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Overcoming barriers to the adoption of climate-friendly practices in agriculture

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OVERCOMING BARRIERS TO THE ADOPTION OF CLIMATE-FRIENDLY PRACTICES IN AGRICULTURE

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Considerable efforts have been devoted to understanding and developing technologies and practices that can help the agricultural sector reduce its greenhouse gas emissions and adapt to the impacts of climate change. The uptake of these “climate-friendly” technologies and practices, however, remains low. This report, based on a comprehensive review of the literature, analyses barriers that may prevent farmers from adopting climate-friendly practices. A multitude of potential barriers exist, some associated with farm-level constraints, others operating at the sector level, or created by existing policies. A series of recommendations are made to properly identify these types of barriers and to select the right instruments that would work to implement effective policy solutions.

Keywords: Agriculture, climate change, technology adoption, climate mitigation and adaptation policies.

JEL: Q16, Q18, Q54.

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Executive Summary

Climate change poses a dual challenge for agriculture, as the sector produces greenhouse gas (GHG) emissions and is also vulnerable to the effects of a changing climate. Considerable research efforts have been devoted to understanding and developing effective technologies and practices that can reduce the sector's GHG emissions, leading to an expanding range of viable options. Similarly, agriculture in many countries has developed a significant capacity to use a range of measures to adapt to the impacts of climate change.

However, the adoption of these mitigation and adaptation measures, practices and technologies (hereafter defined as "climate-friendly") lags behind the research, even though farmers must be taking action now so as to limit the impacts of climate change. Identifying the reasons behind the limited adoption of climate-friendly practices is essential to understand and address this gap. This activity is an important precursor to designing or restructuring policies to stimulate climate-friendly behaviour.

This report analyses the potential barriers to the adoption of climate-friendly practices, ranging from barriers at the farm level through to the national level. This analysis is based on a comprehensive review of the literature. It explores how measures to reduce emissions (mitigation) and those supporting adaptation to the impacts of climate change have different drivers, and how they can face different barriers to adoption. The review of barriers focuses on measures for which the costs of adoption would not be prohibitive, although some may have a positive net cost to farmers but a societal net benefit.

In general, barriers to actions that mitigate GHG emissions are more difficult to overcome, as farmers have fewer intrinsic incentives to act when they do not see direct private benefits. Although adaptation measures enhance the benefits to farmers, removing certain barriers may enhance their adoption of climate-friendly measures.

A number of findings emerge from this review. First, **governments should identify and tackle the existing barriers before designing and implementing new policy measures**. Overcoming existing barriers early on increases the likelihood that the policy successfully achieves its aim or at least ensures that new barriers are not created. Many of the barriers identified in the literature are linked to whether the measures' benefits are a private or public good; if farmers are unable to identify any benefits to changing their practices, they will be reluctant to adopt the measures without a policy imperative. Barriers that stem from farmers' values and attitudes towards the environment and climate change may call for additional engagement.

Second, a **multitude of potential barriers exist that may prevent farmers from adopting climate-friendly practices**. While their relative importance will vary depending upon specific circumstances – including socio-economic characteristics, farming systems, bio-physical conditions, existing infrastructure, regulations and institutions – barriers are evaluated and prioritised in this report based on their reported strength and the degree of agreement they gather in the reviewed literature.

- *Barriers relating to the actual or perceived effects on performance, as well as information and awareness* involved in climate change decision-making and risk management, *play a primary role* in decisions regarding the adoption of climate-friendly measures. Also identified as a high priority is the role of climate and environmental policy in either incentivising action or in creating new barriers.

- *A relatively less important role* is attributed to barriers relating to the cost of adoption, hidden and transaction costs, social and cultural factors, the perception of carbon leakage, and access to credit and the misaligned policies. These factors should also be considered as priority areas for government action unless contradictory evidence is found in the relevant context.
- A third type of barrier may be important to consider, but *is highly dependent on practices and local context*: this includes land tenure and the availability and access to infrastructure and complementary inputs (such as irrigation water). Their importance will vary depending on a country's property rights structures; they may play a relatively smaller role than some of the other barriers found in OECD countries.
- Other barriers, such as those associated with behavioural and cognitive factors, are identified with low or moderate supporting evidence, and are found to be relatively less important overall.

Third, **several of the identified barriers are created by existing policies**: first, through misaligned policies targeting other aims, such as input subsidies designed to support production in marginal areas; second, by creating resentment and stress among farmers regarding their ability to meet the regulations; and third, by exacerbating existing financial vulnerabilities that weaken farmers' adaptive capacities. The first barrier can be addressed through policy reform and ensuring policy coherence. The second and third may be avoided with effective planning.

This analysis highlights **two main approaches to removing barriers** that can be adapted to different circumstances: first, the revision of policies that impede the objectives of climate-friendly agriculture and, secondly, the introduction of targeted initiatives that could directly help remove the identified key barriers.

The preferred combination of measures to overcome barriers is likely to vary by country:

- A combination of "soft" approaches (such as field demonstrations and collaboration between farmers) possibly in conjunction with 'harder' measures (such as measures involving infrastructure, like irrigation or increased housing for livestock) will likely be more successful than simply imposing a regulation at the outset.
- In countries *where agriculture produces a large proportion of GHG emissions, the sector is likely to require adjustments* such as changes to the choice of product, the location of production or the farming system used. In this case, governments should provide educational programmes that enhance the sector's knowledge of the benefits of climate-friendly measures - with the goal of changing both values and entrenched behaviours. To do so they should engage with relevant stakeholders to jointly assess required changes, identify possible ways to do so and select the policy measures that would send appropriate signals.
- Governments of countries *where agricultural emissions make up a lower proportion of the country's GHG emissions*, and where incremental changes may be sufficient to achieve some emissions reductions, should strive to remove existing policy barriers and to provide information and incentives for agricultural producers to take action as appropriate.

1. The imperative to make agriculture more "climate-friendly"

The agricultural sector contributes to climate change through the emission of greenhouse gases (GHGs) and is vulnerable to climate change due to its dependence on climate-sensitive natural resources (Howden et al., 2007). Agriculture directly accounts for 10-12% of total GHG emissions (LULUCF and CO_2 emissions excluded) (Smith et al., 2007a). It is also projected to be particularly exposed to future climate change (Porter et al., 2014); in the absence of adaptation, it is projected to be the second most economically damaged sector from climate change (OECD, 2015c).

The extent to which the agricultural sector can continue to feed a growing global population sustainably will largely be determined by its ability to adapt to climate change. This will require significant changes throughout the sector, which should start with agricultural production systems. Agricultural activities may need to change in some regions, while agricultural practices will generally need to adapt to these new constraints in most regions, supported by innovation and agricultural knowledge.

However, agriculture, particularly in developed countries, presents a conflicting picture with regard to innovation and adaptation. On the one hand, it can be described as highly adaptable and resilient, historically responding to a myriad of factors including market prices, consumer demand as well as changing weather, where "adaptation is the norm rather than the exception" (Rosenzweig and Tubiello 2007, p. 860). On the other hand, agriculture is seen as being very resistant to change, constrained by tradition, support policies, and social and behavioural factors, constraining responses to major changes in paradigm.

Recent analyses suggest that **agriculture is not fulfilling its total GHG mitigation[1] potential**. Although agricultural GHG emissions from OECD countries have declined over the past 20 years (OECD, 2013), agriculture mitigation efforts are needed at the global level and stronger efforts are required for agriculture to reduce the sector's contribution to climate change. As emissions reductions in the sector are particularly complex due to the biological nature of the GHG emitting systems, a large and growing range of mitigation options has been identified (see Smith et al., 2008). Moving beyond the technical feasibility of mitigating emissions, studies have analysed the marginal abatement costs associated with each measure, and used their results to draw marginal abatement cost curves (MACC), representing the cost of each measure reducing an additional unit of carbon equivalent GHG emission (Moran et al., 2011; Smith et al., 2007b; Pellerin et al., 2013; De Cara and Jayet, 2011; Schulte et al., 2012; MacLeod et al., 2015; Sánchez et al., 2016). These analyses show that some mitigation measures may actually generate economic gains for the adopting farmer via a cost reduction (win-win), while others can be implemented at very little cost. Yet, many of these low or "negative" cost measures are not being adopted, contributing to the observed gap between technically possible and probable emissions reductions (Anastasiadis et al., 2012).

Similarly, there is a relatively **low uptake of economically viable adaptation options** in agriculture. Adaptation options are wide-ranging, from incremental changes in management in current systems, to long-term structural and transformative changes in the farm as well as the sector as a whole, with a growing body of research identifying options and their effectiveness (Iglesias et al., 2007; Renaudeau et al., 2012; Hoving et al., 2014). Yet agriculture in many regions may face an "adaptation deficit", or inadequate adaptation to the current climate conditions (Noble et al., 2014).[2] Some adaptive measures, known to be beneficial for the sector's resilience to climate change, are not being adopted by farmers for a number of reasons. For instance, information gaps may prevent farmers from adopting a larger number of practices that encourage resilience; financial constraints may prevent farmers in a

1. Mitigation refers to the reduction or removal of GHGs in the atmosphere.

2. This concept can be understood when considering the counterfactual; if there were no 'adaptation deficit' there would be no agricultural losses resulting from climate events currently or in the future.

number of regions to invest in irrigation or cooling system for livestock; while misaligned incentives may encourage farmers to avoid adopting suitable crop varieties. Autonomous adaptation appears to be insufficient in response to projected climate change, prompting the increased need for public policies (Ignaciuk, 2015).

In order to achieve sufficiently significant emissions reductions and to adapt to the more severe impacts of climate change, it may be necessary to move beyond incremental changes in agricultural production systems (Marshall et al., 2012; Park et al., 2012; Kates et al., 2012). Adaptation, in particular, is much more than a series of discrete technical measures taken in response to specific climate impacts; rather, it is a continual process of reassessment and change implementation by farmers. Similarly GHG mitigation could evolve from marginal changes in practices, towards systemic changes for low carbon agriculture activities.

Effectively meeting the challenge of climate change will require identifying and overcoming the main potential **barriers to the adoption of climate-friendly technologies and practices** by the agricultural sector. This report aims to serve that purpose, using a comprehensive review of the literature that covered 114 articles and reports. Barriers in this report refer to obstacles that impede the adoption of desirable practices, and make adaptation and mitigation less efficient or effective, and may lead to missed opportunities or generate subsequent higher costs. Other barriers may hinder the implementation of relevant policy, but the primary aim of the report is to examine barriers to the adoption of climate friendly practices. The term "climate-friendly" refers to measures and practices that aim primarily to either reduce emissions of GHGs from agricultural practices into the atmosphere, or to adapt to the impacts of climate change affecting the agricultural sector, either now or into the future. This includes measures that may achieve both mitigation and adaptation simultaneously as well as those that may trade off one of these aims against the other, as well as measures that may potentially have a negative impact on production in the short term.[3] The review of barriers focuses on measures that would be cost-effective to implement; i.e. for which the costs of adoption would not be prohibitive, although some may have a positive net cost to farmers but a societal net benefit.[4]

The report identifies a multitude of possible barriers that prevent farmers from adopting climate-friendly measures, ranging from bio-physical constraints to cognitive and behavioural barriers at the farm level, through social and cultural factors to complex institutional constraints. The report also discusses the role for policy in addressing these barriers, and proposes to prioritise policies according to the strength and agreement of evidence in the literature. Policies themselves may generate barriers to the adoption of climate-friendly practices, while remaining inefficient at achieving their primary aims.[5] These types of policies should be identified and subject to reforms. Many of the barriers could be removed, or at least reduced, through the use of targeted and nuanced policy, including through the appropriate framing and dissemination of knowledge. A common finding throughout the literature is that there is a wide heterogeneity in farmers, and a corresponding diversity of drivers, beliefs and actions. This has important implications for policy as there is no single solution. Local conditions, whether biophysical or cultural, cannot be ignored.

The analysis focuses predominantly on evidence from OECD countries, but where relevant, also includes studies from non-OECD countries. The primary sources of literature are peer-reviewed

3. It should be noted that whilst the term 'climate friendly' is relatively new, many of the associated measures and practices have long been part of traditional farm practices in many parts of the world (Richards et al., 2014).

4. Practices with high costs of implementation are not explicitly dealt within this report. For those, obviously, the cost of adoption is a main barrier.

5. Agricultural policies in many countries aim to ensure stable and sustainable food production and a good standard of living for the agricultural community. Recent policies, however, include more and more environmental and climate objectives (OECD, 2016a and 2016b).

academic studies, published reports and, where appropriate, grey literature.[6] Because this specific area of research is relatively new, this report also draws on related literature that does not specifically focus on climate-friendly practices. The review aims to identify the predominant barriers; it does not claim nor attempt to draw from an exhaustive list.

This report builds on previous work, including (OECD, 2012), which reviewed the literature on farmer behaviour and management practices in relation to mitigation and adaptation to climate change. The present study differs from OECD (2012) in that it focuses not only on behavioural practices, but also considers other barriers to adoption, including those beyond the farm level.

Section 2 highlights the drivers for the adoption of new technologies and practices, drawing on the innovation-adoption literature. Section 3 then reviews identified barriers to the adoption of climate-friendly agriculture, focusing first on farm-level barriers before moving to national and policy level barriers. Section 4 examines how policies can help overcome these barriers.

2. Different drivers behind the adoption of adaptation and mitigation measures

The literature on innovation adoption recognises that not all the potential users immediately adopt new technologies or practices that have superior characteristics compared to their predecessors (Diederen et al., 2003). This observation has led to a vast literature attempting to explain the reasons or factors explaining such non-adoption (overviews can be seen in Griliches, 1957; Stoneman, 1983; Thirtle and Ruttan, 1987; Karshenas and Stoneman, 1995; Geroski, 2000; Sunding and Zilberman, 2001). Analysing the barriers to innovation or changes in agricultural practices requires a good understanding of the key drivers to adoption. Box 1 describes theories around the adoption of innovation.

Decisions about whether to adopt adaptation and mitigation measures differ both from each other and from other innovation decisions. Although adaptation and mitigation are often considered together as part of “climate-friendly” measures, in practice they have very different drivers and benefit distributions. In particular, farmers are likely to be more open to adopting adaptation measures than mitigation measures (Arbuckle et al, 2015). The drivers behind adaptation and mitigation are set out in Table 1 according to how they relate to the three key drivers of the induced innovation literature (Box 1). As a consequence of these different drivers, the barriers to the adoption of adaptation and mitigation strategies will also differ. Potential barriers that hinder the adoption of climate-friendly practices in agriculture are discussed in the following section.

Unlike more traditional agriculture innovation, the primary aim of climate-friendly techniques is not to achieve immediate superior financial performance (for example through increasing yield or decreasing costs), although this may occur in some cases. Rather, it focuses on long term resilience (adaptation) and reducing negative externalities (mitigation).

In this respect, the adoption of climate-friendly practices share similarities with adoption of environmental measures. Farmers often perceive climate measures as an additional element to environmental measures; i.e. measures that do not necessarily increase the productivity in the short term and are associated with costs (both monetary and non-monetary). As such, barriers to the adoption of conservation agriculture or conservation management practices are likely to be important. Beginning with Gasson (1973)’s pioneering study, a raft of studies have established that farmers’ goals and values are complex and simple profit maximising assumptions are not sufficient in explaining their behaviour (Defra, 2006, as cited in OECD, 2012). This complexity means that there is no simple formula to explain which factors will be most important in a given case, and that understanding local conditions is key (Knowler and Bradshaw, 2007).

6. References used in this draft report were publications available in English; relevant studies in other languages could be added (if translation is possible).

Box 1. Induced-innovation: Insights from the economic literature

Hayami and Ruttan (1985) developed a theory of induced innovations that closely linked the emergence of innovations with economic conditions. In particular they highlight the role of scarcity, economic opportunities, and the imposition of environmental regulations in driving innovation. Other authors have supported this hypothesis; Sunding and Zilberman (2001) developed it further by noting that technical feasibility, new scientific knowledge, and the right institutional and policy setup were necessary conditions for innovations to be developed and adopted. These concepts can be used to consider the case of climate-friendly innovations.

First, **regulation** is linked with the development of environment-friendly innovations (Sunding and Zilberman, 2001). In the context of agriculture and climate change, very little enforced regulation exists regarding either mitigation or adaptation measures in agriculture. Regulation regarding adaptation in all sectors is necessarily broad and generally refers to the “mainstreaming” of adaptation across existing policies. Most OECD countries have introduced legislation and commitments to reduce GHG emissions, but agriculture is generally excluded due to the many complexities associated with monitoring, reporting and validating (MRV) emissions in the large number of small businesses based on biological systems. The possibility of inclusion remains however and in some countries this may even be sufficient to promote voluntary action (Renwick and Wreford, 2011). At the same time, mitigation of agriculture GHG can also be induced by broader mitigation policies.

The **scarcity** component of the induced innovation hypothesis could be extended to include ‘pressure’ resulting from climatic changes. In the original conceptualisation, scarcity referred to scarcity of a factor of production (for example land or labour), and an increase in scarcity of this factor induced innovations in technology to save on the use of that factor. Replacing scarcity with the term pressure captures more of the drivers of adaptation to climate change: while the land available for production may not change or become scarcer necessarily, it may become less suitable for current production. Pressure in this sense is a key driver for adaptation: the need to change practices in response to actual changes in conditions either now or expected future changes. An agricultural system’s adaptation to climate change is fundamentally hindered by, and vulnerable to, the most limiting factor within the system (Niles et al., 2015). Scarcity or pressure may be less of a driver with regard to mitigation, with perhaps the exception of potential increased fuel costs driving reduced fuel consumption. It may be possible for scarcity to simultaneously trigger mitigation and adaptation, for example in the case of groundwater abstraction where increased energy costs would increase the cost of pumping groundwater, potentially leading to both lower levels of energy use and groundwater abstraction.

In terms of **economic opportunities**, adaptation and mitigation also differ considerably, notably with regard to where the benefits accrue. The primary benefit of mitigation is reduced GHG emissions, which become global public benefits, whereas the benefits of adaptation are much more local and usually private. Mitigation can also generate local private benefits if one considers the wider indirect or ancillary benefits of mitigation actions (for example improved water quality, reduced soil erosion as a result of soil sequestration, or more efficient use of inputs, see Smith et al., 2007b). The costs in both cases are generally borne privately. The timing of the effect may also vary, again in the direct benefit of GHG reduction will only be seen in the future (in terms of avoided global warming), but the indirect benefits will be experienced immediately. With regard to adaptation measures, some benefits will be experienced in the current climate but others will only accrue when the climate changes in future. Both mitigation and adaptation measures are associated with uncertainty: in the case of mitigation the benefit of the action is dependent on global action to reduce emissions, and in the case of adaptation there is usually high uncertainty relating to the projected changes in climate.

All of these factors contribute to the decisions that farmers and others make regarding the adoption of climate-friendly measures in agriculture, and illustrate the differences between adaptation and mitigation as well as the differences between these measures and existing “conservation” or innovation measures in agriculture.

Source: Hayami and Ruttan (1985); Renwick and Wreford (2011); Smith et al. (2007b); Sunding and Zilberman (2001).

Table 1. Adaptation and mitigation have different drivers

Driver		Adaptation	Mitigation
Regulation		No direct policy but influenced by other policies	Regulations exist but are not enforced in agriculture. Potential inclusion in regulation may provide some motivation for action. Influenced by other policies.
Scarcity or 'pressure'		Yes	Not significant – (perhaps fuel use, use of certain mineral fertilisers).
Economic opportunities	Benefits	Most accrue privately (local)	Direct benefits accrue publically (global). Indirect/ancillary benefits may accrue privately (local).
	Costs	Private (usually)	Private.
	Timing	Many immediate Some future[1]	Direct benefits future. Indirect/ancillary benefits immediate.
	Certainty of effect	High uncertainty (around future climate)	Direct benefits depend on global action so uncertain. Permanence of measures uncertain. Indirect/ancillary benefits have greater certainty.

Note: 1. In the case of agricultural adaptations, many decisions can be made in the short term. In other sectors, such as forestry or the built environment, benefits require much longer time frames to be realised.

3. Identifying barriers that impede the adoption of climate-friendly agricultural practices

There are a number of ways that adoption barriers can be classified. For ease of exposition, barriers identified in the literature are distinguished in Table 2 according to their origin: it separates barriers that originate from individual farmers or that are relevant at the farm level, from barriers that occur either at the sector level or at the national or international policy level. The distinction is made as well with relation to the relevance of a barrier to adaptation or mitigation. The methodology to identify relevant publications is described in Annex 1.

Table 2 provides an indicative assessment of the relative importance of each barrier, based on the information listed in the table and complementary consultation with academic and OECD experts. The table identifies the volume of literature on each type of barrier, based on a systematic review carried out with specific search terms (e.g. "barrier", "adoption", "agriculture", "climate" and "conservation"). The assessment of agreement in the literature is based on authors' assessment of the evidence and arguments presented in the literature; the relative weight of each barrier is assessed based both on the volume of the literature as well as on experts' opinion.[7] While the literature provides the basis for this assessment, it is augmented by experts' understanding of real significant factors, and an overall knowledge of research that may not be reflected in the systematic review. If some barriers have a high volume of associated literature, it does not necessarily mean that the barrier itself is significant, and vice versa. Barriers were deemed to be important if there was high agreement in the literature that the barrier had a significant effect on adoption. Cost-effectiveness of addressing the barrier was not considered in this assessment. It should be emphasised that it is highly challenging to compare diverse studies, sample sizes and approaches in this manner, so the table should be viewed as indicative only, and the subsequent prioritisation of barriers will vary according to specific situations.

7. See Appendix 1 for details.

Table 2. A wide diversity of barriers calls for differentiated policy responses

High | Moderate | Low | Mixed

Type of barrier	Description	Primary focus: A - adaptation, M - mitigation or both	Volume of literature	Agreement in the literature	Indicative relative weight of barrier	Suggested role for policy
FARM LEVEL						
Structural	Tenure	Both	Moderate	Strong	Mixed, depending on practice	Not a policy priority
	Infrastructure and complementary inputs	Both	Moderate	Strong	Mixed, depending on practice	\May consider investment in infrastructure
	Farm succession, age and structure	Both	Moderate	Moderate	Low	Not a policy priority
Economic	Lack of financial benefits; effects on production	M	Moderate	Moderate	High	Communication and education
	Cost of adoption	Both	Moderate	Moderate	Moderate	May consider investment support for certain measures but evidence is mixed
	Hidden and transaction costs	Both	Moderate	Moderate	Moderate	Simplification of regulation
	Access to credit	Both	Moderate	Moderate	Moderate	Depending on underlying reason, public/private finance
Social and Cultural	Cultural capital	M	Moderate	Strong	Moderate	Communication and engagement
Behavioural and cognitive	Beliefs about climate change	Both	High	Low	Low	Communication and engagement
	Perceived long time horizons, uncertainty and risk management	Both		Moderate	Low	Communication and engagement. Provide certainty where possible, for example regulatory certainty
	Competing pressures	Both		Low	Low	Not policy priority
SECTOR AND POLICY LEVEL						
Sector level	Effect of practices on production	M	Low	Moderate	High	Research, communication
	Information and education awareness	Both	Moderate	High	High	Targeted engagement policies and demonstration
	Industry co-operation	Both	Low	Moderate	Low	National regulation
Policy related	Limited extent of climate policy	M	Moderate	Moderate	High	Policy should provide regulatory certainty but first understand barriers and address them through communication and engagement
	Leakage	M	Low	Moderate	Moderate	Global governance
	Reporting and administrative costs	M	Low	Low	Low	International level reform of inventories
	Non-climate related agricultural policies (Input subsidies, production support, subsidised insurance)	Both	Low	Low	Moderate	Identify policy distortions and work across sectors to remove them. Mainstream/integrate climate change goals across sectorial policies

Note: Volume: 0-5 articles = low; 5-15 = moderate; 15+=high. Agreement, relative weight and suggested role for policy determined by expert opinion.

Summary of barriers identified in the literature, with an assessment of the volume of literature, strength of evidence, relative weight, and the suggested role for policy to overcome a barrier. Shading indicates suggested relative importance.

The indicator for volume in Table 2 shows in particular that there is less literature relating to national level barriers, particularly with respect to the policy level. This may indicate a lack of peer-reviewed material (evidence may exist in the form of grey literature or policy papers), or it may indicate a gap that should be addressed. The majority of the reviewed literature sits within the behavioural and cognitive barriers category, although overlaps do exist. For example, many of the behavioural and cognitive studies identify other barriers, such as economic or information-related ones.

As actions to adopt adaptation and mitigation practices have different drivers, they may also be associated with different barriers. Many of the identified differences in barriers stem from the distribution of benefits, and contradictions between private adaptation benefits and the public benefits of mitigation. Differences between mitigation and adaptation barriers are indicated in the third column of Table 2.

The importance of barriers depends very strongly on **local circumstances**, and each decision to adopt new measures will be influenced by a unique combination of factors. Individual studies have found that results regarding the adoption of one category of measures do not apply to other categories of measures (van Dijl et al., 2015). Previous meta-analyses (e.g. Knowler and Bradshaw, 2007) struggle to determine variables that *universally* explain the adoption of climate-friendly (or conservation agriculture) practices, and subsequent studies often contradict earlier ones (Baumgart-Getz et al. 2012). Efforts to promote adoption must be tailored to reflect the local conditions and the barriers themselves are likely to evolve over time.

At the most basic level, biophysical constraints define the appropriate measures for both mitigation and adaptation. The biophysical environment the farm operates in will determine both the climate impacts it is exposed to as well as the appropriate adaptation and mitigation actions to be taken. Land capability, location, climate and environmental quality are important factors in land managers' decisions (Dandy, 2012; van Dijl et al., 2015). Farm size and the dispersion of land parcels can also play an important role in land-management decisions (Baumgart-Getz et al., 2012; Frisvold and Deva, 2012), and some practices are perceived not to be efficient in small-scale farming, or conversely, larger enterprises may lack the agility to change practices quickly. Within a defined land structure, the type of activity also has a role to play in predetermining the potential to adapt or mitigate, e.g., crop-livestock mixed systems can be more resilient than specialised farms. At the same time, biophysical pressures may also present a trigger for transformative adaptation- either by mobilising farmers to shift their enterprise to a more suitable location, or to shift to an entirely different production system (Marshall et al. 2016; Park et al. 2012; Kates et al. 2012).

The rest of the section describes in more detail the barriers to adoption of climate-friendly measures identified via the literature review. As per Table 2, subsection 3.1 starts with a discussion of the farm level barriers (structural, economic, social and cultural, and behavioural barriers). Subsection 3.2 then reviews barriers that exist at the national and government policy levels. Beyond a description of each type of barrier, this overview provides a guide to help determine which barriers could exist in each particular case and thus what policy approaches would be most appropriate.

Barriers at the farm level: from structural constraints to behavioural challenges

A number of factors can affect a farmer's decision to adopt climate-friendly practices. Structural constraints can prevent action in this area; and farmers may also perceive or face significant costs adopting such practices. At the same time, a range of social, cultural and behavioural factors may also affect the farmers' willingness to change practices. This sub-section analyses these factors in light of the reviewed literature.

Structural conditions can discourage the adoption of climate-friendly practices

- Land tenure creates security and certainty for decision-making

Depending on the type of measure under question, land tenure can have important implications for the adoption of climate friendly practices. A meta-analysis of 46 studies (Baumgart-Getz et al., 2012) looking at the adoption of best-management practices[8] found tenure to be a positive indicator of adoption, and the findings are likely to apply to climate friendly measures as well. When farmers do not have long-term security in their land, they are unlikely to adopt any adaptation actions that have longer life-times or involve investment in the land or physical infrastructure, (Sunding and Zilberman, 2001), for example, planting trees, introducing natural flood management, or implementing peatland restoration. With regard to potential emissions trading schemes, Claassen and Morehart (2009) show that farmers who own rather than rent their land may be in a better position to generate carbon offsets. However, a number of climate-friendly practices available in agriculture do not require investments in the land, and other studies have not found a relationship between land tenure and adoption (van Dijl et al., 2015).

- Infrastructure and complementary inputs are necessary

Changes in practice, and the adoption of climate-friendly agriculture measures, will often require **associated infrastructure**, and an absence of these may generate a barrier to adoption for all farmers in a particular region. For instance, surface irrigation may be necessary to continue existing production in response to reduced rainfall, but this adaptation would only be feasible if both irrigation infrastructure (canals, reservoirs) as well as water allocations are available (Niles et al., 2015; Sánchez et al., 2016). Historically, increases in high yield varieties have been accompanied by an intensification of irrigation and fertilisation practices (Sunding and Zilberman, 2001), although in a changing climate with decreased water availability, irrigation may become a maladaptive practice. This notwithstanding, the availability of infrastructure will influence how different systems respond to climate change and adopt climate-friendly practices, so this must be a consideration when designing policies or incentives. Depending on the specific national features a barrier can also be of great importance and therefore become a political priority, such as in Italy. Further studies, for example in the context of irrigation could help demonstrate that political intervention is needed to facilitate adaptation to climate change[9]

- Farm succession and structure, and farmer age affects decision-making

While the literature identifying structural barriers to climate-friendly practices is limited, it is well-known in the innovation literature that structural factors, such as farmer's age or farm's size, can present important barriers to innovation adoption (Diederen et al., 2003; Daberkow and McBride, 2003; Jones, 1963; Karali et al., 2014; Padel, 2001; Paudel et al., 2012; Sanchez et al., 2014; Slee et al., 2006; Vanslembrouck et al., 2002;). An increasing number of farmers have no identified **successor or succession plan** (Fischer and Burton, 2014), which may act as a barrier to investing in adaptation or mitigation options that involve considerable capital or infrastructural investment. Structural problems in the agricultural sector such as small and fragmented farmlands as well as an ageing farmer population are generally considered as barriers to more efficient and sustainable land use (Davis et al., 2009; Giannakis and Bruggeman, 2015; Laepple and Hennessy, 2012). Older farmers are generally less willing to adopt new technologies and practices. While an increase in average farm sizes would generally lead to greater resource efficiency through economies of scale (Davis et al., 2009), younger,

8. Best-management practices in agriculture generally, not specifically climate-friendly practices.

9. Note that irrigation may not always be an appropriate adaptation, depending on the current and future water availability and competing users. Switching to less water-intensive production may increase the overall resilience of the region.

well-educated farmers have also been shown to be more open to adopting more recent, advanced technology as well as environmentally friendly farming practices (Paudel et al., 2012; Karali et al., 2014; Sanchez et al., 2014; Slee et al., 2006).

Economic barriers may be significant

- Actual or perceived lack of financial benefits may prevent adoption

Measures that do not guarantee financial benefits – e.g., that may have a negative **impact on production** or come at a cost to the farmer – are unlikely to be adopted in the absence of other tangible benefits. This is particularly relevant in the case of mitigation practices. Adaptation measures generally generate a private benefit (or avoided cost) for the farmer by limiting the detrimental future impacts of climate change on production; adaptation measures would not be adopted if there was no overall net benefit over time. Anticipated financial benefits are identified as important drivers in the adoption of new agricultural practices (Rochecouste et al., 2015; Maybery et al., 2005; Frost, 2000). Morgan et al. (2015) found perceived financial benefits to be one of the main factors driving the adoption of mitigation practices (across six domains: livestock; soil; fertiliser; water; energy; and vegetation management) among Australian farmers. Similarly, Feliciano et al. (2014) find that the main mitigation practices favoured among Scottish farmers were those related to the reduction of mineral N fertiliser, a change that was also accompanied by cost reduction. Many of the conservation agriculture measures that reduce GHG emissions do increase profitability (Rochecouste et al., 2015); this should be explained and demonstrated to farmers to encourage adoption.

- The cost of adopting new technologies or practices may be prohibitive

Some climate-friendly measures are associated with **high adoption costs at the farm level**, particularly with regard to capital costs, thereby acting as a barrier for some farmers. A number of mitigation strategies, such as precision agriculture technologies, require the purchase of specialised machinery and associated technology, such as GPS and sensors, and possibly machinery modification and reconfiguration. There is evidence that a perceived or actual lack of financial capacity to implement certain practices represents an important impediment to their adoption by farmers (Stuart et al., 2014; Morgan et al., 2015; Sanchez et al., 2014; Rochecouste et al., 2015). Even practices not requiring capital costs may incur entry costs, which deter farmers, such as the cost of planting a cover crop (Sánchez et al., 2016). Adaptation measures may also incur significant capital investment, such as pumps, pipes and sprinklers for irrigation, the construction or modification of shelters, and shifting to alternative varieties or livestock breeds. Credit constraints (discussed in more detail subsequently) may also exacerbate the prohibitive nature of adoption costs.

- Hidden and transaction costs could explain the non-adoption of presumably win-win measures

An **oversimplification of cost** and adoption assumptions may partly explain the non-adoption of seemingly “win-win” measures identified in MACCs (MacLeod et al., 2015). Most assessments of the economic costs of mitigation measures are based on average values which do not take into account the heterogeneity of farms. Moreover, they do not include the possible interactions between mitigation measures, and the opportunity cost thereof. In particular, Moran et al. (2013) identify the potential existence of unobserved transaction costs associated with learning and implementing new techniques (discussed further under information and education) as well as poorly recorded monitoring, reporting and validating (MRV) costs. Farmers’ private transaction costs related to agri-environmental or conservation programme participation have been found to be an important factor explaining their decision to participate and their practice adoption decisions (Falconer, 2000; Falconer and Saunders, 2002; Mettepenningen et al., 2009; Rørstad et al., 2007; Vatn et al., 2002).[10] They may also play a significant role in barring the adoption of climate friendly-practices; for instance, farmers face private

10. See Lankoski (2016) for empirical estimates of farmers’ private transaction costs.

transaction costs when applying for carbon offset or other voluntary schemes. These costs are generally fixed and independent from the size of the farm, causing them to be particularly prohibitive to small entities (Bellassen et al., 2015). Smith et al. (2007b) also surmise that transaction costs present a barrier to the participation in carbon markets, through what they term a brokerage cost, again particularly for smallholders. Additional unreported costs may include those associated with recording and reporting input use. Hence, while it appears from MACCs studies that some measures may be either financially neutral or even income generating for farmers, in reality, they may be associated with potentially significant hidden cost that prevent their widespread adoption (Grosjean et al., 2016).

- Limited access to credit may slow down adoption

As with any business, **access to credit** is a key factor in determining the direction agricultural businesses take with regard to choice of land use and production processes. If a practice is associated with an implementation cost (as discussed above) then access to credit may be an important factor even if the farmer is willing to undertake the practice. Although different from credit, "financial capacity" (in the form of capital) has been found to have the largest impact on adoption of best management practices in the meta-analysis of Baumgart-Getz et al. (2012). The availability of credit is also likely to be a significant factor if climate-friendly practices result in lower yields or profits. For example, farmers have expressed concern that potential reductions in yields may affect their relationships with lenders (Stuart et al., 2014). This particular barrier is of course only applicable for certain practices as many climate-friendly measures will not require any initial investment or cost, or may even increase yields or decrease costs.

Social and cultural factors play an important role in farmers' decisions

Farmers identify themselves strongly with their occupation, their work place, the land and the animals, making it difficult to disentangle themselves from the **farm, traditions, and practices** (Barcley et al., 2005; Burton, 2004a; Duesberg et al., 2013; Gasson, 1973; Gillmor, 1999; Grubbstroem and Soovaelli-Sepping, 2012; Kuehne, 2013; Mann, 2007; Riley, 2011; Riley, 2015). Farming also provides the farmer with a sense of identity, occupation, control, and status in the community, as well as social and cultural capital (Bika, 2007; Burton, 2004a; Burton et al., 2008; Errington, 2002; Gillmor, 1999; Ingram and Kirwan, 2011; Kuehne, 2013; Riley, 2012). These inherent identities can have an important influence on farmers' attitudes to and decisions to adopt climate-friendly practices.

In many parts of the world, farming is a traditional occupation that has been continued from generation to generation. For various reasons, certain practices may be seen as appropriate and acceptable, and others less so. For example, farmers in many countries tend to have a negative attitude towards woodland planting; reflecting a 'deep cultural divide' between farming and forestry (WEAG, 2012 cited in Feliciano et al. 2014; Cooper and Rosin, 2014; Burton, 2004b). Bridging this cultural divide would have highly positive implications for addressing climate change, as there are multiple benefits from on-farm tree planting (or agroforestry systems), both for mitigation and adaptation to climate change, as well as for biodiversity, water quality, and recreation (Willis et al., 2003).

Many farmers display "deeply embedded psychological and moral reasons for focusing on food production" (Clark and Johnson, 1993). They often argue that agriculture is addressing food security and "feeding the world", and should be exempt from **GHG emission** reduction efforts (Rosin, 2013).[11] Burton et al. (2008) discuss the role of 'cultural capital' in agriculture, where identical categories of perception and appreciation are developed among farmers so that skills can be appreciated and rewarded. Measures that may (in the short term at least) result in lower yields for example, are likely to

11. This perception is related to other social and cultural barriers, as well as to the discussion on the effects of climate friendly measures on production, where countries tend to adopt the argument of improving efficiency and reducing emissions per unit of product rather than reducing absolute emissions

threaten the perception of what makes a 'good farmer', and farmers are understandably reluctant (even subconsciously) to take this step. The existence of this phenomenon is shown by farmers being more likely to adopt certain measures if their neighbours have a positive attitude towards the practice and are likely to keep on adopting such practices if the neighbours are also determined to do so (van Dijl et al., 2015; Kuhfuss et al., 2015).

Emotional or cultural attachments to land or activity can act both as an enhancer and barrier to **adaptation**. Farmers that have strong emotional or cultural attachments to their land and land use are more likely to be encouraged to protect the land for future generations. But they may also be unwilling to undertake significant adaptation action, such as a physical relocation of activity to a more suitable location (Eakin et al., 2015; Marshall et al., 2012) or a change in activity to one more appropriate in a changing climate (Adger et al., 2011, Adger et al., 2009).

Farmers may be exposed to a range of behavioural and cognitive barriers

- Beliefs and experience of climate change have a modest impact on adoption

Believing that climate change is real has only a modest impact on whether people adopt climate-friendly measures (Hornsey et al., 2016); instead focusing on *why* people hold their views is likely to be more fruitful in changing behaviour than attempting to directly change these views. Some studies have reported relationships between the belief that climate change is occurring and is due to human activity, and the likelihood of adopting adaptation and mitigation practices (Arbuckle et al., 2013; Stuart et al., 2014). In general, farmers who are sceptical about climate change are less likely to adopt climate-friendly practices, but if the practices are framed as addressing weather variability instead, they may support such practices (Arbuckle et al., 2013).[12]

Farmers' perception on whether or not they are able to affect the situation influences the adoption rate. Many farmers do not consider their individual, potential contribution to the mitigation effort as something that matters and therefore are not encouraged to undertake any effort. On the one hand they may underestimate their own GHG-footprint; on the other hand they may also perceive that their action will not matter if all other farmers don't undertake such action (Greiner and Gregg, 2011). Farmers' perception of their own ability to adapt to the impact is also critical.

Personal experience with climate change (or extreme weather events) may have a significant effect on the adoption of climate-friendly agricultural practices although the link between the two is debated in the literature. The "Psychological Distance Theory" (Liberman et al., 2002) suggests that events perceived to be closer either spatially, temporally, socially or in certainty, are more salient and have a greater influence on individual's decisions (Spence et al., 2012). The theory is validated partially in the case of climate change; some studies find that personal experience with climate change events influence attitudes towards climate change (Niles et al., 2016), but other studies failed to determine a difference in attitudes between those affected by climate impacts and the general population (Whitmarsh, 2008) or a change in attitudes before and after an extreme event (Carlton et al., 2015). The general consensus in the literature is that experience is not correlated with climate change *belief* (Hornsey et al., 2016), and that climate change beliefs play only a modest role in adoption of climate-friendly measures. It is likely that individuals' worldviews and political loyalties influence the way they search, remember and assimilate evidence around climate change (*ibid*). Of course, farmers who are exposed to repeated changes in weather will generally adapt their practices in response, wherever possible (Wreford and Adger, 2010). But adaptations made in anticipation of future changes, and many mitigation actions – particularly those without immediate benefits to the farmer – may be more influenced by the concept of psychological distance.

12. Other factors such as status in a group can also be influential and lead farmers to refuse win-win innovations (Grolleau, 2014).

- Perceived long time horizons, uncertainty and risk management can discourage the uptake of climate-friendly practices

Uncertainty about future climate changes may discourage the adoption of long term adaption actions (e.g. Eakin et al., 2015). Adaptation can be improved by a wide range of farm-level actions, from relatively short-term decisions made in response to observed changes in weather, such as changing crop variety or adjusting the timing of operations, to decisions that require a longer time to be fully effective (long lead time) or even be seemingly irreversible (long life time), such as planting shelterbelts or building housing to protect animals from heat stress. Farmers may not be willing to engage into the latter, given that these are long term investments that may not pay off. As seen in Box 2, uncertainty is a key reason for farmers' reluctance to even discuss climate change adaptation in Australia. However, given the complexity, timescales and uncertainties involved in regional climate prediction, climate scenarios will always be inherently uncertain,[13] and waiting for more certain projections may increase the vulnerability as well as the cost of implementation of adaptation measures.

Relative risk perception can also play a role in farmers' willingness to adopt climate-friendly measures. In the context of climate change, risk perception and appraisal are based on an individual's perception of threats, opportunities, exposure and severity (Grothmann and Patt, 2005). Individuals assess the relative risks of different phenomena in terms of the perceived probability of being exposed to their impact and how harmful the impact will be relative to their appraisal of how harmful and urgent other problems or challenges may be (*ibid*). In this setting, climate concerns may be attributed a low priority.

Box 2. Why is it difficult to discuss climate change with farmers? Evidence from Australia

To better understand the non-adoption of farmers in climate adaptation projects, Robertson and Murray-Pior (2016) surveyed Australian farmers about their willingness to discuss the impacts of, and their adaptation to, climate change. They identify five key reasons why it is difficult for farmers to discuss these issues.

1. Climate change is a slow-moving phenomenon and projections are uncertain
2: Time horizons for farm planning are relatively short and managing the ‘‘here and now’’ of climate (and price and cost) variability takes precedence
3. There is confidence in the ability of technological progress to keep pace with negative impacts of climate change
4. Biophysical science does not have much to offer to support longer term more transformational decisions
5. Communication is difficult in a contentious environment.

The authors then recommend a series of action to cope with these issues, emphasising the need to focus on farm management practices rather than optimal systems, and finding ways to regain the trust of farmers on climate change issue, notably by involving farm and agriculture specialist in participatory communication approaches.

Source: Robertson and Murray-Prior (2016).

With the urgency of action in the face of already observable impacts, adaptation decisions will need to be made in the absence of certainty; existing analytical approaches to taking decisions under uncertainty may help guide farmers. In light of uncertainties, strategies should aim to be "robust" against a wide range of plausible climate change projections (Dessai and van der Slujis, 2007; Hallegatte, 2009; Hallegatte et al., 2012; Lempert and Schlesinger, 2000). Robust decision-making in general terms obviates the need to wait for better climate information, as robust adaptations would

13. Uncertainty in climate projections stems from four main sources: 1. Modelling uncertainty, which stems from our incomplete understanding of the climate system and the inability of climate models to represent the real system perfectly; 2. Natural climate variability; 3. Uncertainty in our future emissions; 4. Uncertainty resulting from downscaling projections (Jenkins et al., 2009).

increase resilience regardless of how the climate changes. Under conditions of deep uncertainty as in the case of climate change, and recognising that often climate is only one of a myriad drivers, an approach emphasising robust decision-making is less likely to be constrained by limits to knowledge (Dessai and Hulme, 2007). Communicating these approaches to farmers and advisers may be a useful mechanism to overcome the barrier posed by uncertainty. Economic appraisal tools include real-options appraisal, portfolio analysis and formal robust decision making (Dittrich et al., 2016a; Dittrich et al., 2016b), although their formal application is complex and may itself present a barrier to its use. The underlying concepts however may provide useful approaches to guide decision-making. For instance, moving to a diversified livestock herd with different temperature tolerances thereby trading off optimal performance in the current climate for more resilience against temperature extremes (an application of portfolio analysis). Similarly, natural flood risk management measures to protect livestock and agricultural land can be implemented in stages and scaled up over time in the least costly way of the potential full design if considered from the beginning (real options analysis).

- Farmers face competing pressures

Farmers are business managers and as such must deal holistically with a range of financial and time requirements. Individually these demands may not be time consuming or costly. But owner-operating farmers are working on their own and are time constrained. Adapting to and mitigating the causes of climate change may not be as high a priority as other pressures. Farmers must balance these competing demands, with their own priorities (Frost, 2000). Additionally, climate change may be seen as one of several environmental requirements farmers should consider (Thareau et al., 2015).

Furthermore, farmers may only be willing to implement climate-friendly measures that require minimum efforts, and those that require more effort, such as farm woodland planting, may be less attractive (Feliciano et al., 2014). Studies have found “easiness of implementation” as being a reason for adoption of certain practices and a lack of time or staff or labour as an impediment (Greiner and Gregg, 2011). This may be related to the status quo bias in behavioural economics, where individuals tend to prefer the status quo, or by abiding by previous decisions (Shogren, 2012).

Barriers at the sector and policy levels: misperceptions and insufficient policy efforts

Farmers’ propensity to adopt climate-friendly practices may also be influenced by sector-wide or national factors, stemming in part from policies and activities of other actors. First, the access to and level of information about climate change, its effects, and the possible macro-effects that mitigating emissions may have on production could play a significant role in farmers’ willingness to consider climate-friendly practices. Second, supply chain decisions and contracting schemes may have an influence on farm’s decisions. Third, the focus and type of climate policy as it relates to agriculture, both domestically and in competing countries can also play a role, as well as its accounting in the international emissions inventory. Lastly, non-climate related agricultural policies may also encourage farmers to engage into climate-incompatible practices.

Actual and perceived effect on production

A clearly identified barrier to adoption of mitigation measures is the perception that they will affect the farm’s production, and, on a national scale, affect the production of the entire sector[14] (Greiner and Gregg, 2011). At the national scale, in countries where agriculture is an important contributor to the economy and also a significant source of emissions, mitigation obligations tend to be resisted because of their perceived potential effect on production. Here the rhetoric tends to focus on increased efficiency and thereby reducing emissions per unit of product rather than attempting to reduce overall emissions

14. This is particularly the case with respect to mitigation practices: the aim of adaptation is usually to avoid negative effects on yield and production losses, but some adaptation options may require accepting lower than optimal productivity over a longer term to avoid catastrophic losses in the future, perhaps through diversification for example.

from the sector (New Zealand Agricultural Greenhouse Gas Research Centre, 2014). While efficiency is part of the solution., evidence suggests that some of the emissions savings from efficiency might be offset by those associated with increased production, the so-called Jevons' Paradox (Alcott, 2005). At the same time, such efficiency gains can encourage lower footprint production activities at a higher scale, eventually reducing the regional or global sector's emissions. Other options are available that balance production and GHG mitigation objectives however, the agricultural sector together with the other sectors of the economy should ultimately strive to reduce the absolute GHG emissions (see earlier discussion regarding MACC curves).

Governments are often unwilling to scale back their own agricultural production or restrict inputs if they perceive that their competitors are not taking the same measures. They fear a competitive disadvantage, concerned that other, less efficient producers will simply fill the supply gap leading to an increase in global emissions (a concept called carbon "leakage", see Lee et al., 2006, discussed further below). For example, New Zealand has stated it will only introduce reduction obligations for biological emissions from agriculture if there are technologies available to reduce these emissions and international competitors also take sufficient actions (New Zealand Government, 2014).

Insufficient information and awareness plays a role in limiting climate change efforts

Although the "information deficit model" (e.g. Irwin and Wynne, 1996), which assumes that once the public receives the appropriate information they will then act rationally, is now outdated, information and education remain an important factor in promoting awareness and adoption of climate-friendly measures in agriculture. Some farmers are still uninformed about agriculture's contribution to climate change: for instance, many corn farmers in a study based in Michigan, United States, had no prior exposure to information about the linkages between nitrogen fertiliser, N_2O, and climate change (Stuart et al., 2012). The lack of knowledge about potential climate-friendly measures and how to implement them is also identified as a barrier across other countries. Farmers and stakeholders in a Scottish study mentioned a lack of information and education as a constraint for adopting certain mitigation measures, particularly in relation to nitrogen fixation through the use of legumes, a finding replicated among Spanish farmers (Sánchez et al., 2016), and access to and quality of information was identified as having an important impact on adoption of best management practices (Baumgart-Getz et al., 2012).

The way in which information about climate change is communicated is mentioned in several studies as being important: a positive approach focusing on empowering farmers to take action to address climate change is generally more successful at engaging people and minimising defensive reactions (Niles et al., 2013; Stuart et al., 2014). Communication of the on-farm benefits of adopting climate-friendly measures is more likely to drive adoption than policy drivers (Rochecouste et al., 2015). *Who* provides the information is also critical (OECD, 2015b): Farmers may have some sources they trust more than others, and indeed some sources may be less impartial than others. In one study, farmers gained the most information on fertiliser application from fertiliser dealers themselves, and had little understanding of the consequences for the climate of over-application of N fertiliser (Stuart et al., 2014). Examples of showcasing role models from the farming community and allowing them to explain changes they have made, the costs involved and the results achieved have been shown anecdotally to be successful (Buffett, 2016). In some areas certain extension services have chosen not to mention climate change for fear of creating distrust among farmers (ibid).

There is a general consensus in the literature that there is a need for a targeted, segmented approach to extension with farmers (Arbuckle et al., 2013). Drawing on insights presented under other barriers, targeting information in a way that appeals to people's values, without crowding out other desirable behaviours, may be more helpful than simply providing increasing quantities of information. A useful, practical discussion around encouraging behaviour change is presented in Crompton (2010).

Establishing networks to share examples of climate-friendly practices, and encouraging farmers to co-operate with each other and share information and experiences may be a mechanism to move beyond the existing barriers. Being connected to an agency or local networks of farmers was identified as having one of the largest impacts on adoption of best management practice (Baumgart-Getz et al., 2012), and networks are identified in several studies as being critical to the adoption of innovation (Knickel et al., 2009), and in changing behaviour regarding adaptation and mitigation (OECD, 2012). Farmers make decisions in a number of "nested, hierarchical" scales (Lyle, 2015), which influence and interact with each other and ultimately affect farmers' decision making. Lyle (2015) presents this model with the "hazardscape" at the outermost scale, and the individual at the innermost working out towards the household, the farm and the community. It is useful to keep this conceptualisation in mind when considering farmers' decisions, as they are influenced and shaped by a range of networks.

Industry co-operation and agreements

Certain types of agricultural production (such as seed corn production in the United States) are tied to commercial contracts, where farmers are bound to a competitive contract system that focuses on yields and encourages them to apply more nitrogen fertiliser than other farmers (Stuart et al., 2014). Farmers participating in these contract programmes may be actively encouraged by the company to increase their fertiliser application rates, and farmers may feel they are unable to address climate change issues (through reducing nitrogen fertiliser usage) given their production contracts.[15]

Post-production, market chain-related constraints may also induce disincentives for farmers to adopt climate friendly activities. For instance, shifting to new low-emission or climate resilient crop alternatives will not be profitable in the absence of an effective marketing chain (from storage units to retail, e.g. Meynard et al., 2013). Well-established industries with processing factories for a certain product may also encourage buying companies and farmers to avoid changing options (OECD, 2017b). In dry regions of India, textile and sugar manufactures have long been established with a network of processing factories, lowering incentives for both food and clothing companies and farmers to move away from highly water consuming sugarcane and cotton.

Institutions play an influential role in shaping farmers' decisions and helping them make strategic choices with implications for livelihoods and sustainable development (Agrawal, 2008). Greiner and Gregg (2011) find a perception that the industry (in this case beef in Australia) did not have a consolidated position on conservation measures and did not provide recommended industry best practice standards. On the other hand, businesses can encourage good environmental practice and become a driver rather than a barrier. For example, Global GAP (Good Agricultural Practice) creates private incentives for the adoption of sustainable practices globally, and provides voluntary certification schemes. Producers and suppliers are able to join this programme. Similarly, some of the larger supermarkets are also driving good practice.[16]

Both the absence of and poorly designed climate policy can create barriers to adoption

The absence of explicit references to agriculture in international climate policy – most recently in the Paris Agreement – could act as an indirect barrier to agriculture mitigation practices, in that it does not encourage countries to take action in this area. While the whole economy approach provides flexibility and avoids unnecessary burden on some sectors, the avoidance of simply mentioning the

15. At the same time, some contracts with industry require specific fertilizer rate to ensure a specific quality of grains; for instance, in the case of bread cereals (wheat or rye), specified applications can help ensure higher protein content and better baking properties. In such case, farmers might be paid less for lower N content of their grains, discouraging them to apply lower N rates, but the trade-off involves quality versus environment.

16. For instance, the British supermarket chain Tesco, which in 2007 initiated the Tesco Sustainable Dairy Group (TSDG), which provides information and advice to farmers on reducing their carbon footprint on farm, as well as improvements in animal welfare and general sustainability. They also hold an annual conference for TSDG farmers and opportunities for the farmers to meet and exchange information

objective of reducing GHG emissions in agriculture, despite its importance especially in non-CO2 emissions, leaves the room for UNFCCC ratifying countries to neglect sector specific actions.[17]

As a result of the absence of explicit reference to agriculture in international climate agreements, and because of the complexity involved with many producers managing biological systems, there are only few examples of policies regulating agricultural GHG emissions. But farmers arguably will not adopt otherwise (short-term) unprofitable agricultural mitigation practices in the absence of government policy or incentives (Smith et al., 2007b). While in principle agriculture could be governed by similar policies as other sectors – including market-based measures such as taxes or tradable permits; standards and regulations; subsidies and tax credits; information instruments and management tools; R&D investment; promoting the deployment and diffusion of technological mitigation options; and voluntary compliance programmes (Gerber et al., 2010). The inherent complexity of large numbers of heterogeneous small firms managing uncertain biological systems means that the application, and particularly the monitoring, reporting and validating, of these policies is not straightforward. This is especially true where policies target particular practices. Some other instruments, such as N_2O tax, may be easier to implement.

The employment of policy measures has been low and is dominated by subsidies, grants and incentives, and voluntary offset programmes (Cooper et al., 2013). New Zealand has been the only country to attempt to incorporate agriculture into the Emissions Trading Scheme (ETS) at the national level, [18] although biological emissions from agriculture are not yet included. The agricultural sector in New Zealand will only incur surrender obligations if there are technologies available to reduce these emissions and if New Zealand's international competitors are "taking sufficient action on their emissions" (New Zealand Government, 2014). Sub-national programmes are being developed in the United States, including a Californian ETS, and the Regional Greenhouse Gas Initiative (RGII) involving nine states, which allows offset allowances for certain agricultural activities.

In contrast, the "threat" of regulation may be sufficient to promote the voluntary adoption of mitigation measures among producers. Farmers may want to be seen to be addressing the problem without regulation, thereby removing the need for legislation and the associated compliance costs and administration (Cooper et al., 2013; Renwick and Wreford, 2011).

Even when applied to the agriculture sector, the design of climate mitigation policy may limit the adoption of climate-friendly practices (Niles et al., 2013; Barnes and Toma, 2012), for two main reasons. First, climate policies may in theory affect the adaptive capacity of agricultural systems to respond to climate changes if they require resources and costs that exacerbate vulnerabilities. In other words, responding to a new climate mitigation policy may require farmers to divert resources (time, labour, capital) away from adapting to actual impacts, leaving them more vulnerable. This concern has been expressed by farmers, particularly in relation to the administrative burden of regulatory reporting, e.g. in the case of fertiliser and pesticide use (Niles et al., 2013). No evidence was found that regulations have effectively increased vulnerability. Still, this concern highlights the importance of integrating

17. Slight progress has been observed in the G20. In January 2017, G20 agriculture minister declared that they "emphasise the need for agriculture and forestry to adapt to climate change and also emphasise their role in its mitigation", striving to enhance their capacity to do so (G20, 2017b). The Action Plan they also adopted remain relatively vague: "We will take action to implement the Paris Agreement in the agricultural sector." (G20, 2017a).

18. Several U.S. state or regional programs have attempted to incorporate agriculture into ETSs through sales of offsets. California has an emissions trading program that provides for sale of agricultural offsets from methane capture from manure management systems, as does the Regional Greenhouse Gas Initiative (RGGI), a cooperative initiative to reduce greenhouse gas emissions involving nine north-eastern U.S. States. Several voluntary offset programs also allow participation of agricultural producers through practices such as soil carbon sequestration and fertilizer management.

policies and the unintended consequences of misaligned policies. The concept of "Climate Smart Agriculture" promotes such integration; it advocates the development of measures that achieve both mitigation and adaptation goals, as well as meeting food security aspirations. It may therefore have a role to play, although meeting three goals simultaneously will not always be feasible.

A second reason for climate policies or even the *possibility* of climate policies, creating barriers is by creating general hostility towards any climate action. It may be the case that policies play perhaps an even more important role than climatic drivers in influencing both positive and negative adaptive behaviours to climate change (Adger et al., 2009). And negative experience with past local environmental policy is a much stronger predictor of climate change attitudes than personal experience of climate impacts (Niles et al., 2013), although as discussed subsequently, beliefs about climate change have only a modest impact on adoption. However, the authors also found that farmers may be able to overlook their negative perceptions towards policy and adopt climate-friendly practices, if the government provides the right incentive to do so. Encouraging societal demand for climate regulation may be a useful mechanism to encourage mitigating behaviour (Ockwell et al., 2009).

Box 3. Farmers have heterogeneous values and motivations

Farmers, as individuals, are motivated by different factors, which will influence their perceptions of climate change and the appropriate action for them to take. Several studies have classified farmers into different types, according to their beliefs, values and motivations (Barnes and Toma, 2012; Hall and Wreford, 2012; Greiner and Gregg, 2011; Maybery et al., 2005). This segmentation may help identify the driving forces behind farmer's decision making. For example, three motivating factors were found for beef grazing farmers in Australia: 'economic or financial' motivation, 'conservation and lifestyle' motivation and 'social' motivation (Greiner and Gregg, 2011). Other authors find similar groups of motivations. Unsurprisingly, farmers driven primarily by economic and financial motivation rate the opportunity cost elements (potential loss of production) of adopting climate-friendly measures as a more important consideration than farmers who are motivated by conservation and lifestyle or social factors.

Individuals' beliefs and motivations stem from their values, which can be grouped into intrinsic values (self-transcending, altruistic, community), and extrinsic (self-enhancement, power, financial-success) (Schwarz, 2006). Correlations are found between individuals' values and their behaviour (Bardi and Schwarz, 2003; Roccas and Sagiv, 2010). A meta-analysis of 25 polls and 171 academic studies across 56 nations (Hornsey et al., 2016) found that values, ideologies and political affiliation was a much stronger predictor of climate change belief than other variables including education, knowledge and experience with extreme weather events. Furthermore, values research has important implications for policy incentives for adoption of climate-friendly practices as it demonstrates that a focus on financial benefits to encourage the adoption of pro-environmental behaviour may have undesirable consequences in the longer term as it reinforces worldviews that are incompatible with pro-environmental behaviour, 'crowding out' altruistic intentions (Crompton, 2010). While the literature still has to develop empirical analysis on the specific case of climate friendly agriculture, there is some empirical evidence that financial incentives can crowd out the adoption of biodiversity and ecosystem conservation programs (Rode et al., 2015).

Monetary rewards weaken intrinsic, self-transcending intentions: so a farmer for example may have intended to adopt a mitigation practice that may have negatively affected their production because he/she felt it 'was the right thing to do', that they 'were doing their bit' towards climate change. If a financial incentive was then offered this removes the altruistic motivations and may result in the farmer not adopting the behaviour at all. If this effect holds, monetary rewards have the opposite effect of their intention (Shogren, 2012). Evidence relating to adoption of conservation agriculture practices identifies fundamental differences in motivation for subsidised and non-subsidised practices (e.g., Lokhorst et al., 2011). However, while the proportions of altruistically motivated farmers will vary between regions, it is likely that they comprise a smaller proportion of the farming population than more conventionally profit-driven producers and therefore the net benefit of financial rewards in encouraging adoption of climate-friendly practices would be positive. While it would be beneficial for policy-makers to understand the composition of farmers in their region and their primary motivations before proceeding with interventions, practically, it is unlikely to be feasible to apply differentiated policies

Source: Bardi and Schwarz (2003); Barnes and Toma (2012); Crompton (2010); Greiner and Gregg (2011); Hall and Wreford (2012); Lokhorst et al. (2011); Maybery et al. (2005); Roccas and Sagiv (2010); Schwarz, (2006); Shogren (2012).

Policies, as well as risk communication and advice within the agricultural community should ideally be differentiated across regions and places, addressing different farmer types as well as land uses. Policies tend to address farmers as a homogenous group, but considerable evidence exists to suggest that this is not the case, and that farmers hold considerably different values from each other, resulting in differing attitudes and behaviours (e.g., see Barnes and Toma, 2012; Greiner and Gregg, 2011; Maybery et al., 2005; Morgan et al. , 2015) (Box 3). Furthermore, significant heterogeneity exists between farms systems themselves, and they are affected differently by climate impacts depending on their bio-physical and ecological contexts, as discussed at the outset.

Possible carbon leakage

The concept of carbon “leakage”(Lee et al., 2006), whereby the emissions reduced by one country through stricter environmental controls or greater voluntary adoption of mitigating measures by actors, are increased in another country with weaker environmental protection, is often cited as a reason for not reducing emissions (Smith et al., 2007b). While there are a number of causes of such leakage, the most direct driver is the imposition of higher costs in the country imposing the regulation, reducing that country’s competitiveness. *Ex ante* analysis of European agricultural emissions reductions suggest that leakage may indeed be significant (Van Doorslaer et al., 2015), although this may vary depending on the mechanisms used to incentivise mitigation, and the assumptions of the model used, particularly on the availability and uptake of technological mitigation options, and agricultural productivity growth inside and outside the European Union. Another study (Leip et al., 2010) finds that including agriculture in the EU ETS would reduce EU emissions by 19.3% and increase emissions in the rest of the world by 6%. So the picture is by no means clear and no *ex post* analysis is yet available. A first best solution is that of international cooperation on common goals, the Paris Agreement and associated efforts to encourage GHG mitigation actions in different countries may contribute to lessen that concern. A range of other approaches has been studied, including measures that may in some case have negative trade implication (Condon and Ignaciuk, 2013).

Reporting and administrative disincentives to act

The national level reporting of GHG emissions through the IPCC inventories may present a barrier to mitigation, as many mitigation practices are not captured in this process nor are the benefits of carbon storage accounted for. The IPCC Inventory Guidelines (IPCC, 2006) format has three tiers of calculating emissions, with Tier 1 having very broad categories of activities and simple, fixed region emission factors. Unless countries adopt a Tier 3 methodology, which allows for more precise recording of activities and systems, many emissions reduction practices, such as altering the feed composition, improving the timing of fertiliser application, or other soil management practices, will not be captured (Smith et al., 2007b). This feature of national inventories presents an important barrier to the adoption of certain emission reductions practices as there is little incentive to adopt them if they will not have any effect on the countries’ reported emissions. Furthermore, some of the efficient mitigation measures are classified under the LULUCF sector (Land Use, Land Use Change and Forestry), such as new cultivation methods for organic soils (Huan-Niemi et al., 2015). However this particular barrier is only important if the inventory is the main vehicle for incentivising mitigation, and there is some scope for farmers and countries to use more detailed reporting if necessary.

Sector-attribution of GHG emission reductions may also reduce incentives to act. Although overall it does not make a difference which sector reduces the emissions, a sector (or government ministry) not properly acknowledged for reducing emissions may be discouraged from engaging into mitigation actions. For instance, credits for fuel efficiency improvements in agriculture are often accounted as energy sector achievements, ignoring the role of agricultural actors.

Barriers may also be caused by misaligned agricultural policies

Policies designed to support production, such as input subsidies, production support, subsidised insurance for marketable risks, and tax exemptions in challenging circumstances may distort the signals given to producers that they should be adopting climate friendly practices.

Orthodox economic advice discourages input subsidies due to their propensity to distort resource allocation, and their inefficiency and inequity in transferring resources. For instance, electricity and grain production subsidies in Northwest India support groundwater overdraft and greenhouse gas emissions (GSI, 2010; OECD, 2015a). [19] But in the longer term the more critical problems with these types of subsidies in the context of climate change are the continued support of production in areas that are no longer appropriate, depleting groundwater in areas that are already water scarce and becoming more so under climate change, increasing future vulnerability and creating a barrier to transformation. By encouraging intensive groundwater use, such subsidies may also contribute to pollution, salinization, stream depletion and other external impacts (OECD, 2015a).

Similar problems exist with fertiliser subsidies, which are used in Indonesia for example (Osorio et al., 2011), which aim to increase yields and preserve national food security, as well as the wider objectives of farmers' welfare, poverty alleviation or price stabilisation. The policies may encourage farmers to apply fertiliser above the optimum rate, which has negative effects on productivity as well as the contribution to greater N_2O emissions, undermining mitigation aims, and also appear to have limited success in addressing poverty alleviation (Osorio et al., 2011). Countries that maintain production support measures should consider decoupling them from production, and may consider conditioning them based on environmental performance, including continued suitability of the production under changing environmental conditions.

Expectations that formal institutions for risk management, e.g. insurance, will protect individuals from risk can provide a barrier to individuals taking action themselves (Linnerooth-Bayer and Hochrainer-Stigler, 2014; Eakin et al., 2015). For instance, evidence shows that farmers who opted for yield insurance were significantly less likely to adopt risk mitigating irrigation (Foudi and Erdlenbruch, 2012). Similarly, Annan and Schlenker (2015) showed that US farmers with federal crop insurance opt for more heat sensitive crops than others, and reduced incentive to engage in climate change adaptation. On the other hand, insurance instruments can be designed to provide incentives for adaptation by using reduced premiums to reward investment in risk-reducing activities (Linnerooth-Bayer and Hochrainer-Stigler, 2014).

By design, some policies may be more accepted by farmers and therefore may stimulate higher adoption rates. Farmers tend to prefer instruments that do not directly affect the costs of production. For instance Swiss farmers in general prefer to choose "climate-standards" on vehicles or on construction, or eventually see a tax on GHG intensive food as an option to stimulate emission reduction as opposed to the instruments that would directly increase their costs such as a levy on gasoline or heating fuels and additional taxes on agricultural inputs (Karrer, 2012).

4. Overcoming barriers to climate-friendly agriculture: Which policy actions?

Identifying high priority, locally-relevant barriers

As shown in section 3, agriculture faces a wide range of diverse barriers to the adoption of climate-friendly practices. Some of these barriers are directly linked to government policy, while others relate to farmers' own decisions but can potentially be influenced by policy. This multitude of barriers also matches the diversity in environmental conditions, types of farmers, institutional and policy environments.

The way policy makers respond to these barriers will have an effect on the uptake of climate-friendly practices. It is necessary to prioritise the order in which barriers are addressed in order to increase the cost-efficiency of policies that stimulate the uptake of climate-friendly practices. Two steps are deemed necessary.

19. Multiple report have found that energy subsidies in Mexico and India have increased water use, leading to high energy use and financial costs, with very limited benefits for farmers. Economic studies have shown that reducing or removing these subsidies would result in significant reduced groundwater uses there (OECD, 2015a).

First, decision makers should *identify which types of barrier are prevalent in their agricultural sector.* This could be done by interacting with farmers themselves, extension services, researchers and other stakeholders using the list of 18 key barriers provided above. This would also help avoid expenditure on ineffective programmes. Although farmers have mentioned a lack of financial incentives as presenting a barrier to their adoption of certain measures (Greiner and Gregg, 2011), they have been less supportive of these incentives. This indicates that they would rather adopt different practices to maximise efficiency rather than, for example, be paid to reduce fertiliser application (Stuart et al., 2014). In this case there may have an insufficient level of incentive or a different type of incentive may have been more successful.

Second, policy makers should *evaluate which of the identified barriers are of highest priority to address.* Policy makers will need to reflect on the characteristics of their own sector and region (such as the types of production systems, the environmental conditions, the volume of emissions from their sector and the relative contribution to their national emissions, as well as the mitigation priorities of their nation) when considering which barriers to prioritise. If agriculture is a significant source of emissions in their country and large volumes of emissions reductions are required, the sector is likely to require transformative changes to its production systems. In this case, the ideal course of action would involve a targeted knowledge exchange programme to understand and address underlying values and entrenched behaviours within the sector, and engaging stakeholders to jointly identify the changes required, possible ways to do so and the policy measures that would send appropriate signals. This may take several years if not decades to be successful, but would ultimately enable cheaper and more effective policy implementation in the future. In other areas where agricultural emissions are not significant and incremental changes may be sufficient to achieve some emissions reductions, removing the policy barriers and providing information and incentives where appropriate may be all that is necessary.

Acknowledging remaining uncertainties, this review has identified four categories of barriers to the adoption of climate friendly practices in terms of their relative importance and policy relevance, as observed in the literature.

- First, the barriers that have been recognised as important with sufficiently robust evidence in the literature can be considered of high priority. These are: the farm-level barrier of an actual or perceived lack of financial benefit; the national-level barrier of the actual or perceived effect on production, insufficient information and education; and the limited and undeveloped climate policy. Responding to these barriers, often via targeted communication and engagement should be prioritised as much as possible.
- A second tier of barriers have a significant influence on the adoption of climate-friendly practices but do not have as strong supporting evidence. Three farmer level barriers fit into this category: the cost of adoption; hidden and transaction costs; access to credit; and social and cultural factors. Perceived carbon leakage and misaligned policies also fit into this category. These should also be considered as relative priority areas of actions unless contradictory evidence is found in the relevant context.
- A third tier consists of barriers that could limit the adoption of certain climate-friendly practices: land tenure and infrastructure. These areas should warrant attention while also be subject to further research in different contexts.
- A last group of barriers may be worth addressing but are likely not to be the most critical. These include behavioural and cognitive factors, farm succession, industry cooperation, administrative barriers and policy distortions. In some regions these barriers may represent a significant hurdle to the adoption of climate-friendly practices, but in general across OECD countries they play a relatively smaller role than some of the other barriers discussed.

Selecting the correct instrument to overcome the barriers

Climate policy should not ignore agriculture, even if the sector may require a certain degree of customisation to fully achieve policy aims. For example, there is significant discussion regarding a cross-sector carbon tax. While such a tax may be relatively straightforward to apply within the transportation or energy sectors, taxing the bio-physical environment is far more complicated. Indeed, each methane emitting livestock operation typically raises different breeds of animals of different ages, based on different feed, and so on, each of which affect taxable emissions.

Removing identified barriers should stimulate uptake of climate friendly practices but when that is not the case, *additional policy actions* may be deemed necessary to encourage the uptake of climate-friendly practices. Where barriers to adoption exist because of the public good nature of adaptation or mitigation measures, Pannell (2010) develops a framework to determine the roles for policy depending on the respective private and public net benefits. He suggests using positive incentives where public net benefits are highly positive and private net benefits close to zero, and extension (i.e. knowledge provision) where public net benefits are highly positive and private net benefits slightly positive. For example extension would be appropriate for mitigation options with high abatement potential that could be achieved at no financial cost to the farmer. In situations where private costs outweigh, or are similar to public net benefits, Pannell suggests that technological developments would be the most appropriate tool to encourage action. Where the private net benefits outweigh the public net costs no public policy action is required, which is also the case for many private adaptation measures. In cases where the private net benefits are slightly positive but the public net benefits are highly negative, Pannell (2010) recommends negative incentives (i.e. regulations and prohibitions), as in the case of production generating significant GHG emissions, for example the over-application of fertiliser. The latter may also occur in this context as the result of cumulative private adaptations leading to adverse public good outcomes – for example, the over-abstraction of water for irrigation leading to reduced river flows or aquifer depletion and the associated negative environmental and recreational externalities.[20]

Adaptation in agriculture generates predominantly private benefits, unless in cases where public goods are provided, such as flood management or coastal area protection. The costs of non-adoption are borne by farmers in the form of reduced or lost production and other than ensuring food security, and possibly maintaining rural communities, the role for policy in overcoming barriers to adaptation is limited and lies primarily in information provision and engagement. However, when costs of adaptation are high but provide public benefits to many, the government may consider providing a financial contribution. For example, in Italy, the Finance Act of December 2015 empowered the government to the introduction of a payment system for ecosystem and environmental services (PSEA). Moreover, when the very existence of the agricultural practice is heavily dependent on irrigation, public intervention may be justified in order to maintain the positive externalities generated by both the agricultural practice and irrigation itself. Zucaro (2014) quantifies these benefits in the Italian agricultural context using the choice experiment method. Ignaciuk (2015) and OECD (2017a) discuss in more detail when policy actions may be needed to help farmers adapt.

In the case of *mitigation*, indirect effects may generate positive private benefits for the farmers, but the primary aim is of a public good nature and therefore policy action may be required to overcome barriers. In theory it may be useful for government to help overcome implementation barriers to mitigation through measures that require an initial investment via cost-share, or possibly other instruments such as microfinance, and R&D incentives (Fankhauser et al., 2008). A number of authors recommend the use of incentives, or payments to encourage the adoption of climate-friendly policies (e.g. Barnes and Toma, 2012) based on studies of farmers' attitudes towards climate change. Feliciano et al. (2014) find the mitigation practices most preferred to be adopted or expanded in future by farmers

20. Meta-analyses of on the adoption of conservation or best management practices, could provide interesting insights into the most effective instruments in particular contexts (see, for example, Baumgart-Getz et al., 2012; Prokopy et al. 2008).

in Scotland are those that reduce costs and increase profit, and the authors suggest that some incentive may be required to increase the adoption of the least preferred mitigation practices, and those that produce public goods, such as peat-land restoration. “Nudging” farmers, i.e. conveying information to them on other farmer’s decisions may help to increase adoption rate (Kuhfuss et al., 2015). At the same time, such incentive programmes are not sufficient if other barriers are not accounted for; as argued in this report even income generating (negative costs) measures may not be adopted by farmers in all cases. Furthermore certain incentive measures may also lead to unwanted effects (crowding out).

The analysis highlights two main approaches that could be adapted to different circumstances: *first, the revisions of policies that counteract the objectives of climate-friendly agriculture*, and, *second, the introduction of targeted initiatives that will directly help remove the identified key barriers*. This doesn't contradict the need to adapt the type of policy response to the identified priority barriers and the local or national agricultural context. In countries where agriculture constitutes a large proportion of emissions, the sector is likely to require significant adjustments, such as shifts in production type, location or farming system. In this case, governments should offer targeted knowledge enhancing programme with the goal of understanding values and lowering the role of entrenched behaviours within the sector. To do so they should engage with relevant stakeholders to jointly assess the required changes, identify possible ways to do so and select the policy measures that would send appropriate signals. In contrast, governments of countries where agricultural emissions make up a lower proportion of the country’s GHG emissions, and where incremental changes may be sufficient to achieve some emissions reductions, should thrive to remove existing policy barriers and to provide information and incentives for action where appropriate.

A case study from Scotland reports the promises of innovative targeted and customised initiatives to reduce farmers’ emissions (Box 4). This approach addresses some of the barriers identified throughout the report in a relatively low-cost way. Other countries have implemented similar programmes, including Switzerland and France.

Box 4. Farming For a Better Climate in Scotland

Farming For a Better Climate (FFBC) is a policy initiative by the Scottish Government and provided by Scotland’s Rural College. It works with farmers to find ‘practical ways to move towards a more profitable, low carbon future, adapt to a changing climate and secure farm viability for future generations’ (SG, 2008). The Scottish Government (SG) aims to deliver reduction targets within the agricultural sector, partly though a voluntary approach and the FFBC initiative provides a framework for promoting relevant actions by farmers, across five key areas: (a) using energy and fuels efficiently; (b) developing renewable energy, (c) locking carbon into the soil and vegetation, (d) optimising the application of fertiliser and manures, and (e) optimising livestock management and storage of waste.

By basing the scheme around volunteer Climate Change Focus Farmers and their farmer discussion groups, it immediately breaks down some of the barriers discussed in this report. By providing an opportunity for discussion, demonstrations and implementation of some of the climate-friendly practices within the five key areas, the scheme addresses any information deficit among farmers, but furthermore it may also target some of the behavioural barriers. Social concerns around cultural capital, being seen to be a good farmer, and practical concerns around productivity and cost can be addressed through farmers engaging with each other and being directly involved. The practices adopted are tailored to the specific characteristics (location, farm type etc.) of the focus farm. Farmers within the discussion groups can observe and be involved in these practices, see the outcomes and discuss with their colleagues the pros and cons, challenges and practicalities. Sources trusted by farmers (advisory services; industry specialists) are involved, and concrete evidence is shown on commercial farms rather than research stations.

Evidence of the impact of FFBC measures the environmental and financial performance of farms and has demonstrated through the FFBC Focus Farm programme. For the first round of Climate Change Focus Farmers from 2010 to 2013, the four volunteer farms, on average, reduced their carbon footprint by around 10% with no loss of production. Savings ranged from GBP 11 000 to 37 000 with additional financial savings and carbon savings likely in the future as measures continue to take effect (personal communication with R. Audsley, 2016).

Though the policy has yet to be formally evaluated, it is argued that the policy is effective for the following reasons: i) the focus farms allow demonstration or trial of mitigation and adaptation measures; ii) the on farm meetings give farmers the opportunity to see and hear a range of other ideas and exchange information with both industry specialists and other working farmers about the effectiveness/costs/time regarding some of these measures; iii) the webpages and social media accounts also provide additional information as to what others have done to improve farm efficiency and reduce the farm carbon footprint as a result of these actions.

FFBC is relatively simple to implement as it is an adaptation of a successful knowledge exchange programme (focus farms) that have been shown to be successful for improving business performance. Clearly its ultimate success must be measured by the uptake of the practices among farmers throughout Scotland, and evidence of this is not yet available. The government has indicated if sufficient emissions reductions from agriculture are not achieved it will consider a regulatory approach. However, it appears that this voluntary approach fosters a positive attitude towards climate-friendly practices among farmers rather than creating defensiveness and scepticism.

Source: Scottish Government (2008), “Farming for a Better Climate”, Edinburgh.
www.gov.scot/Topics/farmingrural/Agriculture/Environment/climatechange/Advice
Program website: www.sruc.ac.uk/climatechange/farmingforabetterclimate/.

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Annex 1.

Methodology

A systematic review methodology was employed to identify the studies used to inform the insights in this report. A systematic literature review is a summary and assessment of the state of knowledge on a given topic or research question, structured to rigorously summarize existing understanding (Ford et al. 2011).The search engines Scopus, Web of Science and Science Direct were searched using the keyword, title, and abstract search terms "barrier, adoption, agriculture, climate change". This initially returned more than 600 entries, but by applying the defined inclusion and exclusion criteria (Table A1) to the primary literature body on the keyword, title, and abstract level, the total number of papers was reduced to 46. Another search was carried out replacing the terms "climate change" with "conservation" which returned 42 results. Application of the snowball technique and inclusion of relevant work from the researchers' personal libraries generated a number of additional studies for inclusion in the literature database. Once all potential search avenues were exhausted, the final literature body of 114 studies was established.

The studies identified consist both of empirical studies and more theoretical/conceptual studies. Both types are included. The articles were scanned to determine the types of barriers they addressed: these barriers formed the basis for the categories of barriers in Table 2. The assessment of agreement in the literature was based on the author's judgment of the literature; the relative weight of each barrier was assessed based both on the literature as well as expert opinion. While the literature provided the basis for this assessment, it was augmented by experts' understanding of reality and knowledge of research that may not have been identified in the systematic review.

Table A1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Empirical study or review of barriers to adoption	
Type of study: peer reviewed article, book, book chapter, report	Type of study: Working paper, conference paper
Must be focused on the agricultural sector	Non-agricultural sector
OECD country	Non-OECD country
English language publication	Non-English language publication
Date range: within the last ten years	Older than ten years (exceptions for key literature identified during snowball process)