consults during the intervention development process (Table 15).

The extent of each engagement activity was in-depth, with stakeholder engagement activities ranging in length from 1 to 3 hours and requiring active participation from the stakeholders.

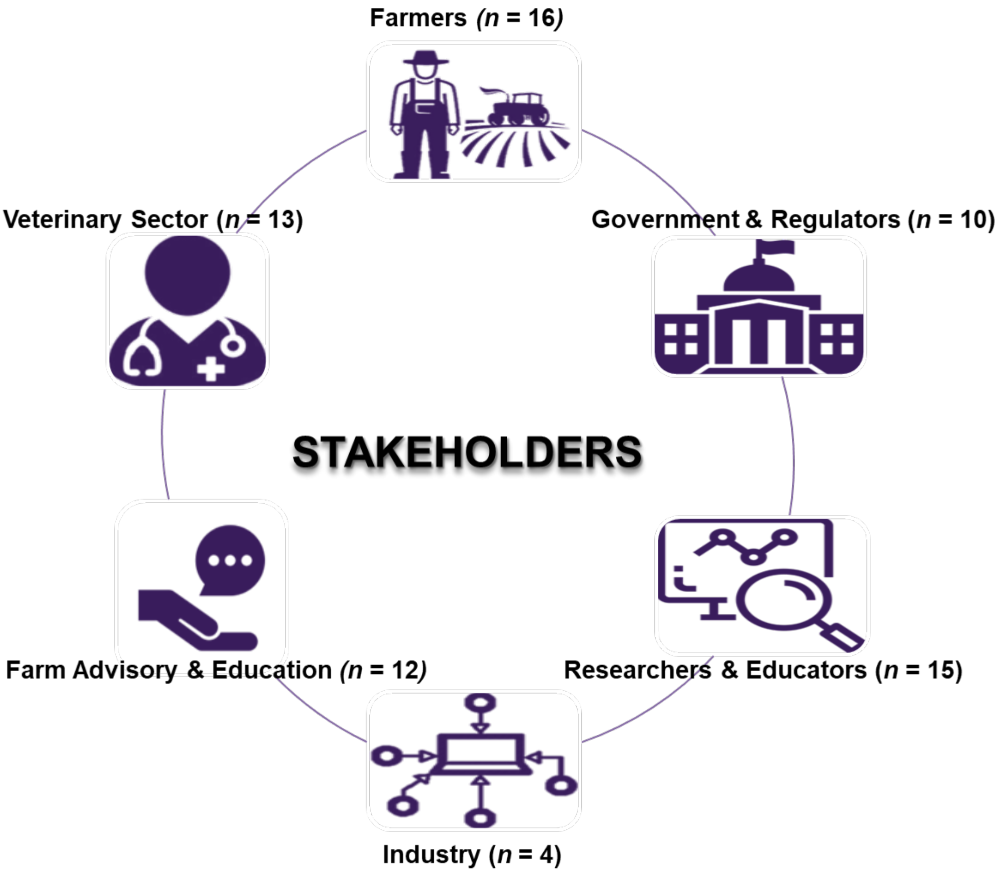


Figure 15: Categories of the stakeholders involved in the codesign of behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use.

Table 15: Timeline of stakeholder input for codesign process for behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use

Month	Participants	Method	Aim	Insights / Implications
Identifying stakeholders for engagement				
March 2019	Stakeholder advisory board and antimicrobial use research team	Face-to-face participatory workshop (n = 12)	Conduct participatory brainstorming activities to create a stakeholder map	Broadened the range and type of stakeholders to be considered for stakeholder engagement during codesign of interventions

Codesigning ideas for behaviour-change interventions				
August 2020	Lecturers involved in the training of student vets	One-to-one stakeholder consults by telephone or through ZOOM (n = 2)	Gather input on successful training strategies for vets and student vets	Insights gathered for training-based interventions from those with experience delivering and taking part in vet training or continuing professional development in Ireland
September 2020	Animal health experts, farm advisors, farmers, cooperative representatives, researchers	Small group stakeholder consults through ZOOM (n = 12)	Gather input on feasible behaviour-change interventions for pig and dairy farms in context of follow-on research proposal	Insights gathered on logistics for delivering specialised training, value of a community of practice approach and insights on best approaches for monitoring antibiotic use on farms
October 2020	Knowledge-transfer experts in education and advisory	One-to-on stakeholder consults by telephone or through ZOOM (n = 2)	Gather information on continuing professional development for farm advisors and logistics of delivering training to farm advisors as part of a behaviour-change intervention	Provided insights from those with experience in knowledge transfer, on farm initiatives, behaviour-change programmes or farm innovation
November 2020	Farmers from the pig, dairy, beef and sheep industries	One-to-one stakeholder consults by telephone or through ZOOM (n = 10)	Gather insights into farmers' views and understanding of antibiotic use and good antibiotic stewardship	Provide insights from farmers across different sectors and regions on antimicrobial use practices, and drivers of change
March to May 2021	Animal health experts, veterinary and farm advisor trainers, behavioural scientists, policy-makers and vets	One-to-one stakeholder consults by telephone or through ZOOM (n = 6)	Gather input on successful training strategies for vets and farm advisors	Gain insights from those with experience delivering, regulating and taking part in vet training / continuing professional development to plan logistics of vet and advisor training–based interventions, discuss best way to recruit, discuss vets' past training to establish how to pitch training interventions

March to May 2021	Animal health experts, farmers, vets and farm advisors	One-to-one stakeholder consults by telephone or through ZOOM (n = 7)	Gather practical, local knowledge of farming sectors to create case study development worksheets as training materials for vets and farm advisors	Gain insights from those with experience delivering or participating in herd-health consults working in dairy or pig industries
March to May 2021	Animal health experts, farmers, vets and farm advisors	One-to-one stakeholder consults by telephone or through ZOOM (n = 6)	Identify critical control points in dairy and pig sectors to codesign practice-ready tools to be used on farm to improve hygiene practices	Gain insights on specific expertise in "gold standard" practice in the dairy and pig sectors
Refining ideas for behaviour-change interventions				
August 2021	Animal health experts, veterinary and farm advisor trainers, behavioural scientists, policy makers, vets, farmers, people in the industry	Online interactive exercise using survey and video software (n = 35)	Carry out a multi-actor "APEASE" evaluation of behaviour-change interventions for supporting responsible antimicrobial use on farms	Gain user feedback and sense checking; refinement and validation of 7 behaviour-change interventions

c) Portfolio of behaviour-change interventions

The 7 behaviour-change interventions are outlined in detail in a separate stand-alone report, "*Portfolio of behaviour-change interventions*". The user-friendly report contains a broad range of intervention recommendations that can be used to target knowledge, behaviour and attitudes across agrisectors. It outlines key theories in the area of behavioural and social science and draws on relevant literature from human and animal health.

Each chapter covers a single behaviour-change intervention and provides a rationale and reference to theories of behaviour change, a description of what could be included in the intervention, the likely users of the intervention, the target group (for example farmers or vets) and the recommended behaviour-change techniques (the so-called "ingredients" of the behaviour-change interventions). Where relevant, examples of successful interventions or initiatives are referenced and relevant quotations or data reported. Also included are signposts to relevant resources that would help to further inform the implementation of a behaviour-change intervention. The 7 behaviour-change interventions are briefly described in this report, in Tables 16 to 22.

A prioritisation of the behaviour-change interventions based on the online, interactive exercise provides an indication of community acceptance and appetite for each of the interventions (Figure 16). All interventions were generally well received, with few giving lower prioritisation to any intervention. Intervention options "A" (message framing) and "C" (communications training) received the highest prioritisation across the stakeholders.

Behaviour-change Intervention Option A: Reframe the way we talk about antibiotics

Table 16: Overview of "Intervention Option A: Reframe the way we talk about antibiotics", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option A: Reframe the way we talk about antibiotics	
What does this intervention do?	Rigorously consider the language we use when communicating to farmers and vets about antibiotics and antibiotic resistance.
Who might use this intervention?	Any individual or body who has a responsibility to communicate with farmers and vets about antibiotics and antibiotic resistance.
What's the behavioural science?	A psychology-based strategy called "cognitive reframing" or "framing" helps individuals to think or feel differently about doing a given behaviour. "Framing principles" are strategies used to develop effective messages or communications.
How might this intervention be put into practice?	Principles of message-framing followed any time a communication is designed to encourage farmers and vets to change behaviour to address antibiotic use. Messages codesigned and pretested with end-users before using more widely.
What could this intervention achieve?	Motivate farmers and vets to *want* to change their behaviour, and to feel *ready* to change their behaviour.

Behaviour-change Intervention Option B: Undertake a "One Health" cross-border awareness campaign

Table 17: Overview of "Intervention Option B: Undertake a 'One Health' cross-border awareness campaign", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option B: Undertake a "One Health" cross-border awareness campaign	
What does this intervention do?	A "One Health" all-island public awareness communications campaign.
Who might use this intervention?	Any individual or body who has a responsibility to communicate with the public about antibiotics and antibiotic resistance across animal, human and environmental health.
What's the behavioural science?	"Othering" and "other-blaming" is a common strategy we employ when we seek to attribute blame. We often view a problem to be caused by some group other than our own group, resulting in inaction within our own group. "Othering" is a common feature of "One Health" crises.
How might this intervention be put into practice?	Develop a set of consistent and collaborative communication materials (posters, infographics, videos, social media content) that can be used locally in different settings (hospitals, veterinary practices, clinics, educational settings and so on).
What could this intervention achieve?	Motivate "collective responsibility" of all members of the public by highlighting how antimicrobial resistance and prudent antibiotic use is important and relevant to everyone.

Behaviour-change Intervention Option C: Provide specialised communications training for animal health professionals

Table 18: Overview of "Intervention Option C: Provide specialised communications training for animal health professionals", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option C: Provide specialised communications training for animal health professionals	
What does this intervention do?	Train vets and farm advisors in the use of "motivational interviewing" and / or "behaviour-change techniques".
Who might use this intervention?	Farm advisors and vets could be trained in these techniques during initial and continued education / training opportunities.
What's the behavioural science?	Taking a "top-down", expert-led approach to communicating with clients can lead to the client feeling that they have no control and can in fact have the opposite to the desired effect. Rather than engaging in the conversation, a client can start to think of reasons *not* to change, in what is known as "psychological reactance", leading to a reduction in engagement with their veterinary practitioner or farm advisor. More collaborative approaches (such as motivational interviewing) have proven effective in targeting motivations to want to change.
How might this intervention be put into practice?	Farm advisors would be trained in the use of behaviour-change techniques and vets would be trained in the use of motivational interviewing. Advisors and vets would then put their skills into practice when they carry out consults on farms.
What could this intervention achieve?	Motivate farmers to *want* to change their behaviour, and to feel *ready* to change their behaviour, and provide vets and farm advisors with increased capacity and skills to support their clients.

Behaviour-change Intervention Option D: Provide specialised communications training for animal health professionals

Table 19: Overview of "Intervention Option D: Provide specialised communications training for animal health professionals", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option D: Provide specialised communications training for animal health professionals	
What does this intervention do?	Develop user-friendly tools that can be used on farms to promote new habits that will improve animal health and reduce the need for antimicrobials.

Who might use this intervention?	Any individual or body who has a responsibility to help farmers to make changes on their farm to address antibiotic use.
What's the behavioural science?	Adding prompts or cues into the environment that clearly explain a desired behaviour can help to promote new habit formation. A good example of this is the visual posters we see in most bathrooms explaining how to properly wash your hands to prevent the spread of germs. We also know that involving end-users in the design process of these visual cues helps to ensure the usability of the tools created.
How might this intervention be put into practice?	By working with different actors, user-friendly tools that provide good practice animal health advice can be designed and implemented on the farm.
What could this intervention achieve?	Provide farmers with practical, implementable advice in a user-friendly way to prompt the formation of new habits that support responsible use of antimicrobials.

Behaviour-change Intervention Option E: Encourage peer-to-peer social support and modelling good farming practices for farmers

Table 20: Overview of "Intervention Option E: Encourage peer-to-peer social support and modelling good farming practices for famers", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option E: Encourage peer-to-peer social support and modelling good farming practices for farmers	
What does this intervention do?	Provide farmers with opportunities to observe other farmers who are similar to them performing target "good" behaviours (for example enacting specific animal health management practices), within a supportive environment.
Who might use this intervention?	Any individual or body who has a responsibility to help farmers to make changes on their farm to address antibiotic use.

What's the behavioural science?	Human behaviour is learned through observation of others. Other farmers modelling a behaviour can be a very effective method for behaviour change, particularly if the individual sees the "model" farmer receiving reinforcement for the behaviour (for example a financial reward, improved herd health, encouragement from others). Learning from others and seeing others receive reinforcement can improve a person's self-efficacy and behavioural capability – they will feel more confident that they can perform the behaviour.
How might this intervention be put into practice?	The "what": Success stories communicated through case studies, videos or articles; farm discussion groups, farm walks or peer-to-peer facilitated meet-ups. The "how to" increase self-efficacy and capability: Enact "mastery" experiences; improve physical and emotional states; verbal persuasion; and vicarious experiences ("modelling").
What could this intervention achieve?	Increase self-efficacy, capability and confidence of farmers to engage in target "good" animal health management practices.

Behaviour-change Intervention Option F: Support farmers to monitor their antibiotic use

Table 21: Overview of "Intervention Option F: Support farmers to monitor their antibiotic use", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option F: Support farmers to monitor their antibiotic use	
What does this intervention do?	Provide a method for the farmer to monitor and record their antibiotic use.

Who might use this intervention?	Any individual or body who has a responsibility to help farmers to make changes on their farm to address antibiotic use.
What's the behavioural science?	Self-monitoring (or "benchmarking") draws individual attention to one's current behaviour, identifies areas for improvement and helps keep people on track to achieve goals. A pedometer is a good example of self-monitoring: a person keeps track of their daily steps in order to track how close they are to achieving certain activity goals.
How might this intervention be put into practice?	The farmer consistently and frequently uses a given method for monitoring antibiotic use. Importantly, they also observe and reflect on the data or feedback from monitoring (for example viewing trends in use over time) and consider how the data compares to a particular goal they may have set for themselves.
What could this intervention achieve?	Help farmers to keep track of their antibiotic use and spot patterns. Provide positive reinforcement for a behaviour that leads to reduced use of antimicrobials. Increase intrinsic motivation of farmer to want to change their behaviour.

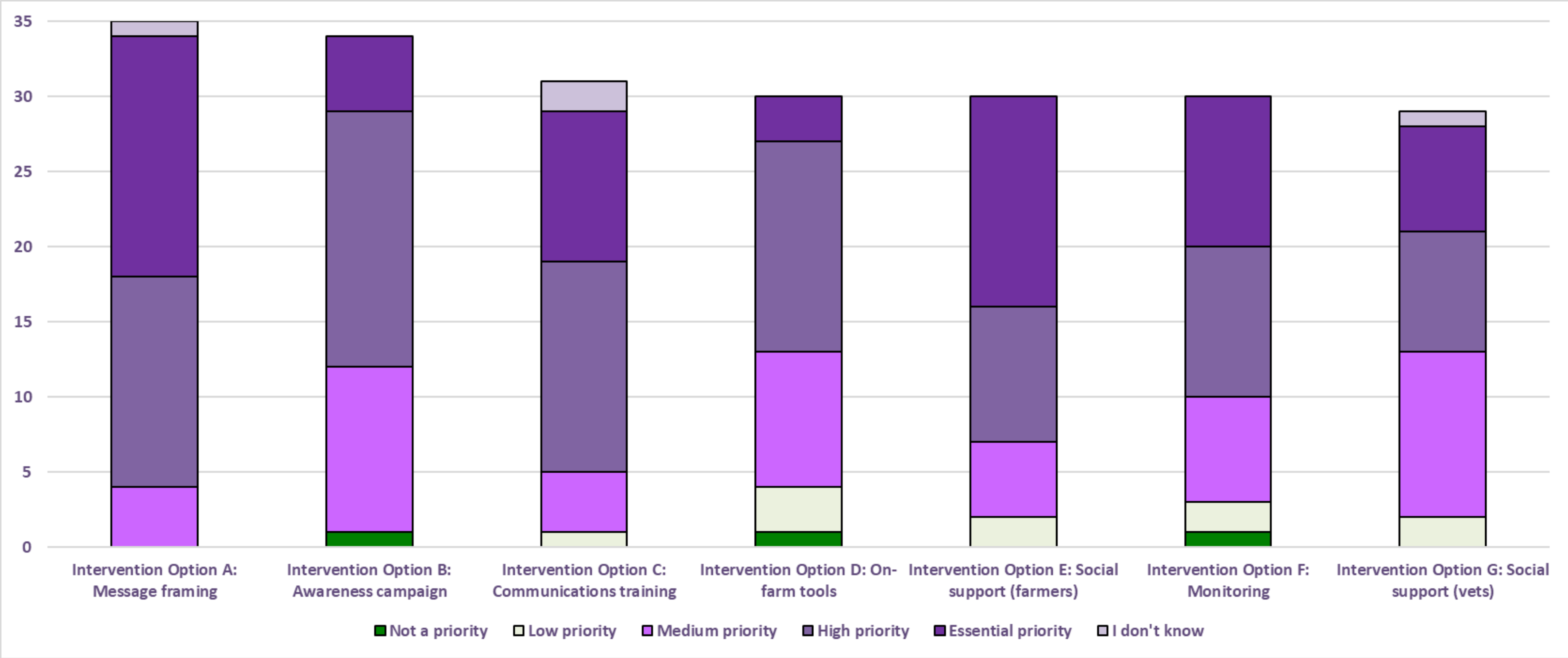
Behaviour-change Intervention Option G: Develop a supportive community for vets to champion good antibiotic stewardship

Table 22: Overview of "Intervention Option G: Develop a supportive community for vets to champion good antibiotic stewardship", a behaviour-change intervention idea to promote and facilitate good animal health practices and responsible antimicrobial use

Intervention Option G: Develop a supportive community for vets to champion good antibiotic stewardship	
What does this intervention do?	Empower veterinary practitioners to start a conversation within their own practice in relation to antimicrobial stewardship.
Who might use this intervention?	Veterinary practitioners and agencies supporting education and development of vets.

What's the behavioural science?	Research shows that forging antimicrobial stewardship "champions" and communities of practice through face-to-face and educational online activities can be an effective way to bring about behaviour change.
How might this intervention be put into practice?	The intervention could involve cementing individual veterinary practitioners' intentions and intrinsic motivation around antibiotic prescribing by designing their own behaviour-change intervention within their practice, with the support of behavioural scientists.
What could this intervention achieve?	Increase veterinary practitioners' motivation to engage with colleagues in relation to antimicrobial resistance and antimicrobial stewardship and promote the conversation from both a "top-down" and "bottom-up" approach with individual veterinary practitioners as well as veterinary organisations and governmental bodies.

Figure 16: A graph showing prioritisation of behaviour-change intervention ideas to promote and facilitate good animal health practices and responsible antimicrobial use, by stakeholders engaged in an online, interactive exercise.



d) Behaviour-change intervention in focus: Provide specialised communications training for animal health professionals

As well as the portfolio of interventions, behaviour-change intervention option "C" has been further developed and prepared for implementation and evaluation in the follow-on "AMU-FARM" (antimicrobial usage on farms) project. Two manuals have been developed for the delivery of 2 training programmes for vets and farm advisors in behaviour-change techniques and motivational interviewing. These training programmes have both been tailored from programmes delivered and evaluated in the UK and Sweden and adapted specifically for an Irish context. The manuals include professional competencies required to take part in the training, relevance to animal health and AMR, recommended timelines and structure, delivery logistics and training evaluation methods.

3.3.4 Task 3 deliverables and outputs

The outcomes for the project "deliverables" (the specific work produced, or delivered, that enabled the objectives to be met) for Task 3 are shown in Table 23.

Table 23: Deliverables from Task 3, the codesign of behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use

Task 3 deliverables	Task 3 outcomes
1. Literature review on intervention development	Done
2. Codesign of interventions: [~~participatory workshops (NI)~~] stakeholder consults and online, interactive exercise to refine interventions*	Done
3. Analysis of data from codesign [~~workshops~~] stakeholder consults and online, interactive exercise to refine interventions*	Done
4. Development of portfolio of intervention options	Done
5. Intervention acceptability and feasibility evaluation [~~workshops~~] online exercise (NI & Ireland)*	Done
6. Analysis of data from acceptability and feasibility evaluation [~~workshops~~] online exercise*	Done

Task 3 deliverables	Task 3 outcomes
7. Final intervention recommendations	Done

** Due to Covid-19 restrictions, face-to-face workshops could not be held. Telephone and online consults and an online, interactive exercise took place to achieve the original aims.*

In addition to satisfying the deliverable outcomes of the project, there have been several opportunities to showcase and promote the valuable work undertaken within Task 3 of this project (Table 24).

Table 24: Promotional or "outreach" activities showcasing outputs from Task 3, the codesign of behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use

Outreach activity	Audience and description of activity	Title	Date
Media outreach	A 2-minute video shown at an international "webinar" (an online seminar) hosted by VirtualVet.eu to mark World Antimicrobial Awareness Week 2020	Behaviour-change interventions targeting antimicrobials in agriculture	18–24 November 2020
Conference	Presentation at the 75th Association for Veterinary Teaching and Research Work (AVTRW) Conference	Exploring the relationship between mastitis risk perceptions and farmers' readiness to engage in milk recording	14–15 September 2021
Conference	Presentation at the 17th Annual Psychology, Health and Medicine Conference	Examining attitudes, knowledge and behaviour of farmers and	May 2020

Outreach activity	Audience and description of activity	Title	Date
		veterinarians to reduce the use of antimicrobials on farms in Ireland	
Conference	Animal Welfare Research Network (AWRN) Workshop: "Novel methods of human behaviour change for improving animal welfare"	Behaviour change and antimicrobial resistance	March 2020
Media outreach	Press release and media engagement to launch project	Research projects underway focusing on animal health and welfare on the island of Ireland	June 21 2019
Media outreach	Article in RTÉ's *Brainstorm*. Available online at https://www.rte.ie/brainstorm/2021/0107/1188209-antibiotic-resistance-superbugs-farming-eu/	Can we change our behaviour to prevent superbugs?	January 7 2021
Journal article	Article in *Veterinary Ireland Journal.* Available online at http://www.veterinaryirelandjournal.com/focus/255-communication-innovation-supports-vet-s-role-in-driving-change-in-animal-health-management	Communication innovation supports vet's role in driving change in animal health management	6 July 2021
Journal article	Article in *Preventive Veterinary Medicine*, 193:105393. Available online at https://pubmed.ncbi.nlm.nih.gov/34098233/	Exploring the relationship between mastitis risk	August 2021

Outreach activity	Audience and description of activity	Title	Date
		perception and farmers' readiness to engage in milk recording (Á. Regan and colleagues, 2021)	
Stakeholder presentation	Presentation delivered to the iNAP Animal Health Implementation Committee	Antimicrobial use in agriculture: Update on social and behavioural science research activities	4 December 2020
Stakeholder presentation	Presentation delivered to the iNAP Animal Health Implementation Committee	Antimicrobial use in agriculture: Social and behavioural science underlying behaviour change	22 April 2020
Stakeholder presentation	Presentation delivered to European Commission / iNAP Animal Health Implementation Committee Meeting	Use of antimicrobials in animal health on the island of Ireland: Knowledge,	9 October 2019

Outreach activity	Audience and description of activity	Title	Date
		attitudes and behaviour	
Stakeholder presentation	Presentation delivered to the CellCheck Implementation Group	Identifying barriers and facilitators to milk recording amongst Irish farmers	25 February 2020
Stakeholder presentation	Presentation delivered to the Milk Recording Campaign industry group	Identifying barriers and facilitators to milk recording amongst Irish farmers	21 November 2020

4 Project modifications

Task 1: Desk-based study to determine current usage of antimicrobials and alternatives in animal health on the island of Ireland

Project modifications for Task 1 include the slight alteration of the specific objectives as laid out in the research proposal:

- "*To undertake an in-depth review to identify and collate the current data available on on-farm practices in relation to the use of antimicrobials on the IOI.*"

  We were unable to include data from NI as any data from NI is aggregated with data from Great Britain and published for the UK as a whole. This finding identifies a significant knowledge gap for the sector.
- "*To explore the use of antimicrobials in dairy-producing and meat-producing animals, taking into account, where possible, the contribution of each sector to the problem of AMR in the food chain.*"

  This objective was excluded as supporting data was not available. The use of antimicrobials in dairy-producing and meat-producing animals was explored; however, exploring the contribution of each sector to the problem of AMR in the food chain was not included due to a lack of sufficient supporting evidence.
- "*To carry out, where possible, secondary data analyses on available data on on-farm practices in relation to the use of antimicrobials and on available data on the use of alternatives to using antimicrobials in animal health.*"

  This objective was explored but excluded from review as the data was deemed insufficient for a full in-depth review.

Task 2: Behavioural analysis to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to use of alternatives in animal health on the island of Ireland

Project modifications for Task 2:

- Originally, recruitment of participants to the famer survey was going to rely heavily on attending and distributing surveys at farming events such as the Balmoral Show in NI and the National Ploughing Championships in ireland to obtain a representative sample for the IOI. However, due to the COVID-19 pandemic, these events were cancelled and unlikely to go ahead within the project timeframe. Therefore, data collection utilised various methods such as online, postal and telephone surveys to collect a representative sample. This approach relied heavily on assistance from project partners Teagasc, UCD and the stakeholder advisory committee to circulate the survey to as many farmers as possible. A press release was also issued and picked up by national media, with an open invite for farmers and vets to participate in the surveys.
- Based on the findings from Task 1, feedback from the farmer survey questionnaire pilot and, in particular, the stakeholder advisory board, it was agreed by the research team that the farmer survey would be administered only to the dairy, beef, sheep and pig sectors and not to the poultry sector. Levels of AMU in the poultry sector have significantly decreased in recent years and this sector has been the focus of much previous intervention. Furthermore, farmers in this enterprise operate at a very different level to other sectors (highly commercialised) and so the "COM-B" survey developed would be less relevant for poultry farmers. Within the resources of the project and the sample size the survey aimed to achieve, it was considered more valuable to reach a higher number of beef, dairy, pig and sheep farmers.
- A solely quantitative survey was written into the initial proposal to assess vets' attitudes. However, given the small sample size of vets available to be recruited, it was felt that a "mixed methods" approach of splitting the survey up into a 10-minute quantitative survey, followed up by an in-depth telephone interview, would maximise the quality of data while alleviating participant burden.

Task 3: Codesign of behaviour-change interventions to promote and facilitate good animal health practices and responsible antimicrobial use

Project modifications for Task 3 related to impacts due to the emergence of the COVID-19 pandemic:

- The behaviour-change intervention codesign workshops and stakeholder consults in Task 3 were intended to take place in face-to-face settings. Due to the emergence of COVID-19 public health restrictions on movement and close contact in Ireland and in NI, it was not possible to hold, or to plan for, face-to-face workshops. For this reason, we substituted face-to-face workshops for online consultations (one-to-one and small groups) and an online, interactive evaluation exercise to refine and test the interventions, using survey and video software.

5 Discussion and key findings

Determining current usage of antimicrobials and alternatives in animal health on the island of Ireland

Measuring antimicrobial usage at farm level

Currently, on the IOI, national-level AMU data are gathered from the sales of veterinary antimicrobials by the HPRA in Ireland and the VMD in NI. This provides information on the classes of antimicrobials and pharmaceutical forms sold but cannot explain how much antimicrobials are given to each species, nor does it tell us anything about farmers' behaviours in relation to AMU (for example the manner of purchase, administration route, recording, and storage and disposal practices).

A key finding from Task 1 of the project is that there are significant knowledge gaps in AMU in animal health on the IOI. Good quality farm-level data that considers all animal age groups and all forms of AMU is lacking, especially in the less-intensive industries such as beef and sheep, as well as the dairy industry. These findings – particularly the significant knowledge gaps in veterinary AMU – should be communicated to relevant research funding bodies on the IOI.

The monitoring of veterinary AMU is an integral part of antimicrobial stewardship. Access to AMU data will be essential to develop strategies to reduce AMU and lessen the threat of AMR to society. Antimicrobial usage data is recorded both at veterinary practice and farm level. Valuable usage information may be stored in paper records in veterinary practices or on farms, thus the collation of data may be the real challenge.

Whether AMU data is collected as part of a national monitoring system or a research trial, the use of electronic recording systems would promote better accuracy and traceability of treatments particularly at the animal level. While the inventory of empty drug containers has been considered one of the most reliable sources of AMU data collection, the information provided by this method is quantitative and does not provide details on the indications for use, particularly concerning the use of systemic treatments, highlighting the importance of obtaining data from treatment records.

The literature suggests a benefit of recording AMU both at veterinary practice level and farm level. Behaviour-change interventions that specifically target an increase in recording of AMU by vets and farmers would be of benefit.

Alternatives to antimicrobials on farms

As part of Ireland's National Action Plan on AMR (iNAP), Bolton and O'Neill (2019) reviewed methods used in EU Member States to reduce AMU and More (2020) recently published a similar review on European perspectives on efforts to reduce AMU. Both reviews discuss reducing use in animal production as a whole, including monitoring AMU and regulations and restrictions (both voluntary and legislative). Efforts to reduce AMU through modifying behaviour focus on monitoring AMU and regulations and restrictions (both voluntary and legislative). The implementation of national AMU monitoring systems and antimicrobial restrictive legislation has led to AMU reduction in a number of EU Member States.

The World Organisation for Animal Health (OIE) recently published their Fourth Annual Report on antimicrobial agents intended for use in animals (OIE, 2020). Countries who provided only baseline data outlined their barriers to reporting quantities of antimicrobials used. The most-reported barrier was a lack of robust regulatory framework, suggesting countries need regulations in place to ensure the data is collected and reported at a high standard.

While individual farmers and veterinarians have the ability to make change through altering their own behaviours, it is possible that mass behaviour change may require the implementation of strict legislation around reporting and using antimicrobials. Discussions with the relevant stakeholders will provide insight into how AMU behaviour can be changed on the IOI in ways that are both sustainable and feasible for all parties involved. "Top-down" approaches are most effective in coordination with "bottom-up" approaches.

Successfully implementing improved management strategies can have a direct, positive impact on AMU. Reducing overall AMU begins with reducing the need for antimicrobials. Many alternative options for farmers and veterinarians to reduce their AMU begin with reducing disease risk to eliminate the requirement for antimicrobial treatment, which can be achieved through improved management strategies and herd-health planning. However, reducing the preventative use of antimicrobials that, in many cases, is habitual will require changes to both farmer and veterinarian attitudes around AMU and AMR.

Alternative options to AMU should be communicated to farmers and veterinarians. Offering practical solutions and alternatives that are targeted at specific areas of use within their respective profession (farmer or veterinarian) and livestock sector, rather than a general "reduce your antimicrobial use" campaign, will have a greater impact on reducing AMU.

Developing and implementing behaviour-change interventions

The majority of farmers who took part in the farmer survey reported that they had intentions to or had already started to make changes to how they used antibiotics on the farm. This correlates with numerous European countries including Norway, Italy, the Netherlands, Germany and the UK, where farmers recognise their own responsibility to combat imprudent AMU, with the majority of farmers emphasising the desire to actively try to implement strategies to reduce AMU (Higham and colleagues, 2018; Jones and colleagues, 2015; Orpin, 2017).

The participants who took part in the vet online survey and interviews demonstrated a comprehensive awareness, understanding and knowledge of the consequences of imprudent AMU, which agrees with the findings of other European studies (Postma and colleagues, 2015, Rell and colleagues, 2020). Furthermore, similar to other studies, vets expressed a serious commitment to encourage farmers to change practices on farms to reduce disease occurrence and spread, reducing the need for antimicrobials (Hardefeldt and colleagues, 2018; Scherpenzeel and colleagues, 2018).

Historically, studies reported that farmers and vets were sceptical of the extent of the contribution AMU has on AMR and held other sectors accountable, for example human medicine (Hardefeldt and colleagues, 2018; Norris and colleagues, 2019). In contrast, vets and farmers in the present study appeared to acknowledge that it is a collective responsibility of everyone along the chain, from prescriber to end-user, which aligns with the "One Health" message (WHO, 2015a, 2015b).

While acknowledging the role that "top-down" regulatory approaches can play in behaviour change, our research focuses largely on "bottom-up" behaviour-change interventions that can be implemented by key stakeholders in the sector to tackle capability (for example increasing knowledge and awareness), motivation (for example tackling attitudes and beliefs) and opportunity (for example provision of social support). This aligns with the approaches most favoured by farmers themselves – in the farmer survey, farmers rated "new policies and regulations to restrict antibiotic use" on farms as the least-favoured intervention approach. This signals the need to embed "bottom-up" behaviour-change interventions that increase farmers' knowledge, motivation and opportunity for change ahead of any regulations that would enforce such change.

Increasing knowledge and self-efficacy to make changes

Farmers demonstrated a comprehensive knowledge of antimicrobials and AMR with relatively high knowledge scores (subjective and objective), which agrees with other European studies (Di Martino and colleagues, 2018; Golding and colleagues, 2019). Participants that completed the survey indicated that the topic of AMR and "One Health" is widely discussed. This exposure to AMR is beneficial as it reiterates to farmers the importance of tackling the issue of AMR, increasing knowledge of antimicrobials and, by default, increasing compliance with antimicrobial stewardship strategies (Golding and colleagues, 2019, 2019; Higgins and colleagues, 2017).

Hierarchical multiple regression analysis found subjective knowledge to be a predictor variable of responsible behaviour: increased knowledge increased responsible AMU behaviour. This aligns with previous findings that elevating farmer knowledge is a powerful influential factor related to responsible AMU (Kramer and colleagues, 2017; Kigozi and Higenyi, 2017). However, previous studies have demonstrated that, while farmers displayed a decent understanding of AMU and AMR, some confusion and misconceptions remain (Jones and colleagues, 2015; Rayner and colleagues, 2019). While participants had relatively high subjective knowledge scores, this may also mean that it will be difficult to get farmers to seek more information or education on this issue.

Literature has long established that elevated knowledge encourages behaviour change, with studies acknowledging that elevating farmer knowledge through education is the most influential factor related to responsible AMU and practices (Frates and colleagues, 2018; Safari and colleagues, 2018; Kramer and colleagues, 2017; Kigozi and Higenyi, 2017), echoed in the results from this study. While vets from this study reported that education is instrumental in increasing awareness and understanding, vets also emphasised that AMR is a complex and multifaceted topic, therefore stressed that education should be provided to farmers using straightforward language to engage and assist farmers' understanding.

As knowledge is a predictor of practices in the farmer survey it is important to refine and modify materials accordingly through numerous platforms that are attractive, relevant and tailored for farmers, such as online webinars or an interactive platform to facilitate continuous education. Research suggests that a message-framing and codesign approach to developing such materials will be most effective.

It is important to acknowledge that declarative knowledge (knowing *what* needs to be done) alone will not bring about behaviour change; farmers also require procedural knowledge (knowing *how* to do it) and the belief that they are able to put that knowledge into practice. Within the hierarchical multiple regression analysis in the farmer survey, emotion was found to be a predictor variable, with higher emotive score correlated with better practices. Previous literature reported that farmers that are invested in and / or passionate about these practices are more inclined to follow up with progressive behaviours and have a more positive experience with implementation (Orpin, 2017; Scherpenzeel and colleagues, 2016). While self-efficacy was not found as a predictor variable in the hierarchical multiple regression analysis within the farmer survey, Pearson's correlations observed a strong significant relationship between emotions and self-efficacy, indicating that perceived ability to implement practices and feelings towards practices are related. Previous studies recognised that farmers did not feel equipped with the technical knowledge and skills to effectively implement strategies without detrimentally impacting production (Doidge and colleagues, 2020; Higham and colleagues, 2018; Jones and colleagues, 2015; Rayner and colleagues, 2019).

Therefore, it is important to instil this passion and investment amongst farmers, coupled with supporting farmers so that they feel confident in their abilities to make necessary changes on the farm; this, in turn, will elevate their attitudes toward this change. This could be achieved through facilitated discussion with other farmers or observation on other farms that have had proven, positive experiences with these strategies, to demonstrate to farmers that it is relevant, feasible and effective, as farmers frequently referred to these factors when deciding to implement strategies (Garforth and colleague, 2013; O'Kane and colleagues, 2017). Years' experience was found as a predictor for responsible AMU, with increased experience increasing positive behaviour, coupled with the findings that less-experienced farmers rely on peer and social support. Therefore, the opportunity for farm visits or discussion groups to share experiences with other farmers that are modelling the "good" behaviour and have proven experience in successful implementation of antimicrobial stewardship strategies would be beneficial to farmers.

Raising antimicrobial resistance awareness

Interventions aimed at reducing AMU often aim to explain the reasons for reduction – for example, communicating the risks of AMR. Farmers' awareness of the topic of AMR was quite high in this survey. Unsurprisingly, the level of concern of AMR was also high. Interestingly, the level of concern for AMR with "*My family and me*" was highest, while the perceived risk of AMR (likelihood for AMR) to "*My family and me*" was considered low. Similarly, while participants reported that antibiotics were used too much in their own sector, participants credited human medicine and other agricultural sectors to have higher AMU. This is a similar finding to other studies, with farmers considering their own AMU to be lower in comparison to other farmers and sectors (Di Martino and colleagues, 2018; Doidge and colleagues, 2020). This challenge is referred to as "optimism bias", causing an individual to underestimate the possibility of a negative event in the future whereby they believe that they themselves are less likely to experience a negative event (Sharot, 2011). There is a need to consider how best to frame risk communications surrounding AMR to the farming community to instigate action.

Promoting alternative behaviours

There is significant value in emphasising the behaviours that farmers *can* do, rather than emphasising the behaviours they *should not* do: such an approach provides proactive, positive messaging and delivers actionable advice to farmers. In the farmer survey, farm size was found as a predictor variable for responsible AMU. Increased farm size was associated with less responsible AMU. In other studies, farmers were found to believe that consumer demand for cheap produce promotes intensification and poorly managed systems (Coyne and colleagues, 2019; Singer and colleagues, 2019). The promotion of alternative practices to tackle common problems on farms and alleviate disease occurrence would be beneficial. For instance, mastitis is a common problem within dairy herds, and dairy herds in Ireland have made progress towards SDCT (selective dry cow therapy) under the guidance of the "CellCheck" programme coordinated by AHI (AHI, 2020; Martin and colleagues, 2020). Other studies have observed Bovine Respiratory Disease (BRD) as a common cause of illness and fatality in beef farms, so the vaccination for BRD within beef herds would reduce disease incidence, thus alleviating reliance on antibiotics (Department for Health and Social Care in the UK, 2019; Earley and colleagues, 2018). Promotion of targeted vaccination programmes would be beneficial and likely to be well received among the farming community as the current farmer survey showed that subsidised vaccination programmes were considered the most helpful interventions to make changes to AMU on farms.

The promotion and implementation of vaccinations was extensively discussed as an effective alternative to AMU. Endorsement of vaccination programmes would promote farmer involvement and facilitate disease prevention and reduce AMU (Magalhaes-Sant'Ana and colleagues, 2017; Speksnidjer and colleagues, 2015; Taylor and colleagues, 2020), and incorporating targeted vaccination programmes into farm treatment plans could be a lucrative approach. Furthermore, vets believed laboratory testing (diagnostic and susceptibility) is an effective first step approach to correctly diagnose and treat disease, reassuring vets on treatment choice. However, they also acknowledge it was impractical due to the increased cost and time associated with testing and delayed treatment action. For these reasons, vets found it difficult to convince farmers to perform tests, as farmers wanted animals treated quickly (Coyne and colleagues, 2016; Hardefeldt and colleagues, 2018; Magalhaes-Sant'Ana and colleagues, 2017). This sentiment persisted in farmers within this survey, therefore work should be done to improve the mechanisms of laboratory testing to lessen waiting times for results to make this tool more appealing and suitable for famers and vets.

Vets have a key role to play in promoting alternative behaviours. The majority of farmers cited that they used veterinary services to prescribe medication, provide advice on herd-health plans, laboratory testing and vaccination programmes. These are positive findings, as the majority of participants utilised vets' services for advice on practices that are considered preventive, for example improved herd health and vaccinations, despite only 50 per cent of farmers seeking advice about AMU specifically (Fischer and colleagues, 2019; Garforth and colleagues, 2013). It is evident from worldwide research that vets are considered the primary advisor providing farmers with the most valuable, credible, trustworthy and relatable advice (Di Martino and colleagues, 2018; Fischer and colleagues, 2019; Garforth and colleagues, 2013). Therefore, it stands to reason that the role shift of vets reported in literature is of interest. In addition to their therapeutic role, vets are incorporating a consultative role focused on promoting antimicrobial stewardship approaches (Doidge and colleagues, 2019; Golding and colleagues, 2019).

Leveraging peer-to-peer learning opportunities

Social and peer support was observed in the farmer study as an influential and trusted source of information. This finding is echoed in other studies recognising that farmers' previous experience and sharing experiences with peers remains a trusted and relatable knowledge network frequently favoured over scientific evidence-based advice (Garforth and colleagues, 2013; Garcia and colleagues, 2020). Moreover, discussion groups were the most common source of information, reiterating the importance of this already established platform as a channel to distribute information to farmers in a relevant and efficient manner. Numerous studies indicated that the use of discussion-based platforms has many benefits, including promoting knowledge exchange and provision of practical skills, and provides an opportunity to share positive experiences and discuss strategies to reduce AMU, thus motivating other farmers to make changes (Rayner and colleagues, 2019; Higgins and colleagues, 2017; Golding and colleagues, 2019). Based on the findings from this study, facilitated discussion provides an opportunity for farmers to elevate knowledge and skills in a supportive environment and so instil self-confidence in farmers that are wary of change that the change is feasible.

Numerous reports have identified communication as an effective tool to change behaviour (Golding and colleagues, 2019; Higham and colleagues, 2018) and recognised that farmers sharing experiences with peers remains a trusted and relatable source of information, frequently favoured over scientific evidence-based advice (Garforth and colleagues, 2013, Jones and colleagues, 2015). Discussion groups are already established in Irish agriculture; it stands to reason that further utilisation of this platform provides an opportunity where vets and farmers can openly discuss alternatives and antimicrobial stewardship strategies in a supportive environment. Enabling farmers to share experiences of antimicrobial stewardship strategies, acknowledge and alleviate farmers' concerns and address uncertainties through other farmers and vets that are modelling this behaviour, is essential as studies have highlighted that vets realise that it is important to engage farmers and understand their needs to enable communication and promote positive change (Golding and colleagues, 2019).

Social norms and peer-to-peer influence was also important in the vet survey. Superior influence is frequently reported in literature as a pressure younger or less-experienced vets encounter, believing that older vets relied on treatment plans centred on AMU in comparison to younger vets, and frequently undermining or overruling their treatment plans (Doidge and colleagues, 2019; Speksnidjer and colleagues, 2015). While superior influence was prevalent within this study, a considerable shift within veterinary practices was also discussed where more experienced vets were looking to younger vets for advice on antimicrobial stewardship practices. Therefore, similar to farmers, discussion groups or mentoring approaches could also be made available to vets, so that vets that consider themselves as "stewardship champions" can inspire other vets to follow. Such an approach for vets has shown success, for example where veterinary study groups in Switzerland enabled continuous education and improved attitudes of vets towards antimicrobial stewardship strategies (Pucken and colleagues, 2019). Improving vets' attitudes towards antimicrobial stewardship strategies is valuable as it will simultaneously influence farmers' perceptions, resulting in successful implementation of antimicrobial stewardship strategies such as SDCT (Scherpenzeel and colleagues, 2018; Speksnidjer and colleagues, 2015).

Improving communications between farmers and their farm advisors and vets

Vets in this study and other studies reported that some farmers are wary about making changes on the farm, with vets indicating that it is difficult to engage farmers and motivate behaviour change due to uncertainty, insufficient knowledge and perceived benefits for AMU (Cattaneo and colleagues, 2009; Higgins and colleagues, 2017). Client pressure is one of the most commonly reported difficulties in literature that vets encounter. Vets frequently experience pressure to prescribe antimicrobials due to client expectation or preference to maintain relationships (Gibbons and colleagues, 2021; Golding and colleagues, 2019). Participants in this study also discussed that client pressure persists within practices. Interestingly, in addition to client pressure, the majority of vets also felt pressure to prescribe due to farmers' ability to obtain antimicrobials from other practices. Therefore, client pressure, coupled with the pressure of a farmer's obtaining treatments from other veterinary practices, needs to be addressed. Unanimously, vets in this study believed that assigning one vet to a farm would promote responsible AMU. Previous studies reported that assigning one vet to a farm has numerous benefits, including elevated veterinary knowledge and experience of a farm providing a complete insight to livestock status when prescribing antimicrobials and suggesting strategies (Doidge and colleagues, 2019, Golding and colleagues, 2019). Assigning one vet to a farm provides a consistent treatment approach in addition to avoiding conflicts with other farmers and colleagues (Magalhaes-Sant'Ana and colleagues, 2017; Speksnidjer and colleagues, 2015). Therefore, such an approach would enable cohesive and consistent messaging and harmonise treatment plans and prescribing behaviours.

Improving communications between vets and their clients can also support to overcome these challenges. Studies in clinical settings have observed favourable outcomes for training clinical staff in motivational interviewing, improving communication for client and patient, resulting in client and patient satisfaction and team cohesion (Söderlund and colleagues, 2011; Pollak and colleagues, 2016). Training vets to utilise this approach may improve understanding and communication in this instrumental relationship. As mentioned earlier, discussion groups have been suggested as a beneficial platform for communication. Educational materials such as presentations from experts (vets), training programmes, and information resources such as leaflets could be incorporated and distributed at these events. Vets suggested that farmers' workshops or discussion groups were an important strategy to encourage stewardship. This platform facilitates vet-and-farmer collaboration to share positive experiences and discuss strategies, thus motivating other farmers to make changes (Golding and colleagues, 2019; Higgins and colleagues, 2017).

The project has drawn on the small amount of behavioural science literature in the agrifood sector, in particular the work done in the UK (for example Rees and colleagues, 2021) and Sweden (for example Svensson and colleagues, 2020) to inform the development of skills-based interventions for vets and farm advisors. It has improved on this, however, applying psychological practitioner skills to existing work by using a behaviour-change training strategy used by health psychologists in the NHS in Scotland to train animal health professionals in short, evidence-based communication strategies (using behaviour-change techniques) that can be employed in even very short conversations with clients. There is also the opportunity to extend this work not just to vets but also to farm advisors, who could be trained in behaviour-change techniques.

A tailored and gradual approach to behaviour change

While vets in this study displayed a commitment and enthusiasm to reduce AMU on Irish farms, vets were also concerned that abrupt changes to existing treatment plans where antimicrobials are necessary, without the improvements on farm management strategies, would significantly jeopardise animals' welfare, emphasising that each farm is individual and reporting that a successful treatment plan or stewardship strategy on one farm may be unsuccessful on another. Additionally, vets in this study and other studies reported that farmer reluctance and cynicism to implement strategies could compromise animal welfare (Coyne and colleagues, 2016; Golding and colleagues, 2019; Higgins and colleagues, 2017), with vets acknowledging that news of unsuccessful strategies would circulate throughout the farming community, diminishing confidence in strategies and increasing fear and uncertainty surrounding strategies. Therefore, a vet's ability to evaluate a farmer's personality along with capability is fundamentally important. To address the barriers discussed, vets suggested 2 actions that would promote the desired responsible AMU that could be implemented simultaneously.

Vets believed that a tailored and gradual approach on farms will significantly improve farm management practices. The benefits of such an approach are multifaceted. A tailored approach enables farmers and vets to identify specific concerns or issues on their farms and come up with a unique approach together, taking into consideration the farmer's capabilities and personality. Previous studies have proven that this collaborative approach grounded on communication is necessary to elicit a shared ownership and investment to combat AMR, cultivating trust in this fundamentally important relationship (Golding and colleagues, 2019; Higham and colleagues, 2018). Moreover, vets suggested that taking a gradual approach, addressing 1 or 2 issues at a time, proves to the farmer that these behaviours are feasible and effective, thus providing farmers with the confidence, skill set and support necessary to enable the transition to reduce reliance on antimicrobials (Di Martino and colleagues, 2018; Golding and colleagues, 2019; Higham and colleagues, 2018; Rayner and colleagues, 2019; Schneider and colleagues, 2018). Lunenburg (2011) reported that setting specific, attainable goals performs better, thus increasing farmers' confidence in their abilities and encouraging the implementation of more complex strategies in the future, facilitating and providing sustained behaviour change. This gradual, collaborative approach centred on communication and goal-setting is good, as it demonstrates to farmers that antimicrobial stewardship strategies are feasible and beneficial to improve herd heath while maintaining productivity. In addition, it instils farmers with confidence in their abilities to successfully implement antimicrobial stewardship strategies, encouraging them to adopt more.

6 Conclusions

This AMU project provides an in-depth mapping of behaviours and practices that need to be targeted for behaviour change, and the main factors driving or preventing farmers and veterinarians from engaging in these behaviours and practices. As well as providing this empirical understanding, the project goes a step further and provides evidence-based and codesigned options for interventions that can target these drivers and barriers of behaviour change. The collaborative nature of the codesign approach can help to engender a sense of ownership, transparency and inclusiveness amongst key actors in the development and implementation of intervention options that will be key to their success.

This study is the first on the IOI to explore veterinary AMU in all livestock sectors and has highlighted significant gaps in the knowledge of AMU in food-producing animals on the IOI. The study calls attention to the need for comprehensive farm-level data on AMU to be collected and made available both in Ireland but particularly in NI, where no farm-level data were available separate from the data for the whole of the UK. Farm-level usage data will provide insight into the trends of use and allow for targeted interventions. The efficacy of reduction strategies will be improved if they can be targeted at specific behaviours, patterns of use and specific high-usage farms.

The monitoring of veterinary AMU is an integral part of antimicrobial stewardship. Access to AMU data will be essential to develop strategies to reduce AMU and lessen the threat of AMR to society. The standardisation of data collection methods will allow for comparison within and between species. Antimicrobial usage data collection systems will be developed in the future to ensure Ireland complies with EU regulations; however, there will be challenges in collecting robust and accurate data. In the short term, smaller surveillance studies would be beneficial to build on knowledge of AMU in food-producing animals, especially in less-intensive industries such as beef and sheep, where information is currently lacking.

This study is the first to use a survey centred on the behavioural COM-B Model to ascertain farmers' current behaviours around antimicrobials on the IOI. The survey has provided significant learnings in terms of identifying farmers' readiness to change, knowledge levels, motivations and resources available. It should be noted, this is the first attempt at a self-report scale to measure responsible AMU (the “dependent variable”). Therefore, this new tool to measure responsible AMU requires validation. Moreover, this survey was the first to incorporate the COM-B Model for behaviour change into survey design in an agricultural setting. This project provided an opportunity to pilot the behaviour scale and the COM-B measures used in the current survey, providing numerous methodological learnings to enable further survey refinement going forward.

Both farmers and vets demonstrate an interest in reducing antimicrobials and responsible use of antimicrobials. Findings from this study found that behaviour-change interventions should focus on

- Fostering and strengthening relationships and communication between farmers and vets
- Improving skills and self-efficacy through continuous education and training for both vets and farmers
- Supporting realistic change on farms through a graded and tailored approach
- Leveraging peer-to-peer learning and modelling

Overall, strategy design should encourage incremental behaviour change so that farmers and vets feel capable to implement antimicrobial stewardship strategies. Therefore, careful consideration and an evidence-based approach is required to develop intricate interventions and strategies for optimum effect to elicit successful and sustained behaviour change.

The research team has liaised with a range of stakeholders on this project to learn more about how best to develop and implement behaviour-change interventions within the agricultural sector. “Top-down” policy changes work best when supported by “bottom-up” initiatives. In this AMU research project we have identified interventions and supports that will help farmers, farm advisors and vets to work together in a collaborative way to improve animal health on farms and reduce the need for antibiotic use. Legislation has and will continue to play a significant role in framing the approach undertaken to address AMU in Irish agriculture. Evidence suggests interventions aimed at bringing about behaviour change that focus solely on restrictive, legislative measures are not as successful as interventions that combine restrictive *and* enabling measures (for example education and training, restructuring the environment, communications and messaging, incentives and intervention targeting).

For this reason, we would recommend a continued focus on bringing about behaviour change bearing in mind these multi-faceted components.

7 Added value and anticipated benefits

This project, researching the use of antimicrobials and alternatives in animal health on the IOI, has led to added value and anticipated benefits in a number of different areas, classified using the impact taxonomy developed by the European Science Foundation (ESF, 2012).

Scientific impact: Advances in understanding, method, theory and application

The AMU project produced the *first review of veterinary antimicrobial use* in all livestock sectors Ireland, providing an overview of all data currently available and identifying important knowledge gaps. The project is also the *first study to apply the theoretical COM-B Model and Behaviour Change Wheel* to the study of AMU in the farming sector on the IOI, advancing the application of this theoretical framework to new areas. The project has also developed a new *self-report AMU measure*, which measures farmers' AMU behavioural patterns, and piloted it in a national survey, providing data for testing of the validity and reliability of the scale.

Cultural impact: Contribution to understanding of ideas and reality, values and beliefs

The AMU project has developed a *portfolio of behaviour-change interventions*. This portfolio, which will be publicly available, will offer stakeholders a behavioural lens through which to consider the challenges of AMR and AMU on the IOI. The report outlines 7 ideas that can be taken, adapted and put into practice by the agrifood community to support good animal health practices and responsible AMU on farms.

Educational impact: Contributing to education, training and capacity building

The AMU project has developed a *specialised training programme* aimed at equipping animal health professionals, such as vets and farm advisors, with communication skills and strategies to create a collaborative relationship with their clients and for increasing motivation where required. The course is designed to train animal health professionals in the practice of "motivational interviewing", a collaborative communication approach developed by psychologists and used extensively in human health settings that draws on individuals' inner motivation to change, rather than external pressures. The *Motivational Interviewing training programme* will be delivered to the first cohort of vets in 2022 as part of the follow-on "AMU-FARM" (antimicrobial usage on farms) project. The provision of technical animal-health advice and information using specialised communication strategies can improve awareness and understanding of AMR and influence motivations to reduce AMU in the farming community.

Social impact: Contributing to community welfare, quality of life, behaviour, practices and activities of people and groups

Behavioural insights produced by the AMU project and disseminated widely to stakeholders have highlighted the impact at an individual and interpersonal level of the new regulations being introduced in 2022 and the challenges that farmers and animal health professionals will require support with. Through ongoing stakeholder engagement and empirical research it has become clear that providing expertise in behaviour change can help to navigate the new measures required to reduce the risk of AMR at policy, community, interpersonal and individual levels. From discussion with stakeholders it is evident that the ideas outlined in the *portfolio of behaviour-change interventions* have the potential to reach beyond a direct impact on levels of AMU on the IOI to potentially enhance the wellbeing of those involved in the care of animals by providing social support and acknowledging the relational and psychological factors that influence AMU.

Technological impact: Contribution to the creation of product, process and service innovations

The AMU research project launched an *antibiotic use calculator for dairy herds* for use in Ireland, during World Antimicrobial Awareness Week 2020. The calculator aims to help farmers self-monitor their use of antibiotics, acting as a tool to support behaviour change. Our partners in the desk-based study to determine current usage of antimicrobials and alternatives on the IOI, adapted the University of Nottingham Dairy Antimicrobial Usage

Calculator for use in an Irish setting. The tool is available as a Microsoft® Excel® document and is publicly available to download for free in the "AMR" section of the Teagasc website. A press release was issued by Teagasc announcing the launch of the tool to the farming community. The impact of this tool is to allow farmers and vets to self-monitor their antibiotic use, observe trends, set goals, monitor progress and take action. This tool empowers farmers and vets to take "bottom-up" change at the individual farm level to tackle overuse or misuse of antibiotics.

8 References

Animal Health Ireland (AHI). 2020. *CellCheckIreland*. Available online at animalhealthireland.ie/programmes/cellcheck/introduction. Accessed 15 July 2020.

Alarcon, P., Wieland, B., Mateus, A. L. and Dewberry, C. 2014. Pig farmers' perceptions, attitudes, influences and management of information in the decision-making process for disease control. *Preventive Veterinary Medicine*, 116(3): 223–242.

Bager, F., Bortolaia, V., Ellis-Iversen, J., Hendriksen, R. S., Borck Høg, B., Jensen, L. B., Jensen, A. N., de Knegt, L., Korsgaard, H., Dalby, T., Hammerum, A. M., Hasman, H., Kuhn, K. G., Hoffmann, S., Larsen, A. R., Laursen, M., Nielsen, E. M., Olsen, S. S., Petersen, A., ... DANRES Study Group. 2016. *DANMAP 2015: Use of Antimicrobial Agents and Occurrence of Antimicrobial Resistance in Bacteria from Food Animals, Food and Humans in Denmark*. Amager, Copenhagen, Denmark: Statens Serum Institut. Available online at http://www.danmap.org/~/media/Projekt%20sites/Danmap/DANMAP%20reports/DANMAP%20%202015/DANMAP%202015.ashx

Bland, J. M. and Altman, D. G. 1997. Statistics notes: Cronbach's alpha. *BMJ*, 314(7080): 572.

Boateng G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R. and Young, S. L. 2018. Best Practices for Developing and Validating Scales for Health, Social, and Behavioral Research: A Primer. *Frontiers in Public Health,* 6:149.

Bolton, J. and O'Neill, L. 2019. To *Carry Out a Study in Relation to Methods That Have Been Deployed in Other Member States to Reduce the Use of Antimicrobials, Specifically Antibiotics, on Farms and Share it with Industry*. Department of Agriculture, Food and the Marine in Ireland. Available online at https://www.agriculture.gov.ie/media/migration/animalhealthwelfare/amr/inap/iNAPAnimalHealthImplementationCommitteeReportProject30011019.pdf Accessed 17 February 2020.

Braun, V. and Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2): 77–101.

Cane, J., O'Connor, D. and Michie, S. 2012. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science*, 7(1): 1–17.

Cattaneo, A. A., Wilson, R., Doohan, D. and LeJeune, J. T. 2009. Bovine veterinarians' knowledge, beliefs, and practices regarding antibiotic resistance on Ohio dairy farms. *Journal of Dairy Science*, 92(7):3494–3502.

Chan, Y. H., Fan, M. M., Fok, C. M., Lok, Z. L., Ni, M., Sin, C. F., Wong, K. K., Wong, S. M., Yeung, R., Yeung, T. T., Chow, W. C., Lam, T. H. and Schooling, C. M. 2012. Antibiotics nonadherence and knowledge in a community with the world's leading prevalence of antibiotics resistance: Implications for public health intervention. *American Journal of Infection Control*, 40(2):113–117.

Collineau, L., Bougeard, S., Backhans, A., Dewulf, J., Emanuelson, U., Beilage, E. G., Lehebel, A., Loesken, S., Postma, M., Sjölund, M., Stärk, K. D., Visschers, V. H. M. and Belloc, C. 2018. Application of multiblock modelling to identify key drivers for antimicrobial use in pig production in four European countries. *Epidemiology and Infection*, 146(8):1003–1014.

Cotta, M. O., Robertson, M. S., Tacey, M., Marshall, C., Thursky, K. A., Liew, D. and Buising, K. L. 2014. Attitudes towards antimicrobial stewardship: Results from a large private hospital in Australia. *Healthcare Infection*, 19(3):89–94.

Coyne, L. A., Latham, S., Dawson, S., Donald, I., Pearson, R., Smith, R., Williams, N. and Pinchbeck, G. 2019. Exploring perspectives on antimicrobial use in livestock: A mixed-methods study of UK pig farmers. *Frontiers in Veterinary Science*, 6:257.

Coyne, L. A., Latham, S. M., Williams, N. J., Dawson, S., Donald, I. J., Pearson, R. B., Smith, R. F. and Pinchbeck, G. L. 2016. Understanding the culture of antimicrobial prescribing in agriculture: A qualitative study of UK pig veterinary surgeons. *Journal of Antimicrobial Chemotherapy*, 71(11):3300–3312.

Department of Agriculture, Food and the Marine, 2019. Code of Good Practice Regarding the Responsible Prescribing and Use of Antibiotics in Farm Animals.

Department of Agriculture, Food and the Marine, Agri-Food and Biosciences Institute. All Island Animal Disease Surveillance Report 2016 [Internet]. 2017 Available online at https://www.agriculture.gov.ie/media/migration/animalhealthwelfare/labservice/rvlreports/AIDSRReport016230118.pdf

Department of Health and Social Care in the UK. 2019. *Tackling Antimicrobial Resistance 2019–2024: The UK's Five-year National Action Plan*. United Kingdom: HM Government. Available online at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/784894/UK_AMR_5_year_national_action_plan.pdf . Accessed 3 March 2021.

Di Martino, G., Crovato, S., Pinto, A., Dorotea, T., Mascarello, G., Brunetta, R., Agnoletti, F. and Bonfanti, L. 2018. Farmers' attitudes towards antimicrobial use and awareness of antimicrobial resistance: A comparative study among turkey and rabbit farmers. *Italian Journal of Animal Science*, 18(1):194–201.

Doidge, C., Hudson, C., Lovatt, F. and Kaler, J. 2019. To prescribe or not to prescribe? A factorial survey to explore veterinarians' decision making when prescribing antimicrobials to sheep and beef farmers in the UK. *PloS One*, 14(4):e0213855.

Doidge, C., Ruston, A., Lovatt, F., Hudson, C., King, L. and Kaler, J. 2020. Farmers' perceptions of preventing antibiotic resistance on sheep and beef farms: Risk, responsibility and action. *Frontiers in Veterinary Science*, 7:524.

Earley, B., Tiernan, K., Duffy, C., Dunn, A., Waters, S., Morrison, S. and McGee, M. 2018. Effect of suckler cow vaccination against glycoprotein E (gE)-negative bovine herpesvirus type 1 (BoHV-1) on passive immunity and physiological response to subsequent bovine respiratory disease vaccination of their progeny. *Research in Veterinary Science*, 118:43–51.

Echeverria, S. E., Diez-Roux, A. V. and Link, B.G. 2004. Reliability of self-reported neighborhood characteristics. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 81(4):682–701.

Eldredge, L. K., Markham, C. M., Ruiter, R. A. C., Fernández, M. E., Kok, G. and Parcel, G. S. 2016. *Planning Health Promotion Programs: An Intervention Mapping Approach (4th ed.)*. San Francisco, United States of America: Jossey-Bass.

Escobar, M. P. and Demeritt, D. 2017. Paperwork and the decoupling of audit and animal welfare: The challenges of materiality for better regulation. *Environment and Planning C: Politics and Space*, 35(1):169–190, doi:10.1177/0263774X16646771.

European Centre for Disease Prevention and Control (ECDC), European Food Safety Authority (EFSA) and European Medicines Agency (EMA). 2017. ECDC/EFSA/EMA second joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals – Joint Interagency Antimicrobial Consumption and Resistance Analysis (JIACRA) Report. *EFSA Journal*, 15(7):e04872, doi:10.2903/j.efsa.2017.4872.

European Commission (EC). 2017. *A European One Health Action Plan Against Antimicrobial Resistance (AMR).* (Procedure File 2017/2254[INI]). EC. Available online at amr_2017_action-plan.pdf (europa.eu).

European Commission (EC). 2020. *Farm to Fork Strategy*. EC. Available online at https://ec.europa.eu/food/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf .

European Commission (EC). 2021. Horizon Europe Strategic Plan (2021 – 2024). Available online at https://ec.europa.eu/info/sites/default/files/research_and_innovation/funding/documents/ec_rtd_horizon-europe-strategic-plan-2021-24.pdf

European Medicines Agency (EMA). 2018. European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) interactive database. EMA. Available online at https://www.ema.europa.eu/en/veterinary-regulatory/overview/antimicrobial-resistance/european-surveillance-veterinary-antimicrobial-consumption-esvac . Accessed 15 September 2020.

European Medicines Agency (EMA) Committee for Medicinal Products for Veterinary Use (CVMP) and European Food Safety Authority (EFSA) Panel on Biological Hazards (BIOHAZ). 2017. EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety (RONAFA). *EFSA Journal* 15(1):e04666, doi.org/10.2903/j.efsa.2017.4666 (wiley.com).

European Science Foundation. 2012. The Challenges of Impact Assessment. Available online at: http://archives.esf.org/coordinating-research/mo-fora/evaluation-of-publicly-funded-research.html

European Union (EU). 2019. Regulation (EU) 2019/6 of the European Parliament and of the Council of 11 December 2018 on veterinary medicinal products and repealing Directive 2001/82/EC (Text with EEA relevance). *Official Journal of the European Union*, L4:43–167.

Available online at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0006&from=EN .

Fischer, K., Sjöström, K., Stiernström, A. and Emanuelson, U. 2019. Dairy farmers' perspectives on antibiotic use: A qualitative study. *Journal of Dairy Science*, 102(3):2724–2737.

Fornell, C. and Larcker, D. F. 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1):39–50.

Francis, J., Eccles, M. P., Johnston, M., Walker, A. E., Grimshaw, J. M., Foy, R., Kaner, E. F., Smith, L. and Bonetti, D. 2004. Constructing questionnaires based on the theory of planned behaviour: A manual for health services researchers. *Quality of Life and Management of Living Resources; Centre for Health Services Research.* Available online at https://openaccess.city.ac.uk/id/eprint/1735/ .

Frates, E. P., Xiao, R. C., Simeon, K., McCargo, T., Guo, M. and Stern, T. A. 2016. Increasing knowledge and confidence in behavioral change: A pilot study. *The Primary Care Companion for CNS Disorders*, 18(6), doi:10.4088/PCC.16m01962.

Garcia, J. D., Huff, A. G. and Huff, E. S. 2020. Understanding farmers' biosecurity beliefs and behaviours related to antimicrobial resistant bacteria in Michigan, USA. *Animal Production Science*, 60(5):674–682.

Garforth, C. J., Bailey, A. P. and Tranter, R. B. 2013. Farmers' attitudes to disease risk management in England: A comparative analysis of sheep and pig farmers. *Preventive Veterinary Medicine*, 110(3–4):456–466.

Gibbons, J. F., Boland, F., Buckley, J. F., Butler, F., Egan, J., Fanning, S., Markey, B. K. and Leonard, F.C. 2012. Influences on antimicrobial prescribing behaviour of veterinary practitioners in cattle practice in Ireland. *The Veterinary Record*, 172(1):14.

Golding, S. E., Ogden, J. and Higgins, H. M. 2019. Shared goals, different barriers: A qualitative study of UK veterinarians' and farmers' beliefs about antimicrobial resistance and stewardship. *Frontiers in Veterinary Science*, 6:132.

Habing, G., Djordjevic, C., Schuenemann, G.M. and Lakritz, J., 2016. Understanding antimicrobial stewardship: Disease severity treatment thresholds and antimicrobial alternatives among organic and conventional calf producers. Preventive veterinary medicine, 130, pp.77-85.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E. and Tatham, R. L. 1998. *Multivariate Data Analysis Vol. 5, No. 3* (pp. 207–219). Upper Saddle River, New Jersey, United States of America: Prentice Hall.

Hardefeldt, L. Y., Gilkerson, J. R., Billman-Jacobe, H., Stevenson, M. A., Thursky, K., Bailey, K. E. and Browning, G. F. 2018. Barriers to and enablers of implementing antimicrobial stewardship programs in veterinary practices. *Journal of Veterinary Internal Medicine*, 32(3):1092–1099.

Health Products Regulatory Authority (HPRA). 2019*. Report on Consumption of Veterinary Antibiotics in Ireland During 2018*. HPRA. Available online at https://www.hpra.ie/docs/default-source/default-document-library/report-on-consumption-of-veterinary-antibiotics-in-ireland-during-2018.pdf?sfvrsn=0 . Accessed 28 November 2019.

Higgins, H. M., Golding, S. E., Mouncey, J., Nanjiani, I. and Cook, A. J. C. 2017. Understanding veterinarians' prescribing decisions on antibiotic dry cow therapy. *Journal of Dairy Science*, 100(4):2909–2916.

Higham, L. E., Deakin, A., Tivey, E., Porteus, V., Ridgway, S. and Rayner, A. C. 2018. A survey of dairy cow farmers in the United Kingdom: Knowledge, attitudes and practices surrounding antimicrobial use and resistance. *The Veterinary Record*, 183(24):746.

Jones, P. J., Marier, E. A., Tranter, R. B., Wu, G., Watson, E. and Teale, C. J. 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. *Preventive Veterinary Medicine*, 121(1–2):30–40.

Kigozi, M. M. and Higenyi, J. 2017. Evaluation of farmers' knowledge and application of guidelines on use of veterinary antibiotics in layer poultry production in Mukono district, central Uganda. *Livestock Research for Rural Development*, 29:176.

Kramer, T., Jansen, L. E., Lipman, L. J., Smit, L. A., Heederik, D. J. and Dorado-García, A. 2017. Farmers' knowledge and expectations of antimicrobial use and resistance are strongly related to usage in Dutch livestock sectors. *Preventive Veterinary Medicine*, 147:142–148.

Lunenburg, F. C. 2011. Goal-setting theory of motivation. *International Journal of Management, Business, and Administration*, 15(1):1–6.

Macken-Walsh, A. 2019. Multi-actor co-design of extension interventions: Paradoxes arising in three cases in the Republic of Ireland. *The Journal of Agricultural Education and Extension*, 25:245–265.

Magalhães-Sant'Ana, M., More, S. J., Morton, D. B. and Hanlon, A. J. 2017. Challenges facing the veterinary profession in Ireland: 2. On-farm use of veterinary antimicrobials. *Irish Veterinary Journal*, 70(1):28.

Martin, H., Manzanilla, E. G., More, S. J., O'Neill, L., Bradford, L., Carty, C. I., Collins, Á. B. and McAloon, C. G. 2020. Current antimicrobial use in farm animals in the Republic of Ireland. *Irish Veterinary Journal*, 73(1):11.

Masterton, R. 2008. The importance and future of antimicrobial surveillance studies. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, 47(1):21–31.

Menard, S. 2002. *Applied Logistic Regression Analysis (Vol. 106)*. Sage Publications Inc. Available online at https://dx.doi.org/10.4135/9781412983433 .

Michie, S., Van Stralen, M. M. and West, R. 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1):42.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J. and Wood, C. E. 2013. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioural Medicine*, 46(1):81–95.

Moorman, C,. Diehl, K., Brinberg, D., and Kidwell, B. 2004. Subjective Knowledge, Search Locations, and Consumer Choice. *Journal of Consumer Research*, 31(3):673-680.

More, S. J. 2020. European perspectives on efforts to reduce antimicrobial usage in food animal production. *Irish Veterinary Journal*, 73(2).

Moreno, M. A. 2014. Opinions of Spanish pig producers on the role, the level and the risk to public health of antimicrobial use in pigs. *Research in Veterinary Science*, 97(1):26–31.

Morgans, L. C., Bolt, S., Bruno-McClung, E., van Dijk, L., Escobar, M. P., Buller, H. J., Main, D. C. J and Reyher, K. K. 2021. A participatory, farmer-led approach to changing practices around antimicrobial use on UK farms. *Journal of Dairy Science*, 104(2):2212–2230.

Myers, R. H. 1990. *Classical and Modern Regression with Applications (Vol. 2)* p. 488. Belmont, California, United States of America: Duxbury Press.

Netherlands Veterinary Medicines Institute (SDa). 2019. *Usage of Antibiotics in Agricultural Livestock in the Netherlands in 2018. Trends and Benchmarking of Livestock Farms and Veterinarians*. 2019. Available online at https://cdn.i-pulse.nl/autoriteitdiergeneesmiddelen/userfiles/Publications/2018-def-rapport1.pdf . Accessed 13 August 2021.

National Institute for Health and Care Excellence (NICE). 2014. *Behaviour Change: Individual Approaches*. Available online at https://www.nice.org.uk/guidance/ph49 .

Norris, J. M., Zhuo, A., Govendir, M., Rowbotham, S. J., Labbate, M., Degeling, C., Gilbert, G. L., Dominey-Howes, D. and Ward, M. P. 2019. Factors influencing the behaviour and perceptions of Australian veterinarians towards antibiotic use and antimicrobial resistance. *PLoS One*, 14(10):e0223534.

O'Kane, H., Ferguson, E., Kaler, J. and Green, L. 2017. Associations between sheep farmer attitudes, beliefs, emotions and personality, and their barriers to uptake of best practice: The example of footrot. *Preventive Veterinary Medicine*, 139(Part B):123–133.

O'Neill, J. 2014. *Review on Antimicrobial Resistance. Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations*. United Kingdom: HM Government. Available online at https://www.jpiamr.eu/wp-content/uploads/2014/12/AMR-Review-Paper-Tackling-a-crisis-for-the-health-and-wealth-of-nations_1-2.pdf .

Orpin, P. 2017. What can we learn from farmers experiences and attitudes to Selective Dry Cow Therapy? *Cattle Practice*, 25(Part 3):130–139.

Penry, J. F., Brightling, P. B., Dyson, R. S. and Paine, M. S. 2011. Developing new veterinary services in milk quality: A review of a recent mastitis risk management co-development in Australia. *New Zealand Veterinary Journal*, 59(1):24–27.

Pollak, K. I., Nagy, P., Bigger, J., Bilheimer, A., Lyna, P., Gao, X., Lancaster, M., Watkins, R. C., Johnson, F., Batish, S., Skelton, J. A. and Armstrong, S. 2016. Effect of teaching motivational interviewing via communication coaching on clinician and patient satisfaction in primary care and pediatric obesity-focused offices. *Patient Education and Counseling*, 99(2):300–303.

Postma, M., Stärk, K. D., Sjölund, M., Backhans, A., Beilage, E. G., Lösken, S., Belloc, C., Collineau, L., Iten, D., Visschers, V. and Nielsen, E. O. 2015. Alternatives to the use of antimicrobial agents in pig production: A multi-country expert-ranking of perceived effectiveness, feasibility and return on investment. *Preventive Veterinary Medicine*, 118(4):457–466.

Prochaska, J. O. and DiClemente, C. C. 1986. “Toward a comprehensive model of change.” In *Treating Addictive Behaviors* (pp. 3–27). Boston, Massachusetts, United States of America: Springer.

Pucken, V. B., Schüpbach-Regula, G., Gerber, M., Salis Gross, C., and Bodmer, M. 2019. Veterinary peer study groups as a method of continuous education-A new approach to identify and address factors associated with antimicrobial prescribing. *PloS one,* 14(9), e0222497.

Rattray, J. and Jones, M. C. 2007. Essential elements of questionnaire design and development. *Journal of Clinical Nursing*, 16(2):234–243.

Rayner, A. C., Higham, L. E., Gill, R., Michalski, J. P. and Deakin, A. 2019. A survey of free-range egg farmers in the United Kingdom: Knowledge, attitudes and practices surrounding antimicrobial use and resistance. *Veterinary and Animal Science*, 8:100072.

Rees, G. M., Bard, A. and Reyher, K. K. 2021. Designing a national Veterinary Prescribing Champion programme for Welsh veterinary practices: The Arwain Vet Cymru project. *Antibiotics (Basel, Switzerland)*, 10(3):253.

Regan, Á., Sweeney, S., McKernan, C., Benson, T., Hyland, J. and Dean, M. 2021. Impact of the Covid-19 pandemic on food consumers' awareness of antimicrobial resistance, OneHealth, and animal welfare information on food labels. *Frontiers in Veterinary Science*, 8:678509.

Rell, J., Wunsch, N., Home, R., Kaske, M., Walkenhorst, M. and Vaarst, M. 2020. Stakeholders’ perceptions of the challenges to improving calf health and reducing antimicrobial use in Swiss veal production. *Preventive Veterinary Medicine*, 179:104970.

Roche, S. 2013. “Johne’s Disease on Canadian Dairy Farms: What it Means for farmers.” https://www.youtube.com/watch?v=u0Y0ew5yM08 .

Safari, A., Salehzadeh, R., Panahi, R. and Abolghasemian, S. 2018. Multiple pathways linking environmental knowledge and awareness to employees’ green behavior. *Corporate Governance: The International Journal of Business in Society*, 18(1) doi:10.1108/CG-08-2016-0168.

Scherpenzeel, C. G. M., Santman-Berends, I. M. G. A. and Lam, T. J. G. M. 2018. Veterinarians' attitudes toward antimicrobial use and selective dry cow treatment in the Netherlands. *Journal of Dairy Science*, 101(7):6336–6345.

Scherpenzeel, C. G. M., Tijs, S. H. W., Den Uijl, I. E. M., Santman-Berends, I. M. G. A., Velthuis, A. G. J. and Lam, T. J. G. M. 2016. Farmers' attitude toward the introduction of selective dry cow therapy. *Journal of Dairy Science*, 99(10):8259–8266.

Schneider, S., Salm, F., Vincze, S., Moeser, A., Petruschke, I., Schmücker, K., Ludwig, N., Hanke, R., Schröder, C., Gropmann, A., Behnke, M., Lübker-Becker, A., Wieler, L. H., Hagel, S., Pletz, M. W., Gensichen, J., Gastmeier, P and the RAI Study Group. 2018. Perceptions and attitudes regarding antibiotic resistance in Germany: A cross-sectoral survey amongst physicians, veterinarians, farmers and the general public. *Journal of Antimicrobial Chemotherapy*, 73(7):1984–1988.

Schwarzer, R. and Renner, B. 2009. *Health-specific Self-efficacy Scales* p.14. Berlin, Germany: Freie Universität Berlin.

Sharot, T. 2011. The optimism bias. *Current Biology*, 21(23):R941–R945.

Singer, R. S., Porter, L. J., Thomson, D. U., Gage, M., Beaudoin, A. and Wishnie, J. K. 2019. Raising animals without antibiotics: Producer and veterinarian experiences and opinions. *Frontiers in Veterinary Science*, 6:452.

Söderlund, L. L., Madson, M. B., Rubak, S. and Nilsen, P. 2011. A systematic review of motivational interviewing training for general health care practitioners. *Patient Education and Counseling*, 84(1):16–26.

Speksnijder, D. C., Jaarsma, D. A., Verheij, T. J. and Wagenaar, J. A. 2015. Attitudes and perceptions of Dutch veterinarians on their role in the reduction of antimicrobial use in farm animals. *Preventive Veterinary Medicine*, 121(3–4):365–373.

Svensson, C., Wickström, H., Emanuelson, U., Bard, A. M., Reyher, K. K. and Forsberg, L. 2020. Training in motivational interviewing improves cattle veterinarians' communication skills for herd health management. *The Veterinary Record*, 187(5):191, doi: 10.1136/vr.105646.

Taylor, D. D., Martin, J. N., Morley, P. S., Belk, K. E., White, A. E. and Scallan Walter, E. J. 2020. Survey of production animal veterinarians' prescription practices, factors influencing antimicrobial drug use, and perceptions of and attitudes toward antimicrobial resistance. *Journal of the American Veterinary Medical Association*, 257(1):87–96.

Veterinary Medicines Directorate (VMD). 2019. UK Veterinary Antibiotic Resistance and Sales Surveillance Report (UK-VARSS 2018). VMD. Available online at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842678/PCDOCS-_1705145-v1-UK-VARSS_2018_Report__2019__FINAL_v2.pdf . Accessed 15 January 2020.

Van Dijk, L., Hayton, A., Main, D. C. J., Booth, A., King, A., Barrett, D. C., Buller, H. J. and Reyner, K. K. 2016. Participatory Policy Making by dairy producers to reduce anti-microbial use on farms. *Zoonoses and Public Health*, 64(6):476–484, doi: 10.1111/zph.12329.

Visschers, V. H., Iten, D. M., Riklin, A., Hartmann, S., Sidler, X. and Siegrist, M. 2014. Swiss pig farmers' perception and usage of antibiotics during the fattening period. *Livestock Science*, 162(1):223–232.

World Health Organization (WHO). 2011. *Tackling Antibiotic Resistance from a Food Safety Perspective in Europe*. Geneva, Switzerland: WHO. Available online at https://www.euro.who.int/en/publications/abstracts/tackling-antibiotic-resistance-from-a-food-safety-perspective-in-europe (who.int).

World Health Organization (WHOa). 2015. *Global Action Plan on Antimicrobial Resistance*. Geneva, Switzerland: WHO. Available online at https://apps.who.int/iris/bitstream/handle/10665/193736/9789241509763_eng.pdf?sequence=1 (who.int). Accessed 13 December 2019.

World Health Organization (WHOb). 2015. *Antibiotic Resistance: Multi-Country Public Awareness Survey*. Geneva, Switzerland: World Health Organization. Available online at https://apps.who.int/iris/bitstream/handle/10665/194460/9789241509817_eng.pdf;jsessionid=601BEBF7FA0112F0894D95F6695D8EBB?sequence=1 (who.int).

World Health Organization (WHO). 2017. Fact Sheet: Antimicrobial Resistance 1–5. Geneva, Switzerland: WHO. Available online at https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance (who.int).

World Organisation for Animal Health (OIE). 2020. *Fourth OIE Annual Report on the Use of Antimicrobial Agents Intended for Use in Animals*. Paris, France: OIE. Available at:

https://www.oie.int/fileadmin/Home/eng/Our_scientific_expertise/docs/pdf/A_Fourth_Annual_Report_AMU.pdf . Accessed 2 March 2020.

9 Glossary of acronyms

AM – Antimicrobial

AMU – Antimicrobial Use

CIA – Critically Important Antimicrobials

DAFM – Department of Agriculture, Food & the Marine

IOI – Island of Ireland

NI – Northern Ireland

SDCT – Selective Dry Cow Therapy

10 Appendices

Appendix 1: Farmer survey

Understanding Irish Farmers' Views about Antibiotics: Cross-sector Survey

Q1. Please enter a 4-digit code.

To generate your code, please follow the instructions:

First letter: First letter of the town you were born

Second- & third digits: Last 2 numbers of your phone number

Fourth Letter: First letter of your primary school

Q2. What is your age?

Q3. Please indicate in which **county** in Ireland/Northern Ireland your farm is located.

Q4. Please indicate which agricultural sector you work in.

Beef	
Dairy	
Pig	
Sheep	
Combination / Mixed	
None of the above	

Q5. Please indicate the herd size of your farm.

If you have a mixed enterprise, please fill in the options that are relevant to you.

Beef (breeding)	The number of *breeding cows* on my farm is:	
Beef (dry stock)	The maximum number of *stock* on the farm at any point during the year is:	
Dairy	The number of *dairy cows* on my farm is:	

Pig (Breeding /Integrated)	The number of *sows* on my farm is:	
Pig (Finishing only)	The number of *finishers* on my farm is:	
Sheep	The number of *ewes* on my farm is:	

Q6. If you have a **mixed enterprise**, please indicate the dominant sector within your business. **Please keep this sector in mind when answering the remaining questions.**

If you already selected 'beef', dairy', 'pig' or 'sheep', go to Q7

Beef	
Dairy	
Pig	
Sheep	

The following questions aim to gather information on how antibiotics are used in Ireland. Please think about how you normally use antibiotics on your farm when answering the questions.

Remember that all answers are completely anonymous and will only be used to gain an overall picture, rather than to measure antibiotic use on individual farms.

If you are unsure about answering something, please select 'I don't know'.

Q7. Please indicate how often you do the following practices on your farm.

	Never	Rarely	Sometimes	Frequently	Always	I don't know	Prefer not to say
I follow the dosage instructions given by the vet when using an antibiotic							
I follow the instructions given by the vet on how to administer an antibiotic							
I follow the instructions for storing antibiotics safely (e.g., refrigeration)							
I store antibiotics in a secure location such as a locked fridge or medicine cabinet							
I follow the instructions for disposing of antibiotics safely once they are expired or empty							
I record the antibiotic usage on my farm							
If the animal looks better, I stop the antibiotic before the end of the prescription							
I give the full course of antibiotics as written in the prescription							
I keep a stock of antibiotics on my farm to treat common diseases							
Giving antibiotics to animals to prevent disease (e.g., blanket use) is part of my animal health management routine							
If an animal gets sick, I give antibiotics to the whole group to prevent the spread of disease							
I share antibiotics with other farmers if they are stuck.							
I get the antibiotics I use on my farm directly from a vet							
When animals get sick, I use antibiotics before consulting a vet.							

Q8. When do you record your antibiotic usage?

Immediately after I use the antibiotic	
Weekly	
Monthly	
Quarterly	
Annually	
Before an inspection	
Never	

Q9. Please choose a box that best represents your farm practices in relation to antibiotics used on your farm: ***(circle box)***

I don't have any intention to change how I use antibiotics.	I know that I should change how I use antibiotics, but I'm not ready to	I intend to start making changes to how I use antibiotics.
I have started to make changes to how I use antibiotics.	I have successfully made changes to how I use antibiotics.	I tried to make changes to how I use antibiotics, but the changes

Q10. Please indicate your agreement with these statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I believe antibiotics are used too much in agriculture					

I believe antibiotics are used too much in human medicine					
I believe antibiotics are used too much in my sector					
I believe antibiotics are used too much in other sectors					

Q11. Please indicate your agreement with the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of how to use antibiotics					
I feel like I have enough knowledge about antibiotics					
Compared to the average farmer, I know a lot about how to use antibiotics					
I believe I use antibiotics responsibly on my farm					

Q12. To the best of your knowledge, do you think these statements are true or false? Then answer 'how sure you are that the answer you gave is correct?'

	How sure are you that the answer you gave is correct?

	True	False	Very unsure	Quite unsure	Slightly unsure	Quite sure	Very sure
Antibiotics can kill bacteria							
Overuse of antibiotics makes them become ineffective to treat animals							
The active ingredient in antibiotics given to farm animals are the same as those given to humans							
Overuse of antibiotics makes them become ineffective to treat humans							
Bacteria which are resistant to antibiotics in farm animals can be transferred to humans							
Antibiotics can kill viruses							
Certain antibiotics are reserved for human use							

Q13. Please select 'yes', 'no', or 'I don't know' for the following statements.

	Yes	No
I am aware of the issue of antibiotic resistance		

	Yes	No	I don't know
Antibiotic resistance is a problem in my country and worldwide			
Antibiotic resistance is an issue that could affect me or my family			

Q14. Please select 'yes' or 'no', for the following statements.

	Yes	No
I am aware of the topic of 'One Health'		
I am aware of the links between animal health practices and human health		
I am aware of the link between antibiotic use on farm and antibiotic resistance in humans		

Please read this explanation of the term 'antibiotic resistance':

Antibiotics are used to kill bacteria. They are an important medicine for treating infections in humans and animals. However, the more antibiotics are used, the less effective they become at killing the harmful bacteria. This is known as *antibiotic resistance*. You might also have heard of it as *antimicrobial resistance* ('AMR'). Antibiotic resistance means illnesses in both human and animals are much harder to treat.

Q15. How concerned are you about antibiotic resistance for...

	Not at all concerned	Slightly Concerned	Moderately concerned	Very Concerned	Extremely concerned
... your animals' health					
...human health					
... you and your family's health					

Q16: Please indicate your feelings of risk for the following statements.

	Very low	Low	Moderate	High	Very high
The risks to the **average person** of antibiotic resistance are…					
The risks to the **average farm animal** of antibiotic resistance are…					
The risks to **my animals** of antibiotic resistance are …					
The risks to **my family and me** of antibiotic resistance are….					

Q17. Please indicate your agreement to the following statements.

A good farmer is one who…

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
… is progressive in using new farming approaches and strategies					
…makes decisions based on evidence and data					
…keeps up to date with the latest scientific advice and recommended practices					

Q18. How much responsibility do you believe lies with each of the following groups to **take action** to reduce the risk of antibiotic resistance for humans and animals?

	Not at all responsible	Slightly responsible	Moderately responsible	Very responsible	Extremely responsible
Food Consumers					

Food processors / manufacturers					
Restaurants / fast food chains / caterers					
Farmers in my sector					
Farmers in other sectors					
Retailers					
Government departments (including DAFM, DAERA)					
Medical doctors					
Veterinarians					
Scientists					
Pharmaceutical companies					
Public organisations (e.g., NHS, HSE, WHO)					

Please read the following...

John is a farmer who has recently made changes to how he uses antibiotics. He made a plan to manage his herd's health and prevent disease occurring. He now no longer uses antibiotics with his whole herd to prevent disease breaking out (blanket use), and where possible only gives antibiotics to the animals who show clinical signs of disease.

Q19. I have made similar changes to John on my farm.

Yes	
No	

I don't know	

Q20. If you had to stop blanket use of antibiotics, and make the same changes as John on your farm, how do you think it would make you feel?

	1	2	3	4	5	
Dissatisfied						Satisfied
Foolish						Wise
Worried						Calm

Q21. Please indicate your agreement with the following statements.

If I had to stop the blanket use of antibiotics...

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am confident that I can make changes similar to John on my farm.					
I am confident that I would know what to do					
I believe I have the ability to make changes similar to John					

Q22. If you had to stop blanket use of antibiotics, how helpful do you think any of the following would be to help you to make similar changes to John on your farm?

	Not at all Helpful	Slightly Helpful	Moderately Helpful	Very Helpful	Extremely helpful
New government financial grants to support antibiotic reduction on farms					
Subsidised vaccination programmes					
Publish national averages for antibiotic use across sectors					

New policies and regulations to restrict antibiotic use on farms					
Consumers paying more for produce coming from farms which have proven responsible antibiotic use					
A quality assurance scheme which would include using a new label/logo to alert consumers to produce coming from farms which have proven responsible antibiotic use					
A farmer receiving a financial bonus from the processor for taking action to reduce their antibiotic use on the farm					

Q23. What services do you avail of from your vet? (tick as many as applicable)

To prescribe medication to treat animals	
To carry out procedures (e.g., birthing, castration)	
Mandatory testing (e.g., TB testing)	
To carry out a welfare assessment (e.g., tail biting risk)	
To carry out a biosecurity assessment	
Laboratory testing to diagnose disease	
To get advice on herd health management	
To get advice on reducing antibiotic use	
To plan vaccine programmes	
To make herd health plans	
To get nutrition advice	
None of the above	

Other (*please specify*)	

Q24. When an animal is sick, how often do you consult the following for advice...

	Never	Rarely	Sometimes	Frequently	Always
Myself / my own judgement					
Someone else on my farm					
Another farmer					
A farmer discussion group					
A farm advisor					
A vet					
An additional vet or vets for a second opinion					
Social Media e.g. (Facebook, WhatsApp, Twitter)					
Internet (other than social media e.g., google)					

Q25. Please indicate how strongly you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I feel under pressure from my vet to reduce antibiotic use on my farm					
Communication between my vet and I is good					

Q26. Do you have a farm advisor?

If you answer '***Yes'*** please go to **Q27**.
If you select ***'No***, please go to **Q29.**

Yes	
No	

Q27. What services do you avail of from your farm advisor? (tick as many as applicable)

To get advice on herd health management	
To get advice on reducing antibiotic use	
To plan vaccine programmes	
To make herd health plans	
To make a biosecurity plan	
To get nutrition advice	
To attend a discussion group	
None of the above	
Other (please *specify*)	

Q28. Please indicate how strongly you agree or disagree with the following statement.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I feel under pressure from my farm advisor to reduce antibiotic use on my farm					

Q29. How often do you **get advice from other farmers** on the following? e.g. In conversation/discussion groups/online.

	Never	Rarely	Sometimes	Frequently	Always
Herd health management					
Reducing antibiotic use					
Animal Vaccine programmes					
Biosecurity on the farm					
Treating sick animals					
Animal Nutrition					

Q30. Please indicate how strongly you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I feel under pressure from consumers to reduce antibiotic use on my farm					

I feel under pressure from the Department of Agriculture (DAFM/DAERA) to reduce antibiotic use on my farm					
Hearing from other farmers about their experiences influences my decisions around antibiotics					

Q31. Have you ever learned about antibiotic resistance during formal education/training?

Yes	
No	

Q32. Have you ever been to an online or in-person event (e.g., webinar, conference, farm walk) where antibiotic resistance on farms was discussed?

Yes	
No	

Q33. Are you currently a member of a farm advisor led/ facilitated discussion group?

Yes	
No	

Q34. Have you ever looked for information on antibiotic resistance from…? *(please select as many as applicable)*

A discussion group	
A conference	
A farm walk	
A newspaper	
A webinar	
Social media	
The internet (other than a webinar or social media)	
None of the above	
Other (*please specify)*	

Q35. Please rate your level of agreement with the following statements:

Compared to before the COVID-19 Pandemic …

	Strongly Disagree	Disagree	Neither Agree nor disagree	Agree	Strongly Agree
…I am now more aware of antibiotic resistance					
… I am now more likely to take action to reduce the use of antibiotics on my farm					
…I am now more aware of the connection between animal health and human health					

Q36. In what capacity do you work on the farm? (Full-time = >26 h/week **OR** Part-time = <26h/week)

Full-time	
Part-time	

Q37. Do you have a job off the farm?

Yes	
No	

Q38. How many years of farming experience do you have within your sector?

Q39. How many people work on the farm full time, (including yourself, if you work full time)? *(Full-time = >26 h/week)*

Q40. How many people work on the farm part time (include yourself if you work part time*)? (Part-time = <26h/week)*

Q41. Is there a succession plan in place for your farm?

Yes	
No	
In the process of doing one	
Don’t know	
Prefer not to answer	

Q42. What is your gender?

Male	
Female	
Other	

Q43: What is your marital status?

Married	
Single (never married)	
Widowed	
Divorced	
Separated	
Living with partner	
Prefer not to say	

Q44. What is your highest level of agricultural education or training?

One/two-year certificate in agriculture (e.g., Green Cert)	
Short term agricultural training, less than 60 hours	
Short term agricultural training, more than 60 hours	
Third level degree in agriculture	
None	
Other (7)	
Prefer not to answer	

Q45. In which region is your farm based?
If you have a farming enterprise in both the North and Ireland, please indicate where your main enterprise is

Northern Ireland	
Ireland	

Q46. What is the total annual income of your household from all sources before any tax and national insurance contributions?

If you share your household with individuals unrelated to you (not a family member or your partner), please count only your personal income. **Include all income from on-farm and off-farm employment and benefits.**

If you are not sure of your household income, please estimate.

Northern Ireland

Under £10,000 per annum	**SD 8**
£10,001 - £20,000 per annum	
£20,001 - £30,000 per annum	
£30,001 - £40,000 per annum	
£40,001 - £50,000 per annum	
£50,001 - £60,000 per annum	
£60,001 - £70,000 per annum	
£70,001 - £80,000 per annum	
£80,001 - £90,000 per annum	
£90,001 - £100,000 per annum	
£100,001 - £150,000 per annum	
£150,001 - £200,000 per annum	
£200,001 - £500,000 per annum	
£500,001 or more	
Prefer not to answer	

Ireland

Less than €20,000 per annum	
€20,001 – €40,000 per annum	
€40,001 – €60,000 per annum	
€60,001 – €80,000 per annum	
€80,001 – €120,000 per annum	
€120,001 – €160,000 per annum	
€160,001 - €200,000 per annum	
€200,001 - €400,000 per annum	
€400,001 - €800,000 per annum	

€800,001 or more per annum	
Prefer not to answer	

Thank you for taking the time to complete the survey!

Appendix 2: Vet online survey

Online Survey Questions (approx. 10 minutes)

To generate your code, please follow the instructions:

First letter: First letter of the town you were born

Second- & third digits: Last 2 numbers of your phone number

Fourth Letter: First letter of your primary school

Q1. In which county is your practice located?

Prefer not to say

Q2. How much of your time you dedicate to the following species? (estimated percentage of time %)

Pets	
Horses	

>40%

CLOSE

Q3. Please indicate in which agricultural sector do you work in? (select as many as applicable)

Beef	
Dairy	
Porcine	
Poultry	
Sheep	

Horses	
Pets	
Other	

Q4. Please indicate the sectors you consider yourself to specialise in. *(select as many as applicable)*

Beef	
Dairy	
Porcine	
Poultry	
Sheep	
Mixed	

Full-time		
Part-time		
Prefer not to say		

Q6. What is your age?

	<18, CLOSE

Q7. How many years of veterinary experience do you have practicing veterinary medicine?

Prefer not to say	

Q8. How many people in your practice? (fulltime/part time) (Full- time equivalent = 1 person and an individual working on Part-time basis =0.5)

Prefer not to say	

Q9. Please indicate your involvement in the practice.

Practice owner	
Practice partner	
Working on payroll	
Other … (*please specify*)	
Prefer not to say	

Q10. I identify my gender as:

Male	
Female	
Other	

Quantitative Questions

Q11. Please indicate whether you think the following statements are correct.

			How certain are you of your answer?				
	True	Untrue	**Very unsure**	**Quite unsure**	**Slightly unsure**	**Quite sure**	**Very sure**
Antibiotics are used to cure infections caused by viruses	1	2					
Bacteria can become resistant to antibiotics when antibiotics are frequently used	1	2					
Overuse of antibiotics can lead to loss of sensitivity of antibiotics **(antimicrobial resistance)**							
Misuse of antibiotics can lead to loss of sensitivity of antibiotics **(antimicrobial resistance)**							
Certain antibiotics are reserved for human use	1	2					

Q12. On a scale of 1 – 7, where 1 is highly skilled and 7 is unskilled, how equipped do you feel to do the following

	1 Highly skilled						**7 Unskilled**
I am able to identify the correct antibiotic for an infection.	1	2	3	4	5	6	7
I am able to calculate the correct dose of antibiotics for animals	1	2	3	4	5	6	7
I am able to calculate and administer the correct duration the antibiotics are used for	1	2	3	4	5	6	7
I am able to record relevant antibiotic usage information for each farm within my practice	1	2	3	4	5	6	7
I am able to monitor and record antibiotic use within my practice	1	2	3	4	5	6	7

I am able to comply to antibiotic protocols when treating animals	1	2	3	4	5	6	7
I am able to educate farmers about the use of alternative therapies to treat common diseases on their farm (e.g. vaccines, anti-inflammatories)	1	2	3	4	5	6	7

Q13. Please indicate your agreement with the following statements

I Intend to …	Strongly Disagree	Disagree	Somewhat Disagree	Neither	Somewhat Agree	Agree	Strongly Agree
…Reduce antibiotic use in my practice	1	2	3	4	5	6	7
…Use antibiotics responsibly in my practice	1	2	3	4	5	6	7
…Adhere to antibiotic selection protocols and recommendations before prescribing antibiotics (e.g. susceptibility and diagnostic testing)	1	2	3	4	5	6	7
…Encourage the implementation of alternative methods to using antibiotics e.g. use of vaccines	1	2	3	4	5	6	7

Q14. Please indicate your agreement with the following statements

How concerned are you about antimicrobial resistance for…	Not at all concerned			Neutral			Extremely concerning
…humans	1	2	3	4	5	6	7
… animals	1	2	3	4	5	6	7

Q15. On a scale of 1 to 7, how helpful do you think the following strategies would be to encourage good antibiotic practice on farms?

	Very unhelpful			Neither			Very helpful
Put in place new policies and regulations to restrict antibiotic use	1	2	3	4	5	6	7
Implement legal action should policies and legislation not be adhered to	1	2	3	4	5	6	7
Provide financial incentives or grants to support the use of alternatives to antibiotics	1	2	3	4	5	6	7
Change current procedure where veterinarians profit from antibiotic use	1	2	3	4	5	6	7
Provide educational training programs for all farmers on antibiotics and preventing infectious disease	1	2	3	4	5	6	7
Provision of tailored herd health plans and routine visits for clients	1	2	3	4	5	6	7
Assign one contracted vet to a farm	1	2	3	4	5	6	7
Publish antibiotic usage data on each farm 3 times a year	1	2	3	4	5	6	7
Improve diagnostic and susceptibility testing procedures	1	2	3	4	5	6	7
Provide training and support to improve communication skills of vet	1	2	3	4	5	6	7

Compulsory CPD for veterinarians on antimicrobial use	1	2	3	4	5	6	7
Mandatory antibiotic use recording for farms	1	2	3	4	5	6	7
Mandatory antibiotic prescribing recording for veterinary practices	1	2	3	4	5	6	7

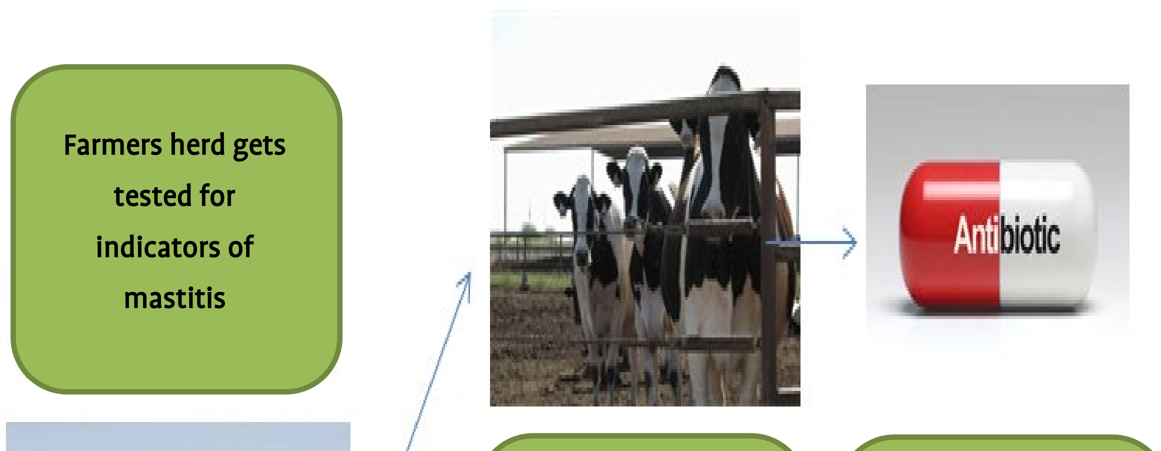
Q16. What strategy do you feel would be the most effective in encouraging good antimicrobial practice? And Why?

Q17. What strategy do you feel would be the least effective in encouraging good antimicrobial practice? And Why?

Instructions to participant: Take a look at these different scenarios of vets prescribing antibiotics to farmers. Please answer the questions that follow.

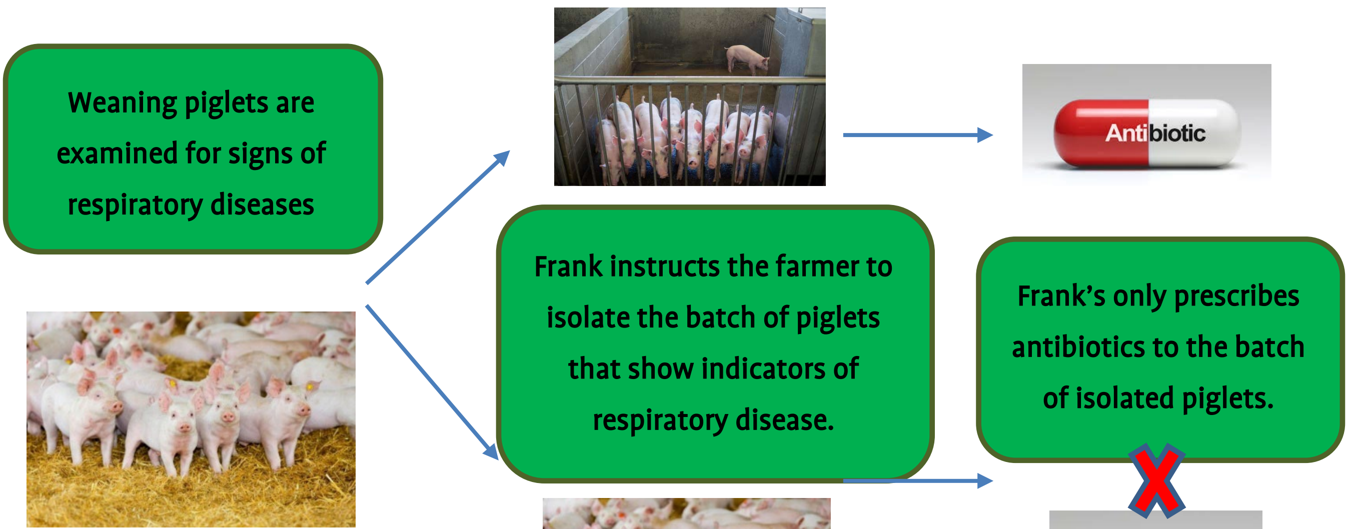
Dairy

Frank is a vet and his client is a dairy farmer getting ready to dry off his herd. Together with his client, they discuss the latest milk recordings for the herd. Only 7% of cows have high cell counts. Frank decides to prescribe the high cell count cows with dry cow antibiotic tubes but does not give antibiotic treatment to the remaining herd.



Pigs

Frank is a vet, and his client is a pig farmer. Frank carries out an examination to see if any weaning piglets' have respiratory disease. Frank found that one batch of piglets have respiratory disease. So, Frank instructs the farmer isolate this batch of pigs and gives them antibiotic treatment. He does not prescribe antibiotic treatment to the remaining batches of piglets.



Beef

Frank is a vet, and his client is a beef farmer. His client recently bought weanlings, two of the weanlings out of a pen of 10 are diagnosed with pneumonia. So, Frank treats these 2 calves with antibiotics. He does not give antibiotic treatment to the remaining calves in the pen.

Weanling calves are examined for indicators of

Frank instructs farmer to isolate the two weanlings with

Frank only prescribes antibiotics to the two isolated

Sheep

Frank is a vet and his client is a sheep farmer. In the past, Frank's client has always prescribed antibiotics at birth to prevent disease in lambs. His client has not had any issue with young lamb diseases for the past three years. After a discussion with the client, Frank has decided he will not prescribe antibiotics to all of the lambs, and only treat sick lambs.

Frank has decided not to give lambs antibiotics at birth

Frank instructs his client to only to isolate and

Q18. Please answer the following questions, keeping in mind the scenarios provided.

Q19. What are your views on these treatment plans?

Q20. What would make you encourage a farmer to go down this treatment route?

How often do you make similar decisions to Frank in your practice?

Q21. What, If anything, would stop you from going down this treatment route?

Q22. What alternative treatment plans would you consider? And Why?

Q23. How do you feel about suggesting treatment options to farmers that do not involve antibiotics?

<u>Telephone Interview with Vets</u>

Qualitative Questions

To generate your code, please follow the instructions:

First letter: First letter of the town you were born

Second- & third digits: Last 2 numbers of your phone number

Fourth Letter: First letter of your primary school

Q24. Talk a wee bit about what you think are the consequences of antimicrobial resistance?

Q25. Who do you feel is responsible for antimicrobial resistance?

Q26. What do you think are the ***<u>benefits</u>*** associated with **reducing** antimicrobial use on farms?

Q27. What do you think are the ***<u>risks</u>*** associated with reducing antimicrobial use on farms?

Q28. How do you view your professional responsibility towards antimicrobial use and antimicrobial resistance?

Q30. How would you describe your access to training focused on antimicrobials?

Q31. Do you have access to peer support in relation to reducing antimicrobial use?

Q32. How do your superiors influence your prescribing behaviour, if at all?

Q33. What do you think your peer's views on antimicrobial use and antimicrobial resistance are?

Q34. Whose advice and opinion do you most respect around antimicrobial usage? And why?

Q35. What are your experiences of client pressure and prescribing treatment plans?

Q36. What do you think would help improve the relationship between farmers and vets when it comes to reducing antibiotics?

Thank you for taking the time to complete the survey!

Appendix 3: Characteristics of participants in a survey of 392 farmers in a behavioural analysis to assess attitudes to antimicrobials and antimicrobial resistance and identify drivers, barriers and facilitators to use of alternatives in animal health on the island of Ireland

		Total participants and percentage of total (%)
Total		**392**
Region	Northern Ireland Ireland	181 (46) 211 (54)
Gender	Male Female Other	346 (88) 45 (11) 1 (<1)
Age	18–39 years 40–59 years 60+ years	128 (33) 201 (51) 63 (16)
Sector	Beef Dairy Pig Sheep	81 (21) 228 (58) 24 (6) 59 (15)
Level of agricultural education	Short-term agricultural training, less than 60 hours Short-term agricultural training, more than 60 hours One- or two-year certificate in agriculture (for example the Ireland "Green Cert") Third-level degree in agriculture None Prefer not to answer	16 (4) 23 (6) 159 (41) 115 (29) 69 (17) 10 (3)
Years' experience	0–20 years 21–30 years 31+ years	135 (34) 105 (51) 152 (15)
Hours worked	Full-time (more than 26 hours per week) Part-time (less than 26 hours per week)	285 (73) 107 (27)
Another job off the farm	Yes No	156 (40) 236 (60)
Succession plan	Yes No In the process of doing one Don't know Prefer not to answer	172 (44) 128 (33) 55 (14) 16 (4) 21 (5)
Marital status	Married	294 (75)

	Single (never married)	65 (16)
	Widowed	3 (1)
	Divorced	3 (1)
	Separated	1 (0)
	Living with partner	23 (6)
	Prefer not to say	3 (1)
Farm size	Small	29 (7)
	Medium	163 (42)
	Large	200 (51)

11 References

Burrell, A. and Regan, Á. January 8 2021. "Can we change our behaviour to prevent superbugs?" *RTÉ Brainstorm*. Available online at https://www.rte.ie/brainstorm/2021/0107/1188209-antibiotic-resistance-superbugs-farming-eu/

Martin, H. 2020. *Dairy Antibiotic Use Calculator*. Available online at https://www.teagasc.ie/animals/amr/prudent-use/

Martin, H. M., Garcia Manzanilla, E., More, S. J., O'Neill, L., Bradford, L., Carty, C. I., Collins, A. B. and McAloon, C. G. 2020. Current antimicrobial use in farm animals in the Republic of Ireland. *Irish Veterinary Journal,* 73(11). Available online at https://doi.org/10.1186/s13620-020-00165-z

Martin, H., McKernan, C., Burrell, A. and Regan, Á. November 2020. "Antimicrobials – Handle With Care: AMU Video Series." VirtualVet. Available online at https://www.virtualvet.eu/media

Regan, Á. and Burrell, A. 2021. Communication innovation supports vet's role in driving change in animal health management. *Veterinary Ireland Journal,* 11(7):407–409.

Regan, Á., Burrell, A., McKernan, C., Martin, H., Benson, T., McAloon, C., Garcia Manzanilla, E. and Dean, M. 2021. *Use of Antimicrobials in Animal Health on the Island of Ireland: Behaviour Change Interventions.* Athenry, Ireland: Teagasc.

Regan, Á., Clifford, S., Burrell, A., Balaine, L. and Dillon, E. 2021. Exploring the relationship between mastitis risk perception and farmers' readiness to engage in milk recording. *Preventative Veterinary Medicine,* 193: 105393. Available online at https://doi.org/10.1016/j.prevetmed.2021.105393

safefood

7 Eastgate Avenue, Eastgate, Little Island, Co.Cork, T45 RX01
7 Ascall an Gheata Thoir, An tOiléan Beag, Co. Chorcaí, T45 RX01
7 Aistyett Avenue, Aistyett, Wee Isle, Co. Cork, T45 RX01

Tel +353 (0)21 230 4100

Email: info@**safefood**.net

@**safefood**_net

@**safefood**_net

Helpline
ROI 0818 40 4567 **NI** 0800 085 1683