Chapter 4
Adaptation

The scope of adaptation

The chapters above have reviewed estimates of the major impacts of climate change on agriculture and related resources at the global scale. Faced with these threats and challenges, there are two major responses for policy intervention in agriculture. The first strategy is to reduce the rate and magnitude of climate change itself through reducing the human causes of climate change *i.e.* mitigation of greenhouse gases, which is discussed in detail in Chapter 5. The second (and complementary) option[1] is to promote adaptation to climate change to minimise the impacts and take advantage of new opportunities. Adaptation in the climate change context may also involve adjusting to changes resulting from climate impacts elsewhere in the world (such as the possible effects on markets, changing comparative advantage, increased migration) or changes resulting from mitigation actions (such as increased biofuel production and changes in land-use). There is also a need for a multi-sectoral planning approach, integrating the different aspects of agricultural production, particularly soil and water management.

Adaptation to climate change is typically characterised as an adjustment in ecological, social or economic systems in response to observed or expected changes in climatic stimuli and their effects and impacts, in order to alleviate adverse impacts of change or take advantage of new opportunities. Adaptation can therefore involve both building adaptive capacity – thereby increasing the ability of individuals, groups, or organisations to adapt to changes – and implementing adaptation decisions, *i.e.* transforming that capacity into action. Both dimensions of adaptation can be implemented in preparation for, or in response to, impacts generated

[1] While in some senses mitigation and adaptation may be viewed as substitutes, in practice they are complementary actions and both will be necessary to address the challenge of climate change. Adaptation will be necessary to adapt to changes resulting from historical emissions and mitigation will be necessary to avoid the worse impacts of climate change.

by a changing climate. Hence adaptation is a continuous stream of activities, actions, decisions and attitudes that informs decisions about all aspects of life, and that reflects existing social norms and processes. There are many classifications of adaptation options (summarised in Smit *et al.*, 2000) based on their purpose, mode of implementation, or on the institutional form they take.

Reilly and Schimmelpfenning (2000) point out that some adaptation occurs without explicit recognition of changing risk, while other adaptations incorporate specific climate information into decisions. Since unintentional adaptation has the capacity to reduce the effectiveness of purposeful adaptation, the integration of adaptation actions and policies across sectors remains a key challenge to achieve effective adaptation in practice.

The major types of adaptation are:

- ***Reducing the sensitivity*** of the affected system, which can be achieved, for example, by investing in flood defences or increased reservoir storage capacity; planting hardier crops that can withstand more climate variability; or ensuring that infrastructure in flood-prone areas is constructed to allow flooding.
- ***Altering the exposure*** of a system to the effects of climate change, which can be achieved, for example, by investing in hazard preparedness and early warnings, such as seasonal forecasts and other anticipatory actions.
- ***Increasing the resilience*** of social and ecological systems, which can be achieved through generic actions which aim to conserve resources, but also include specific measures to enable specific populations to recover from loss (Tompkins and Adger, 2004).

Adaptation options in agriculture involve different agents and scales and include actions by producers, input and food industries and government agencies, with individuals acting for private benefit, and public agencies seeking to maximise public good aspects of adaptation. In the United Kingdom, for example, public policy investments have been made in education for the wider society on the potential impacts of climate change and society's role in creating and managing those impacts. These investments have been made through agencies such as the UK Climate Impacts Programme (UKCIP, 2003). Ultimately, the purpose of such investment is to alter behaviour and increase society’s ability to cope with future impacts. Such investment is expected to enable individuals to start to respond to climate change, to promote uptake of new technology, to enable them to internalise the costs of responding to climate impacts, and to reduce future investments in disaster management.

Table 4.1 classifies the responses as accruing in either the public or private domain. Some elements of investment in climate change response are "public" and include conservation of nationally or internationally important habitats. Others are effectively private. If private firms in the water industry invest in knowledge of climate change risks, the costs and the benefits of this response are private. Climate change planning by governments at present tends to concentrate on providing public goods such as scenario information, risk assessments in the public domain, and public awareness campaigns (UKCIP, 2003; Hulme *et al.*, 2002). Hence, many response programmes at present avoid providing subsidies to private adaptation decisions. But the public and private elements of responding to climate change are not fixed: they are shaped by institutional and regulatory features in each sector of the economy. Further, they can change from public, to private and back again over time. In the UK the water supply utilities invest substantially in projections of water demand and supply under climate change for the benefit of their shareholders, while the public regulatory agencies seek to fulfil the same objectives of sustainability for public good aspects of water availability (documented by Arnell and Delaney, 2006).

The major actions for adaptation in agriculture are summarised in Table 4.2, distinguishing between technological development (which can be induced by both public and private investment); technological adoption; government programmes and insurance; and farm-level financial management. This classification was developed by examining options in arable farming regions in Canada where farmers have a high awareness of potential impacts from climate change (Smit and Skinner, 2002). Each of the categories and types of adaptation are presently undertaken to some extent and most are broadly applicable throughout OECD countries. A comprehensive list of specific adaptation actions in agriculture is provided in AEA (2007), produced for the EU Commission.

In less-developed or poorer countries adaptation strategies are more about maintaining livelihoods and coping with climate variability. Agrawal (2008) discusses five basic coping strategies in the context of environmental risks to livelihoods: mobility, storage, diversification, communal pooling and exchange. *Mobility* pools risks across space, and is particularly useful if clear information about the spatial and temporal changes in climate is available. *Storage* pools risks across time, and, assuming well constructed infrastructure and low perishability, represents an effective measure at a given point in time. *Diversification* pools risks across assets and resources of households and farms. This can occur in relation to productive and non-productive assets and employment strategies. Diversification often involves a trade-off between returns and security. *Communal pooling* pools risks across households, and is characterised by joint action by members of a group with the objective of pooling both risks and resources. *Exchange* may be the most versatile option, and is of course the basis for most of our market and trading systems today. An example of market-based adaptation to climate change is weather-related insurance schemes designed for agricultural or pastoralist populations. Aspects of some of these more basic coping strategies may be utilised in developed-country agricultural systems as well.

Table 4.1. Examples of adaptation options by timing and by responsibility

		Timing of response	
		Anticipatory *(ex ante)*	**Reactive *(ex post)***
Responsibility for response	**Private**	Private insurance markets Private research and development and investments	Adjustments in insurance markets Identification of least-cost adaptation options
	Public	Public infrastructure provision (*e.g.* irrigation infrastructure) Risk communication to agricultural sector and public Publicly available research and development	Post-disaster recovery Compensation for impacts Insurance underwriting

Source: Adapted from Tompkins and Adger (2005); Smit *et al.* (2001).

Table 4.2. Types and examples of adaptation options at different levels in agriculture

Adaptation	Examples	Implementation
Technological development	Crop development	Public and private investment in new crop varieties and hybrids to increase tolerance to water and heat stress or other relevant adverse conditions
	Weather and climate information systems	Public and private investments in monthly and seasonal forecasting, and early warning systems
	Resource management innovations	Public and private investment in water management innovations to address moisture deficiencies and risk of drought and changing seasonality of precipitation
Technological adoption	Farm production innovations	Diversification of crop types and varieties including crop substitution. Diversifying livestock types and breeds and changing seasonality of feedlot practices
	Land-use changes	Changing location of crop and livestock production and fallow rotations to address economic risks associated with climate change
	Irrigation	Implement on-farm irrigation practices to avoid recurrent drought risk
	Timing of operations	Changing timing of operations to address changing duration of growing seasons and associated changes in temperature and moisture

(Continued on next page)

Table 4.2. (continued)

Adaptation	Example	Implementation
Government programmes and insurance	Agricultural support programmes	Modification of crop insurance programmes to influence farm-level risk management strategies. Changes in *ad hoc* compensation and assistance for extreme events and disasters (*e.g.* animal diseases). Modify support and incentive programmes to influence farm-management practices.
	Private insurance	Encouragement of markets for private insurance of production, infrastructure and income
	Complementary resource management programmes	Development of public policies for water resource conservation and complementary conservation objectives.
Farm financial management	Private crop insurance	Uptake of private (or publicly encouraged) crop insurance or income insurance
	Crop shares and futures	
	Income stabilisation and diversification	Diversification of household income to include less weather-sensitive options.

Source: Adapted from Smit and Skinner (2002).

Adaptation in agriculture observed

Not all adaptation actions require conscious knowledge of climate change risks (see Reilly and Schimmelpfenning, 2000). In the UK, Tompkins *et al.* (2005) have described over 340 adaptations to climate currently underway. Their inventory includes examples of adaptation to climate change in the public and private sectors, as well as community groups, non-governmental organisations (NGOs), other associations and networks (including, for example, trade associations) and individuals. In the United Kingdom, agriculture, in common with other sectors, is at an early stage in adaptation although the examples collected reveal some general patterns. Few of the observed and classified adaptation involve resource use change in the present day. Most examples reflect anticipatory planning for climate change. Planning for climate change impacts is implemented through scenario development and risk assessment. In the United Kingdom, the UK Climate Impacts Programme provides scenarios of change that are used by regional planning authorities and trade associations, including, for example, the Country Landowners' Association and National Farmers' Union, in setting priorities for action.

UK agriculture faces the challenge of climate change in coming decades. The impacts of higher mean temperature, increased precipitation and storms, and a rise in sea level all have serious implications for the United Kingdom's agricultural sector (Defra, 2005). It is widely anticipated that the range of arable crops currently grown will move northwards (area of forage maize has already been highlighted as an indicator of climate change): the area grown has risen from approximately 20 000 ha in 1985 to over 100 000 ha in 1995, only partly due to improved plant varieties (Subak *et al.,* 2000). Types of adaptation in the farming sector include switching to alternative crops, shifting crops from areas that are vulnerable to drought, or investing in equipment that helps to reduce the severity of the impacts of climate change.

It is anticipated that agricultural businesses will need to adapt to the effect of climate change to ensure economic viability. For example, the costs of the 1995 summer drought to the agriculture industry have been estimated at a loss of GBP 457 million due to reduced income and capital costs (Subak *et al.*, 2000). Evidence suggests that those farmers who implemented adaptation and management changes at that time secured advantages over others (Defra, 2005).

There are, however, also some policy changes and laws being implemented which will affect adaptation possibilities in the future. The majority of the adaptations in the UK identified by Tompkins *et al.* (2005) are occurring in the public sector. As yet, there is little evidence of behavioural change in either the public or private sector. Most of the examples are occurring at the national scale, in the devolved administrations and at the regional scale, with few examples at local levels. There appear to be very few, if any, adaptations that have been undertaken solely in response to expected climate change. This is in clear contrast to reported mitigation actions such as investment in biofuels as a contribution to renewable energy.

This result is common throughout the world. In Canada, most individual farmers respond primarily to extreme events such as prolonged drought and unseasonal or excessive rainfall. In a survey in Ontario, 80% of respondent farmers judged extreme events to be the most significant impact to which adaptation was required, rather than changing growing season length or heat stress (Smit *et al.*, 1996). However, in some parts of Canada, adaptation programmes are quite advanced, such as in Alberta, where the provincial government has established the Alberta Climate Change Adaptation Team, which initiated province-wide and multi-sectoral assessments of vulnerability and adaptation strategies. In many cases, significant adaptation could be achieved and supported with adjustments to existing programmes and policy mechanisms (Lemmen *et al.*, 2008).

There is some evidence from the United Kingdom to suggest that awareness of climate change and its impacts are generally high among agencies with responsibility for agriculture and farmers (Tompkins *et al.*, 2005). Yet there is little evidence of individually planned adaptation to the impacts of climate change. In this sector there are a number of research programmes and emerging government guidelines that aim to address the long-term impacts of climate change. These actions are largely helping to build adaptive capacity, *i.e.* building up the knowledge about the likely impacts of climate change and appropriate responses needed. Regulations and policies to promote land-use practices may, however, have adaptation co-benefits or act as entry points for projects and programmes to engage in adaptation measures. These include agri-environment schemes. It is, however, too early to determine whether these actions will be effective or considered successful in the face of evolving climate risks.

The evidence on present-day adaptations in the UK agricultural sector has highlighted a lack of initial adaptation response despite relatively high awareness. It is much easier to find unplanned adaptations than planned adaptations and most planned adaptations fall into the category "building adaptive capacity" rather than "implementing adaptation". This finding may underestimate the actual extent of implementation. Some of these schemes and regulations (such as the Countryside Stewardship Scheme) are already affecting individual land-owners' actions, albeit individuals may be responding to the scheme requirements or regulation rather than considering climate change *per se.* Regional examples of adaptation include efforts by the East of England Regional Assembly, which stresses in its East of England Climate Change Impacts Study (2004) the need to adapt to water resource pressures. The Environmental Stewardship Scheme and the Water Act could, for example, create business opportunities for irrigators to trade water, invest in water saving and so on. Trickle irrigation, which promises lower water use, has expanded to cover 5% of the irrigated area in England

and Wales (Knox and Weatherhead, 2005), and reports by farmers in 2001 indicate that over 50% of the irrigated area in England is now scheduled by methods that account for seasonal water availability (Weatherhead and Danert, 2002). Building farmer awareness of the possible impacts of climate change, communicating their adaptation options and their benefits, and working to remove any barriers to action are important roles for public policy.

In Australia, risk assessments for climate change impacts on various sectors of agriculture demonstrate that there are high potential returns to planned anticipatory adaptation. Howden and Jones (2004), for example, find that adaptation in the major arable-growing regions, through changing planting dates and varieties, is likely to be highly effective. They estimate impacts for a full range of climate scenarios over the incoming decades along with assessments of CO_2 fertilization response (Asseng *et al.*, 2004). They find high regional differences in impacts: Western Australian regions were likely to have significant yield reductions by 2070, while North-eastern Australia was likely to have moderate increases in yield. The benefits of adaptation in the wheat industry nationally are estimated to be substantial: benefits of around USD 160 million per year in present prices (though with a range of USD 70-350 million per year, depending on adoption rates, range of climatic stresses and other factors).

Virtually all present discussions of adaptation to climate change in agriculture involve water resource management and the potential for water stress as a key driver for change. A study of regional agricultural adaptation in the Okanagan Basin in British Columbia in Canada (Cohen *et al.*, 2004) highlights potential interventions for adaptation to increase efficiency in water use. Agriculture in this region currently extracts 200 million cubic metres of weather annually to support high-value fruit trees, vines and pasture and forage. A range of ongoing adaptations were identified that involved both agricultural and non-agricultural users, including domestic water metering, irrigation metering, wastewater reclamation and re-use and amalgamation of individual water utilities. These adaptations are required currently since projections of climate change suggest higher demand due to higher summer temperatures and reduced supply. Introduction of charges for irrigation reduced demand by 10% while domestic metering in the region also yielded water-use efficiency gains. The important element of the initiatives for adaptation in the Okanagan is that the stakeholders involved, both in agriculture and outside it, have heightened awareness of the demand and supply issues raised by climate change through major stakeholder dialogues. Hence the suite of policies implemented in the region has a higher degree of legitimacy and ultimately of endorsement by the key sectors involved (Cohen *et al.*, 2004).

In developing countries, many rural communities have developed responses to address high levels of current climate variability. In the Sahel, farmers face extreme irregularity in rainfall, with annual rainfall declining and drought frequency and intensity increasing. As a response to this, farmers have adapted their practices and adopted other income-generating activities in order to cope with this variability (Agrawal, 2008).

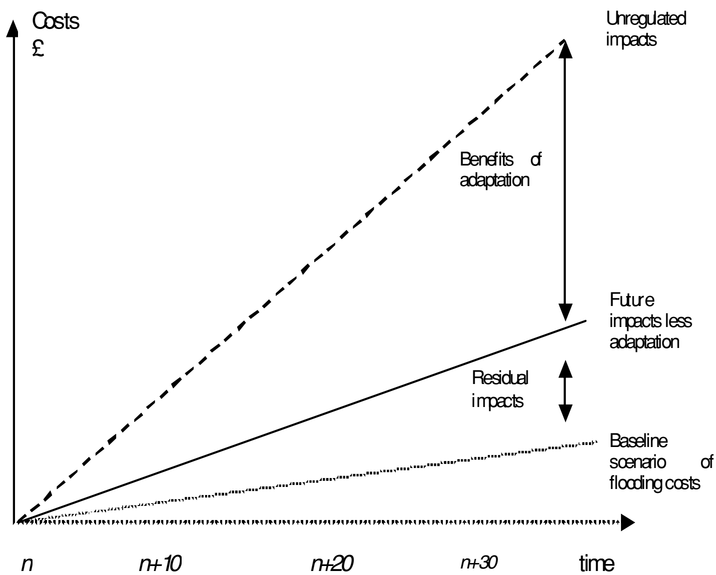
Estimating the costs and benefits of adaptation

It is only recently that studies examining the cost of adaptation have begun to emerge. Some, such as a report on the costs of adaptation to the global economy by the UNFCCC (UNFCCC, 2007), produce large-scale global costs, based on the investment and financial flows required to address climate change. For all sectors studied (which include agriculture) the investment and financial flows required to adapt to projected climate changes could be more than USD 100 billion per year several decades from now. This would be around 0.06-0.21% of projected GDP by 2030. Oxfam (2007) estimates the costs for financing adaptation in developing countries to be at least USD 50 billion per year, while the World Bank (World Bank, 2006) estimates costs of around USD 10-40 billion annually. Such estimates are useful for comparison with global mitigation costs.

However, large-scale global cost estimates mask the distributional impacts of adaptation and do not provide sufficient information for decision-making at a local or national level. In order to allocate finite resources and to prioritise alternative adaptation measures, a more detailed sectoral approach is required. Understanding the costs and benefits of adaptation actions is critical for practical decision-making.

Quantifying the costs and benefits of adaptation to climate change is, however, notoriously complex. Unlike mitigation, adaptation is a continual process, rather than a one-off action or outcome, and society, or farmers, are unlikely to be fully adapted to climate change. Indeed, we are vulnerable to current climate variability, and routinely bear climate-related losses as it is. These impacts are known in climate change literature as residual impacts, the impacts that society on some level has decided are acceptable. Residual impacts make costing adaptation difficult, as these must somehow be netted out of impact costing; *i.e.* not all the impacts will be avoided, therefore the cost of inaction does not necessarily translate directly into the benefits of adaptation. In addition, the baseline for comparison with inaction is also changing over time as climate change impacts are already routinely absorbed into management practices (or adapted to). Furthermore, many adaptation actions may have non-climate ancillary benefits, which may need to be taken into account in the valuation. These elements complicate any notion of efficient adaptation. Figure 4.1 illustrates the costs of climate impacts over time, for no adaptation (dashed line), with adaptation (solid line), and the baseline scenario of impacts with no climate change (dotted line). The baseline is increasing because the value of production and assets is assumed to increase over time. The difference between the solid and dashed lines represents the benefits of adaptation, while the difference between the dotted and solid lines represents residual impacts which will not be able to be adapted to. Residual impacts will vary both temporally and spatially.

Figure 4.1. Costs and benefits of adaptation



Source: Adapted from Metroeconomica (2004).

Literature on the costs of agricultural adaptation is limited. This may in part be because the focus of adaptation is on farm-level adjustments such as changes in timing of planting, or crop choices that are low cost. It is also the case that the distinction between public and private responsibilities has given rise to inertia in defining cost data and deriving overall estimates.

The European Environment Agency (EEA, 2007) highlights the need to monitor the effectiveness of adaptation strategies and actions, and provide an analysis of EU policy frameworks from an economic perspective. The report also highlights methodological issues in estimating costs of adaptation, and reviews studies on the costs of adaptation to date. Agrawala and Fankhauser (2008) provide a critical assessment of adaptation costs and benefits in key climate-sensitive areas, as well as across sectors at the national and global levels. They do not provide specific costs for agricultural adaptations, although they examine market and regulatory mechanisms that may be used to incentivise adaptation actions.

The role for public policy in adaptation

Given the combined public and private good nature of the benefits of adaptation in agriculture and related sectors, what is the role for public policy in tackling these climate change risks? This chapter considers rationales for public intervention in adaptation.

The public-private issue is important since it represents real trade-offs in policy. Governments in Europe, for example, continue to intervene in agricultural markets to reach public policy objectives of conservation, food security and farming and rural sector income support through the Common Agricultural Policy, even though the benefits may actually accrue to capital values in land (Allanson and Hubbard, 1999) But there may be less willingness to invest in climate change responses if all the benefits are perceived to be "private" – *i.e.* accrue to individual farmers, insurance companies or emerging weather futures markets. The mix of private and public good climate change impacts is the landscape against which government responses and investment priorities are determined.

The first rationale for promoting adaptation is to protect those parts of the agricultural sector and communities in rural areas that have the least ability to cope. As discussed above, agricultural regions facing climate change are subject to multiple stresses associated with market re-structuring, marginal productivity, and in the case of developing countries, lack of public infrastructure, high disease burden and many other factors that limit the ability to adapt. In addition, adaptation focussed on the most vulnerable is implicit in the Articles of the Framework Convention on Climate Change (Adger *et al.*, 2006), and is the basis for deriving potential international transfers to developing countries for adaptation (Baer, 2006). A survey of adaptation responses across the world by Adger *et al.* (2006) finds that adaptation is often directed towards greatest resource efficiency, rather than focussed on vulnerability reduction. Enhancing adaptive capacity, particularly that of disadvantaged rural populations, is likely to be more fruitful than identifying specifically how a given group in a particular area will be affected by climate change (Agrawal, 2008).

The second public policy response is the provision of high-quality information on the risks, vulnerability and threats posed by climate change. Such information includes scenarios of change at the global scale, as discussed in this report. But it also involves significant investment in the incorporation of climate information into land-use planning and other forms of regulation, hence the need for policy integration across government sectors, such as agriculture, planning and health, where climate change risks interact.

The third area of public policy response is in the provision and enhancement of the public good aspects of agricultural production and land-use. There are direct and demonstrable interactions between habitat and species protection with climate change impacts on water and vegetation and agricultural response (as demonstrated by Berry *et al.,* 2006 [for Europe]). Climate change impacts represent enhanced reasons for agri-environment policies and incentives to promote biodiversity conservation within the farming landscape, given the potential for habitat decline and species extinction throughout the world. Policies to promote food security at global and regional scales are also imperative, given the potential threats, and most importantly the potential uncertainty, in aggregate production in key regions such as South Asia and Russia.

In planning an adaptation strategy for the EU, the *White Paper on Adaptation* (European Commission, 2007) seeks to "define the role of the EU in adaptation policies so as to integrate adaptation fully into relevant European policies, to identify good, cost-effective practice in the development of adaptation policy and to foster learning".

The *White Paper* provided a first attempt at addressing the appropriate roles for public policy, arguing for a multi-level approach to adaptation governance in the EU, with specific roles at the European, national, regional and local levels. The main role at the European level was seen as the integration (or mainstreaming) of climate adaptation into policies across sectors, where the EU has specific competencies, including agriculture, fisheries, water, biodiversity, health, transport and energy.

Swart *et al.* (2009) analyse National Adaptation Strategies in ten European countries (Denmark, Finland, France, Germany, Latvia, the Netherlands, Portugal, Spain, Sweden and the United Kingdom). They find that the countries studied are adopting a variety of approaches based on their own cultural norms, political systems, and assessment of the risks posed by climate change. The report also identifies a number of common strengths and weaknesses in these plans, including a lack of co-ordination between sectors, and cross-sectoral conflicts. In addition, the national focus of most strategies ignores the threats (or opportunities) through global systems and networks.

Aaheim *et al.* (2008) argue that the role for public policy relating to adaptation covers seven objectives:

- Information, knowledge and learning;
- Early-warning and disaster relief;
- Facilitating adaptation in the market;
- Mainstreaming climate policy;
- Infrastructure planning and development;
- Regulating adaptations spillovers; and
- Compensating for the unequal distribution of climate impacts.

Given these policy imperatives for adaptation there is also a need to recognise how adaptation fits with other policy objectives of sustainability and whether certain adaptations themselves are desirable (see also Adger *et al.,* 2005; Mendelsohn, 2000; Hanneman, 2000; Burton *et al.,* 2002; Berkhout, 2005). Adaptation to climate change therefore can be evaluated through generic principles of policy appraisal seeking to promote equitable, effective, efficient and legitimate policies and investments harmonious with wider sustainability (Adger *et al.,* 2003; 2005). Defining success simply in terms of the effectiveness of meeting these objectives, however, is not sufficient for two reasons. First, whilst an action may be successful in terms of one stated objective, it may impose externalities at other spatial and temporal scales – what appears successful in the short term turns out to be less successful in the longer term. The rush to install domestic and commercial air-conditioning in western Europe following summer heatwaves, for example, represents an effective adaptation for its adopters, but is based on energy- and emissions-intensive technologies and therefore may not be sustainable in the long term (unless the energy is derived from renewable sources). Second, whilst an action may be effective for the adapting agent, it may produce negative externalities and spatial spillovers, potentially increasing impacts on others or reducing their capacity to adapt. Such adaptations are known in the literature as maladaptations. This may be particularly relevant in agriculture, where the success of farm-scale adaptations (in terms of both private and public good outcomes) is dependent on responses in contiguous areas of land on other farms.

Effectiveness relates to the capacity of an adaptation action to achieve its expressed objectives. Effectiveness can either be gauged through reducing impacts and exposure to them or in terms of reducing risk and avoiding danger and promoting security. The effectiveness of an adaptation action may depend on the future uncertain state of the world. Two key indicators of the effectiveness of an adaptation action are therefore robustness to uncertainty and flexibility, or ability to change in response to altered circumstances.

Efficiency in adaptation requires avoidance of under- or over-investment in adaptation technologies. In agriculture some investments in buildings, water infrastructure and land improvement are long-term investments where over- or under-shooting is a distinct possibility (Mendelsohn, 2000). These are known as the costs of misplaced foresight. While there is presently some theoretical research on adaptation to climate change as a learning strategy (Kelly *et al.,* 2005; Ingham *et al.,* 2007), this issue has yet to be examined in any detail in agriculture. Kelly *et al.* (2005) estimate so-called "adjustment" costs for farming regions in the United States' Midwest, simulating learning from one climate change state to the next through assuming a restricted profit function. They found that these adjustment costs were 1.4% of land rents for one simulated unanticipated climatic shock. A further issue in the efficiency of adaptation response is the valuation issues surrounding public good provision. Any assessment of the efficiency of an adaptation that incorporates only goods with market proxies (such as property, human health, or economic production) risks seriously underestimating both costs and benefits. Government-led adaptation to climate change often stresses public good elements of the problem such as ecological and aesthetic impacts and non-traded ecosystem goods and services, as much as private market impacts (Fankhauser *et al.,* 1999; Azar, 1998).

Equity of outcome in adaptation intervention and legitimacy of decision-making are both central to the resilience and ultimate perceived success of adaptation. They are important for instrumental reasons: development which is inequitable undermines the potential for welfare gains in the future, and developments which lack legitimacy have less chance of full implementation (see Cohen *et al.*, 2004; Adger *et al.*, 2006).

Policy instruments for adaptation

In agriculture, possible policy instruments may include price signals and market mechanisms; insurance instruments; microfinance; and R&D incentives (Fankhauser *et al.,* 2008).

The insurance sector (risk sharing) is likely to play a key role in future adaptation decisions, whether through traditional indemnity-based insurance, or through other options that may be more suitable for climate-based insurance, such as index-based schemes, weather derivatives or catastrophe bonds. For more detail on these schemes refer to Barnett and Mahul (2007); Fankhauser *et al.* (2008); and Mills (2007). Ideally, insurance can create incentives for adaptation and reducing risk by sending market signals about the climate risk and encouraging risk-reducing behaviour through discounted premiums. However, in reality this may not occur in exactly this way, because of uncertainty about actual climate impacts, budget constraints and structural, social and cultural barriers which prevent individuals and businesses from adapting, particularly if relocation would be the most appropriate adaptation. While insurance is likely to be an important mechanism in distributing risk and may create incentives for adaptation, subscribing to private insurance may not in itself necessarily lead to an adaptation of activity. In addition, as climate risks increase, insurance costs will also increase and may prove to be too costly for some actors, leaving them highly vulnerable to climate change. Insurance is in most cases a private decision rather than a public policy, and in some cases public intervention may be necessary to facilitate the sharing of climate risks between the insurance sector and the state.

EU member states use agricultural insurance to varying extents. Variation arises from the types of risks that are insured, how they are bundled (*e.g.* single-risk insurance, combined insurance, yield insurance), and how they are shared between the private and public sectors. In some cases the public sector heavily subsidises insurance premiums, while in other cases *ad hoc* aid and calamity funds are offered by the government.

Spain has one of the most advanced and elaborate agriculture insurance systems in the EU, based on the principle that the cost of subsidising insurance premiums is less costly than emergency relief payments following a disaster. In the event that public funds are provided for drought relief, farmers who opted not to buy crop insurance when it was available are not eligible for government funds to provide relief. Insurance coverage is close to 45% for all the agricultural production (and above 70% for winter cereals and fruits). In addition, Spain has an Insurance Compensation Scheme, a public organisation which acts as a reinsurer of agricultural risks (among others).

Table 4.3 shows a comparison of some EU insurance regimes. In France there is very low government subsidisation of insurance premiums (2.4%) compared to the other Mediterranean countries. However, the French government provides significantly greater *ad-hoc* aid – EUR 156 million per year on average over the 1996-2005 period, compared to less than EUR 5 million on average per year for both Spain and Portugal.

Table 4.3. Comparison of agriculture insurance systems for EU Mediterranean countries

	Single-risk insurance	Combined insurance	Yield insurance	Calamities fund	*Ad hoc* aids	Premium insured value (%)	Insurance subsidies (%)
France	P	P	PS	GS	–	1.7%	2.4%
Greece	G	GC+GS+G	–	–	GF	2.5%	no data
Italy	PS	PS	PS	GF	–	7.4%	67.0%
Portugal	PS	PS	–	GS	–	8.4%	68.0%
Spain	PS	PS	PS	–	GF	6.3%	41.0%

Legend:
S = Subsidised; P = Private, non-subsidised; PS = Private, partially subsidised; G = Public, non-subsidised; GS = Public, partially subsidised; GF = Public, free; – = Non-existing.

Source: European Commission (2006).

The differences in insurance coverage between countries may influence the adaptations that take place in those countries. As well as reducing reliance on disaster aid *ex post,* insurance can act as an important vehicle in shaping behaviour. In attempting to reduce vulnerability to extreme weather, insurance cover may be made conditional on appropriate risk-reducing measures being taken. In this way adaptation can be encouraged to a much greater extent than through unconditional post-disaster aid.

Fankhauser *et al.* (2008) discuss the role of environmental pricing, particularly in water markets, in encouraging and promoting adaptation to climate change. More generally, the appropriate pricing of natural resources can in fact improve the resilience of ecosystems and enable them to cope better with climate change. The identification and protection of ecosystem services, such as watershed protection through appropriate agricultural management and/or forest cover, can provide protection against flooding and erosion, as well as regulating the water table and minimising water pollution.

Public-private partnership is also an area that could contribute usefully to facilitating adaptation. As well as the financial benefits, public sector involvement sends a clear signal to private industry and individuals that the public sector takes adaptation seriously and is committed to it. Barriers to adaptation identified in some sectors include uncertainty regarding future policy commitment to adaptation: therefore, if the public sector is itself engaged in adaptation activities, this may remove some of these barriers. Examples of public-private partnership exist in other sectors, such as health, education and research and development. In agriculture, the most relevant public-private partnership is likely to occur in R&D, where the development of technology may facilitate adaptation. Examples already exist in crop development – for example, the Drought Tolerant Maize for Africa (DTMA) project, which links scientists with national agricultural research institutions, NGOs and private-sector seed companies.[2]

Figure 4.2 illustrates a schematic representation of how public-private partnerships might work as a first step to analysing how institutions across the public, civic and private boundaries could work jointly to help facilitate adaptation. This was developed in Agrawal (2008) and is based on the premise that institutions and organisations in both the private and public domains have inherent limitations through the nature of their specific focus. By collaborating with other organisations they may be able to fill gaps or remove weaknesses and provide a more comprehensive approach to addressing climate change.

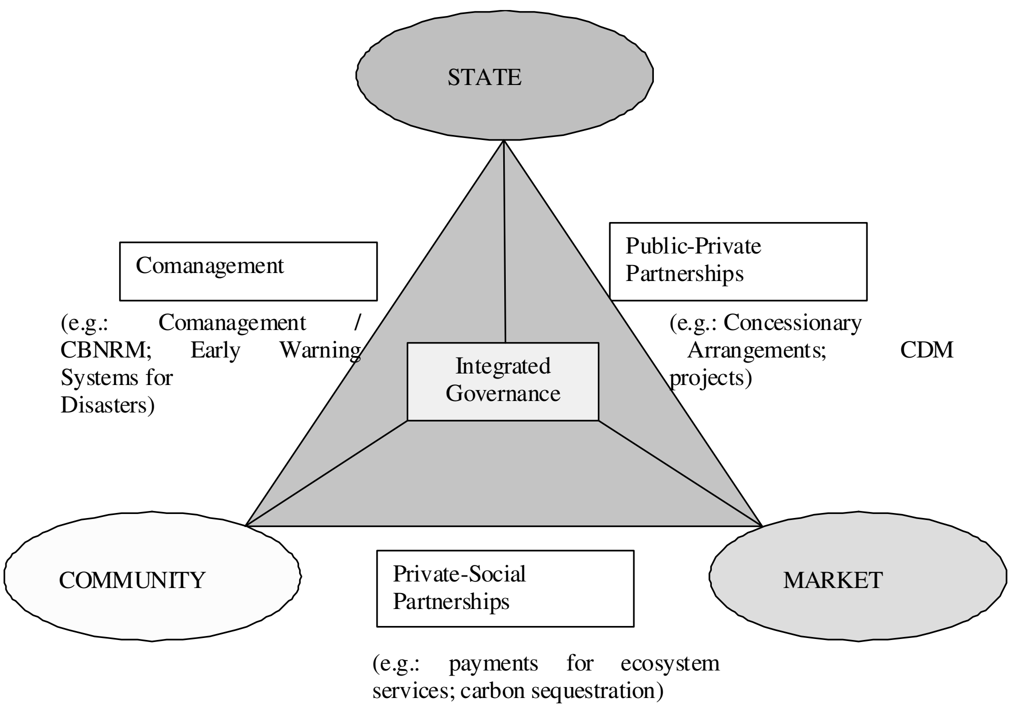
In summary, there are significant challenges in promoting adaptation to climate change through policy intervention in agriculture at global and national scales. This report has concentrated on some more generic adaptation issues rather than focussing on specific adaptation measures that might be adopted within farming systems. While economic efficiency (*i.e.* cost-benefit analysis) provides a rational basis for adaption planning, it is important to recognise a number of complicating factors that limit adaptation responses relative to mitigation action. The first is that while mitigation is likely to be more of a mandatory requirement with immediate one-off actions, adaptation responses are continual processes requiring constant refinement as damage scenarios become more certain and/or impacts become increasingly apparent. The costs of on-going adaptation and the residual impacts lead to complications in identifying the costs and benefit of adaptation, and in determining the distributional impacts of future adaptation.

A second complication is in terms of co-ordinating how private adaptation responses can be reconciled with desirable public good outcomes. We have noted that the proper valuation (and conservation) of environmental public goods can increase resilience, and we note that their conservation often requires collective action by landowners. But little is known about how the promotion of private adaptation will impact on those

2 http://dtma.cimmyt.org/.

same public goods, or how these impacts can be minimised through co-operative adaptation planning. This leads to a final observation on the respective private and public good roles. There is clearly a public interest role in the conservation of public goods, and in the facilitation of private resilience. But in the absence of more definitive impact scenarios, that role is largely limited to information provision and investment in research to understand how co-ordinated action can work. There is currently a limited evidence base on comprehensive adaptation measures, particularly on livestock systems and their costs. Part of the public good role should be to develop inventories of adaptation measures and reconcile these with mitigation requirements.

Figure 4.2. Diagram of collaborative institutional arrangements for environmental action in the context of climate change



Source: Agrarwal, (2008).

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