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Achieving successful farmer engagement on greenhouse gas emission mitigation

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Abstract

This paper explores the potential for farmers' engagement on the issues related to greenhouse gas (GHG) emission mitigation in extensive low-input livestock farming systems. The framework used was based on Participatory Action Research (PAR). This involved integrating quantitative evidence on GHG emission impacts at the farm level and qualitative data on the obstacles to the adoption of innovation based on farmers' perceptions and attitudes to climate change. The study aims at building social capital among 14 farmers in the South West and West Midlands regions in England, and it evaluates the potential for adoption of emission mitigation strategies. The Rapid Farm Practices Appraisal (RFPA) tool was created to assess farm practices based on their mitigation potential. Practices were assessed twice over 6-9 months. Semi-structured interviews were used to assess barriers and opportunities to farmer engagement and on-farm innovation. Farmers were invited to a focus group meeting to network with other farmers and engage with researchers. All farmers participated in the 2 farm assessments, but only half the farmers adopted changes in farm management. All farmers appreciated the RFPA tool, the clearness of the information provided and the focus of the tool on practices directly. The main obstacles to innovation were limited financial capital, lack of trust in government action and confusion over the effectiveness of farm advice on mitigation. The lack of long-term flexibility of agricultural policies and the source of information greatly influenced the acceptance of advice. Results suggest the potential for the expansion of the RFPA tool to include economic assessment of farm practices and the engagement of a larger pool of farmers and farming systems. The tool could be used to support the GHG Action Plan and future environmental policies, and as an integrated self-assessment tool for farmers under Environmental Stewardship Schemes.

Keywords: agricultural extension, participatory research, greenhouse gas emissions, low-input farming, livestock, farmer engagement

Introduction

The latest report from the Intergovernmental Panel on Climate Change (IPCC) estimated that is *"extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together"* (IPCC, 2013). Among human activities, farming and the impact of livestock on the environment and farmers' livelihood has gained increasing visibility in the past two decades, in particular in terms of greenhouse gas (GHG) emissions. GHG emissions from livestock systems have been estimated to amount to 14.5% of global emissions (FAO, 2013). Livestock are responsible for 37% of methane (CH_4) emissions, originating predominantly from ruminant enteric fermentation processes and for 65% of nitrous oxide (N_2O) emissions originating from manures and fertilisers use (FAO, 2010). With an estimated 1.7 billion animals, livestock production represents an important economic sector, generating 40% of the global agricultural domestic product, employing around 1.3 billion people, occupying ¼ of the Earth land surface area and utilising ⅓ of the total available arable land to produce animal feed (ibid). It is thus reasonable to assume that any action that attempts to tackle the issue of GHG emissions from livestock will have repercussions not only on production and markets, but also on farmers' livelihoods and income generation.

In the UK, the Climate Change Act of 2008 aims at reducing GHG emissions by 80% from the 1990 baseline by 2050 (United Kingdom Parliament, 2008) and a series of measures have been put into place by the UK Government in order to improve agricultural practices, businesses' competitiveness and promote environmental conservation (DEFRA, 2007; Natural England, 2011). The Greenhouse Gas Action Plan of 2009 addressed the issue of emissions from the agricultural sector with an initial update on the gases' inventories and a review of the mitigation strategies available (NFU, 2011). Agriculture accounts for about 9% of the total GHG emissions in the UK (DEFRA, 2012, p.3). The breakdown of this figure referring to emissions in England attributes 32% to CH_4 from ruminant digestion processes and the production and use of manure and slurry, and 61% to N_2O from the use the use of synthetic and organic fertilisers used both in crop and livestock feed production (DEFRA, 2012, p.3)

In order to reduce emissions at the farm level, it is essential to consider farm practices that are directly under farmers' control. However, it is also important to consider the current challenges that farmers are facing and how farmers' attitudes to climate change are affecting their decisions. The purpose of this article is to present the results from the implementation of a multidisciplinary methodology to establish effective knowledge transfer between an academic institution and a group of extensive low-input livestock farmers based in the South West and West Midlands regions in England.

Practical challenges

Greenhouse gas emission mitigation

Farmers face a number of challenges in considering how to reduce GHG emissions: knowledge of mitigation, the level of support and advice available and the attitudes of farmers per se. There is a large body of evidence on GHG mitigation strategies for farms, of which the following gives an overview.

In spite of the residual uncertainty surrounding the validity of results from carbon calculators available for the agricultural sector, a substantial scientific literature provides useful options for farmers who want to reduce their carbon footprint. Practices included increased concentrates and use of legumes as forage help reducing nitrogen and CH_4 losses. A reduction of crude protein content in the diet of ruminant and monogastric livestock effectively reduces N_2O losses (Arriaga et al., 2010; Philippe et al., 2006). Improving feed conversion efficiency is also a key factor in reducing emissions per animal or per unit of output; e.g. meat, milk (Waghorn et al., 2006). The frequency of manure removal from housing units, the type of litter, type of floor and its regular flushing and cleaning reduce CH_4 and N_2O emissions from livestock housing (Hamelin et al., 2010; Misselbrook et al., 2006). Treatment of solid and liquid manures influences emission rates from manure storage: low temperatures, aeration and composting reduce CH_4 emissions; straw addition, the use of covers and the separate treatment of solid and liquid fractions reduce N_2O losses (Chadwick et al., 2011; Sommer et al., 2009; Stenglein et al., 2011). Conversely, CH_4 emissions from anaerobic digestion of manures have the potential to be harnessed as a source of energy (Fangueiro et al., 2008). The use of legumes in pastures, shorter rotational grazing patterns and attention to soil management (i.e. avoiding waterlogging and compaction) reduce both N_2O and CH_4 losses (Eckard et al., 2010). When manure is applied to soils, it is important to consider timing and application rate, in order to avoid application of excess nitrogen. Various application methods have also proven to be beneficial in reducing emissions from soils (Snyder et al., 2009).

Integrated assessment of farm sustainability

Although all European member states have adopted National Adaptation Strategies to cope with the impacts of climate change, the implementation of such strategies can provide mixed results. This is the case of the United Kingdom which, like Denmark, has developed a National Adaptation Strategy that addresses a variety of sectors, including agriculture, but still faces a number of challenges linked to the uncertainty surrounding scientific knowledge about the effectiveness and reliability of GHG mitigation strategies, the involvement of multi-level actors (i.e. government agencies, local agencies, private sector) and the development of a transparent knowledge network infrastructure (Biesbroek et al., 2010). A further obstacle is the design and implementation of an effective methodology to evaluate the impact of climate change action on farming, because the fragmentation of climate change studies and knowledge transfer (i.e. communication without using technical terminology) remain major barriers to the formulation of a widely accepted model to engage with the public on mitigation strategies (Hofmann et al., 2011). Issues may also arise from the assessment of trade-offs, as a change in farm practices may result in an improvement in GHG emission mitigation, but it may also have a negative effect on other aspects of farming e.g. transportation, socio-economic constraints (de Boer et al., 2011). Based on a thorough analysis of the most recent GHG mitigation studies, de Boer et al. (2011, p.424) suggest that *"the full potential of a mitigation option to achieve a net reduction of GHGs or its trade-offs with other aspects of sustainability (e.g. animal* *welfare) are not generally addressed in the literature."* However, environmental issues are difficult to assess in terms of socio-economic impact and cost-effectiveness, with results that may vary greatly depending on the size and type of farm, as well as on the current national economic situation i.e. cost of inputs (Vellinga et al., 2011).

Influences on decision-making

Farmers' perceptions of mitigation strategies are key to understanding the potential for adoption of new policies to incentivise emissions reduction. A recent survey of experts and farmers evaluated a series of mitigation options in terms of effectiveness according to experts and in terms of practicality according to farmers (Jones et al., 2013). The results showed that the adoption of mitigation strategies may vary significantly based on advice and support given to farmers and that *"flexible policies are needed to enable farmers to select the mitigation measures that are most suited to their own situation"* (Jones et al., 2013, p. 54). Furthermore, government policies have multiple influences on farmers' attitudes and decision-making. Policies that incentivise conservation actions and help in accessing financial support are considered beneficial to improve farm practices (Deressa et al., 2009), whilst lack of both information and social capital have a negative effect (Islam et al., 2013).

Networks of influence play an important role in promoting innovation among farmers (Oreszczyn et al., 2010). They foster farmer-to-farmer knowledge sharing and complement scientific research carried out by academia, independent research institutions or government agencies. Understanding the value of farmers' knowledge and their contribution to the successful application of scientific research is essential to promote effective communication and capacity building (Virji et al., 2012). However, there is a historical difference between scientific knowledge and local knowledge (Raymond et al., 2010). The latter is based on practical experience and anecdotal knowledge; therefore it is usually not considered to have a real value in formal scientific research.

In the agricultural sector, social interactions, networks and behaviours are influenced by individuals' knowledge and experiences, and the gap in communication between researchers and farmers can affect the successful implementation of innovation strategies (Castellanos et al., 2013). Farmers tend to rely more on peers' experiences and knowledge, rather than on advice given by scientists, and influential individuals within farmers groups can have a greater impact on group members than scientific advisors, as a result of shared values and understandings characterising the group (McKenzie, 2011). To counter this, successful farmer-driven innovation can be achieved through activities that generate knowledge and network interactions between researchers and farmer groups. This approach is essential to gain credibility and trust from farmers and it will help researchers focus on practical problems, rather than proposing solutions based on theoretical models (Klerkx et al., 2012).

Agricultural extension services

External influences on farmers' attitudes are represented by the media, extension officers and 'experts'. The role of extension officers as experts and coordinators is to provide in person technical knowledge to farmers (Takemura et al., 2014). However, one of the greatest challenges is that over the past 30 years, government funding for extension and advisory work in the UK, as well as in other European countries, has been significantly reduced. Extension services now vary in efficiency and impact, relying mostly on privatised, and therefore fragmented, action (Swanson and Rajalahti, 2010). Drawing from experiences in the developing world, Islam et al. (2013) suggest that farmers' reluctance to embrace change or adopt on-farm innovation could be dealt with by using a long-term, broader approach to extension that includes formal and non-formal education, rather than relying solely on narrower approaches based on purely technical advice that does not take into consideration social implications of change. In spite of the need for substantial government investment, this strategy presents multiple advantages, as it generates knowledge transfer activities, promotes advances and innovation in the agricultural sector, ensuring transparency and knowledge sharing. Farmers appreciate being presented with possible innovative solutions from both technical or environmental and economic point of view that consider cost-effectiveness and allow them to be co-researchers. These links enable researchers and policy makers to reach a better understanding of the underlying factors that influence farmers' decision-making. Promoting farmers, researchers and government agencies has obvious benefits in terms of policy-making and the implementation of future policies addressing natural resource management and Good Agricultural Practices (GAP) such as the prevention of soil erosion, the correct application of fertilisers, the management of soil organic content, water resources, animal health and welfare (Kings and Ilbery, 2010).

Innovation needs to overcome the barriers created by scepticism over climate change on the one hand and how the UK government is addressing the issue in the agricultural sector, and on the other hand the dichotomy in goals and objectives between farmers and researchers who do not carry out applied research directly linked to farming practices (Islam et al., 2013).

Materials and Methods

Participatory Action Research (PAR)

PAR is described as *"a reflective process of progressive problem-solving led by individuals working with others to improve the way they address issues and solve problems"*, where different actors engage at various levels, building social and cultural capital in order to find collective solutions (German et al., 2012; Pretty and Buck, 2002). Limitations of PAR can be briefly summarised with the use of experts outside of the community, context-dependent results, possible researchers' bias due to their thoughts and opinions, and power relationships between researchers and other participants (Neef and Neubert, 2011). However, this approach was chosen because it aims at empowering farmers and promoting innovation, fostering communication between researchers and farmers during the entire process. It then monitors change, reflects on achievements and failures and proposes new action to drive change. Elsewhere PAR has been successfully adopted to achieve stakeholder engagement (Mapfumo et al., 2013; Oliver et al., 2012). Barriers to collaboration are primarily the lack of communication among parties and the lack of long-term flexibility of environmental schemes (Emery and Franks, 2012). The difficulties in communication can be overcome by adopting a pragmatic approach to research oriented toward practical problem-solving activities (Le Gal et al, 2011). The key steps towards the establishment of successful collaboration between researchers and farmers are: i) the understanding of farmers' knowledge and perceptions of the problems related to on-farm GHG emissions; ii) the provision of transparent knowledge transfer from scientists, in a language that is understandable by farmers and iii) the fostering of farmer-to-farmer networks to promote knowledge sharing and build cultural and social capital.

Sample selection

The study did not aim at representing the whole of the British livestock farming sector. It was set up to pilot a methodology for farmer engagement that can be adopted on wider scales at a later stage on a representative sample.

During spring 2011, a total of 60 farmers were contacted at farming conferences in the South West and by telephone or email, using business directories. Farmers were asked the type of production adopted and invited to participate in the study. Fourteen (14) farmers accepted the invitation: 11 certified organic farms and 3 conventional farms following organic principles, identified as uncertified organic.

The criteria for the selection of farmers for this study were:-

- Location: South West and West Midlands regions, as they represent strongholds of livestock farming:
- Sector: livestock i.e. dairy, beef, pig, poultry, mixed livestock-arable (i.e. fodder);
- Type of production: low-input extensive farming systems. For the purpose of this study farms were identified as small to medium-scale and practicing low-input extensive methods, in order to be able to investigate GHG emission mitigation in farms managing grassland and pasture with low-mechanisation and limited use of labour and fertilisers.

The following framework combines a science-based farm management options assessment with qualitative farmers' behaviour research in order to provide practical advice on reducing farm emissions, in depth knowledge of the current problems livestock farmers face when dealing with GHG mitigation, and the drivers and obstacles to innovation at the farm level. This approach initially involved an assessment of farm practices against GHG mitigation strategies. It then continued with the analysis of farmers' knowledge of climate change and GHG mitigation, their interest in it or lack thereof, and the main obstacles to GHG mitigation at the farm level. The framework can be divided in 3 main activities; the development of the Rapid Farm Practices Appraisal (RFPA) tool, farm visits and farmers group meetings (Figure 1).

Design of the Rapid Farm Practices Appraisal tool

The Rapid Farm Practices Appraisal (RFPA) tool consists of decision trees, scoring tables and a booklet containing recommendations for farmers in order to reduce CH_4 and N_2O emissions. The initial phase involved the review of the scientific literature citing *in vivo* studies that quantify emission mitigation. The review identified key areas for interventions. Livestock farm practices were divided into 5 areas: dietary management, livestock housing, manure storage and treatment, grazing and pasture management, and manure application to field. Each section was analysed using:-

Scoring tables: each practice was assigned a Farm Management Score (FMS) (i.e. (+) the practice was adopted; (-) the practice was not adopted; (0) the practice was not compliant with farm profile) and a Mitigation Potential Score (MPS) (i.e. 1: <10% reduction; 2: 10-30% reduction; 3: >30% reduction).

Decision trees: the implementation of the practices in each section was assessed using a simple Yes / No questionnaire. Each decision tree provided a reference that was linked to the guidelines booklet.

Guidelines booklet: the review of scientific literature was used as a foundation to provide targeted recommendations to the farmer, based on farm-specific contexts. Each recommendation included the practice, the expected outcome (i.e. estimated GHG emissions reduction) and a brief explanation avoiding technical, scientific jargon whenever a simpler vocabulary could be used.

The decision trees and the guidelines booklet provided a straightforward analysis of farm practices management by linking each practice to recommendations specifically tailored for the farm. This approach intended to show to farmers the validity of the recommendations given, which did not rely on general farm profiles with varying degrees of similarities with the actual farm being assessed. The scoring tables gave an overview of the specific potential impact of the agri-business in terms of emissions. The scoring system was based on a review of scientific literature on GHG emission mitigation and it allowed the monitoring of the farm impact in terms of GHG emissions, over time in the case of a change in farm practices management. It could also be used to forecast possible variations in such impact based on changes in farm practices.

Farm visits

The second phase consisted of inviting a pilot set of farmers to participate in the study. Each farm was visited twice and semi-structured interviews were used on both occasions. During the first visit, farmers were interviewed on the current farm management. The RFPA tool was used to generate a detailed, tailored report presented to the farmer, promoting discussion on the topics touched.

A second visit was organised after 6-9 months to monitor changes in farm management using the RFPA tool. Farmers were also interviewed on how they take decisions on farm. The second assessment was done using a PEST analysis model (Byars, 1991) used to analyse factors influencing business management, including environmental factors. A total of 17 factors were considered relevant for the study, type of farm and production system (Table 1) and farmers were asked whether they take any into account or not. It was integrated by farmers' narrative responses, which were coded using a simple taxonomy system in order to group similar answers, providing greater insight on the motivations behind each answer, as different motivations could be given for the same answer. The purpose of the second visit was two-fold: it assessed changes in farm management and farmers' acceptance of recommendations based on scientific knowledge of GHG mitigation from a practical point of view; whilst the second interview assessed farmers' perceptions of mitigation and their relationships with factors internal and external to their farming system.

Farmers' focus group meeting

The last phase of the study included a farmers' focus group meeting. All participants were invited to present their views on the study and its methodology, and to discuss opportunities for action at the community level and for further research and partnerships between academia and farmers. The event was open to farmers that did not participate in the study, in order to engage on a wider scale. Farmers presented their experiences of the study and participants were then split into groups, each group discussing issues related to a topic of concern; e.g. livestock feeding, grassland and pasture management, manure storage and treatment. Participants were encouraged to voice their concerns over issues related to GHG emissions and to propose actions to tackle them. The meeting served as an opportunity to network with other farmers, share experiences and possible solutions.

Data analysis

Results obtained from the study were quantitative data regarding the implementation of practices that mitigate GHG emissions and qualitative data on farmers' attitudes to climate change, in particular the barriers and opportunities for the adoption of GHG emission mitigation options.

Quantitative data obtained using the RFPA tool were reported as number of changes in farm practices over the total number of possible changes. Percentages of estimated GHG emission mitigation were provided for each farm following the farm practices scoring system described.

Qualitative data were obtained using semi-structured interviews. Percentages were provided for positive, negative and neutral responses over the total number of farmers interviewed. Analysis of individual case studies was used to highlight circumstances that were considered to have a possible influence on specific farmers' responses. Narrative responses were analysed by coding concepts such as trust, knowledge, risk, experience, following the methodology described by Gläser and Laudel (2013).

Results

All 14 farms were visited twice and farmers participated in the farm management practices assessments and responded to the interview on factors influencing decision-making on farm. The methodological approach and the use of the RFPA tool received positive feedback from farmers (Figure 2).

Eight out of 14 farmers expressed scepticism over carbon footprinting tools for agri-businesses. However, half of the farmers implemented changes within the 6-9 months. Changes in practices related to grazing and pasture management, manure application to field, manure storage and treatment and dietary management were observed in 2 farms per each section. One farm improved practices related to livestock housing and 2 farms implemented changes in more than one sector.

Nine out of 14 farmers expressed confusion and mistrust regarding the support provided by the government and 4 farmers stated a lack of time and interest in government initiatives. Twelve farms were under Environmental Stewardship (ES) schemes, with 8 farms under Higher Level Stewardship (HLS) agreement and 4 farms under Organic Entry Level Stewardship (OELS) agreement. Nine farmers stated that information provided by DEFRA did not seem to match with their farm profile and they were often sceptical over the validity of the recommendations provided. The relationship farmers had with ES and regulations showed great diversity. Only one farmer stated that he is prepared to follow the guidelines to apply for grants, provided the proposed solution is viable. In most cases, these farmers believed that grants were not worth the amount of work one has to go through.

Five farmers acknowledged that agricultural consultants provide valuable information and support and farmers were ready to pay for the service. However, 6 farmers remained cynical about possible ulterior motives behind scientific farm advice. Thirteen out of 14 farmers stated that the trust in the individual (i.e. researcher, adviser) was a positive influence on their decisions because they appreciate personal contact with the adviser, especially if the person has no obvious marketing agenda. Ten out of 14 farmers stated that the source of scientific knowledge was key to their acceptance of the information.

Two farmers did not show interest in participating in the farmers' focus group, while the other 12 farmers were actively involved in the discussions, in some cases acting as delegates for their local farmer groups, so as to report back to a wider number of farmers on the benefits from meeting with the researchers involved in the study.

Discussion

The farmers interviewed considered the RFPA tool to be more useful in providing practical alternatives, rather than a series of figures to represent the sources of emissions. Farmers considered the latter as a limitation of carbon footprint calculators. The methodology was well accepted by farmers, mostly because of its practical approach to GHG emission mitigation and the clearness of the information provided, which is in line with what was found by Islam et al. (2013) and Llewellyn (2007) regarding farmers' uptake of advice.

Farmers showed interest in practices that required limited or no direct financial input, resulting in a perceived low economic risk with benefits in term of productivity and emission mitigation. Limited financial capital and labour force availability were main reasons given for lack of change in farm management. Practices that showed multiple benefits including mitigation were more easily adopted within 1 year from the first assessment.

The RFPA tool helped identify the practices sections in which improvements in emission mitigation were registered over time (Figure 3). Results analysed by section vary because of the relative importance of each practice within a farming system. Each farm was assessed individually. As an example, in the case of farms adopting a pasture-based system all year long, sections of dietary management and livestock housing were not included in the farm assessment. Therefore, the total percentage of practices that were changed during the study has relative importance due to the specificity of each farming system analysed.

Obstacles and barriers to change

While it is not unreasonable to expect that farms may have financial difficulties throughout the years, the farmers' semi-structured interviews revealed that more than half of the farmers considered 3 of the 5 financial factors assessed not to have any influence on their decisions. These factors were either considered as *"part of the game"* (i.e. agricultural consultants) or the farmers had relevant experience. Farmers cited problems related to the lack of support from banks and the need to take risks. The year 2012 was very tough on farmers due to weather events that affected production (DEFRA, 2013). However, even though the need to prioritise yearly actions was cited among the negative effects of having to produce efficiently and sustainably on limited budgets, 1 farmer attributed a positive influence to financial limitations and adopted a rolling programme year on year of small investments to avoid borrowing money. These results highlight the importance of in-depth studies of farmers' attitudes and perceptions to on-farm innovation, as one condition can be seen as a hindrance by some or an opportunity for improvement by others (Mills et al., 2013).

Difficulties in implementing on-farm innovation can be linked to financial pressure, as supported by the work of Barnes et al. (2010) on the motivations to GHG mitigation in a wide range of agri-businesses (i.e. arable, dairy, beef) which suggests that the main driver for change is economic, followed by improving management practices and market pressure. This is in line with the results of the study.

In this study, farms were almost exclusively organic pasture-based systems, with only very short overwintering based on climatic conditions, and 8 farms were family-run businesses. The choice of pasture-based systems could be linked to reduced running costs (i.e. labour, housing, inputs), but it could be ascribed to lifestyle choices. The organic livestock farmers interviewed saw financial limitations as obvious barriers to improvement in farm management practices; however, organic farmers tend to rely on government subsidies for their business to remain sustainable but are often critical of government action (Kings and Ilbery, 2010).

Although interested in improving farm practices in order to reduce emissions, they did not find that advice given under ES schemes always matched with practices that are recommended to mitigate emissions. Ten farmers stated that the issue of integrating ES and GHG emission mitigation is not taken seriously by the Government, and believed that the Government gives conflicting advice on farm practices, in particular regarding waste management.

As an example, increasing the amount of legumes (e.g. clover) in ruminant diets is an effective strategy to mitigate emissions from enteric fermentation. However, farmers under HLS agreement may encounter difficulties in increasing the percentage of legumes in their livestock diets based on HLS prescriptions i.e. seed mixes allowed on HF10 permanent grassland usually include just around 20% clover. One farmer stated that he was not interested in signing the HLS agreement because he would have to take too much land off production and he didn't want to alter the balance he took some time and effort to reach on farm.

Although these results cannot be representative of the entire livestock farming sector, as differences in farmers' attitudes and behaviour could be present based on farms size, type of production, whether following conventional and organic principles, they could provide valuable insight on farmers' perceptions of government policies in relation to GHG emission mitigation. They seem to highlight the importance of transparent and effective extension advisory services, with an emphasis on consistency of face-to-face interaction and knowledge exchange between farmers and government agencies, as found by Rydberg et al. (2008). Similar issues were found by Hernández-Jover et al. (2012) among small-scale pig farmers in Australia, where the lack of trust in state agencies was linked to the lack of extension services and to previous negative experiences.

Farmers interviewed were not against on-farm innovation and scientific studies that can benefit the environment, livestock and more in general, agri-businesses. They were open to interactions and they voiced repeatedly the desire to have their say on government policies regarding GHG emission mitigation. However, results showed that their proactive attitude seems to be hindered by confusion and lack of confidence in governmental strategies to disseminate scientific knowledge.

Eight farmers cited that they do not trust the scientific basis of GHG mitigation. The reasons given were related to the source and funding of certain studies. It is reasonable to hypothesise that the farmers who responded to the interview citing a lack of trust in the government were also less likely to trust scientific studies cited in official documents, manuals and handbooks provided by the government. However, only 3 out of 14 farmers cited both factors as negative influences on their decisions. Two farmers stated that they do trust science, but they made a clear distinction between lab-driven science and evidence-based science. They preferred to look for scientific information from research facilities like Animal & Grassland Research and Innovation Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland or Rothamsted Research, North Wyke in Okehampton, Devon, which they consider as centres that carry out research with an outlook on its practical application, rather than adopting a science-for-scientists approach.

Opportunities and drivers for change

During the focus group meeting, farmers voiced their wish to have access to unbiased scientific knowledge as in this context, scepticism can be considered a double-edged sword, which may discourage some to engage with the wider community, but it may also motivate others to look for other sources of knowledge that could be perceived as more valuable.

The role of social networks in natural resources management has been the focus of extensive research in recent years. The current challenges facing researchers of complex socio-ecological systems are highlighted in studies undertaking context-dependant research in both the developed and the developing world (e.g. Bodin and Tengö, 2010; Cornell et al., 2013). The understanding of complex socio-environmental dynamics ensures a more effective management of environmental resources and fosters cohesive, productive and sustainable rural communities (Feola and Binder, 2010).

The study addressed the dynamics within the three types of social capital (Table 2). The 14 farmers interviewed tend to rely on local or regional farmers' groups (i.e. Pasture-Fed Livestock Association, Tamar Valley Organic Group, Conservative Rural Affairs Group) to find information, advice and support. Therefore, although the farmers were not selected based on their membership of such associations, it is reasonable to suggest that their proactive attitude to knowledge sharing within the study could have been influenced by pre-existing similar activities. However, farmers' knowledge of the topic addressed by the study was relatively limited.

Farmers showed openness to interact with advisers with earned credibility, highlighting the need for agricultural advisers to be highly competent in their field (Solano et al., 2006). Farmers appreciated not only the support given but

also the fact that their own knowledge and experience were valued during the study. This result confirms that participatory approaches allow researchers to positively interact with farmers in a transparent and effective way and highlights the importance of the way science is communicated and advisers present themselves to farmers (Schöll and Binder, 2009).
Building up from a strong pre-existing *bonding social capital*, which refers to the links between like-minded people or with homogeneous characteristics (Schuller et al., 2000), farmers in the study showed competent use of information technologies. As an example of farmer-to-farmer interaction, all farmers used e-emails and 8 out of 14 farmers participated in discussions on on-line forums. On-line communication was considered economical and fast, an effective way to raise a voice and possibly make connection with more farmers across the country. Such context could be considered favourable to promote *linking social capital* between farmers, researchers and policy makers (Keeley, B., 2007).

Farmers' attitudes and perceptions of climate change are influenced by a complex web of factors, ranging from economic pressure, to environmental conservation, to the social implication in terms of long-term sustainability of rural livelihood (Mills et al., 2013). The peculiarity of the sector lies in the fact that each agri-business is unique in its impact on the environment and the community as a whole. Research aiming at improving livestock farms practices to reduce the impact of GHG emissions needs to take into account the multi-faceted characteristics of rural livelihood and acknowledge that the one-model-fits-all approach cannot apply (Fischer and Glenk, 2011). It is also important to remember that *"knowledge integration, the blending of concepts from two or more disciplines to create innovative new worldviews, is a key process in attempts to increase the sustainability of human activities on Earth"* (Newell et al., 2005, p. 299). Recent research suggests that when addressing current environmental problems, embracing multidisciplinarity is an effective way to establish collaborative action between farmers, researchers, the private sector and government, in order to address practical issues facing the agricultural sector (Feola and Binder, 2010).

Understanding farmers' knowledge and perceptions is the first necessary step towards the integration of local and scientific knowledge, therefore ensuring successful environmental management (Oenema et al., 2011). This critical step represents the strength and the weakness of any engagement methodology. Integrating farmers' knowledge with scientific research is needed to improve existing situations and adopt the best agricultural practices based on specific environmental, social and economic contexts.

Farmers' drivers to innovation and engagement with the research community are not only financial (Cocklin et al., 2007). The results of this study show that the factors with the greatest positive influence are the trust in the advisor and the interest in environmental matters; while the factors most negatively affecting farmers are represented by financial limitations and the lack of trust in government action (Figure 4). Farmers are more inclined to accept knowledge shared within farmer-to-farmer groups or within other interests groups where knowledge is drawn not only from scientific research, but more importantly from experience. Unlike in the industry sector, where the process of categorisation and standardisation of best practices is easier to implement, in the agricultural sector the impact of innovation has greater inconsistency due to the variability in the size, type and geographic context of agri-businesses (Raymond et al., 2010). Categorisation and standardisation have obvious limitations, which reflect in the disconnection between science-driven agricultural research and its practical application at farm level. Therefore, researchers need to gain credibility to farmers in order to overcome this social divide and achieve successful participatory research (Oreszczyn et al., 2010). Extension agents need to engage with individuals within the farmers' groups which might have greater influence on other members, ensuring that advice is context-dependant and establishing a consistent and transparent communication channel with farmers (Matouš et al., 2010). The process requires time and resources that research institutions may not have. Greater investments from the government in supporting public-funded extension services would ensure consistency in advisory outcomes. This would also address the barrier to engagement represented by farmers' frustration and lack of trust over unclear government agency.

The framework presented here could be used by researchers and extension practitioners and be scaled up to embrace larger farms and networks, with farms differing in size and type of production (i.e. organic vs conventional, small-scale vs large-scale) or market links (i.e. local producers vs producers for big retailers), and could provide valuable information to integrate with studies on the influence of consumers' demands for climate-friendly products.
The success of the RFPA tool with farmers in this study suggest the possibility for it to be used without the help of an agricultural advisor or researcher, and potentially be integrated in the current self-assessment procedure under Environmental Stewardships Schemes. Further testing of the tool is needed on a wider scale, including different farming groups, in order to evaluate its potential for collaborative research and its use to highlight the key issues that need to be addressed in future environmental policies (NFU, 2012), benefiting both policy-makers and farmers, ensuring the continuity and effectiveness of agricultural policy in England.

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Figure 1. Methodology timeline.

Note: RFPA: Rapid Farm Practices Appraisal

Figure 2. Farm assessment report feedback survey. Farmers were asked to give a score to each survey question, ranging from “not at all satisfied” to “extremely satisfied” (n = 11).

Figure 3. Comparison of RFPA tool results between the first and second farm assessment.

Figure 4. Impact of factors influencing farmer decision-making (n = 17). Note: refer to Table 1 for factors description.

Table 1. Factors influencing decision-making at the farm level, grouped according to PESTE analysis models.

Type of factor	Reference	Description
Political	P1	Trust in official reports i.e. government (DEFRA, Environment Agency)
	P2	Trust in source of recommendations (institution) i.e. research centres, universities, associations
	P3	Support in integrating Environmental Stewardship schemes (i.e. ELS, OELS, HLS) and GHG emissions reduction
	P4	The level of bureaucracy linked to obtaining grants
Economic	E1	Financial constraint, i.e. limited budget
	E2	Current management is profitable already
	E3	External support for budget and farm management matters
	E4	Cost of agricultural consultants
	E5	Labour force availability
Social	S1	Trust in source of recommendations (individual) i.e. the person conducting the study
	S2	Community support
	S3	Previous bad experiences i.e. consultants, community actions, interest groups
Technological	T1	Trust in scientific basis of GHG emissions reduction strategies
	T2	Trust in assessment tools currently available i.e. carbon accounting tools
	T3	User-friendliness of assessment tools
Environmental	En1	Interest in conservation and environmental matters
	En2	Renewable energy more important greenhouse gas emissions reduction

Table 2. Outline of social capital dimensions and their inclusion in the study.

Social Capital	Characteristics	Actors	Engagement activities	Observations	Opportunities
Bonding	Homogeneous	Extensive low-input livestock farmers (ELILF)	- Knowledge sharing and knowledge transfer: farmer-to-farmer	- Strong bonds within groups - Sub-groups: e.g. interest groups (PFLA), geographic (TVOG), political (CRAG)	- Very open to dialogue with farmers from other groups - Knowledge sharing
Bridging	Heterogeneous	ELILF – interest groups	- Knowledge sharing: farmers network expansion - Capacity building: fostering social capital	- Self-selective - Self-promoting - "Virtual", Online networks	- Online communication preferred: economical, fast and easy way to have a voice, make connections, attract other SSLF out of the main networks
Linking	Heterogeneous	ELILF – Researchers (academia)	- Knowledge sharing: farmer-to-researcher - Knowledge transfer: researcher-to-farmer	- Lack of trust - Researchers seen as distant from reality	- Importance of knowledge transfer - SSLF request for more interaction (translational research)
		ELILF – Government	Beyond the scope of the study	- Lack of trust in policies - Confusion - Fear of hidden agendas - Top-down approach	- Will to influence policy making - Will to have a voice (ELILF) - Understanding that researchers and farmers need one another to influence policy making
		Government – Researchers (academia)	Beyond the scope of the study	- Difficulty in obtaining funding for certain types of projects	- Promote importance of social capital in environmental assessment to support policy making
		Government – National Agencies and larger groups (e.g. large producers)	Beyond the scope of the study	- Commercial interests - Stats to support policy making	- ELILF do not feel they can identify with types of farms used in studies to support policy making - Reports don't represent all types of realities

Keys: ELILF: Extensive low-input livestock farmers, PFLA: Pasture-Fed Livestock Association, TVOG: Tamar Valley Organic Group, CRAG: Conservative Rural Affairs Group.