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Behaviour change and attitudes in the Scottish agricultural sector – a rapid evidence assessment

Bethan Thompson, Rosanna Morrison, Kate Stephen, Veronika Eory, Joana Ferreira, Belinda Vigors, Hernan Botero Degiovanni, Andrew Barnes and Luiza Toma, SRUC

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1 Executive summary

The Scottish Government is committed to reducing greenhouse gas (GHG) emissions from agriculture as part of Scotland's target to reach net-zero emissions by 2045. To meet this very challenging target, the sector and Government are likely to have to take steps to ensure uptake of all available emission-reduction technologies and practices, by all farmers. Understanding behavioural change and attitudes will therefore be critical in order to develop policies and work with industry to deliver this goal.

This study explores the evidence for factors behind adoption of climate-friendly agricultural practices. It examines interventions to encourage practice change, and the key factors that influence successful adoption.

For farmers, there are four key types of factors which influence behavioural change. These are summarised below.

FACTOR	Key points	Comment
Personal	General attitudes, include: *Risk* - e.g. openness to change or innovation *Values* – e.g. to environment *Knowledge* – particularly important for new technologies	Most common type of study

FACTOR		Key points	Comment
Institutional	Informal	The social context a farmer operates in, including: *Networks* and connectivity *Norms* – what's right or what's normal *Influence of peers*	More research needed to understand group behaviour
	Formal	The economic, legal and political context, including: *Rules* and regulations *Incentives* e.g. subsidies *Markets*, supply chains and consumer preference	Most evidence relates to farm subsidies or regulation; fewer studies on supply chain factors or private contracting
Farm structural		Farm characteristics: including, for example, *Spatial* area *Herd* size *Type* – such as arable, mixed, livestock *Income* *Geography* and biophysical conditions	Can inform decisions on which practices might be more likely to be adopted, depending on location, farm type etc.
Socio-demographic		Farmer characteristics including, for example: *Age* *Education*	Often captured through mediating influences such as the personal and informal institutional factors

Factors

Main findings from the evidence on adoption factors indicate:

- Most studies analyse the impact of more than one factor on adoption. This is in line with the wide understanding that behaviours are the outcome of interrelated and complementary influences.
- We found adoption was determined partly by earlier or concurrent choices. This may indicate that policy design might benefit from a clearer understanding of the context of previous and concurrent policy choices. This could contribute to better coordination between policy interventions which encourage the adoption of some practices with interventions promoting other behaviours.
- The evidence demonstrates that farmers are influenced by their peers (usually sharing geography and farm type), indicating the need for interventions supporting collaborative networks. However, more research on group behaviour is necessary to support/complement studies of individual behaviour.
- Adoption factors are useful for explaining different behaviour and/or defining shared characteristics of farmers. This helps identify which practices might be

more successfully adopted in a particular region by specific farm types, and thus assist with tailoring policy interventions.

Interventions

Main findings from the evidence on interventions indicate:

- The more closely tailored an intervention is to the characteristics and needs of the target population, the more effective it seems to be.
- Compliance is positively related to the level of incentive payments. This suggests a focus solely on enhancing environmental outcomes may be less effective than coupling them with those interventions better tuned to economic considerations.
- Training and advice, supported within a collaborative framework, are effective on their own and even more so when used as additional incentives to assist other forms of interventions, in both the short and long term. They may be more effective when framed as industry-focused, rather than climate-focused.
- Similarly, compulsory interventions are more effective when supported by a range of other measures, for instance engaging stakeholders.
- Farmers are more likely to participate in finance-based interventions, such as agri-environmental schemes, if they retain some control over implementation, which requires flexible terms and practical monitoring.
- Overall, the research into the effect of interventions on farmers' adoption of sustainable practices is still at an early stage. Further research is required to assess any potential impact.

Contents

List of tables

List of figures

Glossary of terms

Beliefs	They represent subjective probabilities that a specific behaviour will lead to a specific outcome (Ajzen, 1985).
Attitudes	They represent the individual's summary evaluation of a specific behaviour i.e. their understanding of the value, and level of appreciation of that behaviour (Ajzen, 1985).
Perceived behavioural control	It represents the individual's belief that they can influence and control a specific behaviour (Ajzen, 1985).
Subjective norms	They refer to the individual's beliefs that other individuals, whose beliefs are important to the individual, support or put pressure on the individual to perform a specific behaviour (Ajzen, 1985).
Values	They are "conceptions of the desirable that guide the way social actors (e.g., organisational leaders, policy makers, individual persons) select actions, evaluate people and events, and explain their actions and evaluations" (Schwartz, 1999)
Perceived usefulness	It refers to the individual's subjective likelihood that the use of a certain technology will improve their action (Davis et al., 1989).
Perceived ease of use	It refers to the individual's subjective likelihood that the use of a certain technology is within a certain range of their ability (Davis et al., 1989).
Rapid Evidence Assessment (REA)	REAs is "a type of evidence review that aims to provide an informed conclusion on the volume and characteristics of an evidence base, a synthesis of what that evidence indicates and a critical appraisal of that evidence" (Collins et al. 2015).

2 Research objectives

The Scottish Government is committed to reducing greenhouse gas (GHG) emissions from agriculture as part of Scotland's target to reach net-zero emissions by 2045. One route is to ensure the uptake of available emission-reduction technologies and practices by all farmers. Understanding behavioural change and attitudes will be critical in order to develop policies and work with industry to deliver this goal.

Uptake of technology, best practice – and, at times, basic practice – is often implied to be low in the agriculture sector. Some also make distinctions between a more lagged uptake in certain sub-sectors of agriculture. This research explores the evidence for behavioural change and attitudes in the agriculture sector focused on two research questions:

1) What are the most important factors behind climate-friendly agricultural practice adoption? and

2) What interventions have been implemented to encourage practice change and what are the key factors that influenced successful adoption?

We used a Rapid Evidence Assessment (REA – see Annex 1) approach to assess the current state of evidence. This allows a commentary on the evidence itself (volume and characteristics, dominance and gaps), and a critical analysis of what is retrieved.

3 Background

Attitudes and behaviours inform decision making and can be influenced by a number of factors. When combined, these have a complex impact on how decision makers, e.g., farmers, think, behave and respond to their external surroundings when uptaking technologies and practices. Understanding different determinants of behaviour is key if we are to identify effective types of interventions to influence change.

3.1 Theoretical behavioural frameworks

Human behaviour - and the different factors that drive change - has been studied for centuries. This is not the place to recite the detailed approaches, but it may help to understand the broad themes that carry through. On the one hand some argue that behaviour is driven by perfectly rational decisions[1] while on the other there is increasing recognition that making decisions can be a very complex process.

The majority of this literature stems from pioneering theories of behaviour which date back to 1960s[2]. These are presented in Table 1.

[1]Neoclassical economics assumption on rational decisions around profit orientation and operating in a perfect information/competition environment.

[2] Theory of Planned Behaviour (TPB), Diffusion of Innovation Theory (DOI), Technology Acceptance Model (TAM), Theory of Change, and their extensions/applications to decision-pathways to change identified in behavioural research in different sectors and countries.

Table 1: Main theories of behaviour applied to adoption research

Behavioural theory	Authors	Main features
Theory of Planned Behaviour (TPB)	Ajzen (1991) & Fishbein & Ajzen (1975)	Behaviour is determined by intentions, which are in turn determined by attitudes, social norms and perceptions.
Technology Acceptance Model (TAM)	Davis et al. (1989) & Venkatesh and Davis (2000)	The adoption of technology is determined by perceived usefulness and perceived ease of use.
Diffusion of Innovation Theory (DOI)	Rogers (1962)	Adoption of new approaches is influenced by a complex mix of factors and how an individual perceives them – for example, relative advantage, compatibility, complexity, ability to trial, observability. The importance of these factors will vary from person to person e.g., innovators vs laggards.
Theory of Change	Brest (2010)	Recognises that change is a process, and this method helps to identify causal change pathways, that is, the steps needed to achieve desired outcomes.

The two we are most concerned with here are shaded. The first (TPB) is important for understanding what determines behaviour, based on a causal framework linking beliefs, attitudes, perceived behavioural control, subjective norms as predictors of intentions and behaviours. It allows behaviour to be 'framed' through a particular practice, for example agroforestry.

The TPB framework has been extended to accommodate additional factors, such as values, identified to influence specific environmental behaviours. The TPB framework has been applied in various agricultural settings to explain farmers' behaviours[3], as well as in other areas related to human economic behaviour[4].

Building on the TPB framework, the Technology Acceptance Model (TAM) incorporates factors such as 'usefulness' and 'ease of use' to predict usage of a technology; basically, if an individual perceives a technology as "useful" and "easy to use", they are more likely to adopt it.

This approach has been applied to research on agri-environmental adoption of precision agriculture[5], with some on grazing practices and technologies in dairy farming[6]. It has also been extended to accommodate additional factors, further disaggregating 'usefulness' and 'complexity' for an improved understanding of adoption. TAM is useful for identifying factors influencing farmers' adoption of specific technologies and practices, and thus may facilitate further tailored development of agri-environmental practices and technologies[7].

Types of decision

The impact that factors have on decision making depends on:

[3]E.g., Beedell and Rehman, 2000; Hansson, et al., 2012; Läpple and Kelley, 2013; Sutherland, 2010.
[4]E.g., Kautonen, et al., 2015, Kautonen, et al., 2013.
[5]E.g. Adrian, et al., 2005; Reichardt, et al., 2009.
[6]E.g. Flett, et al., 2004; Schaak and Mußhoff, 2018.
[7]For more detail on TPB and TAM applied to uptake of ecological and environmental behaviours in agriculture see https://www.lift-h2020.eu/deliverable-d2-1-drivers-of-farmers-up%e2%80%90take-of-ecological-approaches-a-conceptual-framework-with-a-behavioural-focus/

- the type of decision (short/long term, voluntary action/response to compulsory regulation, day-to-day/structural change to business, etc.),
- professional setting (some such as environmental management, finance, food being more similar to agriculture than others) or
- geography (e.g., decision makers in the UK or other developed countries are likely to be influenced by different sets of factors than those in developing countries).

Most of these factors influence all types of decision-making processes. However, the context will affect the weight they have and type of impact[8].

So, in carrying out such research, the underlying assumptions in design can influence the accuracy of the findings, and in turn, the relevance of the recommendations for behavioural change interventions.

These decisions might be driven by policy interventions, ranging from compulsory measures such as regulation and standards, to public or private financial incentives, training and provision of information, individually or in combination.

3.2 Tools for predicting uptake

There has naturally been a strong interest in methods that help to predict the potential success of an intervention, although the availability of quantitative models and tools to predict adoption is still limited. Existing tools target specific interests (e.g. policymakers, technology providers and development investors), each with a different focus to use them, e.g., guidance for development of policies and regulatory interventions or sustainability-driven market signals (some detail on existing adoption tools, their features and users is presented in Annex 3).

4 The evidence

4.1 Factors of adoption

We assessed a wide breadth of agricultural practices aimed at mitigating directly or indirectly the impact of farming on climate change and the environment. These practices (see Figure 4 in Annex 2) include:

- practices focusing specifically on mitigation of impact on greenhouse gases (GHG)[9],
- climate change friendly practices linked to pest and weed management,
- soil and fertilisation management,
- organic farming,
- precision farming,
- agroforestry, and
- environmental practices linked to water and biodiversity,
- with a number of them under the wider sustainability umbrella[10].

[8] Direct or indirect/mediated by other influences.
[9] These were labelled in the corresponding studies specifically as greenhouse gases mitigation practices.
[10] Either due to the way they were labelled in the studies reviewed e.g., an umbrella term for a number of alternative practices to be implemented as part of agri-environment schemes; or because any further

It is most common for research to consider more than one practice at a time - about a fifth of studies analyse factors of adoption of multiple practice types.

It was common to recognise the possibility of a dependence path, i.e., farmers' adoption behaviour may be partly determined by - and build on - their earlier or concurrent choices[11]. Understanding the existence of these interrelationships is essential so that the effect of different factors on adoption is recognised as part of complex interdependent decisions on adoption.

Most studies analyse the impact of more than one factor on adoption - with under a third of the studies focussing exclusively on one type of factor[12]. This is in line with the almost universally acknowledged fact that behaviours are the outcome of interrelated and complementary influences.

Adoption factors are listed in Table 2.

Table 2: Types of adoption factors

FACTOR		Key points	Comment
Personal		General attitudes, includes *Risk* - e.g. openness to change or innovation *Values* – e.g. to environment *Knowledge* – particularly important for new technologies	Most common type of study
Institutional	Informal	The social context a farmer operates in, including: *Networks* and connectivity *Norms* – what's right or what's normal *Influence of peers*	More research needed to understand group behaviour
	Formal	The economic, legal and political context, including: *Rules* and regulations *Incentives* e.g. subsidies *Markets*, supply chains and consumer preference	Most evidence relates to regulation or farm subsidy; fewer studies on supply chain factors or private contracting
Farm structural		Farm characteristics: including for example *Spatial* area *Herd* size *Type* – such as arable, mixed, livestock *Income* *Geography* and biophysical conditions	Can inform decisions on which practices might be more successful, depending on location, farm type etc.
Socio-demographic		Farmer characteristics including for example *Age* *Education*	Often captured through mediating influences such as the personal and informal institutional factors

disaggregation in those studies occurred elsewhere in the main text i.e., not sufficiently relevant to be mentioned in the abstract or keywords, and thus would only be captured by a systematic review.

[11] Toma et al. 2018

[12] These include about a third of the studies analysing the adoption of practices related to water, sustainability, agroforestry and organic farming, and around a quarter of those focused on the adoption of sustainable soil and fertilisation management, pest and weed management, biodiversity, GHG mitigation, and precision farming.

Personal factors are the most commonly investigated in the adoption literature. General attitudes, such as moral concern (Mzoughi, 2011) where the farmer's world view is taken into account are often included in studies of environmental practices. Attitudes towards risk are another important type of personal factor. For example, risk aversion may preclude farmers from adoption of new practices or technologies (Morton et al., 2017). This is linked to the diffusion of innovation theory (Rogers 1965) where risk aversion is an important way of differentiating between types of farmers in terms of adoption behaviour. This may guide policy interventions and assist tailoring them to better reach segments of the farming population different in terms of needs and receptivity (Barnes and Toma, 2012).

The evidence on the influence of general environmental attitudes is, however, mixed as this is measured differently from one study to another; this inconsistency precludes drawing strong conclusions. All things considered, in terms of driving change, this type of evidence is used to support interventions designed to change minds.

As the attitudes the farmers hold towards practices may be to some extent redundant for voluntary adoption (since unsurprisingly, more positive attitudes tend to be associated with greater uptake), their impact on behaviour is usually analysed in relation to other factors, e.g., knowledge. Knowledge (Läpple and Van Rensburg, 2011; Toma et al. 2018) may influence adoption especially in the case of new technologies where an understanding of the potential costs and benefits is important. Earlier adoption literature viewed the lack of access to information and knowledge transfer as the main reason preventing farmers from adopting new practices. More recently, adoption studies acknowledge its impact interlinked with a multitude of other factors. The strength of its effect on adoption also differs based on the information requirements of a specific practice, e.g. precision agriculture technologies are more knowledge intensive than others (Toma et al. 2018).

Informal institutional factors relate to the social context farmers operate in. Some studies use a measure of connectivity to understand how many organisations a farmer is a member of. Others use self-assessed measures such as social norms (Läpple and Kelley 2013; Kuhfuss et al. 2016). Kuhfuss et al. (2016) ran an experiment to assess farmers' willingness to maintain sustainable practices after the end of their agri-environmental scheme contract. When informed that a majority of the other farmers would maintain sustainable practices without a contract, the odds that participants would also maintain the practices doubled. While the literature presents mixed findings on the magnitude of the effect of informal institutional factors, there is an overall agreement that farmers are influenced by their peers. This may indicate the need for interventions supporting collaborative networks. More research on group behaviour is necessary to support studies of individual behaviour.

Formal institutional factors relate to the legal/political and supply chain/market context within which they operate. This can include factors relating to their supply chain, consumer preferences, regulation or available subsidies, all of which are thought to directly or indirectly affect farmers' decision making. As exemplified by Knuth et al. (2018) much of this focus is on compliance related to subsidies. There is a gap in the evidence in terms of supply chain factors and the influence of private contracts and standards on the adoption of environmental practices. This is further developed in the next section.

Farm structural factors record a range of farm characteristics such as area or herd size, income and geographical/biophysical conditions necessary for the assessment of practices' or technologies' compatibility to farm circumstances. For example, larger farms are more likely to adopt precision practices (Vecchio et al. 2020; Hopkins et al. 2017). These factors are useful to understanding which practices might be more

successfully adopted in a particular region, or by specific farm types, and may assist policymakers with correct targeting of interventions.

Many studies often include **socio-demographic factors** such as age and education. However the evidence for their influence on the adoption of sustainable practices is, again, mixed. This may be due to the complex pathways through which socio-demographics influence decision-making (Burton, 2014). As a consequence, these factors are often assessed indirectly through e.g., personal preferences as described above and their effects may therefore be difficult to capture in the literature.

A similar focus on factor types (Figure 9 in Annex 2) is relevant to the adoption of practices and technologies in other topic areas such as animal welfare and health, with a more specific focus on biosecurity and antimicrobial use.

It is clear that decisions are the result of a complex interplay of different factors over time. Distinguishing between factors affecting the adoption of combinations rather than individual practices is a challenge when selecting the most suitable intervention, and evaluating their impact. Farmers' adoption of multiple practices signals the need for careful coordination between policy interventions encouraging the adoption of some practices with those promoting others.

Some studies focused solely or primarily on one type of factor may make direct references to individual interventions, while studies having identified multiple influences on adoption may recommend an array of these. There are advantages and disadvantages arising from differences in focus related to the choice of potential interventions.

While an emphasis on fewer factors may facilitate a clear identification of the most feasible intervention, it is seldom possible to separate them from the wider context i.e., consider things in a vacuum. Most studies clearly state the limitations to the approach and are usually being used as a reference or basis for studies expanding the palette of adoption factors analysed. More complex behavioural frameworks assess the effect of multiple factors on adoption, and might measure the impact of individual factors.

Most studies focusing solely on factors of adoption make suggestions for potential interventions; however they do not actually assess their impact. The next section examines the smaller number of studies that focus more closely on the relationship between adoption factors and interventions.

Some examples of studies analysing single or multiple practices, and factors of adoption discussed above, are included in Table 3. The studies reviewed and discussed in this section present mixed evidence in terms of actual effect of factors on adoption, primarily due to the differences between the research methodologies used[13]. Thus the evidence does not allow a clear ranking of factors based on their impact on adoption.

[13] This is due to the range of different methods employed - qualitative and quantitative - and not comparable sample sizes, often not (clearly) representative of the target population; differentiated focus on behavioural elements i.e., while almost half of the studies analyse influences on adoption behaviour, many stop earlier in the causality chain and only explore determinants of intentions and/or attitudes. Additionally, the focus on adoption of individual or a mix of practices also influence the magnitude and, at times, the sign of causal relationships.

Table 3: Main factors of adoption of climate and environmentally friendly practices (Examples[14])

Climate/environmentally friendly practices	Adoption factors[15] [16]	Farming activity	Dependent variable	Country[17]	Authors
GHG mitigation practices	Personal factors (perceptions of (environmental impact) (+)	Dairy	Adoption (actual) & Adoption intentions	UK (Scotland)	Glenk et al. (2014)
Pest and weed management (as part of agri-environmental scheme)	Informal institutional factors (descriptive norm) (+)	Permanent crops	Adoption intentions	France	Kuhfuss et al. (2016)
Organic farming practices	Personal factors (knowledge) (+)	Livestock	Adoption (actual)	Ireland	Läpple and Van Rensburg (2011)
	Personal factors (moral concern) (+)	Arable and permanent crops	Adoption (self-reported)	France	Mzoughi (2011)
	Informal institutional factors (subjective norm) (+)	Livestock	Adoption intentions	Ireland	Läpple and Kelley (2013)
Precision farming practices	Farm structural factors (farm size) (+)	Mixed	Adoption attitudes	Italy	Vecchio et al. (2020)
	Socio-demographic factors (education) (+)	Mixed	Adoption attitudes	Italy	Vecchio et al. (2020)

[14] Only some examples are provided as it was deemed unfeasible to include the full list (245 'Adoption' studies). Inclusion of studies in some categories does not imply these studies have focused solely on the factors associated to them in the table. **The examples (further discussed in text) refer to studies which found the aforementioned factors to have a (statistically significant) effect on adoption/intentions**.

[15] 123 studies focused on personal factors, 67 studies on informal institutional factors, 110 studies on farm structural factors, 42 studies on socio-demographic factors, and 42 studies on formal institutional factors.

[16] Signs in parentheses indicate the direction of effect of factor on the dependent variable (adoption or intentions or attitudes)

[17] **The majority of the studies reviewed analyse cases from the European Union members (excluding UK but including Norway), which make for more than half (53%) of the studies focused on adoption factors. Under a tenth are studies focused on the UK. About a fifth include studies focusing on the United States of America, Canada, and New Zealand. The remainder include reviews with a wider distribution.**

Climate/environmentally friendly practices	Adoption factors[15] [16]	Farming activity	Dependent variable	Country[17]	Authors
Agroforestry	Personal factors (self-identity, social norms, perceived behavioural control) (+)	Crops, livestock (various)	Adoption intentions	UK (Scotland)	Hopkins et al. (2017)
	Farm structural factors (farm size, income) (+)	Crops, livestock (various)	Adoption intentions	UK (Scotland)	Hopkins et al. (2017)
	Socio-demographic factors (education, gender, other) (+)	Crops, livestock (various)	Adoption intentions	UK (Scotland)	Hopkins et al. (2017)
Various climate/environmentally friendly practices	Personal factors (risk perceptions) (-)	Arable and permanent crops	Adoption attitudes	USA	Morton et al. (2017)
	Formal institutional factors (Cross Compliance regulations/schemes) (+)	Mixed	Adoption (actual)	Germany	Knuth et al. (2018)
	Formal institutional factors (agri-environment schemes) (+)	Various	Adoption intentions	UK (England), various EU members	Ruto and Garrod (2009)

4.2 Interventions to foster adoption

We will start by considering the *interventions* that have already been implemented to encourage practice change. We will then examine the *key factors* (detailed in Section 4.1) that influenced successful adoption.

The main types of interventions identified in the studies[18] reviewed are:

- voluntary measures[19]
    - engage - referring to support for engagement through e.g. networks and cooperatives,
    - enable - referring to support through provision of resources such as advice and training,
    - exemplify - referring to support through e.g. learning and provision of information, and
    - encourage - referring to support through incentives such as financial instruments, and
- compulsory measures (regulation) (Figure 3 in Annex 2).

Some examples of studies[20] analysing the impact of single or multiple interventions mentioned above are presented in Table 4 and further discussed in the rest of this section. The studies reviewed and discussed in this section present mixed evidence in terms of actual effect of interventions on adoption. Thus, the evidence does not allow a clear ranking of interventions based on their impact on adoption.

[18] Unless otherwise mentioned, the studies discussed here were assessed to have a moderate to high level of robustness and relevance and thus provide a credible foundation for the findings.
[19] Defra's 4Es model, as operationalised in a recent global review paper on incentives for sustainable agricultural practice adoption (Pineiro et al. 2020).
[20] Many of the excluded studies retrieved by the search looked at the effectiveness of a practice or intervention on e.g., bird population, however this was not joined up with information on factors affecting uptake of the practice or intervention. Ideally, we need to combine this type of information more effectively to understand effectiveness of uptake in the real world as opposed to technical assessments of uptake likelihood or difficulty. Pineiro et al. (2020) address this in their review paper of incentives for the adoption of agricultural practices and their outcomes and find only 44 papers that address this end-to-end logic, where all but two studies are framed in a developing country context and are therefore not included here.

Table 4. Main interventions fostering adoption of climate and environmentally friendly practices (Examples of studies analysing successful interventions[21])

Climate/environmentally friendly practices	Type of interventions	Type of interventions[22]	Specific interventions	Farming activity	Interventions & Adoption factors[23]	Country[24]	Authors
Integrated pest management	Voluntary	Engage (through networks and cooperatives)	Government founded pilot farm networks	Arable and horticultural crops	Adoption following intervention	The Netherlands	Wijnands et al. (2014)
Organic farming, other		Enable (through training)	On-farm advice from advisory services	Arable crops	Adoption following intervention	Switzerland	Gabel et al. (2018)
Practices for mitigation of GHG emissions (various)		Exemplify (through information provision)	Governmental communication campaign	Arable crops and livestock	Adoption following intervention & Adoption factors: socio-economic (age -, education +, farm size +), propensity to innovate (+), other	The Netherlands	Moerkerken et al. (2020)
Various sustainable practices e.g., woodland, planting/maintaining hedgerows, other		Encourage (through private finance and standards)	Private agri-environmental schemes	Dairy farming	Adoption of intervention	UK (England)	Coyne et al. (2021)

[21] Only some examples are provided as it was deemed unfeasible to include the full list (124 'Intervention Adoption' studies). A longer list of examples (still not the full 124) is presented in Table 9 in Annex 2. Inclusion of studies in some categories does not imply these studies have focused solely on the interventions associated to them in the table.
[22] 8 studies focused on 'enabling through training' interventions, 7 studies on 'encouraging through private finance and standards', 69 studies on 'encouraging through public finance', 19 studies on 'engaging through networks and cooperatives', 6 studies on 'exemplifying through information provision'; and 5 studies on 'regulation'.
[23] This presents the focus of the study i.e. 'adoption following intervention' refers to adoption of practices as a result of a specific intervention such as provision of advice and training or regulation; 'adoption of intervention' occurs when the intervention is in the form of a payment to join an e.g. agri-environmental scheme; 'adoption & adoption factors' refers to studies analysing both adoption linked to intervention, and the factors influencing it.
[24] **The majority of the studies reviewed analyse cases from the European Union members (not including the UK), which make for more than half (55%) of the studies focused on intervention and adoption. A further tenth are studies focused on the UK. The remainder include studies focusing on the United States of America, Canada, and New Zealand**.

Climate/environmentally friendly practices	Type of interventions	Type of interventions[22]	Specific interventions	Farming activity	Interventions & Adoption factors[23]	Country[24]	Authors
Organic farming, other		Encourage (through public finance)	Agri-environmental schemes	Crops, livestock (various)	Adoption of intervention & Adoption factors: economic incentives	UK (Wales)	Wynne-Jones (2013)
Soil and fertilisation management, change to agroforestry, transition to organic or grass-based system, various	Compulsory	Regulation	Water quality regulation	Crops and livestock	Adoption following intervention	USA New Zealand	Wagner et al. (2020)

About a fifth of studies covered more than one type of intervention[25], with voluntary types of interventions, such as encouragement through private and public financial incentives (e.g., agri-environment schemes or payments for ecosystem services), by far the most common intervention type analysed. This is followed by another more commonly investigated voluntary intervention type, i.e., engaging through networks or cooperatives.

Many studies analysing uptake of multiple practices found that the multiple interventions employed to address their various features need to take into consideration trade-offs between economic, environmental, and social outcomes (Piñeiro et al., 2020).

While there is no consistent evidence in terms of the magnitude of interventions' impact on adoption behaviour, most studies acknowledge that effectiveness of interventions is higher the more closely tailored they are to the characteristics and needs of the farming population targeted.

Financial and market incentives.

The evidence indicates that adoption is influenced by the level of financial incentive.

Many studies found that compliance is positively related to the level of incentive payments (Siebert et al. 2010; Wynne-Jones 2013). Piñeiro et al (2020) undertook a scoping review of incentives designed to motivate farmers to adopt sustainable agricultural practices. They found that, irrespective of the incentive type, interventions leading to short-term economic benefit have a higher adoption rate than those focused exclusively on provision of ecological services.

Coyne et al. (2021) explored the factors that affect participation in private agri-environmental schemes. They found that financial incentives and the willingness to maintain the natural environment were the primary or sole motivators for farmers.

While this is dependent on context[26], the message is clear, i.e., focussing interventions solely on enhancing environmental outcomes may be less effective than coupling them with those better tuned to economic considerations.

With the majority of studies focussing on public finance-based interventions, this may indicate either a gap in the literature analysing the impact of private interventions such as those encouraging sustainable adoption through private finance or through private standards, and/or signal their relatively lower – when compared to public financial or non-financial interventions - occurrence in real life. A better coordination may thus be needed between research on incentives to sustainable behaviours in agriculture and the work in other areas such as sustainable supply chain management[27].

Transaction costs

The evidence suggests that farmers' adoption increases if they retain some control over implementation.

Many studies found that the higher the level of constraints on management practices and the longer contract duration in interventions such as agri-environmental schemes, the lower the participation (Vaissière et al. 2018; Schroeder 2015; Špur 2018). In their study on adoption of farm conservation practices through participation in governmental

[25] These were counted separately with regard to how frequently each intervention type is covered (Figure 2 in Annex 2).
[26] All studies reviewed here focus on developed economies. Review papers may have a broader scope, e.g. Piñeiro et al (2020) include both developed and developing countries. Re the latter, only findings relevant to the aim of this review are mentioned.
[27] The sustainable supply chain management literature is substantial (Rajeev et al. 2017) and portrays the linkages between chain segments and transfer or accumulation of effects leading to behavioural change.

cost-share programmes, Mezzatesta (2013) noted that, as conservation practices may create private net benefits for farmers, they may be adopted often in absence of subsidies. Reasons for self-funded conservation include contract restrictions farmers may not be willing to comply with, or transaction costs (e.g., bureaucracy). More research is needed to understand the primary reasons for self-funding[28].

In line with adoption factors such as managerial and spatial/geophysical constraints, studies analysing the implications of transaction costs on adoption suggest that farmers are more likely to participate in finance-based interventions such as agri-environmental schemes if they retain some control over implementation, which requires flexible terms and practical monitoring.

Collaboration, training and advice

The evidence confirms the importance of training and advice, particularly when set within a collaborative framework. While they can be effective on their own, the benefit is enhanced when used alongside other interventions, e.g. market or regulation based.

- Gabel et al. (2018) indicate the key role of advisory services in promoting sustainable practices through assisting farmers in taking action to preserve or enhance biodiversity on their farms following a mix of public financial interventions and private labelling schemes. This signals the need for clear identification of most relevant sources of training and advice tailored to the target population to facilitate the effective implementation of interventions, particularly when a mix of incentives e.g., policy and market-related are employed.
- Moerkerken et al. (2020) investigate the impact of factors such as state-driven campaigns on adoption of climate change mitigation measures on farms. Their findings indicate that general innovation campaigns in the agricultural sector might be more effective than campaigns focused specifically on climate change mitigation.
- Wijnands et al. (2014) investigate the factors affecting implementation of pesticides reduction programmes on farm and find that engaging stakeholders through networks as part of governmental interventions show real promise in the long term.
- Lemke et al. (2010) investigate incentives for farmers' participation in cost-share conservation programs and find that, in addition to tailored technical and financial assistance, integrated outreach teams comprised of stakeholders and local conservation agencies have a promising role.
- The provision of advice and greater consideration of environmental conservation in policy development were perceived to make joining the conservation schemes more attractive (Schroeder 2015).
- Josefsson et al. (2016) investigate the impact of collective forms of agri-environmental management on farmers' intentions to implement nature conservation practices. Their findings suggest that increasing farmers' awareness of the availability and feasibility of existing collaborative conservation options may have a key role for successful biodiversity conservation in agricultural systems.

Regulation

We found a limited number of studies that addressed regulatory interventions. Overall, the evidence supports pairing compulsory with voluntary interventions for a more effective outcome.

Wagner et al. (2020) in their study analysing compliance with water quality regulation in New Zealand and the USA, found that compulsory interventions are more palatable and effective when supported by a range of other measures e.g., subsidies or market-based. This was apparent due to a range of reactions from the farming populations in answer to

[28] This is particularly important for studies such as Mezzatesta (2013) analysing additionality (net result from an intervention).

regulation, which led to the identification of assisting measures. This highlights the need to take into account the social implications of policy compliance, and design interventions to balance trade-offs between environmental, economic and social impacts. It also confirms findings of other studies that additional interventions may be needed to support compliance and enhance short-term benefits, together increasing the outcomes in the long-term (Piñeiro et al. 2020).

Overall, the research into the effect of interventions of either type on farmers' adoption of sustainable practices is still at an early stage. The evidence does not allow a clear ranking of interventions based on their impact on adoption. Further research combining cross-sectional and time series studies (e.g., observation studies in an experimental context or longitudinal behavioural surveys), is required to allow an accurate assessment of the effect the interventions are likely to achieve.

5 Conclusion

The aim of this study was to complete a rapid evidence assessment to explore the evidence for factors influencing climate-friendly agricultural practice adoption. It examined interventions to encourage practice change, and the key factors that influenced successful adoption.

Main factors of sustainable practice adoption are:

- ***personal*** factors - attitudes, values and perceptions; knowledge and information;
- ***informal institutional*** factors - social norms (e.g., influence of peers);
- ***farm structural*** factors - farm size and income; farm type and geophysical location;
- ***formal institutional*** factors - state and private 'carrot and stick' incentives (e.g., regulation, subsidies, standards);
- while some studies focus on the impact of ***socio-demographics*** as behavioural determinants, most analyse these for the purpose of classification i.e., defining the target population of farmers into different types

The evidence does not allow a clear ranking of factors based on their impact on adoption. This is due to differences in methodologies, breadth of sustainable practices, and interlinkages between adoption factors, which overall make up a complicated landscape of behavioural influences. However, if the number of studies focussing on the different types of factors is anything to go by – as focus usually answers a research need/question - then the bulleted list above may suggest an overall ranking.

Main findings learned from the evidence on adoption factors indicate:

- In line with the almost universally acknowledged fact that behaviours are the outcome of interrelated and complementary influences, most studies analyse the impact of more than one factor on adoption.
- Within the context of a mix of influences, farmers' adoption behaviour is partly determined by and builds on their earlier or concurrent choices, which reflects in adoption of multiple practices; this may indicate a need for coordination between policy interventions encouraging the adoption of some practices with those promoting others.
- The evidence shows an overall agreement that farmers are influenced by their peers (usually sharing geography and farm type), and thus more research on

group behaviour is necessary to support/complement studies of individual behaviour.

- Adoption factors are useful for explaining variance in behaviour and/or defining types of farmers for understanding which practices might be more successfully adopted in a particular region by specific farm types, and thus assist with tailoring policy interventions to better answer the needs of the farming population.

There is no consistent evidence on the magnitude and, implicitly, the ranking of interventions' impact on adoption behaviour. The main reason is the limited evidence on time series studies, with most research on the topic using cross-section data and a mix of revealed and self-reported behaviours.

Research attempts to address the challenge of complexity through analysis of multiple interventions in the context of multiple concerns; just as farmers will implement multiple practices, multiple interventions are needed to address their various features while taking into consideration any economic, environmental, and social trade-offs. While an emphasis on fewer factors may facilitate a clear identification of the most feasible intervention, it is seldom possible to separate them from the wider context i.e., consider things in a vacuum.

Main findings from the evidence on interventions indicate:

- Effectiveness of interventions is higher the more closely tailored they are to the characteristics and needs of the farming population targeted. Targeting interventions might be facilitated by using adoption factors to understand different types of farmers.
- Compliance is positively related to the level of incentive payments, thus indicating that focussing interventions solely on enhancing environmental outcomes may be less effective than coupling them with those better tuned to economic considerations.
- Interventions based on training and communication may be more effective when framed to address aspects closer to the farming industry such as agricultural innovation than when focused specifically on climate change mitigation. Provision of economic knowledge e.g., on costs and benefits linked to adoption of new technologies in addition to footprint information is most relevant to incentivise farmer behaviour.
- Training and advice, supported within a collaborative framework, are effective on their own and even more so when used as additional incentives to assist other forms of interventions, e.g., market or regulation based, enhancing both short-term benefits and long term outcomes.
- Similarly, compulsory interventions are more palatable and effective when supported by a range of other measures, for instance engaging stakeholders through networks as part of governmental interventions.
- Farmers are more likely to participate in finance-based interventions such as agri-environmental schemes if they retain some control over implementation, which requires flexible terms and practical monitoring. This partly justifies farmers' participation in cost-sharing environmental schemes or adoption of self-funded practices, however more research is needed to identify other factors of this specific behaviour.
- The gap in the evidence on the influence of private contracts and standards on the adoption of environmental practices may be resolved through a better coordination between research on incentives to sustainable behaviours in agriculture and the work in other areas such as sustainable supply chain management.

Overall, the research into the effect of interventions of either type on farmers' adoption of sustainable practices is still at an early stage. Further research combining cross-section and time series studies is required to allow an accurate assessment of the effect the interventions are likely to achieve.

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Annex 1 Methodology

A1.1 REA - overview and inherent biases

We undertake a Rapid Evidence Assessment (REA) approach (Collins et al. 2015) to assess the current state of evidence and come to an informed conclusion on the volume and characteristics, including a brief synthesis of what that evidence indicates and a critical appraisal of the evidence highlighting potential gaps. While more in-depth than a literature review, however not as comprehensive as a systematic review (not feasible within the timeframe), REA allows maximising the use of the existing evidence base and provides a clear picture of its suitability.

To offset the inherent biases linked to reviewing a large amount of material within a short timeframe, the analysis includes two steps: the high level systematic mapping of the literature on interventions and/or factors of adoption; and the critical appraisal of a segment of the literature, i.e. studies focusing on both adoption and interventions. In addition, a further exploration, the *deeper dive*, was performed on the latter. However, a number of limitations remain. REA assesses the relative quality of the literature in relation to the aim of the study and, while the overall setup mitigates against researchers' subjectivity, the development of primary and secondary search strings will reflect a certain risk of bias as reliant on researchers' expertise. This risk was alleviated through the good complementarity of skills within the team. The potential exclusion of relevant studies and reports not routinely indexed in the mainstream literature i.e. not picked up by pre-set parameters within pre-set search engines is another risk, which we again mitigated through the well balanced set of skills.

A1.2 REA conceptual framework

The REA protocol was designed following the two research questions:

1. what are the most important factors of climate-friendly agricultural practice adoption (RQ1);
2. what interventions have been implemented to encourage practice change and what are the key factors that influenced successful adoption (RQ2).

The scope of the primary literature search was controlled by a number of criteria:

- geography to ensure comparability to the Scottish level of economic development and climatic conditions i.e. studies based in Europe, Northern USA, Canada and New Zealand (temperate climate);
- sector i.e. agriculture;
- topic i.e. agricultural practices and technologies that aim to reduce or minimise climate and/or environmental impact.

The scope of the secondary and grey literature search included the same geographic and sectoral scope, however it also considered practices and technologies other than climate and the environment such as efficiency, profitability, animal health, animal welfare, biosecurity, renewable energy or farmer wellbeing.

REA conceptual diagram is presented in Figure 1.

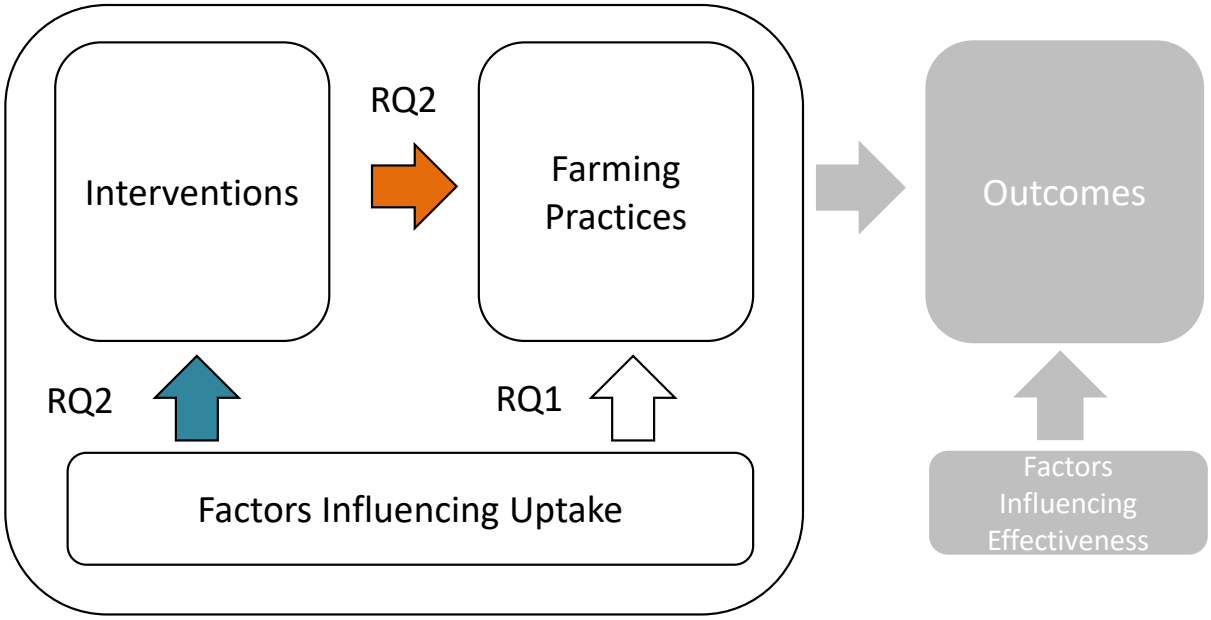

Figure 1: Scope of REA (adapted from Piñeiro et al., 2020)

A1.3 REA protocol

The protocol describes the final search strategy, search strings and inclusion criteria that meet the objectives of the REA undertaken in this report. The focus is on the primary search that was conducted using academic databases. It also describes the strategy for the secondary search for literature.

Research questions:

1) What are the most important factors influencing climate-friendly agricultural practice adoption?
2) What interventions have been implemented to encourage practice change and what are the key factors that influenced successful adoption?

The scope of the searches was restricted by geography, sector and topic.

The scope of the primary search included:

Geography: it considered studies based in Europe, Northern USA, Canada and New Zealand (temperate climates)

Sector: it considered the agricultural sector only

Topic: it considered agricultural practices and technologies that aim to reduce or minimise climate and/or environmental impact

The scope of the secondary and grey literature search included the same geographic and sectoral scope, however it also considered practices and technologies other than climate and the environment such as efficiency, profitability, animal health, animal welfare, biosecurity, renewable energy or farmer wellbeing.

The scope of the primary search string was restricted in order to have a manageable set of results to process within the project timeframe. The next section describes in detail the terms used in the primary search string.

Primary search string components

Population

The choice of geography and sector defined the population for the primary search.

Field	String
Population Inclusion	agri* OR agro* OR farm*

The relevant contexts agreed included: New Zealand, Australia, North America, and Europe. Including these terms risks failing to identify many relevant papers and therefore exclusion terms were used instead. While there is also a risk of missing comparator papers, this is a low risk since comparative studies are rare in this field. This method finds some balance between missing to many studies and including irrelevant studies.

Field	**String**
Population Exclusion	LMIC OR developing OR Africa* OR Asia* OR "Latin America*" OR "South America" OR Amazon* OR Afghanistan OR Albania OR Algeria OR Andorra OR Angola OR Argentina OR Armenia OR Australia* OR Azerbaijan OR Bahamas OR Bahrain OR Bangladesh OR Barb ados OR Belarus OR Belize OR Benin OR Bhutan OR Bolivia OR B otswana OR Brazil* OR Brunei OR Burkina OR Burundi OR Cambo dia OR Cameroon OR Canada OR Verde OR Chad OR Chile OR C hina OR Chinese OR Colombia* OR Comoros OR Congo OR Costa OR Cuba OR Djibout i OR Dominica* OR Timor OR Ecuador OR Egypt OR Salvador OR Guinea* OR Eritrea OR Ethiopia OR Fiji OR Gabon OR Gambia OR Georgia OR Ghana OR Grenada OR Guatemala OR Guyana OR Haiti OR Honduras OR India* OR Indonesia OR Iran OR Iraq OR Is rael* OR Ivory OR Jamaica* OR Japan* OR Jordan OR Kazakhstan OR Kenya* OR Kiribati OR Korea* OR Kosovo OR Kuwait OR Kyr gyzstan OR Laos OR Leban* OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Malaysia OR Maldives OR Mali OR M arshall OR Mauritania OR Mauritius OR Mexico OR Micronesia OR Mongolia OR Morocco OR Mozambique OR Myanmar OR Namibia OR Nepal OR Nicaragua OR Niger* OR Oman OR Pakistan OR Palau OR Panama OR Paraguay OR P eru OR Philippine* OR Qatar OR Russia* OR Rwanda OR Samoa OR Marino OR Principe OR Saudi OR Senegal OR Seychelles OR Leone OR Singapore OR Solomon OR Somalia OR Sudan OR Lan ka OR Suriname OR Swaziland OR Syria OR Taiwan OR Tajikistan OR Tanzania OR Thailand OR Togo OR Tonga OR Trinidad OR T unisia OR Turkmenistan OR Tuvalu OR Uganda OR Ukraine OR Emirates OR Uruguay OR Uzbekistan OR Vanuatu OR Venezuela OR Vietnam OR Yemen OR Zambia OR Zimbabwe

Other exclusion terms were added during search-string development, they were found to occur frequently, but returned irrelevant results.

Field	String
Population Exclusion	NOT (salmon OR fish OR aquaculture OR anaerobic OR engineering OR biochar OR bioenergy OR biogas OR cocoa OR coffee OR offshore OR paddy OR power OR sativa OR smallholder OR tropical OR tobacco)

Intervention

The primary search string included both general and specific interventions terms. The general intervention terms were developed based on Defra's 4Es model, a recent global review paper on incentives for sustainable agricultural practice adoption (Pineiro et al 2020) as well as expert knowledge. The specific intervention terms were developed based on expert knowledge and initial work on the grey literature search.

Field	String
Interventions General	certification OR communication OR connect* OR collaborat* OR compliance OR demonstration OR determination OR economic* OR education* OR extension OR externalit* OR "future proofing" OR grant* OR initiative* OR incentive* OR instrument* OR intervention* OR information OR learning OR loan* OR message* OR manag* OR market* OR network* OR nudg* OR payment* OR peer* OR policy OR policies OR "private standard*" OR program* OR regulat* OR scheme* OR strateg* OR subsidy OR subsidies OR

	support OR tool* OR trad* OR train*

Field	String
Interventions Specific	“conservation reserve” OR “quality incentives” OR “cross compliance” OR “entry level stewardship” OR “ELS” OR “better climate” OR F2F OR “feed-in-tariff” OR focus OR greening OR monitor OR “nitrate vulnerable zone*” OR “nitrate directive” OR NVZ OR “pillar 2” OR “pillar II” OR “productive and sustainable land use” OR “global partnerships in livestock emissions research” OR SRDP OR “sustainable land management and climate adaptation programme” OR “rural development” OR “water framework directive”

Agri-environment was not included, agri and environment were included.

Outcome

The search focused on both factors and interventions and this required specification of general outcome terms. Attitudes, intentions and willingness were added to the search terms.

Field	String
Outcome Change	accept* OR adopt* OR adapt* OR attitude* OR barrier* OR behavio* OR belief* OR conversion OR choice OR decision* OR determinant* OR factors OR

	implement* OR implicat* OR improve* OR insight* OR intent* OR innovat* OR participat* OR perception* OR preference* OR transition* OR uptake OR willing*

For the primary search we restricted the scope of the outcome to climate and environment related practices, technologies, or interventions. First, we identified general terms that are used to describe climate/environment-friendly practices.

Field	String
Outcome Practice General	"best practice*" OR "best management practice*" OR BMP* OR biodivers* OR "climate change" OR "climate friendly" OR "climate resilien*" OR "climate smart" OR conservation OR ecological OR "ecosystem service*" OR emission* OR environment* OR "environment* friendly" OR "good practice*" OR habitat* OR integrated OR "low carbon" OR "low intensity" OR mixed OR organic OR sustainab* OR ((reduc* OR mitigat*) AND GHG*) OR ((reduc* OR mitigat*) AND greenhouse gas*) OR ((reduc* OR mitigat*) AND methane) OR ((reduc* OR mitigat*) AND nitrous) OR ((reduc* OR mitigat*) AND carbon) OR restor* OR sequest* OR "soil biomass" OR "soil carbon"

Second, based on expert input the review team have proposed a set of practices/technologies that they believe have significant emissions reduction potential balanced with cost/ease of adoption and likelihood of finding evidence of related

interventions (i.e. they do not include brand new technologies). The supplemented the studies found using general terms.

Field	String
Outcome Practice_1	*forest* OR s$lvopasto* OR s$lvoarab* OR (integrat* AND (tree* OR wood*))
Outcome Practice_2	(feed* AND additives) OR (“methane reducing” AND feed*) OR (feed AND seaweed) OR (feed AND legume) OR (feed AND 3NOP) OR (feed AND 3-nitrooxypropanol)
Outcome Practice_3	precision
Outcome Practice_4	“nutrient management plan*”
Outcome Practice_5	“grass legume” OR alfalfa OR lucerne OR clover OR “birds foot” OR trefoil OR “nitrogen fixing” OR “biological control*” OR “integrated pest management” OR IPM OR mulching OR “integrated weed management” OR IWM OR tillage OR “crop residue*” OR “cover crop*” OR “catch crop*” OR “gully plug*” OR “buffer strip*” OR “field margin*” OR “crop rotation” OR “crop diversification” OR “inter cropping” OR “mixed cropping” OR “alley cropping” OR “companion plant*” OR “relay cropping” OR fallow

Comparator

Terms that highlight an assessment being made within the study were included in the search.

Field	String
Comparator	“case stud*” OR evaluat* OR impact OR effect* OR assess* OR comparison OR outcome*

Final search string

The breadth of results took precedence to depth. This was reflected in the specification of additional population terms, additional behavioural terms above. It was also reflected in the combination of search fields in the final search string. While it was useful to consider the different elements separately, the final string was developed to ensure that three key elements were present in the title: 1) term to indicate farm/agriculture population 2) term to indicate an intervention or adoption or evaluation verb and 3) term

to indicate environmental/climate technology or practice. All three had to be present for the paper to be included. Thus the string took the general form:

(agri/farm population

AND

intervention/factor term

AND

environmental/practice terms

AND NOT
exclusion terms)

We searched for all document types between 2009 and 2021, and 2009 was chosen since it was the last CAP health-check date. We selected only publications in English. A note on string syntax: in both the Web of Science and Scopus, apostrophes and hyphens were ignored so that “climate change” also returned “climate change” and “climate-change”. Scopus would also return plurals e.g., “climate changes” without need to specify wildcard, whereas Web of Science would not. Therefore, we have included wildcards for consistency.

String development

The search strings were run a number of times in the Web of Science and Scopus to refine and adapt the terms. The litsearchr package in R was used to generate additional search terms and assist with understanding which terms were returning the highest number of results. “Gold standard” papers that we believed the search should return were also identified, and all but one was returned by the search indicating that it was well targeted. One was not, however the reason was due to inclusion of the term innovation in the title. Including this in the search string made the search too broad and moved away from making it environment specific so it was not included.

Results of the primary search

Scopus returned 7886 records, which became 7831 when we checked for exact match distinct titles. WoS returned 6215 records, which became 6171 when we checked for exact match distinct titles. We then checked for exact matches between WoS and Scopus and found 2595 records. These were removed from the Scopus record set so that the total combined records were 11407. These records were loaded into literature review software and a second round of deduplication occurred where we identified a further 1556 duplicate records to be deleted. This left 9851 to be reviewed and a decision made as to whether they should be included or excluded during the first sift.

A set of inclusion / exclusion criteria were developed (below). The titles of 9851 were reviewed on this basis resulting in 848 records of interest. The full texts of 757 of these were found using SRUC and University of Edinburgh library subscriptions or open access on the internet. The 757 full text records underwent a second review at abstract and if necessary full text level based on the inclusion/exclusion criteria. This resulted in 482 records identified able to answer one or more of the research questions. Five reviewers were engaged in this process. After initial reviews were conducted in each round, a discussion about conflicting decisions was had and resolutions agreed to try to ensure consistency. Data on 482 records was extracted and a systematic map created (see below).

Secondary search

An informal secondary search was also conducted that identified agricultural studies from Europe, North America, and New Zealand that assess interventions and/or factors of practice or technology adoption relevant to climate and the environment but also in other areas such as efficiency, profitability, animal health, animal welfare, biosecurity, or farmer wellbeing. We used both published and grey literature for this search, using both expert input and forwards and backwards citation to work through this literature. A list of websites used to search for reports e.g. European Commission, Scottish Natural Heritage were retained. It was believed these provided most examples of Scotland specific uptake and activities.

Inclusion and exclusion criteria

Once the search was completed the following criteria were used to identify which studies should be kept in the review.

1) What are the most important factors of climate-friendly agricultural practice adoption?
2) What interventions have been implemented to encourage practice change and what are the key factors that influenced successful adoption?

Include:

- Studies must focus on effectiveness of intervention on adoption of sustainable agricultural practices OR identify factors associated with adoption, intention to adopt, or attitudes towards adoption of sustainable agricultural practices
- Intentions or attitudes towards adoption must be from farmer/land manager
- Studies must focus on agricultural and/or land-management practices
- Original research (quantitative or qualitative) and/or reviews of existing research
- Studies should be published after 2009 (which follows the 2009 CAP Health Check)

Exclude:

- Focuses on effectiveness of intervention at achieving outcome (e.g. no indication of whether intervention increased adoption)
- Does not identify factors associated with adoption, intention to adopt or attitudes towards adoption of sustainable agricultural practices
- Does not identify attitudes towards the environment or climate in general (must be attitude towards adoption of a practice)
- Intentions or attitudes towards adoption should not be derived from consultants/expert opinion
- Studies that look at renewable and alternative energy only (we may include where it is part of a system e.g. photovoltaic systems), studies that look at aquaculture…
- Studies published before 2009 (which follows the 2009 CAP Health Check)

These criteria mean that studies which look at the effectiveness of an intervention on achieving an environmental outcome are excluded unless the specifically provide information on the rate of adoption within that assessment. Many of the excluded studies retrieved by the search looked at the effectiveness of an practice or intervention on for example, bird population, however this was not joined up with information on factors affecting uptake of the practice or intervention. Ideally we need to combine this type of information more effectively to understand effectiveness x uptake in the real world as opposed to technical assessments of uptake likelihood or difficulty. Pineiro et al. (2020) address this in their review paper of incentives for the adoption of agricultural practices

and their outcomes and find only 44 papers that address this end to end logic, where all but 2 come from a developing country context and are therefore not included here.

Information extraction

As both factors and interventions were required to be included, we used two information extraction templates since they are different types of studies.

High level extraction

- Intervention/Factor/Both
- Study type (Quantitative Experimental, Quantitative Observational, Qualitative, Economic, Review)
- Practice type
- Text read (title/abstract/full text)

Deeper dive extraction

- If intervention describe intervention (multi check boxes in case more than one)
- If factor describe factors tested (multi check boxes for types of factors, perhaps just high level e.g., attitudinal, farm structural etc. rather than specific e.g. attitudes towards environment, tenure)
- Outcome
    - Describe the outcome is measured: was the dependent variable was adoption, intention to adopt or attitudes to adoption (including willingness, perceptions etc.)
    - Practice: describe the agricultural practice targeted by the intervention/for which the factors are identified. This could be a single practice e.g., reduced tillage or it could be multiple practices measured in various ways.
    - Other: change in land-use or other indicators used a proxy for adoption.

The breadth of the questions and volume of results means that only a high level of information can be extracted from the results within the given time frame. The focus has therefore been to describe the volume and characteristics of the evidence base, similar to a systematic map report summarising the relevant literature at high level (Randall et al. 2015).
The search steps are diagrammatically described in Figure 2.

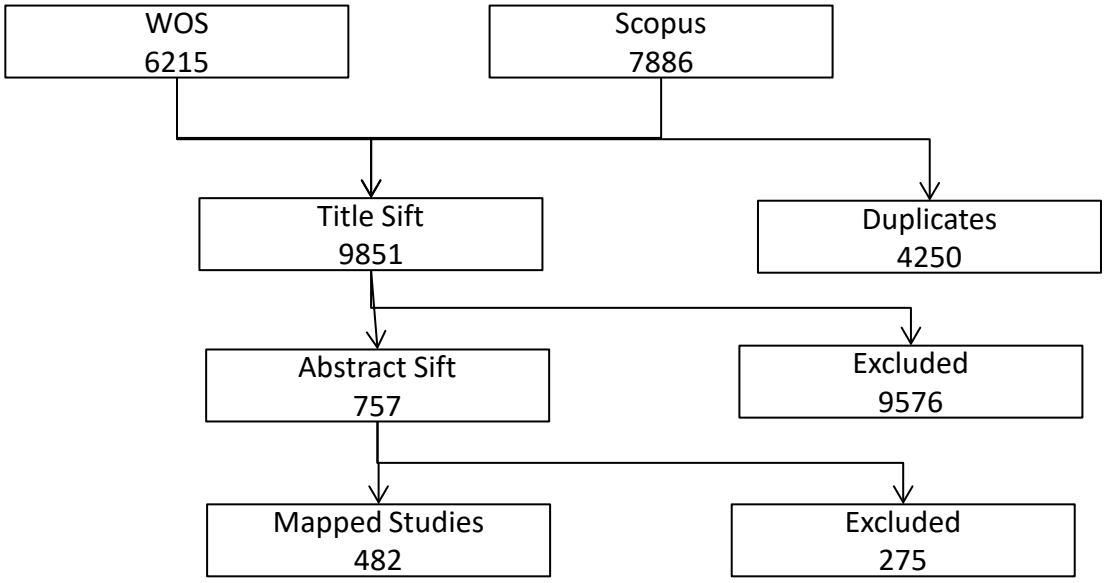

Figure 2: Search flow diagram

Annex 2 Technical findings

A2.1 Schematic map categories

The primary and secondary searches produced 482 and respectively 55 records that met the inclusion criteria. These were categorised into a systematic map based on the two research questions.

- The largest group of documents (245 primary search records and 27 secondary search records) address research question one (what are the most important factors of climate-friendly agricultural practice adoption?) These are studies which have used a range of methods to explore the factors that affect the adoption of more environmentally friendly farming practices, we will call this group 'Adoption' studies for short.
- The second largest group (124 primary search records and 4 secondary search records) address both parts of question two (What interventions have been implemented to encourage practice change and what are the key factors that influenced successful adoption?). These are studies that look at factors that affect the uptake of interventions, we will call them 'Intervention Adoption' studies.
- The third group (113 primary search records and 24 secondary search records) describe interventions that have been implemented but do not go into detail about the different factors that affected their uptake, we will call these 'Intervention' studies.

A2.2. Critical appraisal

The critical appraisal of evidence (*the deep dive*) was conducted on the records included in the 'Intervention Adoption' category that answer research question two in full.

In order to describe the type of intervention analysed by each paper we used Defra's four Es framework: engage, enable, exemplify, and encourage. Some studies covered more than one type of intervention. These were counted separately with regard to how frequently each intervention type is covered (Figure 2). We can see that 'encourage', which includes both private and public financial incentives such as agri-environment schemes or Payments for Ecosystem Services, is by far the most common intervention analysed in this group of papers.

In addition to the critical appraisal of this group of studies, we extracted more detailed information about each intervention such as the scheme name, duration, and structure or, in the case of networks or training, more details of who and what was involved. For quantitative papers, we highlighted the factors tested and those that were significant. For qualitative papers, we described in a narrative way the factors that were found to be important.

We categorised the 'Intervention Adoption' studies based on quality into high (overall score 16-20) (58 studies), moderate (overall score 11-15) (49 studies) and low (overall score <11) (17 studies).

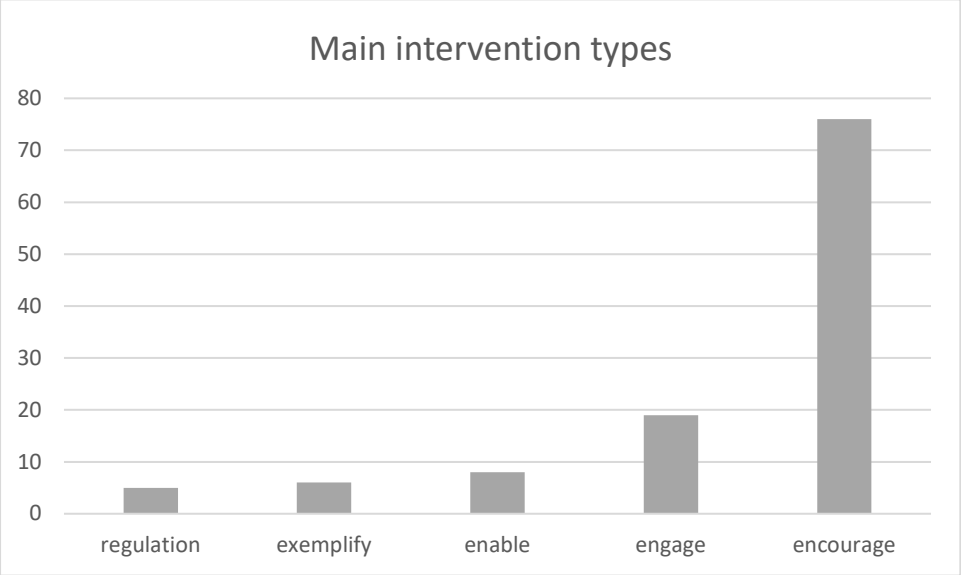

Figure 3: Interventions analysed by Intervention Adoption studies

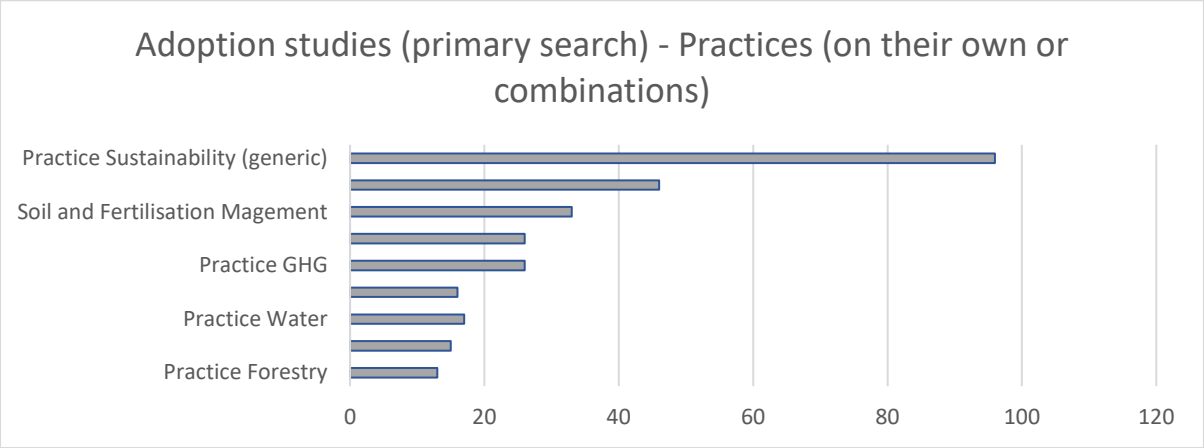

Figure 4: Adoption studies (primary search) - Practices[29]

[29] The types of practices investigated by each paper were recorded at high level. We present here the frequency of practice types, so the total may exceed the total number of papers.

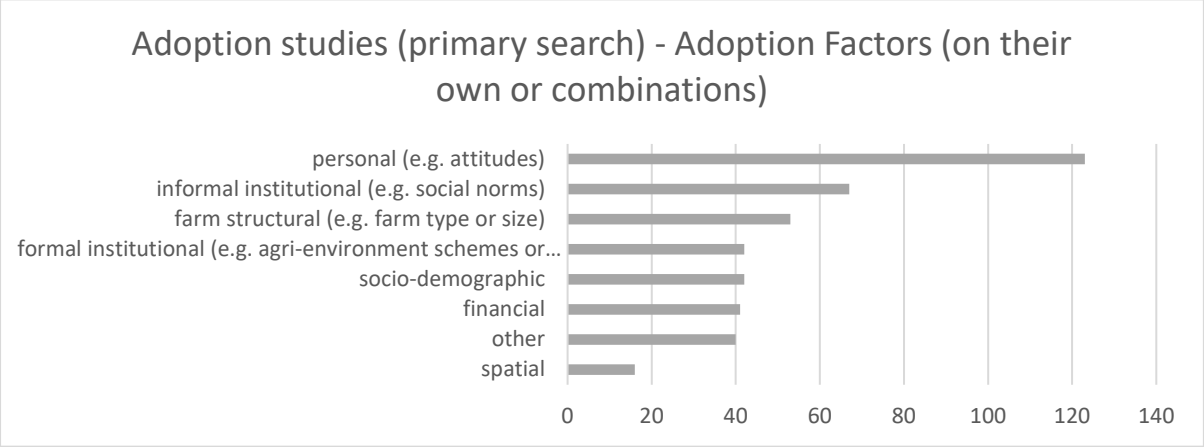

Figure 5: Adoption studies (primary search) - Adoption Factors (on their own or combinations)

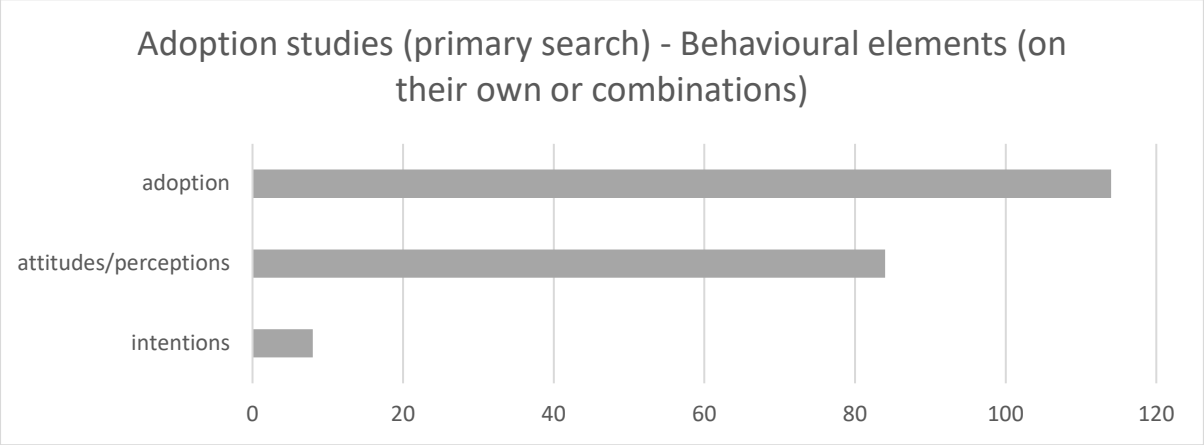

Figure 6: Adoption studies (primary search) - Behavioural elements (on their own or combinations)

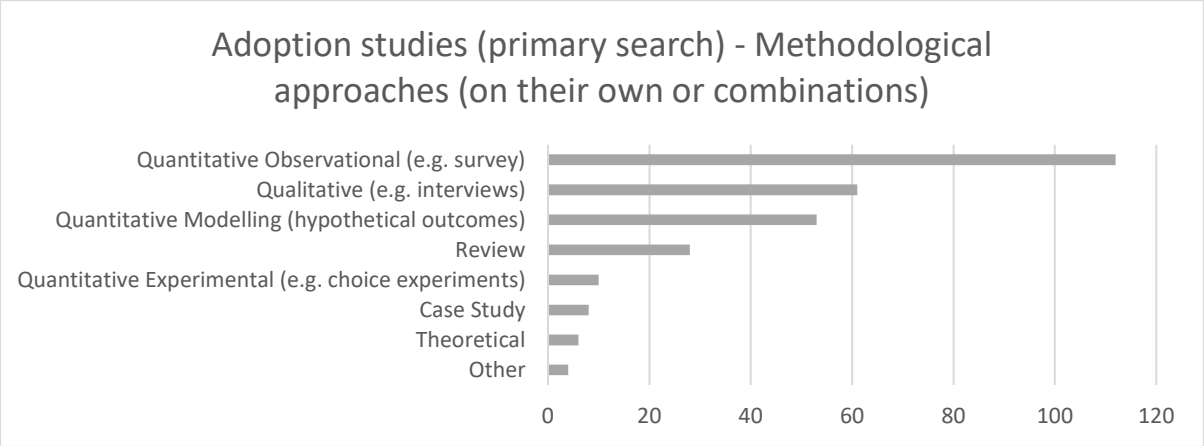

Figure 7: Adoption studies (primary search) - Methodological approaches (on their own or combinations)

The range of methods employed in the studies reviewed[30] support the established progressive dependence of quantitative assessments on in-depth studies, with both equally important in providing evidence on identifying and respectively, estimating effects of factors on adoption.

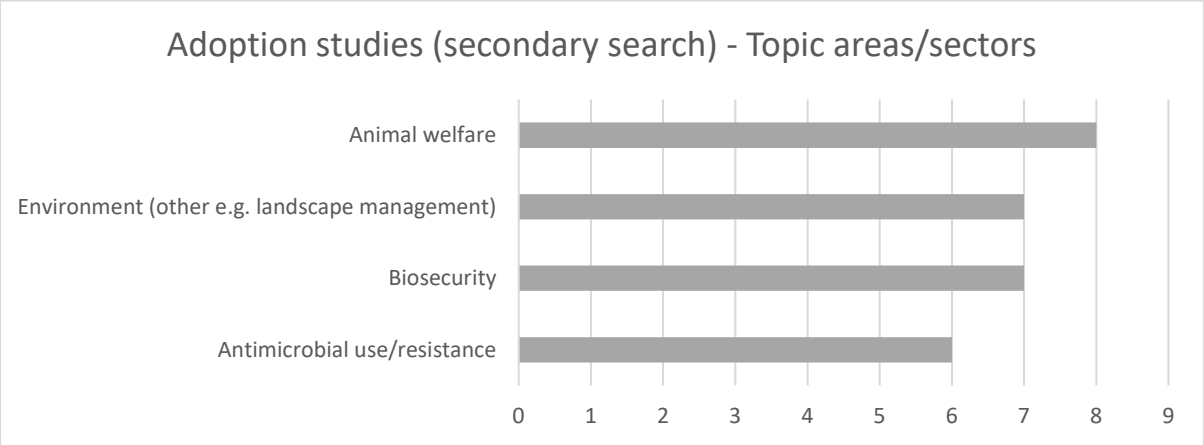

Figure 8: Adoption studies (secondary search) - Topic areas/sectors

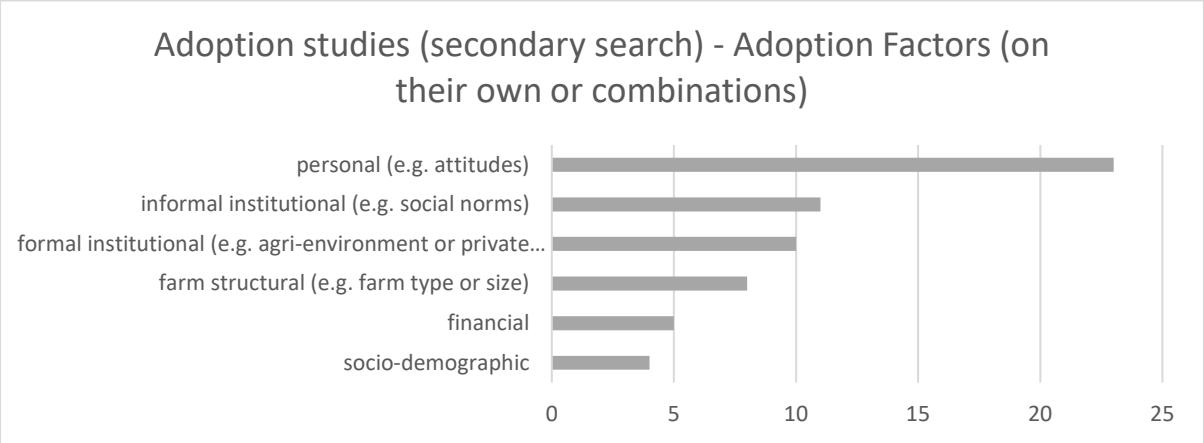

Figure 9: Adoption studies (secondary search) - Adoption Factors (on their own or combinations)

[30] Distilled into quantitative (175) and qualitative (97) studies.

Table 5: Critical appraisal of Intervention Adoption studies – Study frame & appraisal template

Study frame	Appraisal Template Used	Number of studies	Average score
factors affecting participation in intervention e.g. AES scheme	Economic or Modelling	4	16
factors affecting participation in intervention e.g. AES scheme	Qualitative	16	13.88
factors affecting participation in intervention e.g. AES scheme	Quantitative Experimental	24	16.46
factors affecting participation in intervention e.g. AES scheme	Quantitative Observational	28	15.07
factors affecting participation in intervention e.g. AES scheme	NA	4	NA
influence of intervention on practice adoption	Economic or Modelling	2	16.5
influence of intervention on practice adoption	Economic or Modelling; Quantitative Observational	1	12
influence of intervention on practice adoption	Qualitative	11	13.91
influence of intervention on practice adoption	Quantitative Experimental	11	16.55
influence of intervention on practice adoption	Quantitative Observational	12	14.92
influence of intervention on practice adoption	Review or Theory	2	13.5
influence of intervention on practice adoption	NA	2	NA
influence of intervention on practice adoption; factors affecting participation in intervention e.g. AES scheme	Qualitative	1	12
influence of intervention on practice adoption; factors affecting participation in intervention e.g. AES scheme	Quantitative Experimental	3	15.33
influence of intervention on practice adoption; factors affecting participation in intervention e.g. AES scheme	Quantitative Observational	3	14.67

Table 6: Critical appraisal of Intervention Adoption studies – Study Frame A (factors affecting participation in intervention e.g. AES scheme). Intervention_Evidence_Quality

Intervention	Intervention Count	Average Score (max 20)
enable_training	2	14
encourage_private_finance	1	19
encourage_private_standards	3	16
encourage_public_finance	38	15
engage_cooperative	5	13
engage_network	4	15
exemplify_information_provision	3	17
regulation	2	14

Table 7: Critical appraisal of Intervention Adoption studies – Study Frame B (influence of intervention on practice adoption). Intervention_Evidence_Quality

Intervention	Intervention Count	Average Score (max 20)
enable_training	4	14
encourage_private_finance	1	19
encourage_private_standards	1	14
encourage_public_finance	27	15
engage_cooperative	3	15
engage_network	6	14
exemplify_information_provision	3	18
regulation	3	14

Table 8: Critical appraisal of Intervention Adoption studies – Study_Frame C (influence of intervention on practice adoption/factors affecting participation in intervention). Intervention_Evidence_Quality

Intervention	Intervention Count	Average Score (max 20)
enable_training	2	13
encourage_private_finance	1	14
encourage_private_standards	0	NA
encourage_public_finance	4	14
engage_cooperative	1	17
engage_network	0	NA
exemplify_information_provision	0	NA
regulation	0	NA

Table 9: Main interventions fostering adoption of climate and environmentally friendly practices (Examples[31])

Type of interventions[32]	Specific interventions	Authors	Climate/environmentally friendly practices*	Farming activity	Interventions & Adoption factors	Country[33]
Enabling through training	On-farm advice from advisory services	Gabel et al. (2018)	Organic farming, other	Arable crops	Adoption of intervention	Switzerland
	Interactions with nongovernmental entities including extension, watershed programs, land trusts, research organisations, other	Wagner et al. (2020)	Soil and fertilisation management, change to agroforestry, transition to organic or grass-based system, various	Crops and livestock	Adoption following intervention	USA New Zealand
Encouraging through private finance and standards	Private agri-environmental schemes	Coyne et al. (2021)	Various sustainable practices e.g., woodland, planting/maintaining hedgerows, other	Dairy farming	Adoption of intervention	UK (England)
	Private labelling schemes	Gabel et al. (2018)	Organic farming, other	Arable crops	Adoption of intervention	Switzerland
Encouraging through public finance	Ecological compensation areas	Gabel et al. (2018)	Organic farming, other	Arable crops	Adoption of intervention	Switzerland
	Cost-share conservation programmes (various)	Mezzatesta et al. (2013)	conservation tillage, cover crops, filter strips, grassland establishment, other	Crops and livestock (various)	Adoption of intervention & Adoption factors: farm income (-), farm type (-), farm size (+), location (stream adjacency) (+),	USA

[31] Only some examples are provided as it was deemed unfeasible to include the full list (124 'Intervention Adoption' studies). Inclusion of studies in some categories does not imply these studies have focused solely on the interventions associated to them in the table.
[32] 8 studies focused on 'enabling through training' interventions, 7 studies on 'encouraging through private finance and standards', 69 studies on 'encouraging through public finance', 19 studies on 'engaging through networks and cooperatives', 6 studies on 'exemplifying through information provision'; and 5 studies on 'regulation'.
[33] **The majority of the studies reviewed analyse cases from the European Union members (not including the UK), which make for more than half (55%) of the studies focused on intervention and adoption. A further tenth are studies focused on the UK. The remaining include studies focusing on the United States of America, Canada, and New Zealand**.

Type of interventions[32]	Specific interventions	Authors	Climate/environmentally friendly practices*	Farming activity	Interventions & Adoption factors	Country[33]
					education (+), age (-), other	
	Agri-environmental schemes (various)	Pavlis et al. (2016)	organic farming, biodiversity, other	Permanent and arable crops	Adoption of intervention & Adoption factors: subsidy level (+), education (+), age (-), farm size (+), farming engagement level (+), other	EU countries
	Technical or financial assistance from a government agency/entity	Wagner et al. (2020)	Soil and fertilisation management, change to agroforestry, transition to organic or grass-based system, various	Crops and livestock	Adoption following intervention	USA New Zealand
	Agri-environmental schemes	Wynne-Jones (2013)	Organic farming, other	Crops, livestock (various)	Adoption of intervention & Adoption factors: economic incentives	UK (Wales)
Engaging through networks and cooperatives	Government founded pilot farm networks	Wijnands et al. (2014)	Integrated pest management	Arable and horticultural crops	Adoption following intervention	The Netherlands
Exemplifying through information provision	Governmental communication campaign	Moerkerken et al. (2020)	Practices for mitigation of GHG emissions (various)	Arable crops and livestock	Adoption following intervention & Adoption factors: socio-economic (age -, education +, farm size +), propensity to innovate (+), other	The Netherlands
Regulation	Water quality regulation	Wagner et al. (2020)	Soil and fertilisation management, change to agroforestry, transition to organic or grass-based system, various	Crops and livestock	Adoption following intervention	USA New Zealand

Annex 3 A brief review of existing tools for predicting uptake

There has naturally been a strong interest in methods that help to predict the potential success of an intervention, although the availability of quantitative models and tools to predict adoption is still limited. Existing tools target specific interests (e.g. policymakers, technology providers and development investors), each with a different focus to use them, e.g., guidance for development of policies and regulatory interventions or sustainability-driven market signals (some detail on existing tools, their features and users is presented in Annex 3).

In addition to tools targeting policy and other non-farming stakeholders and specifically focused on adoption prediction[34], there are numerous tools linked to adoption of ecological practices, some including an element of prediction, many of which target farmers as their main users. Some of these tools[35] are structured around developing online self-assessment and action plans to assist farmers in meeting the requirements of various sustainability programmes in terms of adoption of sustainable practices and subsequent reduction of their environmental footprint. Wilton (2018) reviews a number of tools[36], which ultimately enable a reduction in the environmental footprint of the agriculture and agri-food sector. Many of these tools are associated with on-farm decision making on aspects such as nutrient stewardship, precision agriculture, soil health, nutrient management, and greenhouse gas reduction.

A wide range of decision-making tools[37] for analysing the impact of ecological practices adoption and provision of ecosystem services in different environments - rural or urban, agricultural or non-agricultural sectors - have been developed in recent years in the United Kingdom (UK) and globally, and more are currently being developed. They have a dual purpose, i.e., to assist farmers in mitigation of carbon and environmental footprint, and to provide policy and other stakeholders with the empirical evidence of impact of interventions.

[34] E.g., ADOPT (Adoption and Diffusion Outcome Prediction Tool) (Kuehne et al., 2017) providing predictions of the rate and peak level of adoption of agricultural practices and estimating the importance of various factors influencing adoption such as economics, risk, environmental outcomes, farmer networks, characteristics of the farm and the farmer, and the ease and convenience of the new practices.

[35]Some of these tools include SAC's Carbon Calculator assessing the carbon footprint of farms (https://www.agrecalc.com/), Teagasc's Carbon Navigator assessing the level of adoption/performance of farms in relation to carbon mitigating technologies (https://www.teagasc.ie/about/our-organisation/connected/online-tools/carbon-navigator/) and The Cool Farm Tool assessing the greenhouse gas emissions, water and biodiversity impact of farms (https://coolfarmtool.org/).

[36]One of these is the Farm Sustainability Readiness Tool of the Alberta Farm Sustainability Extension Working Group (AFSE, 2018), targeting crop farmers and assisting them to meeting socio-economic and environmental sustainability targets (financial viability and reduction of waste and pollution footprint) and conforming with beneficial management practices such as nutrient management and agro-chemical handling and application, labour safety and profitability. This tool is specifically designed to assist early adopters to meet the requirements of specific sustainability certification programs.

[37]The Ecosystems Knowledge Network's Tool Assessor makes a comparison of some of these tools - leading models within the field of natural capital and land use -, their functions and uses (Ecosystems Knowledge Network, 2017). The analysis is focused on tools capable of analysing information and producing an output that can inform decision-making such as public, private and third sector organisations in the UK and elsewhere and assist in management of environmental benefits to society.

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climateXchange

Scotland's centre of expertise connecting climate change research and policy

info@climatexchange.org.uk
+44(0)131 651 4783
@climatexchange_
www.climatexchange.org.uk

ClimateXChange, Edinburgh Climate Change Institute, High School Yard, Edinburgh EH1 1LZ