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Adapting Agriculture to Climate Change

A ROLE FOR PUBLIC POLICIES

Ada Ignaciuk

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Comments are welcome and may be sent to tad.contact@oecd.org.

Abstract

ADAPTING AGRICULTURE TO CLIMATE CHANGE: A ROLE FOR PUBLIC POLICIES

by

Ada Ignaciuk
Agricultural Policy Analyst, OECD

Farmers will undertake many adaptation actions to meet changing climate conditions and will often do so without any government intervention. However, when such actions provide both private and public benefits, the public sector may play a role in how these are developed. This report aims to establish a framework to help identify specific actions that governments could take in this respect and that could avoid sending signals leading to non-adaptation or maladaptation. This report begins with a review of national adaptation strategies for the agricultural sector in OECD countries and highlights different approaches undertaken by governments. It then identifies the main criteria under which governments may take action to increase the resilience of the agricultural sector and its adaptive capacity to climate change. Finally, it discusses strategies to monitor and evaluate adaptation policies.

Keywords: Public policies, adaptation to climate change, adaptation strategies, monitoring and evaluation of adaptation, adaptation of the agricultural sector.

JEL: Q18, Q28, Q54

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Executive summary

Policies will continue to play an important role in complementing and enhancing the capacity of farmers to adapt their practices to potential climate risks

On-farm adaptation measures, such as changing cropping dates or varieties, will continue to be necessary to adapt to weather variability and to shifts in temperature and precipitation, but farmers may also need to invest in various on-farm infrastructure measures, such as more efficient irrigation systems or water storage. Because the benefits of most adaptation measures are local and directly captured by farmers, self-interest should be a sufficient incentive for individuals to adapt, i.e. farmers will act when the private benefits they generate outweigh the costs. However, adaptation efforts at the farm level may fall short of the socially optimal level owing to market failures such as externalities, information asymmetry and moral hazard. Policy interventions are therefore needed to align privately profitable actions with socially desirable outcomes.

While all OECD countries have developed a diversity of national strategies to support climate change adaptation in agriculture, their implementation is still limited

Many OECD countries are actively designing national adaptation strategies and several have progressed to the implementation phase. All OECD countries have created initial national assessments of climate change impacts and vulnerability of the agricultural sector, but only a few have conducted regional assessments. The majority of OECD countries explicitly include capacity development in their prioritisation of adaptation enhancing measures and are increasingly advocating the use of various risk managements strategies. However, too often there is no accompanying strategy to increase the necessary investments in infrastructure to improve the adaptive capacity of farmers to changing climate conditions. A few countries explicitly discuss funding mechanisms.

This report identifies criteria under which public intervention may be warranted to minimise the societal costs of climate change and to improve farmers' resilience to future climate change

Public actions for adaptation may be justified from an economic perspective according to the following criteria: (i) actions that generate knowledge; (ii) actions that facilitate knowledge transfers; (iii) actions that correct for externalities; (iv) actions that prevent financial barriers for adaptation; (v) actions that allow for sharing extreme risks; (vi) actions to correct for institutional and regulatory barriers; and (vii) actions to reduce the barriers that prevent multi-level and multi-scale collaboration.

A clear role for the public sector is to generate and provide accurate and detailed information on the risks and consequences of climate change

Providing accurate and detailed information allows private agents to make timely, well-informed and efficient adaptation decisions. Public and semi-public research and development (R&D) programmes would play an essential role in this respect. An additional role for the public sector is to further support research on risk and vulnerability assessment, including at the sub-regional levels. Although most long-term R&D investment in OECD countries is public, the private sector is increasing its share in developing agricultural technologies that are specifically directed at increasing the resilience of this sector. Thus, the government may further enable

development of private innovations by, for example, addressing investment barriers, ensuring that private knowledge is disseminated, and encouraging, where suitable, public-private partnerships (PPPs) for R&D with public good outcomes.

The public sector should foster adaptation by providing tools for farmers to assess and manage their risks

Rather than proposing a set of "best practices" which may not be easily transferable amongst different locations, government should provide farmers with tools to allow them to assess future weather conditions (via, e.g., weather forecasting or early warning systems). This would allow farmers to undertake early actions to minimise the negative effects of extreme events.

Training, education and extension services may also increase the resilience of the agricultural sector to future climate change

Improved access to information, via training and education, would help farmers and other private agents make rational decisions and undertake adaptation actions. In view of the numerous existing advisory programmes, it is often advisable to streamline adaptation actions into existing institutions and to co-ordinate such actions with the private sector.

Governments should remove disincentives for farmers' adaptive actions

Governments should identify and remove impediments to adaptation, namely distortions in input and output markets and measures that generate conflicting interests, such as potentially harmful subsidies and distorting insurance arrangements. For example, poorly designed insurance premiums that do not adequately reflect underlying risks can impede adaptation or even promote maladaptation; for instance, by reducing incentives to change to more resilient crops or by inducing farming in risky locations or with risky practices.

Current decisions on infrastructure should be climate-proof as they may be crucial for the future resilience of agriculture

It is important to consider current conditions, as well as multiple potential future scenarios when making decisions regarding infrastructure, including but not limited to: water, transport and trade infrastructure. Any new infrastructure system should be climate-proof, to the extent possible, and incorporate the needs of various sectors, including agriculture.

There has been limited monitoring and evaluation of climate change adaptation policies and programmes, but this is critical if support to adaptation in the agricultural sector is to be effective

Currently, there is uncertainty both in terms of climate change effects on agriculture and the effects of policies addressing vulnerability. Monitoring and evaluation generates a learning cycle to support the adjustment of adaptation policy as new climate change information becomes available. However, there have been only limited efforts to conduct such activities, in part due to the relatively short-life span of adaptation policies and the lack of adaptation metrics. Both country-level and project-level monitoring may be used as sources of information to help understand whether the overall level of action at the time of assessment is adequate.

1. Why are adaptation policies important?

Climate change will most likely substantially affect the agricultural sector. Although some potential benefits may be reaped from longer vegetation periods in cool regions or increased carbon fertilisation effects (Stokes and Howden, 2011), the majority of studies agree that global average crop yields are likely to be negatively affected, especially if the average global temperature increases by two degrees or more (Ciscar et al., 2011; Howden et al., 2007; Ignaciuk and Mason D'Croz, 2014; Nelson et al., 2009). Additionally, if global temperatures continue to rise, water scarcity may be significantly exacerbated in many regions and affect local agriculture (Schellnhuber et al., 2013).

To reduce future risks associated with such negative impacts, both mitigation and adaptation actions are needed. Mitigation actions reduce the impact of climate change by decreasing emissions of greenhouse gases (GHGs) or by enhancing carbon sinks. Adaptation[1] measures reduce the negative effects of climate change on agricultural production or amplify the positive ones by adjusting the ecological, social or economic systems (IPCC, 2007). By increasing adaptive capacity and reducing vulnerabilities, the resilience[2] of the socio-economic system can be improved (FAO/OECD, 2012).

There are important methodological aspects that differentiate adaptation from mitigation measures. Mitigation actions benefit all those that may be exposed to the negative effects of climate change; however to bring about significant change, mitigation actions require collective engagements at the national and international levels. Conversely, adaptation actions create, in most cases, a private good and the benefits are enjoyed locally (Mendelsohn, 2012). Unlike local mitigation actions, local adaptation can make a significant difference to local communities. For example, when choosing crop varieties better suited to local conditions or when applying better soil management practices, farmers benefit directly from such actions. Many adaptation actions, therefore, will be undertaken by farmers themselves when the private benefits they generate outweigh the costs involved[3] (Wreford et al., 2010).

In some cases, adaptation actions provide both private and public benefits. For instance, investing in hedges does not only generate benefits for farmers, such as through providing shelter for their livestock or increasing water retention, but also contributes to creating a better microclimate and favourable conditions for local and migrating birds. In other cases, the investment costs for adaptation – e.g. investment in a large water infrastructure system – may be too high for a farmer to act on his own. Such an infrastructure may be important not only for a group of farmers planning to use irrigation technologies, but may also have potential consequences on other parts of the economy and local communities by, for example, providing extra benefits such as additional sources of drinking water and recreational areas.

The existence of public benefits and market failures prompt the question of what role governments may have in supporting climate change adaptation in agriculture. This report aims to highlight the role of public policies in fostering adaptation with a view to helping identify when public intervention is warranted to minimise societal costs of climate change and improve

1. *Adaptation*: A process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014a).

2. *Resilience*: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC, 2014a).

3. The existence of a cost-efficient adaptation measure does not necessary imply its implementation.

farmers' resilience to future climate change. To this end, it identifies a set of guiding principles for government intervention and applies these to a list of well-known adaptation actions, reflecting a range of adaptation types (research and development, capacity building, risk management, infrastructure and funding mechanisms). It also reviews and analyses recent trends in approaches taken by governments to help the agricultural sector adapt to climate change.

This report reviews public adaptation policies in OECD countries and selected key partners, and highlights strategies and approaches that countries are taking to support the agricultural sector, excluding forestry, to adapt. The analysis is based on a review of National Communications (NC) to the United Nations Framework Convention on Climate Change (UNFCCC) and National Adaptation Strategies (NAS) that together cover a wide range of specific government measures for adaptation in agriculture. It also elaborates in more detail the main criteria under which governments may take actions to increase the resilience of the agricultural sector and its adaptive capacity, and examines monitoring and evaluation strategies.

This report builds on previous OECD work. In a broader setting, OECD (2008) points out that the role of government should be limited to providing adaptation as a public good when private actions are insufficient due to external effects or other market failures. Anton et al. (2012) analyse specifically the use of insurance as a risk-reducing measure in agriculture. Wreford et al. (2010) discuss the importance of defining the rationale for government intervention in adaptation for the agricultural sector. Mendelsohn (2012) builds on these findings and elaborates on the aspect of equity. They agree there is scope for public policies in determining the course of adaptation; but do not discuss in detail the criteria for possible public action for increasing resilience within the agricultural sector.

Section 2 of this report presents the main characteristics of adaptation. Section 3 reviews the adaptation activities identified in NCs, NASs and other relevant documents for the agricultural sector in OECD countries and selected emerging economies. Section 4 proposes a framework to help policy makers prioritise their actions and applies this framework to the reviewed set of adaptation actions and identifies current government actions. Section 5 discusses approaches and indicators through which various policies targeting adaptation can be monitored and evaluated. Section 5 provides concluding remarks.

2. Specific characteristics of adaptation

Adaptation to climate change can be defined as the adjustment of behaviour towards actual or expected climate stimuli or their effects, both negative and positive (IPCC, 2007). Adaptation to the adverse effects of climate change is vital to reduce the most negative effects of climate change impact and to increase the resilience of agriculture (among other sectors) to future consequences. Adaptation measures can respond to negative effects of climate change but also be tailored to harness the positive effects.

Overall, adaptation encompasses various types of actions. Adaptation in the agricultural sector may be *autonomous* (reactive), that is when farmers adjust their behaviour by observing changing climate conditions (Mendelsohn, 2012). Many climate adaptation options for agriculture resemble current "best practices" and "sustainable resource management" and do not require farmers to radically change their behaviour in the near term (OECD, 2012; Stokes and Howden, 2011; Wreford et al., 2010). Adaptation may also be *planned*, that is when actions are deliberately planned in order to avoid negative impacts in the future. Examples include investment in more resilient seeds or technologies to improve irrigation efficiency (Ignaciuk and Mason D'Croz, 2014).

The following issues need to be kept in mind while developing adaptation strategies: (i) expectations on future socio-economic developments, (ii) uncertainty of climate change impacts at the global, regional and sub-regional levels, (iii) long-term adaptation horizon and the dynamic character of adaptation actions, (iv) inertia of current socio-economic and governance systems to rapid changes, (v) behavioural aspects; and (vi) the degree to which either adaptation is the sensible option or if an exit strategy is more adequate (adapted from Hallegatte et al., 2011).

Future socio-economic developments will determine to a large extent the development of the agricultural sector and its capacity to adapt. Climate change will also strongly influence agricultural development. Farmers choice of adaptation path will, therefore, depend on anticipated economic and climate developments (Vert et al., 2013).

Decisions, however, about future investments will be taken with a high degree of **uncertainty** related to future climatic conditions, making it difficult to adequately incorporate potential future risks in current decision making (Howden et al., 2007; Barnett and O'Neil, 2010). The need for long-term planning horizons creates additional difficulties for farmers to prepare adaptation actions (Eakin et al., 2009). Uncertainty is also an important factor in policy making. According to Green et al. (2011) "*Decisions are being made around the globe with very limited information on the potential impacts of climate change. State-of-the-science ''best guesses'' will continue to be employed and updated for policy and decision".* To reduce the possibility of creating strategies that result in maladaptation (see Box 1 for examples), policy makers may consider supporting options that are flexible or that are adapted to a large range of possible outcomes of climate scenarios (see Box 2 for more detailed description of such instruments).

This report follows the IPCC AR5 definition of maladaptation[4] (IPCC, 2014a), where maladaptation refers to actions or inaction that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future. Actions in one location or sector that potentially increase the vulnerability of another location or sector, or increase the vulnerability of the target group to future climate change, is also considered maladaptation.

4. The definition of maladaptation used in AR5 has changed subtly to recognize that maladaptation arises not only from inadvertent badly planned adaptation actions, but also from deliberate decisions where wider considerations place greater emphasis on short-term outcomes ahead of longer-term threats, or that discount, or fail to consider, the full range of interactions arising from the planned actions (IPCC, 2014a).

Box 1. Examples of practices leading to maladaptation

Energy subsidies in India

About 90% of water withdrawal in India is used for irrigation. Since the Indian government first began to subsidize energy use, the number of tubewells to pump groundwater increased rapidly, from about 1 million in the 1980s to more than 15 million in 2010. The cost has been substantial. In 2005, farmers received about USD 10 bn. In some states, electricity subsidies were larger than subsidies spent on education and health (Birner et al., 2007). Although the resulting rapid increase of agricultural production has improved the well-being of many farmers, this policy has also resulted in the massive extraction of groundwater (Badiani et al., 2012), and in many places above the recharge capacity threshold. In the most seriously affected north-western states, between 2002 and 2008, an average decline of ground water table 33 cm per year was observed (Rodell et al., 2009). This increases the vulnerability of farmers to future droughts, the occurrence of which may increase due to climate change.

A few policies were established in several states to reverse this costly and inefficient policy. For instance, in Gujarat, a scheme successfully rationalized power supply by decoupling power for agricultural and urban uses (Shah et al., 2008). Farmers received electricity eight hours per day only following an agreed scheme while the rest of the village had 24h access to electricity. Non-farmers clearly benefited from this policy; however, it has worsened the welfare of the marginal farmers.

Monocultures

Monoculture is the practice of producing a single crop over a long period of time in a certain area. The practice of monoculture has been stimulated by political and economic incentives. Specialisation brings obvious benefits to the economy of scale in terms of higher yields and easier mechanization techniques; however, there are disadvantages associated with monocultures. Monocultures lead to easier spread of diseases and pests thereby decreasing resilience to climate change variability that often induces additional stress on plants. In addition, when the produced crop is negatively affected by changing weather or biophysical conditions, farm income may be severely affected. For these reasons, moving toward diversification reduces the risks of maladaptation (Lin, 2011).

Box 2. Adaptation strategies to deal with uncertain climate conditions

Uncertainty is a key issue when designing adaptation strategies, including that associated with assessments of future concentrations of GHGs and their impact on global temperature. The regional distribution of impacts add an additional layer of uncertainties on expected temperature and rainfall evolution since these are even more difficult to project at a lower scale due to the complexity of the global environmental and climatic systems, as well as the imperfect modelling capacities. This is also the case for projecting the responses of the crop and livestock sectors (Challinor, 2009). Decision makers may need, thus, to rethink their strategies and use ‘uncertainty-management’ strategies. Hallegate (2009) proposes five types of strategies:

- “*No-regret*”: The use of measures that yield benefits even in absence of climate change. They may include resource efficiency policies.
- Preference for *reversible and flexible over irreversible choice strategies* to decrease the possible costs of being wrong about future climate change. For instance, early warning systems can be adjusted on a regular basis when new information appears.
- *“Safety margin”* strategies reducing vulnerability at low costs. Such strategies may include, for instance, an implementation of larger than currently necessary drainage pipes in areas that are already exposed to heavy rainfall. These ‘margins’ should be large enough to cope with almost any possible climate change in this century. Such safety margins are likely to be much less expensive to incorporate at the design phase than modifications of the system once it is in place.
- *Institutional tools:* Policy exercises, such as preparation of National Adaptation Plans, help shape strategies to cope with future climate changes. In the present situation, where parameters that used to be known become uncertain, a long-term planning horizon is key to determining where and how to change business practices.
- *Reduction of the lifetime of investments* to avoid long-term commitments. The choice of shorter rotation trees in the forestry sector may be an example of such a strategy.

Source: Hallegate, 2009.

Third, adaptation is a **dynamic process**. Some adaptation measures taken today may become a future maladaptation option if forecasted climate outcomes turned to be wrong. Therefore, flexible adaptation strategies are thus needed to address changing circumstances. The adaptation process requires recurring re-assessments with the possibility for revisions following the availability of new data and information. Howden et al. (2007) state that a key benefit of adaptation research is to understand that short-term response activities affect long-term options, and that policy decisions implemented in the next decades should be designed so as not to undermine the capacity to cope with larger impacts later in the century. For instance, the use of (non-renewable) groundwater to irrigate may solve an immediate problem of local food production but over the long term, such a strategy may lead to the total collapse of agriculture in that area. The time-scale of different adaptation measures vary and needs to be taken into account while preparing adaptation strategies. For example, some investment decisions are taken to have a lasting impact of over several decades (e.g. irrigation), others are revisited annually (e.g. sowing dates).

Fourth, the ability to adjust to changing conditions is necessary to optimise the use of adaptation strategies. However, there is a degree of **inertia in socio-economic systems** that may favour less than optimal strategies or even lead to some maladaptation measures. Such inertia includes cultural, technical and institutional aspects (Hallegatte et al., 2011). The “lock-in” effect is an example of technical inertia. Cowan and Gunby (1996) discuss the “lock-in” effect of chemical pest control compared with Integrated Pest Management (IPM). They claim that if IPM had received the same support as the development synthetic pesticides, it would have been a dominant technology. The empirical evidence shows that IPM is a more profitable technology over a period of time. However, it is knowledge intensive and requires considerable farm management skills; the initial pay-offs are low over a certain period of time as these skills need time before they are acquired and implemented at their optimal level.

Fifth, there may be an important **behavioural aspect** associated with imperfect adaptation. Several agricultural practices and technologies have been identified as having the potential to increase profits, while reducing GHG emissions or contributing to increased farmer’s resilience to climate risks, but are not widely adopted. For example practices related to the use of leguminous crops, or to the timing and extent of pasture management which have been reported as having a “negative cost” for producers while reducing GHG emissions significantly (Pellerin et al., 2013). These “win-win” practices and technologies, however, are only used at a small, if not minimal, scale in OECD countries. The reasons for a low technology uptake may be diverse, ranging from learning gaps, to the risk aversion of farmers towards new practices or the inability to interpret or use available information. The general attitude to potential future benefits versus current costs, i.e. an implicit discount rate, plays a role in the choice of a climate resilient development (Gollier, 2011). Although some adaptation strategies may yield positive benefits in the future, risk-averse farmers may wait to implement these until the technology is proven to be safe and beneficial by pioneers.

Lastly, in some cases adaptation involves a **radical change that** may be too costly or too difficult or even impossible to adapt. For example, Arabica coffee is a main source of income for many smallholder farmers in Nicaragua. These beans are grown in a very narrow climatic niche, and require ample rainfall and mean temperatures of 19–22°C with little intra-annual variation. They generally grow in 15-year cropping cycles and on mountains slopes between 400 and 1400 meters above sea level. If global temperatures rise, production will need to be elevated. It is estimated that under current emission trends, by 2050 80% of the coffee production area in Nicaragua will not be suitable for Arabica production (Vermeulen et al., 2012). Nevertheless, although it may not be optimal to invest in coffee plantations in such places, such decisions are difficult to take for historical, cultural and economic reasons.

3. Review of adaptation activities in the agricultural sector

This section reviews and analyses National Communications (NC)[5] to the UNFCCC[6], National Adaptation Strategies (NAS)[7], as well as national agricultural sector adaptation plans, strategies and programmes to identify adaptation activities in agriculture for the 34 OECD member countries, the European Union (EU), Brazil, China and India. Activities that are designed at the European Union, e.g. those associated with rural development, are discussed separately from the national EU countries policies.

The review of national documents (NC and NAS) and other key (online) publications of national governmental agencies, such as the ministries of agriculture or environmental and intergovernmental climate change agencies, provide a picture of adaptation activities in different countries, in particular those linked to the public sector. The differences related to the availability of online sources for adaptation activities in the agricultural sector between countries, and adaptation activities from the private sector may not be well represented in these governmental sources.[8] Due to time and resource constraints this review is not exhaustive and often based on 5th NCs that are somehow outdated, since not every national 6th NCs were available when the review was conducted.

For most OECD countries, the NAS strategies focus on building adaptation capacity, rather than necessarily setting out concrete adaptation actions. They do not focus on prioritisation of actions (OECD, 2015a). NAS helps to structure critical components of adaptation policy, such as collaboration and coordination among multiple levels of government, planned adaptation, monitoring and evaluation frameworks (Mullan et al., 2013). To make NAS operational in the agricultural sector, some countries have created adaptation programmes with activities in that sector (e.g. Mexican Government, 2009). Other countries, like Spain and Germany, have developed agricultural sector adaptation strategies at the national or sub-national levels (e.g. Extremadura Government, 2011; German Government, 2008).

Adaptation activities

Adaptation activities have been grouped under five themes: (1) research and development, (2) capacity building, (3) risk management, (4) infrastructure and (5) funding mechanisms.

1. Research & development (R&D) examines activities aiming to (a) assess impacts and vulnerabilities of climate change in the agricultural sector; (b) identify and evaluate adaptation options in the agriculture sector; and (c) support the development of technologies and or management practices to enhance resilience in the agriculture sector. For example, such activities include the development of management strategies aimed at an efficient use of resources (e.g. low fertiliser application technologies, more efficient irrigation systems and the

5. Only relevant for Annex I countries in UNFCCC.

6. This review considered the latest NC available at the online database of the UNFCCC from November to December 2013. The 5th NC was reviewed for Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, European Union, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxemburg, Mexico, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, United Kingdom (UK) and the United States. The 6th NC was reviewed for Australia, Hungary, Iceland, New Zealand, Slovakia, Slovenia and Turkey. The 2nd NC was considered for Brazil, Chile, China, India and Israel.

7. NAS can include national adaptation strategies, plans and programmes.

8. There is a growing body of public literature discussing private sector adaptation; however, it deals with various adaptation approaches in, mainly, non-agricultural sectors, e.g. EpE-ONERC (2014) and OECD (2015a).

development of crops of lower nutrient uptake) in agricultural production or the development of biotechnologies[9] to enhance crop resilience in response to climate risks.

2. Capacity building reviews the efforts (a) to increase knowledge and information awareness in the agriculture sector and (b) to mainstream best practices by helping with the implementation of projects or programmes at the farm or agricultural industry levels. Some countries have created online decision-making tools to inform about best practices and possible choices for adaptation in the agricultural sector. In many cases countries have developed special programmes or incorporated some aspects of increasing resilience to climate change in their advisory services to mainstream good adaptation practices at the sub-national or farm levels.

3. Risk management[10] examines if countries have implemented actions associated with (a) insurance used in the agricultural sector (e.g. weather index insurance), (b) weather forecasting, hydrological monitoring and early warning systems linked to the agricultural sector (c) other disaster risk reduction technologies or practices in agriculture, including methodologies and tools to map multiple-risk scenarios at different spatial scales, and frameworks to integrate disaster risks management and climate change adaptation associated with agriculture (FAO, 2013).

4. Infrastructure deals with the implementation of infrastructure aimed at increasing resilience or the adaptive capacity in the agricultural sector, in particular water-related infrastructures such as improved irrigation systems, or water capture or saving infrastructure.

5. Funding mechanisms examines the existence of funding mechanisms for adaptation activities at the farm level. Such mechanisms include financial measures to support farmers to adapt or to provide transitional income support without negatively affecting over the long term farmer's resilience.

Coverage of adaptation activities across OECD countries

Although adaptation to climate change is a relatively new policy area, countries are active in designing adaptation strategies and some have are now at the implementation phase. Priorities, however, vary widely amongst OECD countries.

This section examines the coverage of adaptation activities across OECD countries, the EU, Brazil, China and India based on the themes defined above. Table 1 synthesises the review's findings in the analysed countries and provides information on the following variables:

9. Note that research on biotechnologies includes genetic modification (GM), intragenics, gene shuffling and marker assisted selection (Agrawala et al., 2012). OECD (2009b) highlights how research into agronomic traits to improve yields and resistance to stresses such as drought, salinity and high temperatures has increased rapidly since the 1990s, as shown by the increase in the number of GM field trials of agronomic traits by small and large firms and by public research institutions.

10. Risk management refers to the "concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events" (UNISDR, 2009).

Table 1. Coverage of adaptation in the agricultural sector in National Communications, National Adaptation Strategies and other sources

Countries	Adaptation activities									
	1 Research & development			2 **Capacity building**		3 **Risk management**			4 **Infrastructure**	5 **Funding mechanisms**
	Risk and vulnerability assessment	Identification of adaptation options	R & D	Knowledge and information awareness	Mainstreaming best practices	Insurance	Weather forecasting and early warning system	Other risk management technologies or practices	Water	
Australia	◉	○	○*	⊙		○			◉	⊙
Austria	○	◉		○	◉	○*	◉*			
Belgium	○	○		◉						⊙
Brazil	○	○		○*	◉*				◉*	
Canada	◉	◉	○	◉	◉	◉*	◉	◉	◉*	
Chile	○	○	○			◉			⊙	
China (People's Republic of)	○	○	○		○*				○	
Czech Republic	○	○			◉*					
Denmark	○	○		○						
Estonia	○	○								
European Union	◉	○	○	◉*	◉*		○		◉	◉
Finland	○	○	◉*	○	○	○*	○*			
France	◉	○	○*	○		○*	○		○	
Germany	◉	◉	○*	○*	○*		◉*	◉*		
Greece	○	○								
Hungary	○	○								
Iceland	○	○						○		
India	○	○		○	○	○	○		○	○
Ireland	○	○			○					
Israel	○	○	○				○		○	
Italy	◉	◉		⊙			◉	○	◉	

Countries	Adaptation activities									
	1 Research & development			2 Capacity building		3 Risk management			4 Infrastructure	5 Funding mechanisms
	Risk and vulnerability assessment	Identification of adaptation options	R & D	Knowledge and information awareness	Mainstreaming best practices	Insurance	Weather forecasting and early warning system	Other risk management technologies or practices	Water	
Japan	○	○	○							
Korea	○	○	○			○	○			
Luxemburg	○	○								
Mexico	◉	◉	○	⊙*	○	○			○	○
Netherlands	○	○	○	○				○	◉	○
New Zealand	○	○	⊙	⊙	⊙			○	◉	
Norway	◉	◉		⊙*	○					
Poland	○	○	○	○		○	○	○		
Portugal	○	○	○	○	○	○	○	○	○	
Slovakia	○	○								
Slovenia	○	○								
Spain	○	○				○				
Sweden	○	○		○			○*		○*	
Switzerland	○	○	○*	○*						
Turkey	◉	○	○	○		○	○	○	○	
United Kingdom	◉	◉		◉	⊙					
United States	◉	◉	○*	◉	⊙*	⊙*	○	○*	○	⊙*

Level of intervention: National = ○; sub-national= ◉; farm level = ⊙.

* Other sources. The activity is not mentioned in the NC or the NAS.

Note that the “absence” of a measure does not mean it is not implemented in a country, but that it is not included as a potential adaptation option in the reviewed sources.

- **Activities identified for each theme** (research and development, capacity building, risk management, infrastructure, and funding mechanisms) by country.
- **The level of implementation of the activities**: National, sub-national[11] and farm levels. Classifying these activities into one of these levels is determined by (1) the main level of impact targeted by the adaptation activity and (2) where the key actors implementing the activity are situated[12].
- **Main source of information**: Identifies if the main information source derives either from (1) activities mentioned in the National Communications or National Adaptation Strategies (this does not exclude additional information taken from other sources) or (2) activities identified in other sources of information, such as online websites of national governmental agencies (e.g. Ministries of Agriculture or Environment and Inter-governmental Climate Change Agencies).

4. Framework for establishing adaptation actions

While some adaptations provide public benefits, e.g. practices to increase carbon storage in soils, many others provide more private benefits that accrue to individuals or firms, or to a consortium of such actors. In the latter case, private interest should be a sufficient incentive to undertake measures to adapt (OECD, 2008).

Nonetheless, when private actions fail due to inefficient market functioning or when adaptation actions may benefit wider society, there is a need for public sector intervention. The purpose of this section is to establish a framework to help identify practical actions that governments could take to improve the resilience of farmers to future climate change and to avoid sending signals that lead to potential non adaptation or maladaptation. To achieve this objective, a set of guiding principles for public actions is examined, followed by analyses of where public intervention makes sense and where it is the role of other actors to undertake actions.

Guiding principles for public intervention

The economic literature on agricultural adaptation has focused largely on field- and farmer-scale adaptation. A summary of the main types of on-farm adaptation measures are provided in Table 2. The extent to which these options will be applied depends mainly on the decision-making strategy of individual farmers, taking into account current and anticipated income, historical and potential future climate and current and expected policy setting.

Many adaptation actions are undertaken by private actors and do not require government intervention. Most of the decisions and associated investment costs will be undertaken at the farm level. Because the benefits of such adaptation measures are local and directly captured by farmers, self-interest, in many cases, will be a sufficient incentive for individuals to undertake adaptive measures; i.e. farmers may undertake actions when the private benefits they generate outweigh the costs they involve (OECD, 2008; Mendelsohn, 2012; Wreford et al., 2010).

11. In this review, sub-national level refers to state and provincial levesl and to local (municipal) level activities.

12. For example, a national programme that targets a general public objective is considered to be at the “national level”, but considered at a “farm level” if that level is the key level of intervention of the activity. A provincial or state level adaptation strategy for the agricultural sector is identified as a sub-national level activity even if it has links with national level programmes or projects at the farm level because it coordinates efforts primarily by sub-national authorities and stakeholders.

Table 2. Types of adaptation measures

Options	Examples
Change element	Implement drought or heat resistant crops and or new varieties
	Resistant livestock breeds and types
Change system	Change cropping calendar
	Switch to multi-crop system
	Different management practices
	Investment in irrigation equipment
Change location or livelihood	Migration
	Partial off-farm employment or on-farm non-agricultural activities
	Exit the sector

Source: Adapted from Jarvis et al. (2011).

Besides farmers, other parts of the private sector will play an important role in shaping future farmer's resilience. The private sector possesses financial resources for innovation and seeks profit opportunities. Private sector channels more resources towards short-term R&D than the public sector. A portion of these resources is already used to develop various climate friendly technologies and practices that increase the potential choices of technologies and practices for farmers.

However, adapting the agriculture sector to climate change needs to be more systemic than simply farm-level autonomous activity and may require long-term planning and policy intervention to enhance resilience or adapt to (large) regional climate change effects. This highlights the key role of the public sector as a source of creating an enabling environment to permit private agents to make timely, well-informed and efficient adaptation decisions.

OECD (2008) provides two main reasons why public intervention in adaptation is necessary: (i) the existence of market failures and (ii) the potential provision of adaptation as a public good. More specifically, public actions for adaptation can be justified from an economic perspective according to the following guiding principles (adapted from Hallegatte et al., 2011; Cimato and Mullan, 2010; OECD, 2012):

- *Guiding principle 1*: They contribute to *generating knowledge* in order to overcome market failures in a knowledge generation (due to high uncertainty of the private benefits) and because knowledge is at least partially a public good. The availability of good quality information, access to innovation and R&D is essential to making the right decisions on adaptation.
- *Guiding principle 2*: They facilitate the *transfer of knowledge* to ensure that the public goods aspects of new knowledge *spill over* to the entire economy (OECD, 2012). Asymmetric information provision between various institutions or incorrect information may lead to maladaptation. The benefits of adaptation may reach beyond the sector that adapts. When adaptation is cost-effective, overall income is higher than in the absence of adaptation measures. Such outcomes may stimulate higher investments and therefore induce larger growth (Vivid Economics, 2013).
- *Guiding principle 3*: They *correct for market failures related to non-knowledge-related externalities*. Some private actions may have a negative (or positive) impact on other stakeholders, potentially calling for public action. Examples of this are beneficial management practices (BMPs) such as no-till or reduced-till practices. They benefit farmers, but can also increase soil carbon storage which can benefit society.
- *Guiding principle 4*: They overcome *financial market failures (barriers to access sufficient investments)*. Some adaptation measures may involve a considerable amount of

investment to finance major infrastructure for private-public benefits. This is especially relevant for large water management infrastructures. For example, the development of a dam to secure water supply for residents and agriculture (securing water market), which also creates a recreational space (public good) may require large financial inputs. Governments may create an enabling environment[13] to incentivise the private sector to take action and help reduce the financial barriers (OECD, 2008).

- *Guiding principle 5*: They contribute to *sharing risks* across regions (OECD, 2012). It is seldom the case that an extreme climate event appears simultaneously across different regions. Policies to enhance agricultural trade may contribute to dampen the associated market impacts and support to inter- and intra-regional, acceptably priced, food accessibility (-market stability). Another example of a risk sharing measure is flood control policies, whereby private rural landowners may participate in actions that increase their risks of flooding to reduce vulnerability to flooding in densely populated urban zones (Tompkins and Eakin, 2012).
- *Guiding principle 6:* They contribute to *overcoming institutional and regulatory market failures (barriers)*. Decisions on adaption are not made in a vacuum. Other policies often interfere and may result in suboptimal- or even mal-adaptation. For example, governments that impose instruments with weak enforcement of property rights may create a free riding problem. In the case of groundwater management in India, unclear regulations and weak enforcement did not prevent thousands of illegal wells, thus diminishing future resistance to droughts.
- *Guiding principle 7:* They reduce market failures related to *barriers to multi-level, multi-scale collaboration*. The success of adaptation will depend on collaboration between different levels of governing bodies, including international collaboration and collaboration between multi-level and multi-sectorial bodies. Moreover, governments may need to work as brokers of co-ordinated decisions and actions between various stakeholders that would not happen otherwise. For instance, decisions about the available amount of water to be discharged from trans-border rivers are taken at the international level. Within a country, several levels of governance may be involved in water management. More importantly, close co-operation between different sectors is necessary in order to establish the most efficient water sharing rules. Thus governments may find it necessary to co-ordinate such actions and facilitate negotiations between and across various institutions and stakeholders.

Finally, while market failures may present a case for government intervention, this should be weighed against costs of such intervention or against the costs of inaction. In some cases, "government failure" may also be significant; government intervention can actually worsen the outcome. For example, subsidies on water withdrawal for irrigation may boost current production, but in the long run can lead to water depletion and cause greater problems to farmers. Another example of government support that led to unintentional consequences are the subsidies on water efficient irrigation measures to manage groundwater resources in Kansas, US. These subsidies led to greater abstraction of groundwater overall because eligible farmers used these improvements to shift to more water-intensive crops (Pfeiffer and Lin, 2013). It is clear that each government intervention should be carefully considered.

Given the fact that adaptation policies are in their infancy, monitoring and evaluation is key to learning from their implementation on how to make them more efficient. For these reasons,

13. A positive enabling environment for agriculture comprises a multifaceted setting for the sector and economy wide of non-distorting and stable policies, adequate provision of public goods, good governance through laws and regulations that address market failures, and strong and effective institutions through which government measures and activities are operationalised.

Section 5 is dedicated to a discussion on various approaches on how to measure and monitor progress of adaptation policies.

Reviewing public interventions in adaptation actions

Section 3 discussed five different types of government led adaptation actions in agriculture (research and development, capacity building, risk management, infrastructure and funding mechanisms). Using the guiding principles, Table 3 evaluates a number of prominent examples of each type of action and highlights the potential reasons for government action and considerations that call for caution before any public intervention is taken.

The general picture that emerges for most types of adaptation actions is there are good reasons for governments to carefully assess whether they need or can contribute in a useful way. On the one hand, the government can play a key role in distributing knowledge to improve the functioning of the agricultural sector, or in sharing climate-related risks. On the other hand, there is a danger that governments will intervene when socially optimal actions would also have emerged through private actions, for instance in research and development of climate-resilient crops.

The clear role of the public sector is to provide the most accurate and detailed information on the risks of climate change that allow farmers and other private agents to make rational decisions and undertake adaptation actions. Rather than providing ready solutions, such as providing “best practices”, governments may provide an enabling environment for farmers by removing disincentives for farmers’ adaptive actions and providing tools helping farmers assess and manage their risks. Disincentives that could be targeted include potentially environmentally harmful agricultural subsidies and trade barriers.

In order to help farmer’s reduce their exposure to extreme risks, many governments partially subsidise crop and income insurances. While establishing incentives for adaptation in the agricultural sector is critical, Anton et al. (2012) conclude that managing “normal risks” should fall directly under the responsibility of farmers and that governments should not be tempted to cover all risks. However, the design of current agricultural policies often does not distinguish between covering normal and high risks and result in covering part of the normal risk. Thus, governments need to balance the need to overcome market failures and provide public goods with the imperfections of government action. The resulting trade-off is specific to each type of adaptation action. Each adaptation type is discussed in more detail below.

Given the considerations in Table 3 and public budget constraints, it is logical that governments are moving away from traditional types of interventions, such as public R&D activities with short-term private benefits, towards activities related to stimulating private action. To increase the efficiency of many adaptation actions, including R&D and innovations, governments may seek engagement with the private sector. OECD work on Innovation in Agriculture (OECD, 2013a) and Innovation Strategy (OECD, 2010ab) confirms that co-operation between various actors, both public and private, increases the efficiency of public spending and contributes to better diffusion of adaptation. For Public Private Partnerships (PPPs) to be successful, they need to be supported by ancillary policy instruments including regulation and legal arrangements (OECD, 2008; OECD 2013a).

Table 3. Summary of the conclusions on the public priorities of intervention in adaptation to climate change in agriculture

	Adaptation activities	Related guiding principles for public intervention	Level of government	Conditions under which "climate change" actions appear legitimate	
				Potential reasons	Considerations
Research and development	Impact and vulnerability assessment	Generating knowledge	(Inter)-National	Important to produce knowledge on risks and consequences and increase awareness.	
	Identification of adaptation options	Transfer of knowledge and spill over effects	National – Sub-national – Local	Especially important for those regions that may expect high climate change impacts in the agricultural sector.	Majority of such options are non-regret options for current climate conditions and where possible they are already adopted or should be adopted even in the absence of climate change.
	R&D	Generating knowledge	(Inter)-National – Sub-national	It may be especially important for minor crops and livestock (filling gaps in the private sector R&D). Public R&D is important especially for research covering long term public benefits.	Increasing role of private sector in these systems. PPPs may be an option to combine public and private benefits.
Capacity building	Knowledge and information awareness	Transfer of knowledge	National – Sub-national – Local	Information provision and training on assessment and management of risks and implementation.	There are more private actors on the market therefore it may be important to find a right niche. Public actions should focus on (long-term) public good aspects.
	Best practices	Transfer of knowledge	National – Sub-national – Local	Important to inform farmers of innovative climate friendly options.	"Best practices" may be very much site specific and not easy to transfer.
Risk management	Insurance	Sharing risks.	National	Well-designed policy premiums may contribute to a better assessment of risks.	Public coverage should not cover "normal" risks. Public intervention may contribute to crowding out the insurance markets and potentially distort the real assessment of risks.
	Other disaster' risk reduction practices	Sharing risks.	National	Important to produce contingency plans for extreme events.	
	Weather forecasting and early warning systems	Generating and transferring knowledge.	National – Sub-national.	Provide high-quality information to farmers and other key stakeholders.	Increasing role of private sector in these systems. Possibly more PPPs.
Infrastructure	Water infrastructure	Reduction of financial barriers and support of multi-scale, multi-level collaboration.	National – Sub-national	Important to support measures to increase resource efficiency and to increase overall resilience.	It is important to address water issues with consent of other stakeholders. Possibly in coordination with private sector.
Funding mechanisms	Funding mechanisms at the farm level	Correct for externalities and overcome financial barriers.	National – Sub-national – Local	When it leads to a systemic change and create champions or pilot projects integrating new practices or technologies. Moreover, where there is a market failure in access to credits.	It may be hard to extract the 'climate change' component.

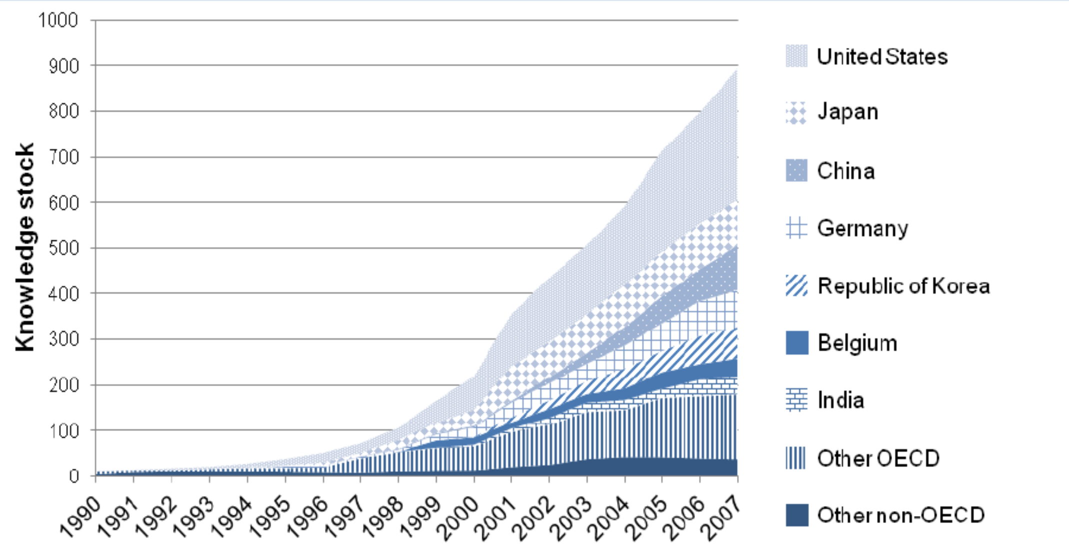
Research and development

Research and development activities, such as the provision of high-quality information and knowledge awareness on climate change impacts, vulnerability and adaptation, may help prepare farmers to deal with climate effects and as such warrant public intervention (OECD, 2009b; Wreford et al., 2010). Until recently, the adaptive capacity of the agricultural sector was largely driven by public sector investments in agricultural research, development and extension activities (Walthall et al., 2012). Public expenditures on research and development are expected to further contribute to agricultural productivity growth and to stimulate innovation (OECD, 2013a). However, the private sector has surpassed the public sector in adaptation-related biotechnologies (OECD, 2009b).

Box 3. The role of the private sector and public sector in research and development of climate change adaptation-related biotechnology for the agricultural sector

The United States, Europe and Japan are the most active players in the development of adaptation-related biotechnology patents.[1] Indeed, OECD countries dominate 80% of patent applications in adaptation-related biotechnologies (Agrawala et al., 2012).

Figure 1. Knowledge stock of adaptation related biotechnology patent applications (1990-2007)



Source: Based on data extracted from EPO/OECD Worldwide Patent Statistical Database (PatStat) in Agrawala et al., 2012.

The private sector plays a key role in the innovation of adaptation-related biotechnologies since four of the five most active patenting organisations are from the private sector. These are BASF Plant Science GmbH, Monsanto, Mendel Biotechnology and Bayer BioScience. However, in some countries such as Japan (Riken Institute), China and Korea the public sector plays a larger role in the development of adaptation related biotechnologies (Agrawala et al., 2012).

The OECD (2009b) developed several principles for policy intervention in biotechnology including (i) to boost research in agricultural and industrial biotechnologies by increasing public research investment, reducing regulatory burdens and encouraging PPPs; and (ii) encourage the use of biotechnology, such as marker assisted selection methods, to address climate change by supporting international agreements to create and sustain markets for environmentally sustainable biotechnology products (OECD, 2009b). However, it noted that adaptation-related biotechnologies in the agricultural sector are not yet identified as common adaptation implementation practices in key national adaptation policy documents among OECD countries. This may indicate that adaptation-related biotechnologies are still in a phase of research and development and that governments are cautious to recognise the role of biotechnologies in climate change adaptation.

1. Agrawala et al. (2012) assessed adaptation crop biotechnology linked to abiotic stress with climate change in terms of (i) drought, (ii) soil salinity and (iii) temperature extremes

An example of an increasing role of the private sector in adaptation-related research is shown in Box 3. Applied research in agricultural practices is often a lucrative business which stimulates various private companies to enter the market or to create partnerships with national research centres. Not surprisingly, the private sector is heavily involved in R&D of profitable crops and their products; therefore, the public sector may fill the niche and explore R&D of minor crops and livestock (Naylor et al., 2004).

Where an explicit public role may be needed is if private actions are insufficient to co-ordinate knowledge creation with the scientific community and private firms. Moreover, government actions are potentially necessary to downscale high-quality, high-level information to specific spatial scales (e.g. from national to regional, local or even farm-level information). Government intervention is also mostly warranted at higher temporal scales (especially long-term strategic and transformational actions), and less so for short-term incremental adaptation options in the agricultural sector (Howden et al., 2007; Park et al., 2012). Adapting agriculture to climate change is an iterative action given the uncertainties and the continuous need to adjust to the changing climate (Howden et al., 2007). In this setting, governments need to identify regions or areas where transformational adaptation is needed in the agricultural sector and plan accordingly. Here, the role of sub-national governments may be critical to coordinating efforts with regional stakeholders and local farmers.

Box 4. Current activities on research and development in relation to adaptation to climate change in agriculture

All 37 analysed countries (34 OECD countries and three emerging countries) and the EU have undertaken an initial national assessment of the impacts, vulnerability and adaptation to climate change in the agricultural sector. National governments usually co-ordinate these assessments with universities or international research centres (the EU has assisted its members to develop initial assessments in agriculture[1]). Austria, Canada, Germany, France, Italy, Mexico, Norway, Turkey, the United Kingdom and the United States have also created assessments at the regional level. In Canada, for example, the provinces and territories have developed partnerships with regional research centres to improve their knowledge on climate change. Quebec provides financial support to the Ouranos consortium for research on adaptation in the agricultural sector (Canadian Government, 2010). Mexico has created the State Climate Change Action Programmes that integrate the agricultural sector into state level vulnerability and adaptation assessments, and are developed by regional universities or research centres (Mexican Government, 2013b; 2013c). The EU prepared its assessment of climate change impacts in the agricultural sector among its members by emphasising the need to integrate adaptation into all key European policies and enhance co-operation at all levels of governance (White Paper, 2009).

Most countries (28 out 37) provide information on impacts, vulnerability and adaptation in the agricultural sector at the national level only. This may be associated with the prevalent uncertainty of climate modelling at higher resolution levels, but also due to the limited research capacity at the regional level (OECD, 2009a).

Only 17 countries have plans or have implemented research and development activities for new technologies associated with adaptation in the agricultural sector.[1] Some countries, e.g. Chile, China, Mexico and the United States, have introduced research on biotechnologies associated with adaptation to climate change. Chile has developed projects to provide genetic improvements to a variety of fruits, crops and forage to increase resistance to climate change. Potato and wheat genotypes have been selected and developed to enhance resistance to drought and high temperature (Chilean Government, 2011). Mexico is promoting research on the genetic diversity of corn and wheat to improve their production and enhance resilience to climate change (Mexican Government, 2012b; 2012c). *Horizon 2020* (2014-2020) which is the largest research and innovation programme in the EU (nearly EUR 80 billion of funding) includes the agricultural sector as an area of research with the aim to increase production efficiency and to cope with climate change, while ensuring sustainability in agriculture.

1. Australia, Canada, Chile, China, Finland, France, Germany, Israel, Japan, Korea, Mexico, the Netherlands, Poland, Portugal, Switzerland, Turkey and the United States.

Capacity building

Capacity building can play an important role in increasing farmer's resilience to climate change in agriculture. It is important to streamline the information on risks and consequences of climate change into existing advisory services and to use new techniques to help farmers assess and manage climate change risks. Public intervention in capacity building may focus on the public goods aspects of agricultural adaptation and on the long-term profit aspects of adaptation actions.

There is a renewed interest across OECD countries in agricultural advisory services that can act as a vehicle to implement measures that help to attain maximum environmental benefits (or reduce harm to the environment) (OECD, 2015b) Such services are not necessarily public and the composition between public and private extension services vary per country. The private sector engages increasingly in providing farmers with tools and training that may help to increase farmers' efficiency in the use of natural resources. Given the existence of numerous advisory programmes, it is often advisable to streamline adaptation actions into existing institutions and co-ordinate such actions with the private sector. These services can be utilised as well to promote adaptation activities and provide farmers with additional tools to cope with changing climate.

Box 5. Current activities on capacity building in relation to adaptation to climate change in agriculture

Most countries (26 out of 37) have created programmes or projects to support capacity building in the agricultural sector on climate change. Knowledge and information awareness activities have been identified in 23 countries, and programmes to mainstream best practices on adaptation in the agricultural sector are mentioned by 16 countries. A key difference among countries is the implementation level (national level, sub-national level or farm level) of capacity building activities in agriculture. A majority of activities are provided at the national or regional level, although a few countries such as Italy, New Zealand, Norway and the United Kingdom, have initiated some activities at the farm level.

The United States Department of Agriculture (USDA) has created *Regional Climate Hubs* to share knowledge and information with farmers at the regional level to support decision-making for adaptation to climate change. These hubs aim to build capacity within USDA to deliver information and guidance on technologies and risk management for the agricultural sector (US Government, 2013). Since 2007, Turkey has periodically used television broadcasting to provide information awareness on climate change to farmers (Turkish Government, 2013). In the United Kingdom, a *Campaign for the Farmed Environment* aims to build national awareness of the priorities for climate change adaptation in the agricultural sector and demonstrate best practices at the farm level in each local area. Canada, Denmark, Finland, the United Kingdom, and the EU have created online decision-making tools for adaptation that include adaptation guidance for the agricultural sector.

The EU addresses capacity building for adaptation via its ***European climate adaptation platform*** **(Climate-ADAPT)**. This platform, launched in March 2012, provides several useful resources to support adaptation policy and decision making such as: a toolset for adaptation planning; projects and case studies' database; and information on adaptation action at all levels, from the EU through regional and national to the local level.[1] The EU has also developed the *Eco-Innovation Action Plan*[2] to support innovations aimed at developing significant and demonstrable progress towards sustainable development by reducing impacts on the environment, enhancing resilience to environmental pressures, or through a more efficient and responsible use of natural resources (European Commission, 2011). Eco-Innovation includes the support of best practices in the agricultural sector, such as using biotechnology to help farmers overcome challenges such as protecting crops against diseases or creating drought tolerant crops that could enhance farmer's resilience to climate change (European Commission, 2011).

1. http://ec.europa.eu/clima/policies/adaptation/what/index_en.htm.

2. The European countries adopting measures under this programme are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom (EU, 2013).

In recent years, private companies have increasingly started to provide information that is downscaled to specific users. Nonetheless, the public sector needs to complement the private sector to provide information and trainings about future risks and opportunities of climate change where the private sector cannot or will not do so (e.g. to small-scale farmers in remote areas). Government intervention may also ensure that information provided to farmers is unbiased and impartial about the range of choices farmers may have. Education, advisory services and training are important for farmers and to facilitate access to technology and knowledge amongst peers (OECD, 2013b).

Many governments have traditionally promoted the use of 'best practices' via a range of programmes in the context of sustainable development or resource efficiency-increasing measures. Many of these practices may be grounded in local knowledge (Vermeulen et al., 2012). However, unless "best practices" are clearly additional and contribute to social welfare, or create additional public benefits, the role of governments may be limited. It may sometimes be difficult to distinguish between the overall best practices and adaptation actions that are "supplementary" actions to increase resilience to climate change. The use of locally appropriate best practices for farmers is often in line with farmers' rationale of profit maximisation, because farmers often possess better information about their particular circumstances.

Box 5 above presents examples of current activities in OECD countries on capacity building in relation to adaptation to climate change in agriculture.

Risk management

Many governments assist farmers by partially subsidising their insurances against loss of yields or income. Anton et al. (2012) argue that managing "normal risks"[14] should fall directly under the responsibility of farmers. They point out that it is possible to identify cost-effective insurance schemes and pinpoint robust options to reduce shocks to farm income.

There are many types of insurance schemes in the agricultural sector, including weather index crop and yield insurance, that can help farmers cope with risks. However, poorly designed premiums that do not adequately reflect the underlying risk can actually impede adaptation or even promote maladaptation by favouring, for example, practices that avoid changes to more resilient crops or induce farming practices in risky locations (OECD, 2008; Mendelshon, 2012).

In the specific field of disaster assistance, subsidised insurance has been popular with governments and farmers, but it tends to crowd out the development of private insurance markets on normal insurable risks and has not been successful in preventing additional *ad hoc* assistance being granted after an event (Anton et al., 2012, OECD, 2008). Similarly, the minimum intervention prices or payments that are triggered when prices or returns are low may even be counter-productive as farmers tend to anticipate these and adjust their behaviour; hence, they tend to induce more risky farming practices.

14. Normal variations in production, prices and weather do not require any specific policy response. They can be directly managed by farmers as part of normal business strategy.

The insurance sector in most OECD countries plays an active role in helping to cope with extreme events (OECD, 2008; Stenek et al., 2010). As climate damages grow and historical weather records become less reliable predictors of future weather, insurance companies may not be willing to cover certain areas and risks or may overcharge coverage fees thereby leaving certain segments of society with no insurance coverage. In such cases, Public Private Partnership (PPPs) may be needed especially for areas of strategic national interest that are faced with increasing climate change impacts (OECD, 2008; FAO, 2013). Such schemes, however, should be designed to cover extreme climate risks only.

Private infrastructure schemes should be well suited to deal with additional risk posed by climate change. However, there are several reasons why many PPPs fail. One is the miscalculation of risks (OECD, 2008). Another is management failure, often on the public sector side. Therefore, and following the World Bank strategies for successful PPPs for agricultural innovation guidance, it is important to select an appropriate partner. It is important at the outset to define a clear objective, the financial contribution on both sides, and to provide transparent information on rules and regulations of public financing and decision making. It is also important to define risk sharing arrangements, for instance clear performance standards that incentivise the private operator to invest in adaptation (OECD, 2008).

Governments may focus on agricultural disaster risk management policies that deal with catastrophic risks that are rare, but cause significant damage to farms at once. Contingency plans should define the procedures, responsibilities and limits of the policy response in advance (Anton et al., 2012).

Weather forecasting is one of the most popular ‘soft’ tools used by farmers. However, sometimes there may be a mismatch between farmers’ needs and the scale, content, format, or accuracy of available information products and services worldwide (Vermeulen et al., 2012). There is an increasing share of private companies providing such services in various regions. Nevertheless, public intervention to promote the provision of high-quality user-friendly information for farmers both in the short-term and in the long-term is needed, especially where the coverage by private companies’ networks is insufficient.

Box 6 presents examples of current activities of OECD countries on risk management in relation to adaptation to climate change in agriculture.

Box 6. Current activities on risk management in relation to adaptation to climate change in agriculture

Fourteen countries[1] mentioned insurance in their NC, NAS or other key source as a mechanism to share risk in the agricultural sector in the context of climate change. Canada has implemented cost-sharing insurance for natural hazards: AgriInsurance helps to stabilize income and asset losses of agricultural producers. It is a scheme governed by the provinces with the contribution of federal resources. In addition, Canada's Federal/Provincial/Territorial AgriRecovery Framework provides producers with the financial capacity to deal with short-term environmental risks, such as disaster resulting from disease, drought and flooding. AgriRecovery assistance can provide producers with the financial capacity to return to production in the short-term so they have the opportunity to adjust to the longer-term environmental change. In Chile, the Agricultural Insurance Committee has created a National Agricultural Sector Emergency and Insurance System that operates through private insurance companies at the regional level with the objective of protecting farmers against economic losses from crop damage caused by extreme changes in climate (Chilean Government, 2013). In Mexico, the Ministry of Agriculture provide an insurance scheme – Agrosemex – that supports agricultural producers at a regional scale against climate extremes. This insurance is linked to information from weather and hydrological monitoring stations which activate insurance payments in case of extreme events. It operates only in those regions where enough quality information from monitoring stations exists. The Mexican government plans to enhance monitoring capacities and expand this insurance to other geographical areas in response to increasing climate change risks (Mexican Government, 2013d).

There are nine countries[1] that have developed other risk-reduction technologies or practices in agriculture. For example, Italy's *National Plan for Irrigation in Support of the Agricultural Sector* includes specific funds to alleviate the effects of climate extreme events such as droughts. In the Netherlands, the *Delta Programme* and *Room for the River* program provide flood protection and fresh water supplies to help to reduce risks of flooding and droughts in agricultural areas (Dutch Government, 2013). New Zealand has established *Rural Support Trusts* to mitigate the impact of adverse climate events on rural families and communities, most of this support takes the form of information on how to farm through the weather event.[3]

Weather forecasting, hydrological monitoring and early warning system technologies have been implemented with an explicit link to the agricultural sector in ten of the countries[4] analysed and are planned in four others.[5] Interestingly, the EU has included the implementation of an EU-wide early warning system in its priority work stream. Although a few European members of the OECD did not include this option in their adaptation strategies, 24 OECD countries are equipped with an early warning system.

Examples of various early warning programs include the US National Drought Mitigation Center (NDMC) and Turkish Monitoring System. The NDMC provides various drought monitoring and meteorological data sources. For example, it supplies weekly drought maps from the US Drought Monitor. Moreover, the Vegetation Drought Response Index (VegDRI) assesses vegetation drought stress using GIS and data from satellites, climatology, and biophysical processes (NDMC, 2014). In Turkey, monitoring stations have been set up in regions with prevalent droughts in order to make seasonal and inter-season projections for crops and support the decision-making process in agricultural areas (Turkish Government, 2013).

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1. Australia, Austria, Canada, Chile, Finland, France, India, Korea, Mexico, Poland, Portugal, Spain, Turkey and the United Sates.
2. Canada, Germany, Iceland, Italy, Netherlands, New Zealand, Poland, Portugal and Turkey.
3. http://www.rural-support.org.nz/.
4. Austria, Canada, Finland, France, Germany, Italy, Portugal, Turkey and United States.
5. India, Israel, Korea and Poland.

Infrastructure

Climate change will likely affect regional precipitation patterns and by extension river runoff and groundwater recharge in the long-run. Governments may aim for an effective water investment plan to improve the resilience of water infrastructure to progressive climate change and climate extremes. Such investments may go beyond the agricultural sector and involve inter-sectoral trade-offs in water use. Therefore, the public sector may co-ordinate some actions and oversee the involvement of various stakeholders in order to discuss future water needs. Large-scale water infrastructures may also involve large investments costs and an important role for public-private partnerships (PPPs) to enable investments that enhance the efficiency of water technologies (FAO, 2013, GOV/PGC(2011)19/FINAL).

Environmental impact assessments are important tools to scrutinise sustainability issues of such investments. Although incorporating climate change impacts and adaptation objectives in environmental impact assessments of new water infrastructure projects may be an option to enhance climate resilience of such infrastructure projects (Agrawala et al., 2012), there are large uncertainties associated with climate change impacts. Such uncertainties may result in inadequate investments if these are not properly considered (Agrawala et al., 2012). Governments may embrace a flexible approach towards long-term infrastructure investments so as to adjust to different sets of climate impact thresholds. Such approaches would be based on a systematic monitoring and evaluation of current situations and incorporating new information about climate change. This often involves a delay in taking any finite decision of a particular investment until, hopefully, more accurate decisions can be taken; however, when decisions needs to be taken quickly, the final decision should also be based on information gained from analysing extreme scenarios. For instance, when designing drainage pipes, one may implement larger diameters to hold more water than currently necessary with the view to potential future floods, as given by an extreme scenario (Box 2).

Farmers are the sole beneficiaries of on-farm irrigation equipment, therefore investments costs should be carried by private individuals. Irrigation systems contribute in various ways to increasing private benefits of farmers; e.g. irrigated fields provide higher yields. Farmers have the options to produce higher value crops and irrigation systems increase resistance to droughts. The public sector's responsibility is, however, to manage public resources such as surface and groundwater. The public sector may provide incentives for farmers to use efficient irrigation systems through adequate water pricing or incorporating water permits.

Box 7. Current activities on infrastructure in relation to adaptation to climate change in agriculture

Water related infrastructure associated with climate change adaptation in the agricultural sector is mentioned explicitly in 14 of the reviewed NASs.[1] This is particularly important in large emerging countries, such as China and India, whose plans include measures such as deploying high efficiency water-saving irrigation and rain-fed water efficiency farming techniques, and to intensify the construction of water resources projects to increase water supply for agriculture (Chinese Government, 2010; Indian Government, 2012).

Israel is implementing improved irrigation efficiency that includes pulse irrigation, recovered wastewater and drip irrigation (Israeli Government, 2010). In New Zealand, an *Irrigation Acceleration Fund* has been created where investment in irrigation infrastructure must be technically and commercially robust and demonstrate a high level of community support (New Zealand Government, 2013).

1. Brazil, Canada, Chile, China, France, India, Israel, Italy, Mexico, the Netherlands, New Zealand, Sweden, Turkey and the United States.

Funding mechanisms

The number of examples under this last type of adaptation measure is relatively small. While there can be a role for governments to overcome financial barriers, this depends crucially on market circumstances (e.g. actual interest rates) and the structure of the financial sector in the country. One reason for creating funding mechanisms may be to support champions or pilot projects that integrate new practices or technologies. Early adopters may initiate the learning process which the end result in higher absorption of the adaptation technologies.

It is often difficult to identify the 'adaptation' component from the proposed project to co-fund credits. With these credits, farmers, in general, tend to invest in measures that increase productivity and that are possibly risk-reducing. Whether or not such investments increase overall resilience is project-specific and should be analysed in each particular context. Thus, while in principle governments may be justified in becoming involved in credit support, for example through microcredits to farmers that do not have access to the commercial financial system, or "guaranties" to reduce private risks of large-scale investments, it is not easy to delineate where public support should end and at what level of financial risk should be left to the private sector.

Box 8. Current activities on funding mechanisms in relation to adaptation to climate change in agriculture

Only five countries[1] individually, have established specific funding mechanisms at the farm level to implement adaptation activities. However, at the EU level, there are many activities designed to support potential adaptation measures in the agricultural sector. About 20% of the total budget of European Commission is dedicated to climate change related actions. For instance, the European Commission has established the *European Agricultural Fund for Rural Development (EAFRD)* that contributes to the improvement of the competitiveness of agriculture, the environment and the countryside, including the quality of life and the management of the rural economy (European Commission, 2009). Additionally, the EU members recently agreed (December 2013) on a reform of the EU Common Agricultural Policy 2014-2020 that includes under Pillar 2 payments related to sustainability and the integration of climate change adaptation in the rural development programme (European Commission, 2013a). The payment amounts will be adjusted on the farmers' compliance with the new regulations. Overall, within the EU rural development policy, climate change mitigation and adaptation is a cross-cutting objective, about 30% of total EAFRD should be spent from climate related projects.[2] Climate-related expenditures are tracked on the annual basis.

In Belgium, the Agricultural Sector Investment Programme provides financial support to farmer's adaptation activities and to actions to address the consequences of climate extreme events (Belgian Government, 2010). Australia, as mentioned in the sub-section on institutional strategy, provides two grants, FarmReady and Reimbursement Grants, to promote adaptation at the farm level.

1. Australia, Belgium, India, Mexico and the Netherlands.
2. http://ec.europa.eu/clima/policies/budget/docs/pr_2013_11_19_en.pdf.

5. Existing methods to monitor and evaluate adaptation actions are not widely used

Approaches for monitoring and evaluation

The introduction of national adaptation plans and policies has created a growing need for adaptation indicators and frameworks for monitoring and evaluation. Such frameworks are not only required to document and to demonstrate the effectiveness of particular actions, but can be used to generate knowledge, and evidence to inform adaptation policy and programming (OECD, 2015c; Bours et al., 2013). Governments and supra-national institutions need such indicators to evaluate adaptation policies in order to direct future policy developments and justify funding decisions. The international community can use them to measure adaptation actions and to move discussion forward at international climate change negotiations, although there are still many political barriers in the UNFCCC negotiations on monitoring, reporting and evaluation (Ellis et al., 2013). General principles, criteria and indicators are, therefore, crucial for both incremental and systemic adaptation in the agricultural sector.

The OECD recommends the following criteria to help guide the design and selection of environmental indicators for devising monitoring and evaluation frameworks (OECD, 1993):

- An indicator should be relevant and useful, i.e. it must provide a representative picture of the environmental condition as well as a basis for international comparisons that are at once simple, easy to interpret and responsive to changes.
- It has to be analytically sound, which means it should be theoretically well-founded and should comply with widely agreed international standards.
- It has to be measurable. The data needed to construct an indicator should be either available or obtainable at a reasonable cost/benefit ratio.

Although interest in policies targeting adaptation is relatively recent, some existing studies provide guidance on how to design monitoring and evaluation (M&E) frameworks for adaptation. The 2008 Global Environmental Facility (GEF) proposed a first framework with a special focus on existing difficulties when assessing the impact of adaptation-related practices. The World Bank has co-developed a monitoring and evaluation framework for Climate Investment Funds which suit as a basis for future monitoring and evaluation of the impact, outcomes and outputs of the Pilot Program for Climate Resilience funded activities.[15] The *Deutche Gesellschaft für Internationale Zusammenarbeit* (GIZ) and the World Resources Institute (WRI) performed a similar exercise in 2011, leading to the development of a roadmap for adaptation practitioners on how to implement project-level monitoring and evaluation systems (GIZ and WRI, 2011). OECD (2015c) reviews these efforts and documents that these frameworks have started to be applied recently to concrete cases.

Even if the monitoring and evaluation frameworks are progressively embedded into national and sub-national planning processes, adaptation policies are often developed with limited systematic information on current implementation or effectiveness (IPCC 2014b). Indeed, although many countries monitor the impact of climate change (e.g. the United States via its Global Change Research Program's Global Information System[16]), most countries are at an early stage of making the NASs operational and are currently establishing monitoring and evaluation frameworks (Bours et al., 2013; Casado-Asensio and Steurer, 2013; European Commission, 2013b).

15. https://www.climateinvestmentfunds.org/cif/node/12507.

16. http://www.globalchange.gov/what-we-do/assessment/indicators.

There are some notable exceptions (OECD, 2015c): the UK's Adaptation Sub-Committee[17] provides regular advice to the government on how the United Kingdom is preparing for the major risks and opportunities deriving from climate change via bi-annual progress reports. The primary purpose of these reports is to test the proposed monitoring and evaluation framework. The first formal evaluation will be published in 2015. The French monitoring and evaluation scheme is also operational. Other countries either propose specific indicators for which the collection of data has not yet started or are still developing a more detailed framework. For example, Germany developed a list of 103 indicators – that are currently under review – to evaluate how its vulnerability to climate change is evolving in 15 action fields (including agriculture). This exercise is based on existing governmental and non-governmental data sources, but not all indicators are computable yet. On the other hand, the Australian 2013 Climate Adaptation Outlook does not yet provide sector specific guidelines or indicators. Instead, it proposes an initial set of 12 general indicators that are currently under consultation (Australian Government, 2013). These indicators, however, can be considered as a first step towards setting of a more detailed monitoring and evaluation framework. A selection of the indicators proposed by Germany for the agricultural sector and the 12 indicators proposed by Australia are presented in Appendix 1.

Because adaptation is *context specific* it is difficult to provide a comprehensive and universal list of indicators (Dinshaw et al., 2015). The recognition of a practice as an adaptation activity is contingent on values, objectives, and risk perceptions (i.e. vulnerability, which in turns varies over time and regions) and the best practices of monitoring and evaluation to implement vary substantially with respect to geographical areas and social groups (OECD, 2013b). The effectiveness of an adaptation action, therefore, depends on the specific context that needs to be taken into consideration. In general, criteria for success and consequently the optimal mix of policy instruments are responsive to a wide variety of economic, social, environmental, geographic and political conditions (e.g. landscape types, sector issues, temporal variation) and one of them can rarely be referred to as the more appropriate or efficient (Dessai and Hulme, 2007). What is potentially useful for a specific group of actors today may not be in the future. Even more likely, it may not be equally valuable for other stakeholders (Debels et al., 2009). The subjectivity that stems from the different values placed on needs and outcomes by different actors results in a lack of consensus on what metrics have to be used (Ford et al., 2013).

A second complication stems from the difficulty in separating the effects of policies specifically aimed at creating adapting capacity from possible spill-overs derived from broader sectoral policies. Isolating the "adaptation component" from other factors can be very difficult. This problem is often referred to as the "*attribution problem*" and becomes more relevant if the purpose of the evaluation is to demonstrate that a specific investment has been worthwhile. If instead the indicators are needed to track trends in the overall status of the systems, attribution becomes less important (Harley et al., 2008).

Third, the *lack of time series of environmental data* can create practical challenges. In addition, because climate change is a relatively new policy area, a further key complication lies in the lack of data on operative practices in place from which to draw upon. Moreover, the effects of many adaptation activities may not emerge for years, some long-term commitments from national authorities to collect and store data is therefore necessary.

17. The Adaptation Sub-Committee of the Committee on Climate Change was established in 2008 to provide independent advice to the UK Government on the impacts of climate change on the UK and assess Government progress in implementing the National Adaptation Programme.

Table 4. Indicators used to assess risk in water scarcity

Type	Indicator of	Indicator	Data availability
Risk	Supply	Security of Supply Index (SOSI)	2002 – 2012
	Overall demand	Freshwater abstraction (non-tidal) by sector	1995 – 2009
	Household demand	Average per capita consumption – all households	2000 – 2011
	Household demand	Average per capita consumption – metered households	2000 – 2011
	Household demand	Average per capita consumption – unmetered households	2000 – 2011
	Agricultural demand	Average volume of water applied for irrigation per hectare by crop type	2005 & 2011
Action	Reducing demand	% of properties with water meters (England and Wales)	2000 – 2012
	Increasing supply	Total leakage (England and Wales)	1992 – 2011
Impact	Water availability	% of reservoir capacity filled (England and Wales)	1988 – 2009
	Water availability	Catchments where water is available for abstraction	2009 – 2011
	Water availability	Compliance with environmental flow indicators (England and Wales)	2009 – 2011

Table 5. Indicators used to assess trends in risk and action in agriculture

Type	Indicator of	Indicator	Data availability
Risk	Agriculture – water availability	Total abstraction for agriculture (surface water and groundwater)	1974 – 2010
		Total water demand for irrigation	1990 – 2010
		Area of crops in climatically suitable locations	2000 & 2010
		Number of catchments with water available for abstraction	2011
Action		Total on-farm reservoir storage capacity	2007-2013; 2005-2010
Risk	Agriculture – soil productivity	Total soil carbon concentration	1978 – 2003; 1978 – 2007
		Total soil carbon concentration in arable soils	1978 – 2007; 1978 – 2003
		Uptake of soil conservation measures on wheat and barley fields (only)	1985 – 2010
Action		Total factor productivity of UK agriculture	1973 – 2010
Risk	Agriculture – technological capacity	R&D spend on agriculture	1987 – 2009
Action		Number of farmers reporting that they are adapting to climate change	2011

Source: Adapted from Adaptation Sub-Committee on Climate Change (2012, 2013).

Fourth, due to the uncertainty in future impact of climate change and the intangibility of autonomous adaptation actions, it is difficult to determine a *benchmark* situation. The lack of a real counterfactual (what would have happened if the adaptation practice had not been put in place) makes the evaluation of adaptation policies more difficult.

A set of three complementary approaches to these challenges – partially following Ford et al. (2013) – is suggested and analysed as a way forward to create a consistent set of indicators: 1) a national outcome-based approach, 2) a preparedness approach and 3) a project-based approach.

National outcome approach

This approach requires defining a specific outcome, either a physical measure or a target that is relevant at the national level, to be monitored throughout time. Because of adaptation's intangible and comprehensive nature, different biophysical indicators should be used as proxies for adaptation capacity depending on the context under consideration. For example, crop area in climatically suitable locations or the number of farmers undertaking training courses. The aim is to measure the changes in exposure to climate change and the trend in taking up adaptation measures to reduce vulnerability and impacts.

The UK's Adaptation Sub-Committee has followed this path by providing a list of indicators to evaluate the major risks identified by the 2012 Climate Change Risk Assessment. A selection of indicators (from the UK list) suitable for the agricultural sector is presented in Table 4 and 5.

Similarly, in the first National Adaptation Plan published in France in 2011, 20 key fields for action (including agriculture) are identified together with 230 measures for monitoring and evaluating progress. The majority of these can be categorised under the concept of National Outcome Approach. The French National Adaptation Plan covers a five-year period from 2011 to 2015 and its monitoring is already operational. A mid-term evaluation has shown that the overall implementation is on track; a final collection of data will be used to produce an overall assessment of this initial plan expected by the end of 2015. A selection of the indicators proposed by France for the monitoring and evaluation of adaptation activities in the agricultural sector is presented in Table 6.

Table 6. Selection of proposed indicators of the French climate change action plan

Action field: Agriculture	
➢ Number of studies available on the database relating to agricultural adaptation to climate change ➢ Number of contracts of agreed objectives signed during the period 2011-2015 which include a climate change adaptation element ➢ Number of studies/publications relating to adaptation of agriculture to climate change produced within the framework of contracts of agreed objectives with a 2015 deadline. ➢ Number of publications on this specific topic aimed at farmers and technical consultants ➢ % of funding from Programme 776 allocated to climate change adaptation (applied research activity and innovation in agriculture) ➢ Number of farms benefitting and utilised agricultural areas covered by Agri-Environmental Measures	➢ Changes in the absorption of agricultural land ➢ Number of animal health epidemiology bulletins addressing the link between disease in animals and climate change. ➢ Number of plant health bulletins relating to the link between plant disease and climate change ➢ Number of regions which have initiated a "Measure 222" and the number of hectares planted ➢ Number of farms benefitting and utilised agricultural areas covered by Biodiversity Agri-Environmental Measures ➢ Proportion of the total surface area insured by crop type

Source: French Government (2011).

The main challenge of many countries in implementing this approach is the limited amount of available relevant data, and countries have shown different levels of commitment to date in gathering indicators, the notable exceptions being the UK and France. The World Resources Institute (WRI) has attempted to address this issue by identifying available indices and datasets and cataloguing existing indicators of environmental sustainability in agriculture in developing countries. Most indicators proposed by the WRI fall under the suggested definition of national-based outcome approach. The exercise performed by the WRI showed that many of the identified indicators are only tangentially related to environmental sustainability and that no indicator impeccably reflects the current state of the world. The authors concluded that greater co-operation among partners with different types of expertise (agriculture experts, statisticians and data gatherers) is needed to increase the amount of sound information available. This must go beyond "repackaging" existing data into a sufficiently robust index of set of indicators (Reytar et al., 2014).

Preparedness measures approach

This approach is based on the assumption that effective and efficient actions by local and national institutions are crucial to determine a country's ability to respond to growing climate-related risks (Adger et al., 2007; Agrawal and Perrin, 2008, Dixit et al., 2011). This approach investigates whether such institutions are prepared for climate change challenges by assessing its preparations for the major risks (and opportunities) due to climate change. Ford et al. (2013) state that this encompasses "the existence of governance structures and processes that determine the presumed ability of a country to build support for action and effectively develop, implement and monitor adaptation interventions". This approach can be used either to assess the state of national institutional capacity for climate change adaptation at a given time or, via a periodical assessment, highlight the direction of change. This approach is often used in developing countries.

The concept of preparedness should not be confused with that of adaptation capacity. Preparedness means actions undertaken to "lay the ground for adaptation to take place" (Ford et al., 2013). For example, such actions may include the production of a NAP, the establishment of a specific national committee on climate change adaptation, the existence of policies that promote soil conservation practices, or the existence of policies promoting nutrient management practices. Adaptation is the actual ability of a system to adjust to climate change, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007). Preparedness might not directly translate into successful adaptation and into an increase of effective adaptation capacity; it can, however, serve as a proxy of national efforts towards increasing the resilience of farmers and of a nation.

A drawback of this approach lies in the difficulty of making a reasonable comparison between countries based on such indicators. Each country develops a unique process for adaptation that best suits its needs and circumstances. For instance, one country may opt for a co-ordinated approach and one centralised institution may be successful in mainstreaming adaptation into the everyday life of farmers. Another country may face an explosive number of institutions to govern adaptive actions which in the end may fall into an inefficiency trap even though it may score higher on the "preparedness index". A possible solution resides in the creation of an overall index of preparedness via these indicators to be used to compare the extent to which countries are working to reduce barriers and enable adaptation (Ford et al., 2013).

Just as for the previous approach, implementing the "preparedness" approach requires further research and data gathering. A list of potential indicators and sources of information for evaluating preparedness for adaptation is presented in Table 7.

Table 7. Potential indicators and sources of information to evaluate preparedness for adaptation

Adaptation architecture	Indicator	Sources of information
Political leadership	Statements of importance and need for adaptation by national leaders; inclusion of adaptation as a policy priority	Speeches at Conference of the Parties meetings; attendance at Conference of the Parties meetings; leadership identified in UNFCCC National Communications or National Adaptation Programmes of Action
Institutional organisation	Lead department / agency identified OR interagency group established; presence of adaptation planning document	Lead organisation specified for UNFCCC National Communications or National Adaptation Programmes of Action; adaptation planning documents
Stakeholder involvement	Stakeholders involved in national climate change assessments and policy consultation; co-authorship on publications	National assessments; stakeholders consultation noted in UNFCCC National Communications; NAPA; establishment of special tasks forces to communicate the (changing) needs of stakeholders.[a]
Climate change information	National climate change assessments produced; existence of NAPA; completion of UNFCCC National Communications; nation-specific peer-reviewed literature	UNFCCC National Communications; peer-reviewed and grey literature review; research needs identification in articles / reports; NAPA
Appropriate use of decision making techniques	Use of decision-making tools (e.g. cost benefit analysis, matrices etc.); use of climate change adaptation frameworks	UNFCCC National Communications; national assessments; NAPA
Consideration of adaptation barriers	Policy reviews to identify barriers	UNFCCC National Communications; national assessments; NAPA
Funding	Identified funds for adaptation; specific program for adaptation	UNFCCC National Communications; national assessments; climate change programs / policies / announcements; peer- reviewed literature
Adaptation research	Research programs for adaptation developed	UNFCCC National Communications; national assessments; climate change programs / policies / announcements; peer- reviewed literature

a) An example of such an initiative is the US Executive Order (1 November 2013) which establishes a task force of state, local and tribal leaders to advise the Administration on the changing needs of communities to adapt to climate change.

Source: Adapted from Ford et al. (2013).

Individual project-based approach

While the first two approaches dealt with national monitoring and evaluation indicators and are particularly suited for national assessments of climate change adaptation capacity, the project-based approach builds on meticulous evaluation of specific adaptation interventions. The central idea resides in the recognition of the evaluation and monitoring of pilot projects and local adaptation programs as key tools to learn important lessons and build knowledge. The aim is to ultimately extract general best practices and agree on what could be defined as successful adaptation in relation to specific risks in the agricultural sector. The first step of this "micro-approach" consists in identifying those projects that are explicitly aimed at fostering adaptation capacity and action in agriculture. A set of specific outcome indicators for tracking progress is then identified. These indicators are likely to have a micro-coverage in terms of geographical exposure (e.g. few communities) and life spans (few years), and to be specific to the programme in question. The data needed to implement this approach are project data and information (often gathered via project-specific surveys).

Lamhauge et al. (2012) analysed 106 documents of adaptation-related projects carried out by six of the major bilateral development agencies with the aim to improve the understanding of monitoring and evaluation of adaptation-related activities in developing countries. The research concludes that monitoring and evaluation frameworks should combine qualitative, quantitative and binary indicators. It may not be sufficient for measuring adaptation capacity and programme impact to look at only one category of indicators. This is also true for monitoring and evaluation frameworks in the agricultural sector.

Norway has implemented an approach where it sources information from project and programme evaluations focusing on how the lessons learned may apply to the regional and national levels. A formal monitoring and evaluation system for adaptation has not been developed. The process is based on a “learning-by-doing” system that develops from surveys with municipalities, to pilot projects and specific adaptation-related local programmes (GIZ, 2013). Data collection is undertaken on a regular basis and the lessons learned from these practices are used to develop a national vulnerability and adaptation assessment (Government of Norway, 2010; Government of Norway, 2011; GIZ 2013).

This approach is certainly not exempt from criticisms and possible problems. The evaluation of a specific project may be subject to hindrances. Specifically, the evaluators need to construct a control group for the comparative evaluations of a given project. The ideal benchmark is the fictitious counterfactual scenario, which describes what would have happened if the specific project had not been put in place. However, there is no such perfect control group due to the geographical, economic and social specificities of each area. Empirical economists working on evaluations of such projects have found ways to deal, under certain hypotheses, with the “counterfactual problem”. Moving from the ideal evaluation via a randomised experiment (rarely able to be performed properly and usually costly), to evaluation techniques such as matching, regression discontinuity, instrumental variables and selection of observables relies on strong assumptions. The literature has come up with solutions that need to be carefully considered before applying them.

Assessing the monitoring and evaluation of adaptation actions

The previous sections suggest that each actions or goals require a suitable evaluation method Monitoring and evaluation frameworks for adaptation should choose between, and combine where possible, the three different approaches discussed above by complementing adaptation-specific projects evaluations with general assessments of trends in few specific outcomes and indicators of preparedness. A combination of country-level and project level monitoring helps to understand whether the overall level of action at the time of assessment is adequate. However, the combination of project and national-level evaluations is in practice extremely difficult.

Table 8. Examples of indicators to monitor and evaluate adaptation activities in the agricultural sector

Adaptation activity		Indicator	Approach	Availa-bility	Source of the indicator
Research and Develop-ment	Risk and vulnerability assessment	Existence of national assessment of impacts and vulnerability in the agricultural sector.	Prepared-ness measures approach	✓	UNFCCC National Communications; national assessments
		Financial support to research centres that work on the agricultural sector and climate change.	Outcome-based approach	✓	UNFCCC National Communications; national assessments
	Identification of adaptation options	Public agricultural R&D expenditure on climate change issues as per cent of agricultural GDP *or* Public expenditure on agricultural R&D.	Outcome-based approach	✓	ASTI database as published in Beintema, Stads, Fuglie, and Heisey. 2012 (www.asti.cgiar.org/pdf/ASTI_global_assessment.pdf)
	R&D of technology	PCT patent applications for agricultural-related innovations.	Outcome-based approach	✓	OECD Science, Technology and Industry Outlook, OECD Database
Capacity building	Knowledge and information awareness	Share of agricultural students in the public sector, number and share of farmers undertaking training courses.	Outcome-based approach	✓	Agricultural Innovation System, a framework for analysing the role of the Government. OECD publication
		Number of training modules/materials published and disseminated, number of hits on web-based platform, number of stakeholders participating in knowledge sharing/training.	Project-based approach	N/A	*National Questionnaire; national and sub-national assessments*
		Number of agricultural schools, colleges and universities	Outcome-based approach	N/A	*National Questionnaire; national and sub-national assessments*
		Professional research staff in Agricultural Research: Number of research staff by degree level	Outcome-based approach	✓	ASTI database
	Mainstream-ing of best practices	Public funding of advisory services, training and extensions initiatives aimed at supporting adaptation in agriculture	Outcome-based approach	✓	OECD PSE/CSE database, 2012
		Existence of training programs for farmers	Prepared-ness measures approach	N/A	*National Questionnaire; national and sub-national assessments*

Table 8. Examples of indicators to monitor and evaluate adaptation activities in the agricultural sector (*cont.*)

Risk manage-ment	Insurance	Number and type of DRR instruments, e.g. insurance instruments promoted	Outcome-based approach	N/A	*National Questionnaire; national and sub-national assessments*
	Other disaster risk reduction technologies or practices	Number of (people benefitting from) water, livestock and natural risk management projects *or* total capacity of crop storage facilities	Outcome-based approach	N/A	*National Questionnaire; national and sub-national assessments*
	Weather forecasting, hydrological monitoring and early warning systems	Number of early warning systems in place	Outcome-based approach	N/A	*National Questionnaire; national and sub-national assessments*
Infra-structure	Water	Total abstraction for agriculture (surface water and groundwater) or agricultural water productivity *or* water stress ratio	Outcome-based approach	✓	OECD Agri-environmental Indicators; OECD *Environmental Data Compendium (2013)*
Funding mecha-nisms	Funding mechanisms for adaptation activities at the farm level	Existence of a funding mechanisms for adaptation activities at the farm level	Prepared-ness measures approach	N/A	*Financial sector, EU*

Any category of indicators, if taken separately, may not be sufficient to draw clear conclusions. For example, a preparedness indicator such as the identification of funds for adaptation does not say anything on their actual use. Even if it were possible to know how much of the designated fund was actually used, the exact extent to which it enhanced adaptive capacity would remain unknown. The same would happen if only a project-based approach were used. Although pilot-projects can be very helpful to shed light on what successful adaptation is in a specific area or sector, "summing up" all the projects taking place in a given country does not always say much on the country's overall preparedness to face climate change and adjust to it. Additionally, such projects in reality tend to be regionally confined and few in number.

Table 8 provides indicators classified by the five themes presented in Section 3 and the three types of approaches presented in Section 4. The proposed set of indicators does not intend to be exhaustive nor complete or applicable to all circumstances. The purpose of this framework is to propose a first step in creating a list of indicators at the individual country level to monitor and evaluate adaptation actions in agriculture.

6. Final remarks: Possible ways forward

The agricultural sector is likely to be substantially affected by climate change. To reduce risks associated with climate change and maintain profitability, farmers will need to adapt to changing socio-economic and climatic conditions. Although autonomous on-farm adaptation will be crucial, not all climate impacts can be easily addressed by farmers. In some cases, long-term planning and policy intervention may be required and public policies may be needed to support and to facilitate the transition towards more resilient agricultural systems. This may help farmers overcome barriers to adaptation that they currently face. Furthermore, for some types of adaptation actions, such as the provision of information on changing regional climatic conditions, the government may need to play a more central role.

Besides specific ways through which governments can intervene to promote adaptation in the agricultural sector, it is vital that climate change gets mainstreamed in general policy making, not least in agricultural and development policies. Unless these policies are "climate-proofed", they may inadvertently hamper adaptation and prevent farmers from taking decisions that improve their resilience to future climatic circumstances. For example, agricultural policies that directly intervene in management practices and lock farmers into current practices that may have historically been best practice but are not well adapted to changing climate, require careful re-evaluation.

Dealing with risks is an increasingly important aspect in agriculture. Governments may assist farmers and other private agents in providing public risk management tools, such as early warning systems. However, to support long-term on-farm adaptation, the focus should be on helping farmers assess and manage their risks rather than on removing or reducing risks.

Finally, more research is needed to assess the economic consequences of major risks from climate change at the regional level to gain a better understanding on the need for adaptation at the local level. Additionally, a choice of well-defined indicators may help to measure the progress and success of specific adaptation measures. These caveats notwithstanding, the assessment provided in review paper, and the resulting observations, can be used as input to help governments to design, implement and adjust their adaptation strategies.

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Appendix 1

Table 1.1. Selection of the proposed indicators for the German climate change action plan

Action Field: Agriculture	Action Field: Soil
➢ Adaptation of management rhythms	➢ Soil water storage in agricultural soils
➢ Cultivation and seed multiplication of warmth-loving crops	➢ Size of grasslands
➢ Varieties of grain maize categorised in maturity groups	➢ Humus reserves of agricultural soils
➢ Cultivation of thermophilic red-wine varieties	➢ Organic soils
➢ Application of pesticides	
➢ Agricultural irrigation	
➢ Shifts in agrophenological states	
➢ Interannual changes in yield	
➢ Quality of yield products	
➢ Insured hail-storm damage in agriculture	
➢ Pest infestation	

Source: Adapted from OECD (2015c), Schönthaler, K., S. Andrian-Werburg and D. Nickel (2011), Entwicklung eines Indikatorensystems für die Deutsche Anpassungsstrategie and den Klimawandel (DAS), Dessau-Roßlau, UBA (updated in January 2013).

Table 1.2. The 12 proposed indicators for the Australian climate change action plan

National indicators	Indicators for the coastal zone
➢ Number of major climate risks satisfying all criteria for good risk allocation	➢ Capacity of planning frameworks to support effective management of climate risks in the costal zone
➢ Effect of climate hazards on land prices	➢ Number of local governments considering climate change risks in land use planning
➢ Percentage of corporations disclosing climate risk	
➢ Percentage of the public who accept that some things might need to be done differently in a changing climate	
➢ Percentage of organisations considering climate change in long-term planning	
➢ Proportion of tertiary courses in engineering, architecture, planning, natural resources management and other relevant disciplines where climate change is integrated into training	
➢ Change in the replacement value of built assets in bushfire flood or costal erosion and inundation zones	
➢ Damages from natural disasters	
➢ Sensitivity of the value of agricultural production to climate extremes	
➢ Extent and condition of key climate-sensitive ecosystems	

Source: Australian Government (2013).