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RESEARCH ARTICLE

Applying a conceptual framework for effective implementation of on-farm greenhouse gas mitigation: Evaluation of knowledge exchange methods in Wales and Uruguay

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HIGHLIGHTS

- **Agricultural knowledge exchange methods used in two countries**
- **Potential impacts on challenges to greenhouse gas mitigation assessed**
- **Methods for initial engagement and widening farmers' perspectives highlighted**
- **Resources for and a renewed research focus on extension systems is vital**

KEYWORDS **agricultural extension, farming, greenhouse gas mitigation, knowledge exchange, stakeholders**

Abstract

Globally, agriculture must tackle many complex challenges to ensure food security for a growing population while safeguarding biodiversity and ecosystem services and contributing to greenhouse gas (GHG) emissions reduction. Effective agricultural knowledge exchange (KE) strategies are vital to implementing GHG emissions mitigation measures. Here, KE activities undertaken by publicly funded extension services in Wales (in the global north) and Uruguay (in the global south) were compared using a previously developed conceptual framework.

The main goals were to assess the utility of the framework and to evaluate KE methods in terms of i) potential challenges to initial engagement, ii) categories of challenge they could address and their potential mode of operation, iii) their potential impacts on non-target stakeholder groups, including iv) the interests and limitations of KE practitioners. Use of the framework highlighted issues including the need to i) tackle initial challenges potentially affecting engagement with mitigation narratives, ii) widen the outlook of stakeholders on climate change and emissions reduction, iii) recognise how KE may affect, and be affected by, non-target stakeholders and, iv) address KE practitioners' needs and outlooks. Priorities for improved implementation of mitigation measures include the use of technical (e.g. modelling) and social (e.g. discussions involving non-food chain actors) KE methods that act on stakeholder interests, with the potential to engage farmers in empowering KE processes for GHG emissions mitigation. A renewed research focus on agricultural extension systems is needed to more effectively apply KE resources to meet sectoral GHG emissions targets.

1 Introduction

The agricultural sector faces the challenge of ensuring food security in the context of a growing world population, requiring increases in food production that can be sustained in the long term, while enhancing ecosystem services and minimising greenhouse gas (GHG) emissions. Transformative change may be needed to achieve these goals (Martin et al., 2013) and solutions must be integrated, recognising impacts and needs across interacting spheres (environmental, economic

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and social) to avoid unintended consequences and identify multi-win solutions (Garibaldi et al., 2017). In the face of these challenges, identification not only of solutions but also of effective implementation strategies is essential if required changes are to be realised on the ground. Effective agricultural knowledge exchange (KE) is therefore vital in the context of challenges to implementing GHG emissions mitigation measures in the agricultural sector (Wreford et al., 2017).

Over time, theory and practice in agricultural extension has shifted, from an emphasis on the top-down transfer of knowledge and regulation (from researchers and policymakers to farmers), to more interactive KE which empowers stakeholders to determine and drive the direction of change (Leeuwis, 2004). This trend reflects a similar change from hard to soft systems approaches to communicating and implementing scientific research (van Paassen et al., 2007). Despite these trends, there remain tensions between local, stakeholder driven processes of change in agricultural practice and pre-existing top-down structures of governance (Colvin et al., 2014).

At the same time, previously unified public provision of KE has fragmented and been replaced with KE provided by a mix of public, private and non-governmental organisations, as market-driven agricultural extension models have become favoured for their assumed efficiency benefits (Knuth and Knierim, 2015). In Europe, these changes have occurred in the context of the Common Agricultural Policy (CAP) which has been criticised for reducing social capital in farming communities through its individualised focus (Leventon et al., 2017).

Against this backdrop of theoretical development and policy change, many practical resources have been developed to support best practice in KE, exemplified by the Global Forum for Rural Advisory Services (GFRAS) Global Good Practice Notes report (Davis et al., 2018) which brings together practical summaries of a wide range of advisory methods to inform KE practitioners, especially those working in the developing world. Still, at different levels agriculture has made slow progress in relation to many of the challenges it faces, such as the need to substantially reduce farming related GHG emissions.

Recent work on implementing GHG mitigation measures on Welsh livestock farms analysed the views of stakeholders on challenges to change and solutions, forming a framework categorising challenges and strategies for improved implementation (Kipling et al., 2019a; Kipling et al., 2019b). This work augmented existing resources which provide information on the practical requirements, strengths and weaknesses of different tools for KE, with a conceptual framework that facilitates critical analysis of the potential impacts of implementation strategies, not only on farmers but also on other rural stakeholders. The main goal of the current study was to apply this conceptual framework to evaluate KE methods used by practitioners in two contrasting countries (Wales, in the global north, and Uruguay in the global south) in order to both, i) test the usefulness of the framework and ii) provide an overview of KE strategies in these countries, their potential to address different challenges, their likely impacts and gaps in capacity.

2 Materials and methods

2.1 Study countries and mitigation measures

Agriculture in Wales falls under the European Union's CAP which provides payments to farmers based on the area of land farmed and adherence to practices aligned with sustainability objectives. Eighty percent of agricultural land in Wales has been classified as 'Less Favoured Areas' for farming (Welsh Government, 2013), reflecting the extent of exposed uplands. A large proportion of farm businesses provide low income levels for an ageing farming population (Morris et al., 2017). The climate is oceanic, with warm winters and wet summers ideal for grass growth. Due to the topography and conditions grass-based sheep and beef production dominate agriculture, with a growing dairy industry in more lowland areas of the country (Morris et al., 2017).

In relation to the challenges facing farming, the Welsh Government is pursuing a target of an 80 % reduction in GHG emissions against 1990 levels across the Welsh economy by 2050. However, by 2015 farming emissions had only fallen by 15 % (Jones et al., 2017) driving the commissioning of research to improve performance (Kipling et al., 2019b). Studies have shown wide differences between the most and least production-efficient farms, indicating potential to improve efficiency and reduce GHG emissions intensity by spreading best practice (Hyland et al., 2016b). A wide range of mitigation measures have been suggested for livestock systems at the UK level (including Wales) and indicate that no single solution will achieve desired emissions reductions; rather, improvements in practice throughout farm systems are required, focussing on measures that avoid carbon leakage by improving production efficiency without altering production levels (Kipling et al., 2019b).

Uruguay lies within the South American Campos, an ecological region of grasslands and pastures with scattered trees and shrubs. Uruguay's climate is temperate, moderate and rainy. The temperature of the coldest month is between -3 °C and 18 °C and the temperature of the warmest months exceeds 22 °C. Precipitation shows high inter-annual variability with an annual total reaching 1300 mm in the north of the country; according to the Koeppen climate classification Uruguay is classified in the 'Cfa' category (Bidegain and Caffera, 1997).

Livestock production is mainly in the form of extensive grassland-based beef and sheep systems. Due to edaphic and climatic conditions, and specifically low phosphorous levels, these systems face agricultural issues including low productivity resulting from poor nutrient value and digestibility of grasses (Royo Pallarés et al., 2005). Sheep production has fallen over recent decades as a result of factors including declining domestic mutton consumption, falling wool prices and issues with sheep rustling (Royo Pallarés et al., 2005). While cattle numbers have risen from 8.69 million head in 1991 to 11.74 million head in 2017, sheep numbers have fallen from a high of 26.6 million in 1991 to 6.6 million in 2017 (FAO, 2019). An historic trend towards agricultural land concentration has increased in recent years, with changing patterns of ownership, rising land prices, increases in land devot-

ed to cropping and forestry, and associated socio-economic changes (Oyhantçabal and Narbondo, 2019). In particular, a large and growing area of the country is occupied by eucalyptus plantations which are of increasing economic importance (Pozo and Säumel, 2018).

In 2016, GHG emissions from the Uruguayan agricultural sector were 16.1 % higher than 1990 levels, and on average between 1990 and 2016, 63 % of emissions by sector resulted from enteric fermentation, and a further 26.9 % from manure left on pasture (FAO, 2019). However, recent research indicates that Uruguayan livestock systems based on natural grasslands provide a range of ecosystem services and have the potential to deliver economic and environmental 'win-wins' (Modernel et al., 2018). As in Wales, differences in economic and environmental performance between farms suggest a potential to reduce GHG emission intensity through the spread of best practice in livestock production (Becoña et al., 2014). In Uruguay's extensive beef cow-calf production systems, effective GHG mitigation measures focus on improved grazing management (stocking rate, forage allowance and pasture improvement) (Becoña et al., 2014).

In Wales, although policymakers and KE practitioners seek to drive change that can reduce GHG emissions, KE for farmers has mostly focussed on improving economic performance, with GHG emissions mitigation tackled implicitly through a drive for improved production efficiency. In contrast, in Uruguay, there has been a more direct strategy to create awareness of the environmental impacts of livestock systems in order to drive change. Given the common goal in the two countries to reduce GHG emissions and other environmental impacts from livestock systems, and shared pressure for sustainable intensification of production, comparisons of differences in the KE methods applied can be the basis for learning between KE practitioners in the two countries. The importance of the livestock sector in relation to the global challenges facing agriculture means that the grassland livestock systems of Wales and Uruguay also provide a case study of KE strategy with relevance beyond the focus countries.

2.2 Study context and conceptual framework

The current study is part of a longer-term research effort *(Figure 1)*. In previous work, analysis of the views of stakeholders associated with the Welsh livestock production sector produced a conceptual framework categorising challenges and solutions relating to the implementation of on-farm GHG mitigation measures (Kipling et al., 2019a; Kipling et al., 2019b) *(Figure 1: A)*. The categories were tested for their relevance to global barriers to climate friendly farming and potential solutions, as reviewed by the OECD (Wreford et al., 2017), with the outcome indicating their general relevance beyond the Welsh context *(Figure 1: B)*. Here, this conceptual framework is applied to assess KE methods used in Uruguay and Wales *(Figure1: C, D)*. The framework consists of various components, which are listed on the next page and which provide the structure for the analyses described below (see Appendix 1 for detailed summary of each).

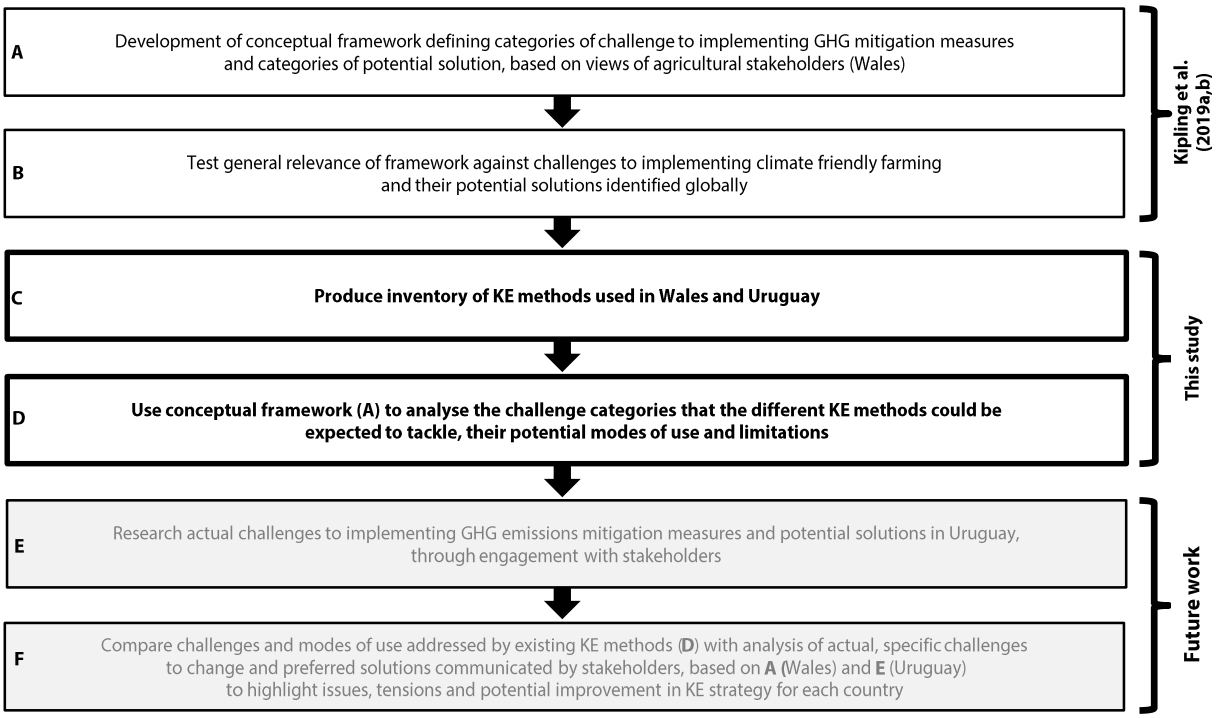

FIGURE 1
Context of current study. Bold text boxes (C, D) = current study, normal text (A, B) = completed research, grey text boxes (E, F) = future work

Four challenge categories:
- Practical limitations
- Knowledge limitations
- Cognitive limitations
- Interests

Three levels of change at which solutions may operate:
- Work around
- Overcome
- Alter

And three approaches to change they may take:
- Accommodate
- Control
- Empower

2.3 Data collection and analysis

Factual descriptions of KE methods utilised were gathered from the two major KE providers in Wales and Uruguay (Farming Connect (FC) https://businesswales.gov.wales/farmingconnect and Plan Agropecuario https://www.planagropecuario.org.uy/web, respectively). The providers were asked to return a list of the KE methods they used (e.g. demonstration farms, factsheets), to describe the goals aimed for in their use (e.g. to ensure farm advisors have up to date knowledge), the target groups aimed at (e.g. farm advisors, young farmers, farmers in general) and how target groups were given access to the KE provided (e.g. via a website, promotion at events). Data were either provided via email or drawn from internal documentation shared with the researchers by the organisations. Based on these data, a summary description of each KE method was prepared. The KE providers checked and approved or amended the descriptions, ensuring accuracy.

The following stages of analysis of collected data were undertaken (the outcomes of each are considered in turn in section 3):

1. In order to gain an overview of KE strategies, a grounded theory approach (in which categories are drawn out of the data rather than being imposed a priori by the investigator – to ensure 'grounding' in the dataset) was used to group the KE methods used in Wales and Uruguay into thematic types and classes according to common aspects and roles.
2. KE method descriptions were assessed to compare the methods applied in Wales and Uruguay.

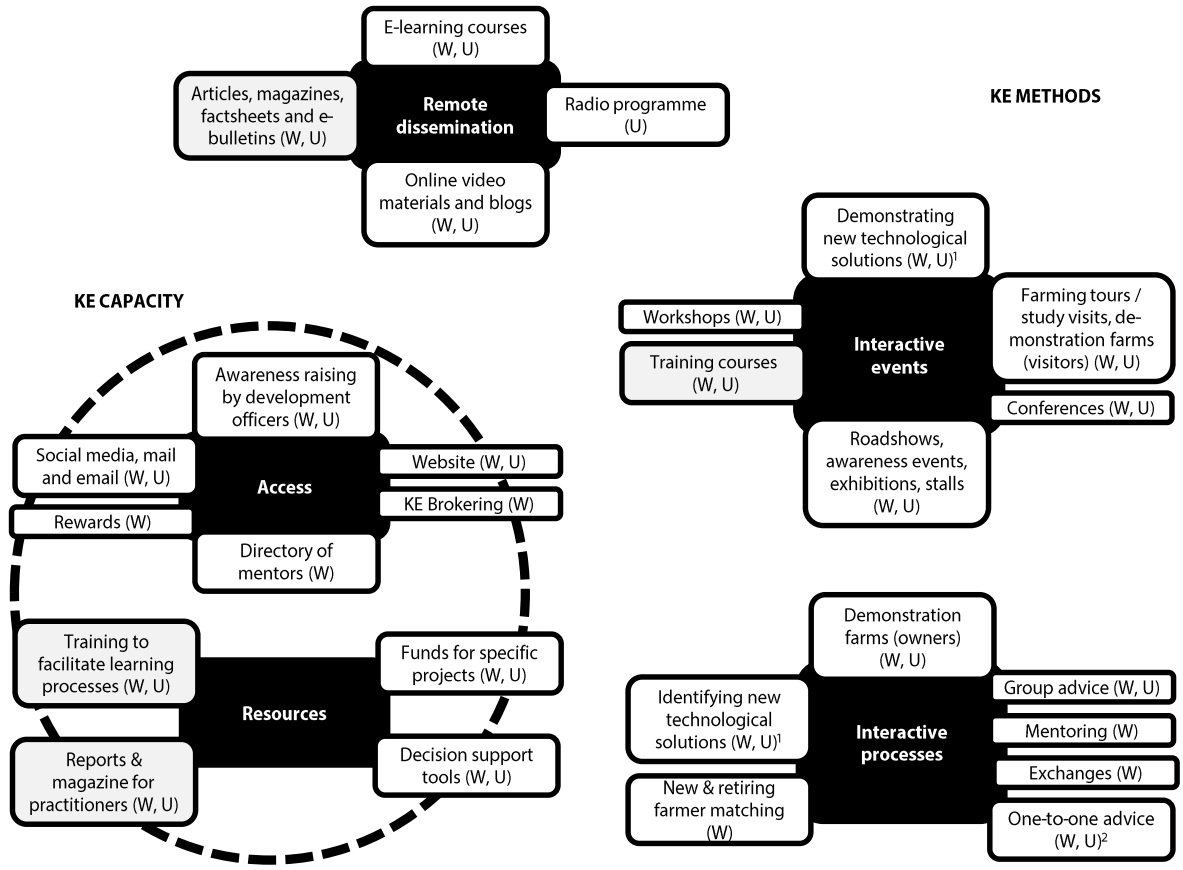

FIGURE 2
Classification of KE methods and KE capacity for Uruguay (U) and Wales (W)
[1]Delivered by the private sector in Uruguay, [2]delivered by the World Bank in Uruguay
Grey boxes = KE methods used both for farmers and as resources for KE practitioners

3. The conceptual framework described above was used to conduct a qualitative assessment of i) potential challenges to initial engagement with KE methods, ii) categories of challenge KE methods could address and their potential mode of operation, iii) the potential impacts of KE methods on non-target stakeholder groups, including iv) the interests and limitations of KE practitioners.
4. The use of the conceptual framework was evaluated.

Assessment of 3 (i) was included as previous research has suggested that individual farmers may not prioritise GHG emissions mitigation, for example due to their perceptions of climate change (Hyland et al., 2016a).

In order to assess 3 (ii), the description of each KE method was considered against the different possible combinations of challenge and solution categories defined in the conceptual framework. For example: a factsheet mainly addresses (by altering – level of change) the challenge categories knowledge limitations and (potentially) cognitive limitations. However, it does not directly address practical limitations and, if the interests of stakeholders are not aligned with its topic, it is not likely to be effective (as an effort is required by the stakeholders to read it). The provision of information is empowering but may be controlling if the aim is to persuade or sell (approach to change). This form of analysis makes explicit and reveals aspects of specific KE methods that might not otherwise be critically evaluated by practitioners. If these aspects are not considered, unintended consequences may occur, or tensions develop between different KE methods applied together (Kipling et al., 2019a). Across the stages of analyses a review of literature was undertaken to ensure theoretical sensitivity. In the following sections, summaries of each element of the analysis are followed by discussions of its implications, grounding in, and relevance to, existing theory.

3 Results and discussion

3.1 Agricultural KE in Wales and Uruguay and challenges to engagement

Data from FC and Plan Agropecuario indicated that a wide range of KE methods are applied in both countries *(Figure 2)*. Information provided fell into two classes: i) KE methods representing resources for stakeholders and, ii) KE capacity initiatives (actions to increase access to KE) and resources underpinning KE activities. Within the class of KE methods, several were grouped as forms of remote dissemination, consisting of a variety of written, verbal or visual forms of information-sharing, while interactive KE methods divided into ongoing KE processes and one-off or short-term events.

In general, potential challenges to farmers engaging with the different KE methods used in Wales and Uruguay were found to be similar although the relative importance of each challenge varied between methods. These challenges are recognised and addressed by KE practitioners in both countries *(Table 1)*. Most access-related KE capacity methods *(Figure 2)* focus on raising awareness of the availability of KE, tackling practical, knowledge and cognitive limitations to engagement; this may be sufficient to encourage engagement when the topics addressed are aligned with farmers' interests. However, research has demonstrated that many farmers lack understanding of how agriculture effects climate change and may be unwilling to accept responsibility for reducing these effects (Hyland et al., 2016a). Therefore, to improve engagement with KE, farmers' interests will need to be addressed at one of the three levels of change: worked around, overcome or altered, to achieve engagement with KE focussed on GHG mitigation. Such interventions will use one of the three approaches to change in the conceptual framework (accommodate, control, empower). A range of

TABLE 1
Challenges to accessing KE methods and solutions employed to address them

Challenge category	Relevance of challenge category to described KE methods	Solutions employed (from *Figure 1*)
Interests	Farmers must have the motivation to engage with resources, so KE methods must work around (accommodate) existing interests. If interests are not fully aligned, partial intake/use is possible, but the expectations of users may not be met. Outcomes may be suboptimal when partial solutions are applied, potentially creating future Interest challenges (loss of trust)	Rewards (KE capacity: Access) for engagement with KE methods provide value to farmers who take part, even if they would not otherwise want to; funded projects (KE capacity: Resources) provide resources to undertake the on-farm changes recommended by KE (helps farmers feel that they can implement what they learn); interaction with others from different backgrounds within engagement, altering interests and reducing interest challenges in relation to future opportunities to engage (KE methods: Interactive events and processes); Information which can be taken in with little effort – working around (accommodating) the challenge – e.g. radio programmes; interactive KE at events already attended by farmers, all of the access-enhancing KE methods
Practical limitations	Farmers need time (and potentially money) to access resources	All access-related tools and the funding to support them (Resources: KE funding)
Knowledge limitations	Farmers need to know the resources exist, and have the skills to access them (e.g. ICT skills)	
Cognitive limitations	Farmers may be overwhelmed with other priorities and not have the mental space to assess the value of engagement	Pro-active access-related tools – e.g. awareness-raising by practitioners approaching farmers; rewards which make the value of engagement immediate and obvious.

combinations of these levels and approaches were identified in methods used to address the challenge category 'interests' in Uruguay and Wales *(Table 1)*.

Accommodating approaches to KE which work around farmers' interests encourage engagement by emphasising the co-benefits of GHG mitigation (e.g. improving production efficiency). Solutions which tackle challenges to engagement through rewards or funding are controlling when applied to overcome interests not aligned with KE topics. Unless the KE method itself can then alter these interests or unless policy forces change, engagement is not likely to stimulate implementation of mitigation measures. Highlighting the dangers of climate change may alter interests and stimulate engagement in a controlling or empowering way (depending on the nature of the intervention) with some research suggesting that farmers may be more willing to implement mitigation measures if they believe climate change will negatively affect their farm (Haden et al., 2012). Finally, KE methods with few challenges to engagement (such as radio programmes) and work on KE capacity to improve access – such as awareness-raising by development officers *(Figure 2)* – may be used to alter interests in an empowering or controlling way. This can be achieved by using these methods i) to disseminate information about climate change and its impacts or ii) as conduits via which more controlling or accommodating advertising of KE activities can be delivered.

Given that KE methods differ in terms of the category and size of challenges to stakeholder engagement with them in different contexts, the use of a mix of KE methods in Uruguay and Wales identified here is one strategy to ensure that different groups of farmers have access to the types of KE best suited to them. This nuanced approach is recognised in the targeted nature of much KE provision in the two countries (e.g. courses for new entrants to farming in Uruguay, one-to-one advice and clinics for harder to reach businesses in Wales). Previous studies have recognised that farmers differ in their preference for advice provision and that communication preferences also differ in relation to different topics – for example with financial matters one-to-one advice may be preferred over group discussions (Hilkens et al., 2018).

Using a mix of KE methods also helps ensure that the quality of information being spread within stakeholder communities, for example through farmer to farmer dissemination, is maintained: interactive events and processes can be backed up by knowledge provided through remote dissemination KE methods. The information provided via these 'one-way' channels can be explained and explored through the use of more interactive KE methods. Again, this strategy is consciously applied in the use of the KE methods examined in this study, one example being the online resources that back up information provided to farmers at events held by FC in Wales. Given the diversity of individual challenges to implementing GHG mitigation measures, a mixed KE strategy may be effective, although identifying which categories of challenge are most important in relation to the uptake of specific measures could help improve the choice of solutions (Kipling et al., 2019b), in this case improving KE provision efficiency.

3.2 Differences between KE methods applied in Wales and Uruguay

Despite large socio-economic and agricultural differences between the two countries, the types of KE methods applied in each were similar at the level of analysis presented. This high level of overlap may reflect similarities in categories of challenge to change faced by agriculture, which appear to be relevant across systems and countries (Kipling et al., 2019b) despite wide diversity in specific challenges (e.g. a farmer in Uruguay may need very different knowledge to a farmer in Wales but knowledge limitations will have relevance to both). The wealth of practical knowledge about KE shared globally through bodies such as the GFRAS (Davis et al., 2018) also offers many resources for those facing similar categories of challenge to learn about and apply relevant KE method to address them.

However, there were also some differences between KE methods applied in Wales and Uruguay. One was the inclusion of radio as a remote dissemination KE method in Uruguay. Although not reported by FC as a KE method used in Wales, at the UK and Welsh national levels radio programmes provide information and discussion on farming and related topics, including the BBC's 'Farming Today' programme (www.bbc.co.uk/programmes/b006qj8q). TV broadcasts also carry programmes for rural communities, such as the weekly farming and countryside magazine series 'Ffermio' (www.ffermio.tv). Given increasing experience of and research into the use of farm radio in the developing world (Oswald, 2019) there may now be lessons to learn for the global north in relation to more tailored use of radio especially on climate change related topics. Using radio may be useful for harder-to-reach farm businesses, in terms of benefits such as the low barriers to farmers engaging with content and the potential for delivering localised, targeted content to remote areas (Oswald, 2019). Modern IT (e.g. mobile phones) facilitates interactive forms of radio KE (e.g. non-response voting, phone-ins) and may help address limitations related to one-way remote dissemination KE methods. At the same time, Gilberds and Myers (2012) emphasise the need for more research to understand the issues related to radio broadcasters as knowledge intermediaries.

The types of interactive KE events reported were the same between Uruguay and Wales, with some differences in the context of their use (e.g. only in Uruguay were courses specifically provided for new entrants to farming). However, in the category of interactive processes, exchanges, mentoring and new and retiring farmer matching, were only used in Wales, while in Uruguay one-to-one advice was provided using World Bank funding rather than being provided by the KE service *(Figure 2)*. These differences may reflect differences in the social context of Wales and Uruguay: in Europe, the CAP has been criticised for the negative impact of its individualised focus on the capacity of farmers to work together (Leventon et al., 2017) while social isolation amongst farmers has been identified as a major issue affecting farmers (Truchot and Andela, 2018). Against this backdrop, KE strategies focussing on bringing together individuals with complementary interests or needs may be particularly beneficial. In more

general terms the social nature of learning makes interaction between farmers in networks a vital element of KE (Klerkx et al., 2010) highlighting the importance of group-based KE methods. As described, efforts to alter stakeholder interests (in this case through exchanging views with others) are likely to be of particular value in relation to GHG mitigation measures which farmers may not initially wish to prioritise.

3.3 Categories of challenge KE methods could address and their potential mode of operation

Analysis with the conceptual framework highlighted how different KE methods might be expected to address the four different categories of challenge to the implementation of GHG mitigation measures described above. Across all KE method types identified, the analysis indicated that providing new knowledge can give insights to stakeholders that order and simplify previous understanding but that provision can also have a potentially negative impact on cognitive limitations by adding complexity to the understanding of participants *(Table 2)* (Kipling et al., 2019b). Studies on the uptake of agro-environment schemes in the UK have previously suggested that both the mechanism and timing of knowledge sharing can be key to the effects of new knowledge, with the provision of large amounts of complex information in response to initial inquiries often overwhelming farmers (Morris et al., 2000). Considering the need for (and challenges relating to) synthesising and applying knowledge, suggests the importance of thinking beyond the provision of knowledge to how knowledge should be put into practice in given contexts. This insight supports the view of Coquil et al. (2018) who describe how, as more transformative changes (e.g. towards agro-ecological farming practices) are undertaken by farmers, the learning process, the roles of KE practitioners and farmers, and their understanding of the system, can all alter; emphasis moves from making knowledge available towards supporting the learning process of farmers as their perspectives and practice change.

Knowledge limitations may be altered by KE methods in an empowering way or, controlled by pressurising or selling approaches *(Table 2)*. Formats in which providers and participants interact have the potential to reduce controlling elements of KE by offering the opportunity for knowledge sharing and enabling practitioners to shape activities to the needs of participants in real time, highlighting learning as a social process (Klerkx et al., 2010). Additionally, it has long been recognised that the environment in which learning interactions take place can have an important impact on learning processes and outcomes. Environment may facilitate different forms of persuasion which may be purposefully

TABLE 2

Summary of expected impacts of KE methods used in Uruguay and Wales on the four categories of challenge to implementing GHG mitigation measures from the conceptual framework. KE method types as in Figure 1

KE method	Practical limitations (PL)	Knowledge limitations (KL)	Cognitive limitations (CL)	Interests (I)
Remote dissemination (for farmers)	No direct change, but alteration of KLs and CLs may reveal ways of addressing PLs that were in fact based on issues of knowledge or understanding	Alter (empower) by direct knowledge provision; controlling element possible in choice of which information to share.	Alter (empower) by provision of new management knowledge/knowledge that simplifies practice. Accommodate (control) if messages are 'sold'. Knowledge may increase perceived complexity, increasing CL. If information is not trusted, it will be evaluated further, again increasing CL.	Alter (empower) through new knowledge and perspectives or overcome/alter (control) if content uses sales approach to re-package old facts or selectively represent new ones.
Interactive events		As for remote dissemination for farmers but knowledge may also grow through interaction with others. Controlling elements may decrease (vs. approaches without interaction) due to chances to question or increase due to physical context and expression of power relations.	As for remote dissemination for farmers but context and practical demonstration can be used to tackle issues of perceived complexity – Alter (empower) – but may also be used to enhance a sales approach – accommodating (control). Presence of other participants may facilitate synthesis of knowledge/evaluation of messages in an empowering way or be another source of control.	As for remote dissemination for farmers but these processes may occur through direct interaction with others as well as with materials. Physical context and the power relations between individuals may have additional effects that control or empower participants.
Interactive processes			Alter (empower) as ongoing processes enable i) difficulties to be identified and addressed, ii) solutions which simplify rather than adding complexity to be developed, and iii) trust to build between those involved – groups acting as networks for ongoing learning.	Alter (empower) through interaction with others. Overcome/ Alter (control) if ideas are 'sold' or if there are power inequalities. If participants are like-minded, may reinforce existing interests (I) – work around (accommodate).

arranged, (e.g. KE providers occupying a raised stage to maintain a separate, controlling position or facilitating empowerment by holding the event in a farm environment that participants feel comfortable in). However, control or empowerment of different groups can also happen accidentally, with positive or negative effects on the goals of the event.

3.4 Potential impacts of methods on non-target stakeholder groups

The conceptual framework focused attention on how the implementation of KE methods can affect the interests and limitations of stakeholders beyond those directly engaged. For the types of KE method defined in *Figure 2*, *Table 3* summarises the nature of these potential impacts.

In relation to the influence of non-target stakeholders on KE, some differences were found between the organisations delivering particular forms of KE in Wales and Uruguay. Within Wales, data on KE methods were collected from FC and KE supplied by other providers (e.g. non-governmental organisations, farm suppliers, veterinarians) were not included, while in response to the shared information from Wales, the Uruguayan KE provider indicated that some of the methods applied in Wales were also available in Uruguay but were provided by other bodies. This mixture of provision brings to the fore the issue of how other stakeholder groups (in this case other KE providers) interact with KE provision.

In particular analysis using the conceptual framework highlighted the potential influence of other stakeholders on KE resulting from both their interests and their limitations *(Table 3)*. This may result in the use of 'controlling' approaches involving pressure to implement or selling of particular solutions to farmers *(Table 2)*. This reveals another challenge for KE practitioners, reflecting the previously recognised complexity of their role in diversified farm advisory systems (Vrain and Lovett, 2016) – the need to identify, understand and manage how other stakeholders influence the scope, content and delivery of KE within the context created by different types of KE methods. In this respect, Uruguayan KE practitioners might draw lessons from the efforts by FC in Wales to avoid sales-type approaches to disseminating information about new technology, including choosing which technologies to highlight based on the views of panels of farmers and KE practitioners before engaging with the companies involved.

A more positive aspect of the influence of non-target stakeholders in relation to GHG mitigation focussed KE activities, is that pressure from customers may drive retailers to try to reduce carbon footprints associated with their suppliers (farmers) (Poore and Nemecek, 2018). In this way, KE processes involving supply chain actors may present opportunities to drive change. Depending on how such drivers act, retailers' pressure for change may represent control over the interests of farmers or an empowering alteration of farmers' interests that enables them to gain higher prices from lower-emissions products. However, consumer preferences for low carbon food products may not always translate into substantial changes in consumption patterns (Kemp et al., 2010) suggesting limits to this driver for change.

TABLE 3

Summary of potential impacts of KE methods on stakeholders not directly engaged.
PL = Practical limitations, KL = Knowledge limitations, CL = Cognitive limitations, I = Interests

KE method	Impacts on non-target stakeholders
Remote dissemination	Other farmers: Empowering alteration of the KLs / CLs of wider groups could arise through the spread of information from those initially engaged. However, there is potential for misinformation / partial information to spread due to the CLs / Is of those passing it on – this may negatively affect: the CLs / KLs of others, the PLs of others if poor knowledge is acted upon, and the trust (Is) of others in future engagement. Information may be spread in a way that seeks to control others' actions, outside the influence of the initial communicator. However, value may be added to knowledge shared by the addition of accumulating experiences of application as information spreads between stakeholders – this may increase levels of trust (or overcome distrust) in external knowledge within the community. Supply chain, research and rural stakeholders: Changes in farmers' KL / CL may affect how they interact with suppliers, customers and those affected by farming activities, including appreciation of their Is, limitations and needs. This may in turn affect the behaviour of those other stakeholders, including their motivation to influence the information farmers receive.
Interactive events	The same issues as identified for remote dissemination apply, plus: Other farmers: Interactions provide opportunities for misunderstandings to be identified and resolved before information is spread further, including weaknesses in the information itself. Facilitated learning / events taking place in a farm context (e.g. demonstration farm visits) may help participants develop a fuller understanding of new knowledge, increasing the likely accuracy of the information they pass on to others. Trust of, and rapport with, KE practitioners built through interactions may motivate more accurate knowledge sharing. KE practitioners: Interactions are likely to alter the limitations and Is of the KE practitioners (and any researchers) involved, potentially improving their understanding of and effectiveness in delivering KE practice (PL, KL, CL) as well as their priorities and motivation (I). However, if only certain groups of stakeholders are engaged (representing particular interests) the outlook (Is) understanding (CL) and knowledge (KL) of KE practitioners may become skewed towards what works for that stakeholder group or towards the Is of that stakeholder group. This may have implications for the style of KE and the content of knowledge shared, and for access to KE by other stakeholders. Supply chain, research and rural stakeholders: Stakeholders with their own Is and limitations may be motivated to shape content, delivery and outcome of interactive events.
Interactive processes	The same issues as identified for interactive events apply but with a decreased likelihood of misinformation or partial information being spread due to the longer-term interaction and growth of understanding within an interactive process (vs. a one-off event). However, influence by specific stakeholders within more involved processes may be deeper. Such influences may increase the possibility that the Is and limitations of KE practitioners become aligned with those of a specific group of stakeholders.

Another revealed potential impact of KE methods on non-target stakeholders *(Table 3)* is how peer to peer spread of shared information could lead to issues with the quality of knowledge being shared. The use of more interactive KE methods and ongoing KE processes could be expected to reduce such problems by providing interactions with providers and opportunities to clarify or question information given. This benefit of KE processes may be particularly relevant in relation to information about GHG mitigation measures, which farmers may not prioritise without engagement in interest-altering interactive activities.

3.5 Interests and limitations of KE practitioners

In both Uruguay and Wales, some KE methods were used as resources for KE practitioners (*Figure 2*: KE capacity: Resources). This recognises the need to support KE practitioners given their key role in how KE methods will be applied and the subsequent outcomes. Previous studies have found that the climate change perspectives of farm advisors can feed through into the advice they give to farmers (Church et al., 2018) suggesting the need to address the interests and limitations of KE practitioners when considering how to improve on-farm implementation of GHG mitigation measures.

In this context, while the use of a mixture of KE methods in Wales and Uruguay may reflect a conscious choice to fulfil strategic goals (see section 3.1) it may also be a pragmatic response to KE practitioners' interests and limitations. In relation to practical limitations (practitioners' time and resources) the in-depth and therefore expensive nature of KE methods (grouped as interactive processes, *Figure 2*) may limit their use in the context of the withdrawal of government funds from KE provision over recent decades (Vrain and Lovett, 2016), as may a lack of skills in facilitating such processes (knowledge limitations). Given the already highly complex role of KE practitioners in diversified advisory landscapes (Vrain and Lovett, 2016) cognitive limitations may affect the extent to which they consider the importance of, learn and use more involved KE methods. Finally, the influence of factors such as the professional self-image of KE practitioners (interests) may also affect the types of KE method made available to farmers.

Considering KE practitioners' interests and limitations highlights that they face challenges in changing their practice. In this study it was observed that, in Wales and Uruguay, KE methods involving more ambitious levels of interaction were reported in discrete, funded, projects (*Figure 2:* KE capacity: Resources) or with limited capacity, relative to broadly available remote dissemination resources. This suggests limitations in the capacity of KE providers to roll out such interactive processes more widely. Addressing these issues, Nettle et al. (2018) examined factors that could support the adoption of novel techniques by KE practitioners, emphasising the need for a supportive context for learning and the importance of processes of experimentation.

Just as potential challenges to farmers accessing KE were identified, analysis of KE methods used as resources for KE practitioners revealed similar potential challenges to engagement by practitioners. However, some unique aspects were revealed. Firstly, the provision of technical information to KE practitioners (*Figure 2:* KE capacity: Reports and magazine for practitioners) highlights the need to effectively bridge the gap between the knowledge domains of researchers and KE practitioners in order to facilitate the integration and co-creation of knowledge from research and practice (Paschen et al., 2018). Differences in the communities or networks of practice (Tagliaventi and Mattarelli, 2006) of these groups can be expected to affect exchange and understanding between them, just as arises between KE practitioners and farmers. This point emphasises the importance of sharing solutions across the research disciplines involved in analysing both research-practitioner and practitioner-stakeholder relationships.

Secondly, analysis using the framework drew attention to how the type and content of KE provided by practitioners may be influenced by the demands of KE recipients (farmers) and other stakeholders, in turn affecting the nature of the topics practitioners themselves demand and engage with for their own development. Such influences may not be conducive to the more transformative changes required to achieve significant reductions in agricultural GHG emissions, given that processes of engagement in which stakeholders are more empowered most often deliver incremental change (Martin et al., 2013). However, KE processes in which farmers are expected to implement externally-derived policies or directions (such as GHG emissions reduction) are more likely to be characterised by bias in power towards the KE practitioner and prescriptiveness in their role, which can have negative consequences on stakeholder attitudes and outcomes (Hilkens et al., 2018; Vrain and Lovett, 2016). A farmer's trust in KE practitioners and the feeling that they are acting in their interests can be vital to the relationship (Ingram, 2008) and this may well be undermined under such circumstances. This tension in KE provision is played out in the way that the privatisation of KE services has led to gaps in provision (Nettle et al., 2017) with demand from farmers (and therefore the supply by KE practitioners reliant on their patronage) not necessarily aligned with policy agendas such as GHG emissions reduction and sustainability.

One potential solution for reducing tensions between the KE topics demanded by stakeholders and societal requirements for agricultural KE came from a specific project in Uruguay. This involved advisors providing farmers with information about the impacts of farming practices on other stakeholders to give the farmers a better understanding of the environmental consequences of their actions and induce them to make changes. Providing open platforms for exchanges between different types of stakeholder has been recommended within processes aimed at developing hybrid, co-generated knowledge to tackle challenges related to agriculture (Nguyen et al., 2014). In this respect, the Uruguayan example may both represent a way to empower bottom-up change towards lower GHG emissions practices by altering farmers' perceptions and enable KE practitioners facilitating such processes to maintain a balanced view of issues without losing the trust of farmers. However, multi-stakeholder interactions must be carefully planned and managed to avoid the

damaging consequences of processes in which farmers feel outnumbered, and to address the challenges of developing trust between farmers and other stakeholder groups (Inman et al., 2018). The application of such techniques as a widely used KE method require changes to be made by farm advisors in terms of their skills and practice, highlighting the need for the provision of carefully designed resources for KE practitioners, including the development of networks for the development and sharing of new knowledge and practice (Nettle et al., 2018).

In addition to KE methods used to provide information and training to KE practitioners, other resources can support improvements in KE practice, including the use of decision support tools to facilitate effective interactions with farmers, for example as 'boundary objects' in social learning processes (Eastwood et al., 2012). Given that one of the advantages of modelling is to make invisible processes visible (van Paassen et al., 2007) they have a clear role in helping tackle issues relating to farmers' understanding of how their systems contribute to GHG emissions (Hyland et al., 2016a). Modelling is used in KE in Wales and Uruguay (*Figure 2:* KE capacity: Resources). However, while in Wales modelling used by FC within its KE programme mainly supports improved farm economic performance, in Uruguay it is being directly applied to investigate how farmers might best reduce emissions through the 'Evaluación Medio Ambiental Ganadera' (EMAG) model (https://www.planagropecuario.org.uy/web/102/contenido/evaluación -medio-ambiental-ganadera.html) (Becoña et al., under review). Participatory modelling of Uruguayan farming systems has also been used to inform best practice in climate change adaptation, demonstrating that in these extensive systems adaptive management rather than rigid prescriptions are most likely to be economically resilient (Dieguez Cameroni et al., 2014). In terms of the conceptual framework applied here, this finding reinforces the importance of empowering KE approaches which build the capacity of stakeholders themselves to manage change and (through this) the need to alter farmer interests in relation to mitigation, rather than simply controlling them. Therefore, if any initial interest-related challenges to engagement with KE methods can be overcome, modelling provides an important resource to support KE. However, processes involving modelling must be transparent about limitations and assumptions in their characterisation of systems, in order to ensure findings are appropriately interpreted and used.

3.6 Use of the conceptual framework

The conceptual framework used here facilitated a systematic appraisal of KE methods used in Uruguay and Wales in terms of their capacity to tackle different categories of potential challenge to the implementation of GHG emissions mitigation measures on livestock farms, including consideration of impacts on non-target stakeholder groups and the challenges to farmer engagement associated with each method. This use of the framework represents a technique for systematically organising the thoughts of the implementers of KE strategies including, forcing them to address aspects of proposed actions that would otherwise have remained implicit or unexplored. Combining this form of analysis of KE methods with an exploration of the actual challenges to change and preferred solutions in a specific location (or for a specific GHG mitigation measure) can facilitate the development of effective KE tailored to specific circumstances. In the context of KE in Wales and Uruguay, further exploration of specific applications of KE methods in each country is also important in order to draw lessons from subtle differences in how the KE methods examined here are actually implemented on the ground. Despite these limitations, this study has highlighted important issues to be addressed by practitioners and researchers in relation to the KE methods reviewed, their strengths and limitations, and has explored differences between the two countries in terms of the KE methods they apply.

4 Conclusions

Analysis of KE methods used in Wales and Uruguay using the conceptual framework highlighted i) the focus of current KE methods in terms of the categories of challenge they are likely to address most effectively, and their different modes of working, ii) the need to recognise how non-target stakeholders may affect the use of (and outcomes associated with) KE methods and, iii) the importance of recognising the particular challenges of delivering KE on GHG emissions mitigation measures versus delivering advice on other topics. KE professionals in the two countries may be able to learn from differences in the KE methods they use and how they are applied (such as, in Uruguay: the use of processes in which farmers engage with non-agricultural stakeholders or the use of modelling that demonstrates to farmers the emissions impacts of their practices and, in Wales: the use of exchanges to share knowledge). This study indicated the utility of the conceptual framework in facilitating critical evaluation of KE methods, going beyond an assessment of their practical efficacy to explore the ways that they could be used to drive change, their limitations and the likely impacts of their application, both on farmers and non-target stakeholder groups. Taking these factors into account can support more effective and efficient KE strategies for on-farm GHG emissions mitigation. It forms the basis for aligning the use of KE methods to the actual mix of challenges experienced in particular locations or environments.

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Appendix 1

Summary of challenge and solution types within the conceptual framework described by Kipling et al. (2019a); challenges fully described in Kipling et al. (2019b). Descriptions focus on farmers but the challenge categories apply to all stakeholder groups.

A 1.1 Categories of challenge to change

Practical limitations:

A range of challenges relating to resources, including the availability of finance, time limitations and the practicality of adjusting existing systems to allow the adoption of changed practices or equipment (e.g. relating to infrastructure or to the environmental context of the farm).

Knowledge limitations:

Relating to stakeholders' awareness of novel management options or technological solutions, level of knowledge about the risks and benefits of a change, and whether they had the skills to implement them.

Cognitive limitations:

Refers to how the complexity of the farm system and the economic, social, environmental and policy pressures on farmers can restrict the mental space available to weigh up the benefits of and synthesise new information about technology or changes to management. Complexity can be added to when information is not trusted (requiring additional evaluation) and when there are many sources of information.

Interests:

All aspects of decision making relating to what stakeholders want to do: an umbrella for widely researched areas relating to the many influences on decision-making.

A 1.2 Solutions Categories

Levels of Change:

Three levels of change were identified:

i) Work around: solutions which do not change or seek to overcome a challenge, but instead avoid it (e.g. aligning all actions with the existing interests of farmers, rather than seeking to change them),

ii) Overcome: solutions which do not remove or reduce a challenge, but give stakeholders the ability (or force them) to overcome it (e.g. providing funds to buy expensive new equipment),

iii) Alter: solutions that actually alter a particular challenge (e.g. new technology may make a particular task much less time consuming, reducing the practical challenge to its implementation).

Approaches to Change:

Three approaches to change were identified, relating to how a specific solution is implemented:

i) Accommodate: accepts that a challenge exists and takes it into account when making changes (e.g. bringing in new roles incrementally to give time for practical changes to be made),

ii) Control: forces or directs change (e.g. regulation to overcome interests that are not aligned to implementation, or providing resources for only certain types of activity),

iii) Empower: enables the stakeholder to take control of the situation and drive change (e.g. providing training in strategic decision making to reduce cognitive limitations and help the stakeholder achieve what they want to).

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