Agriculture and Adaptation to Climate Change – Workshop Report

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1. Introduction

This report summarises the proceedings of the Workshop 'Agriculture and Adaptation to Climate Change', organised by the Organisation for Economic Cooperation and Development (OECD), the Italian National Institute for Agricultural Economics (INEA) and the Food and Agriculture Organisation of the United Nations (FAO), and hosted by INEA in Rome, Italy, on 23-25 June 2010.

The overall theme of the workshop was agriculture's adaptation to climate change and the role of policies in that process over the medium to long term (to 2050). The seven sessions of the workshop covered the following sub-themes: *stakeholder perspectives* (the multiple expectations and demands placed on the agricultural sector worldwide), the linked goals *adaptation and mitigation* (in particular, the prospects for a balanced mix of policies addressing them), *knowledge and information needs* to support adaptation and adaptation policies, the scope for *insurance as an adaptation option* (experiences to date and the role for government) and *adaptation strategies and policies* (as already implemented or planned in various countries). The closing session focused on the *key messages emerging from the workshop*, and the role of OECD and FAO in helping governments apply them.

This report summarises the evidence presented and discussed at the workshop in the following six sections. Section 2 sets out the context and describes the challenges climate change poses to agriculture; section 3 assesses the current state of large-scale models used to simulate the future size and incidence of climate change effects; section 4 reports on adaptation progress at farm level, in the agrotechnology research pipeline, and at the level of institutions and policies and section 5 discusses adaptation to greater weather-related variability and uncertainty. Drawing on the previous sections, section 6 discusses the role for government and policy, and section 7 presents conclusions and recommendations.

2. The challenges facing agriculture and the need for adaptation

2.1. The context

World population is expected to increase by approximately 3 billion by 2050 and world income may be as much as three times higher. Global food demand will rise by two thirds.

If no new policy actions are undertaken, total greenhouse gas (GHG) emissions are likely to be 50% higher than in 2005, with the most rapid growth - and hence a rising share of total emissions - occurring outside OECD countries. Assuming such a scenario, global average temperatures could be 5 or more degrees Celsius higher by the end of the century.

Temperature increases will be non-uniform, with higher rates of warming predicted to occur over land areas, in polar regions and in winter rather than summer. An overall increase in precipitation is very likely, although its spatial distribution is less certain. A higher frequency of extreme and unforeseeable events, such as droughts, cyclones, floods, bushfires, and pest and disease epidemics, is predicted.

The main hotspots for food demand pressure will tend to be in areas experiencing greater climate change effects. Already, water stress is affecting regions that are home to about one-third of the world's population.

2.2. The challenges facing agriculture

Meeting higher global food demand will require unprecedented levels of agricultural productivity from a shrinking natural resource base (especially water and suitable agricultural land[1]). At the same time, agriculture will be expected to maintain or improve its provision of environmental public goods. In some places, climate change is likely to make the trade-off between these co-benefits and food production much steeper. The pressure on land will increase with the ongoing dietary trend towards more animal protein and due to competition from the fuel industry for biomass.

A further challenge will come from the need for agriculture to contribute to climate change mitigation by reducing its own GHG emissions and enhancing its capacity for carbon sequestration. Agriculture is also one of the few sectors that can remove GHGs from the atmosphere, mainly through sequestration in land, and thus off-set emissions from other sectors. Thus, it is crucial to identify adaptation strategies that can reconcile the need to increase food production with climate change mitigation and other environmental goals.
A recurrent theme of the workshop was the need for a holistic approach incorporating the interlinked challenges of climate change adaptation and mitigation, food security and environmental sustainability, in order to promote synergies between them, anticipate conflicts or cross-constraints and prevent perverse outcomes.

2.3. Adaptation as a priority

Agriculture *must* adapt to climate change in order to stay on track with the targets and expectations it faces. Should agriculture become a victim of climate change, the consequences would be globally disastrous and highly destabilising. Whilst farmers have, for centuries, routinely and successfully adapted to changes in weather and climate, the strategies adopted in the past are unlikely to be enough to cope adequately with the impacts of future global climate change.

Climate change adaptation, defined by the IPCC (Intergovernmental Panel on Climate Change) as the adjustment of natural and human systems in response to actual or expected climatic stimuli and their effects, has various strands: reducing the sensitivity of systems affected by climate change, increasing their resilience to climate-related uncertainty and instability, exploiting beneficial new opportunities and coping with adverse consequences.

Agriculture's adaptation may be anticipatory (ex ante) or reactive (ex post), may target the short or the medium-to-long terms, and may occur at one or many of the multiple levels within the complex system comprising agriculture, the natural environment, food production and delivery, and rural communities. Adaptation may be initiated by farmers on an individual basis or coordinated by them at local level. At the other extreme, it may be planned and driven at the level of the sector, region or nation, or even globally, with heavy public sector guidance and support.

A relevant question is to what extent agriculture's adaptation to climate change goes beyond the pursuit of environmentally sustainable agriculture, or indeed differs from the ongoing incremental changes that farmers routinely make to their production methods and choices in

[1] Irrigation already uses 70% of the world's fresh water supply, and will face heavy competition from other sources of demand. Agricultural land area per capita is predicted to decline to 1.5 hectares by 2050.

response to a fluctuating physical environment. In the view of workshop participants, the new elements in this challenge derive from the uncertainties inherent in climate change, and the potential ultimate magnitude of its effects. Climate change is an ongoing, dynamic process whose spatial incidence, speed, timing, and ultimate extent are still very uncertain. This can hinder timely and rational anticipatory responses, and increase the risk of maladaptation[2] (see section 6.3). Moreover, greater uncertainty and instability are themselves a *consequence* of climate change; each successive stage of the climate change process will be characterised by a greater risk of unpredictable and potentially devastating extreme events.

Given governments' recognition of the importance and urgency for agriculture to adapt to climate change, the workshop set out to examine the following questions. How to ensure that adaptation results in an efficient, productive and resilient agriculture? What is the role of government in providing an appropriate institutional and policy environment? Given that adaptation is specific to particular circumstances, how can policies provide the right signals and incentives for farmers?

3. To what extent will climate change affect agriculture?

There was considerable discussion of model-based estimates of the likely damage of climate change to agricultural systems, the current lack of agreement between models and experts, and the evolution of these estimates over time. There was broad agreement that this activity, although promising and answering a real need, is still under development. Current models embody various simplifications (such as average temperatures and yields, limited commodity coverage, absence of catastrophic events, and fixed farm management techniques) that distort simulation results. Most approaches fail to account for adaptation, or do so in a very rudimentary way. Moreover, most models used to simulate climate change effects are too aggregate to provide guidance for targeted policies. The need to downscale these models was stressed, as was the daunting data requirement if downscaled models are to be useful for more targeted ex ante policies.

Simulation models developed for the European Union by the Joint Research Centre indicate that, as regards yield impacts for various crops, there will be winners as well as losers. These models can be downscaled to capture agronomic and some ecological effects at a spatial resolution of 25 km^2, but no economic or agro-management information is available at this level of disaggregation.

The shape of response functions in agro-climatic simulation models is a complex issue, given the likely non-linearities and threshold effects in many key natural processes. For example, in North America, studies show that moderate warming, together with higher CO_2 levels, improves crop and pasture yields in mid to high latitudes, but more extreme warming is yield-reducing in all regions. By contrast, forage quality usually declines linearly with increasing CO_2 concentration due to the effects on plant nitrogen and protein content, as does livestock productivity with rising temperatures.

In addition, simulated climate change effects can depend decisively on the climate change scenario assumed. For example, in Australia, high rainfall scenarios imply improvements in pasture growth in some regions, whereas lower rainfall leads to reduced pasture growth in most temperate regions.

There was consensus that current model simulations are very sensitive to the global warming 'story line' assumed, to many model parameters, and to assumptions about yield growth and

[2] Adaptive strategies that appear beneficial in the short run, but which are counter-productive in the longer run.

farmer responses. Major challenges for model developers include: making parameterisation more flexible to allow for spatial variation and for farmer adaptation over time; capturing the costs of adaptation when adaptation *is* allowed for in the model simulations; and incorporating the invasion of new areas by pests and diseases whilst taking into account that this encroachment itself depends on temperature change.

A complementary methodology was described by the Korean expert for allowing governments to prioritise adaptation measures without the need for detailed, spatially precise forecasts of climate change effects. Beginning with an 'adaptation inventory' of 19 adaptation priorities for Korea's agricultural sector, the Analytic Hierarchy Process[3] methodology was used with a panel of 24 experts. Adopting the criteria of efficiency, effectiveness, feasibility and acceptance, this procedure identified the same top 3 priorities (breeding research and development, infrastructure for agricultural water management, and research and development on production technologies) for both the short and medium terms.

Such results indicate that it is not necessary for governments to wait until simulation models are able to give reliable detailed predictions of the agro-climatic changes before taking action. For example, without recourse to detailed information about the incidence and the nature of climate change effect, the Korean study grounds for the government to encourage or step up fundamental research, and to review institutional arrangements for the sector, so as to facilitate the future implementation of more precisely targeted policies, if deemed appropriate, once the specific incidence and extent of climate change effects become easier to identify.

4. Current situation regarding adaptation

4.1. Experience at farm level

Farmers in a number of countries are already affected by climate change[4]. Left to themselves, farmers tend to treat climate change adaptation as part of their 'business-as-usual' management of environmental risk. They appear, however, more reluctant to adopt strategies requiring longer-term investment given the uncertainty regarding actual future outcomes.

Farmers in both developed and developing countries want to learn from each other. However, successful farm-level adaptation measures are often site-specific, and their success can depend on particular farm or farmer characteristics. How can one move from winning farm- or site-specific outcomes to more generalised recommendations that might be disseminated by extension services or embodied in policy incentives, whilst still respecting the diversity of production conditions? A climate change-relevant classification of farming systems (according to agronomic, ecological, economic and sociological terms) was seen as potentially useful. With a similar aim, the Turkish authorities are developing an agro-ecological zoning system as a basis for generalizing future adaptation strategies. With both these approaches, it is necessary to continue updating key parameters as conditions change.

If farmers are to take voluntary action, they need to see that the benefits of adaptation outweigh the costs. In developed countries, it is commonly thought that various low-cost adaptation options *are* available, even if they are not generalisable everywhere. By contrast, the common perception in developing countries is that low- or zero-cost adaptation options hardly exist, or are infeasible.

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[3] A methodology for complex decision making based on the experience, knowledge and intuition of experts.

[4] For example, nearly 40% of UK farmers surveyed in February 2010, and 57% expected to be affected within 10 years; 33% of farmers surveyed were already taking adaptation measures.

What can explain these contrasting viewpoints? It has to be recognised that in both developed and developing countries, even 'zero-cost' options may in fact involve temporary adjustment costs; for example, growing a new crop or mastering a new tillage practice can involve some years of lower returns while the farmer develops full expertise. As well as this, however, barriers to farm-level adaptation[5] can differ greatly between developed and developing countries, and in developing countries these barriers may raise costs to significant or prohibitive levels. In general, to understand the process better and to guide possible policy intervention, more research is needed on farmer adaptive behaviour: what predisposes farmers to take up adaptation options, what constraints do they face, and what factors make these options more likely to succeed?

Moreover, it is quite difficult in the development context to separate out core development challenges from climate change adaptation needs, which are intricately linked to prevailing development deficits. This can make adaptation options appear truly daunting. Nonetheless, some workshop participants believed it could be constructive to present some core development challenges under their climate change adaptation aspect, if this can raise their profile and facilitate access to climate change funding[6]. Similarly, in developed countries, many actions that are being re-labelled as agricultural adaptation to climate change are already part of existing risk or environmental management responses.

4.2. New technologies: investment, development and dissemination

In the last two decades, agriculture has been downgraded on the policy agenda worldwide, and has lost donor attention in developing countries. Investment in agriculture is much lower globally than in the 1980s. Reversing this trend is an urgent priority, and with a sharpened focus on raising productivity in conjunction with climate change adaptation and mitigation.

The workshop heard about initiatives in the area of plant breeding aimed to bring new drought tolerant crop varieties to farmers in Africa[7]. These projects combine the participation of large private charitable foundations, multinational corporations, international research organisations and farmers who provide field trials and local knowledge. The value of such partnerships for developing and/or transferring new technologies needed for climate change adaptation was emphasised. At the same time, it was acknowledged that commercial corporations will inevitably focus on a few traits and a restricted number of (more commercially valued) crops, and cannot be expected to initiate projects for all those crops that are vital for rural communities threatened by climate change.

Various other highly relevant initiatives were presented, including the Sustainable Crop Production Intensification (SCPI) strategy[8], diversification strategies such as agroforestry[9]

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[5] They include *market failures* (misaligned incentives, public good nature of some adaptation measures), *behavioural barriers* (uncertainty, complexity, inertia), *constrained adaptive capacity* (financial constraints, relevant expertise) and *natural capacity* (as determined by the eco-system's ability to adapt beyond narrow parameters at a reasonable speed).

[6] This is true not only for agriculture but practically all issue areas (public health, disaster risk management, water resource management and so on).

[7] Monsanto's *Sustainable Yield Initiative*, which aims to help corn, soy and cotton farmers in five African countries double yields by 2030 (relative to 2000), whilst reducing the use of energy, water and other inputs per unit of output by one-third. It is estimated that doubling the yields of these crops by 2030 can reduce global GHG emissions by more than 10 bn t of CO2e (by reducing deforestation). *Water Efficient Maize for Africa* (WEMA), led by the African Agricultural Technology Foundation (AATF), again focusing initially on five sub-Saharan countries.

[8] Coordinated by FAO, which involves yield-increasing, input-reducing agronomic management, and includes agronomic practices for increasing crop resilience in the face of more extreme production conditions.

and improved integrated crop-livestock systems, Integrated Production and Pest Management (IPPM)[10], conservation agriculture (CA)[11], and better grassland management[12].

The initiatives described share several key characteristics: a major input of advanced, science-based knowledge in order to unlock new technological potential, and the important role played by participation of farmers and local organisations in the targeted regions during the development phase. These aspects were highlighted in projects across a wide spectrum, from breeding programmes to new resource management systems and specific agronomic practices.

The role of extension in getting new technology to the farmer is vital. Traditionally, research and extension have remained separate, weakening the impact of both. Moreover, extension has virtually disappeared in a large number of countries. Yet the ultimate aim is for farmers to become expert practitioners of new technologies targeted to current and emerging problems. A major effort is required to expand extension capacity and to upgrade extension training standards, as well as to modernise the systems for organising and delivering extension advice. Farmer-to-farmer dissemination via interactive workshops, pilot farms or farmer field school initiatives has an important part to play in extension effort.

A functional, integrated chain from research, through training programmes, to efficient extension services was considered a good investment for all countries. It was observed that, unfortunately, successful examples of such holistic research and delivery systems, which if available might help poor countries to get funding to replicate them, are lacking.

4.3. Action underway at institutional and policy level

Agriculture's adaptation to climate change is now on the planning agenda of a number of OECD countries, which have set up frameworks for prioritising, structuring and monitoring adaptation initiatives[13]. These initiatives differ according to whether their scope is multi-sectoral or specific to the agricultural sector, in the extent of prior stakeholder consultation, prior input of detailed agroclimatic and/or agroeconomic research, and the range of governmental and other public sector institutions involved.

No targeted policies requiring or incentivising specific adaptation actions to be undertaken by farmers were reported, although here it is worth recalling that some actions qualifying as climate change adaptation may already be targeted under the heading of environmental sustainability. This situation contrasts somewhat with the position regarding climate change mitigation, where many countries have already fixed economy-wide targets for reducing GHG emissions, have specified the share of the reduction commitment to be borne by the agricultural sector and are exploring mitigation incentives. Various speakers confirmed, with concrete examples, the existence of exploitable synergies between adaptation and mitigation options.

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[9] For example, the World Agroforestry Centre's initiative to promote more extensive growing of the white-thorn acacia tree (*Faidherbia albida*), which drops its leaves in drought, providing fodder for livestock, improving soil quality and checking erosion.

[10] Already introduced in a number of African countries.

[11] Widely adopted in Canada and Australia and South America. CA benefits are relevant for both climate change adaptation (better water filtration and hence less flooding, improved drought/ temperature tolerance) and mitigation (reduced GHG emission, lower fuel use, higher carbon sequestration).

[12] For example, sown biodiverse pastures (with at least 6 different species or varieties, and a minimum of 25% legumes) under extensive trial in Portugal, which combine the benefits of higher productivity of livestock systems, increased water retention and erosion control, improved soil quality and carbon sequestration.

[13] For example, presentations from DEFRA for England and Wales, Canada, Turkey, Norway, Italy. A US Task Force on climate change adaptation, reporting to the President, is expected to deliver before the end of 2010.

In conjunction with or alongside adaptation initiatives, some countries are also working on or refining national plans for handling a higher frequency of catastrophic extreme events, be they weather-related or triggered by pest and disease outbreaks.

These activities are paralleled in developing countries by the setting up of economy-wide National Adaptation Plans of Action (NAPAs)[14], whose aim is to coordinate the key organisations and activities, and to involve all major stakeholders. Agriculture is one of the front-line sectors in these plans, and the common priority areas across NAPAs include research on drought resistant varieties, seed distribution, land and water management, diversification and disaster risk reduction.

Given the horizontal nature of the climate change process, it is important to consider adaptation by agriculture in the context of other economic sectors and in relation to other threatened policy domains like health, energy and water. At the same time, each sector needs to be treated individually, since the degree and type of vulnerability, as well as the response options, are often highly sector-specific. Adaptation tools and methods may also vary significantly between sectors.

This suggests the need for a complex, multi-layered coordinating structure that might prove unwieldy for information flows, working speed and possibly for decision-making. There seems to be awareness of this potential organisational problem in some countries, but no claims yet for a solution.

5. Adapting to greater variability and uncertainty

5.1. Fostering resilience and adaptive capacity

*Resilienc*e refers to the ability of a system or entity to absorb disturbances while retaining its essential character and functionality. Resilience is negatively related to vulnerability (which links the ideas of susceptibility and inability to cope). *Adaptive capacity* is a broader and more complex concept, denoting *both* the ability to adjust to the various dimensions of change so as to moderate potential damages, exploit opportunities, and cope with consequences, *and* the set of capabilities and resources including institutional readiness (behavioural flexibility) possessed by a country (or a farmer) and that are conducive to effective adaptation.

Workshop participants considered these attributes, at farm level and in chains of interrelated action within regions or countries, to be very important for successful adaptation to climate change. Breaking down these complex concepts into their main elements suggests a number of ‘entry points’ where policy actions could be beneficial, such as freeing access to relevant knowledge and know-how, providing education, training and adaptation financing mechanisms (the latter ideally cross-linked to other goals like food security or mitigation in order to exploit synergies), encouraging diversification and wider participation in decision making, providing safety nets and infrastructure, removing constraints to structural adjustment and input availability, and promoting public awareness.

5.2. Coping with greater risk

Risks affecting agriculture can be segmented into three strata according to the concept of 'risk layering': the *risk retention layer* (frequent events causing relatively small losses), the *market insurance layer* (more significant but less frequent risks, whose damage is quantifiable *ex*

[14] Already in place in 44 countries.

ante and whose probabilities are known based on past events), and the *market failure layer* (risks that generate very large losses at low frequencies).

Farmers are expected to manage risks in the first layer themselves using customary income-smoothing strategies; for risks in the second layer, farmers can use insurance or options, and the challenge for commercial providers of these services is to do so with low, controlled levels of adverse selection and moral hazard; risk in the third layer is hard to pool through insurance, and here governments usually step in with some form of disaster assistance.

Climate change is expected to widen the first and third layers, and to shrink the second[15]. Yet farm insurance may bring adaptation benefits: since it provides greater financial stability for growers, and is frequently required by providers of agricultural credit, insured farmers are more likely to invest in new technologies and management options that facilitate climate change adaptation.

The boundaries between layers are not necessarily 'given' by external factors, and depend partly on the design of insurance mechanisms. Innovative insurance tools and protocols can reduce the cost of providing insurance[16] or incentivise producers to reduce risks[17] and if appropriately designed, insurance can encourage adaptation.

However, insurance simply redistributes risk between agents, and is not *per se* a means of adaptation to underlying changes. It was queried whether a good, comprehensive insurance programme may actually reduce the incentive to adapt, but the expert view was that this can be partially avoided by carefully designed insurance tools. At the same time, farm insurance in developing countries is still not common and could not become common without large transfers from governments. It is unlikely that this could be justified as the best use of government funding in order to assist agriculture.

6. The role for government policy

6.1. What governments can do (or do more)

Improve the institutions and infrastructure for natural resource management.

- *Water*. Tradable water rights were recommended by those countries where they are already implemented[18], and this attracted the interest of other countries with incipient water scarcity.
- *Land*. Tenure insecurity and use of common pool resources have implications for inefficient or environmentally harmful use of land, and usually do not provide a conducive context for farmers' adaptation to climate change. More needs to be done to define and enforce land ownership or user rights, just one of the measures governments can take to incentivise better cropland and grassland management.

  Government can also re-examine the scope for promoting organic soil management and restoring degraded land.

[15] In the US, already around two thirds of farm insurance claims are related to water (drought, floods), but also to pests, diseases and hurricanes.
[16] However, it is not applicable to all risks.
[17] For example, reduced premiums for having adopted certain risk-reducing measures.
[18] In Australia, the relative merits of temporary transfer (favoured by farmers) and permanent transfer are under debate. Issues such as these should be resolved in a climate change perspective.

The question was raised as to whether agriculture's adaptation to climate change should be seen in the broader context of optimal land management strategies in the face of climate change. Whether farmers should be left to decide how to use given land parcels was questioned[19].

Fill knowledge gaps.

- Government-backed environmental indicators may be valuable early warning tools for climate change impacts, and could be extended to include more climate change-relevant trends. Farmers could be asked *which* indicators would help them increase their preparedness for climate change. Challenges include the huge data requirement for downscaling indicators to a level that is meaningful for climate change impacts, and incorporating increased variability (temporal and spatial) into these indicators.
- Despite the challenges facing large-scale simulation models (see section 3), it was felt that they *can* be of use in providing the longer-term perspective needed for planning adaptation strategies over a longer time horizon. These models are generally financed by public money, and governments should maintain this commitment.
- Government has a role to play in strengthening the information chain from research to farmers, via public extension services and policy measures.

Review government subsidies of farm insurance in OECD countries.

Many OECD governments currently subsidise or at least underwrite farm insurance schemes[20]. The sharing of roles between the public and private sectors in this respect should be reappraised in the broader context of farmers' adaptation to climate change. Governments need to ask whether subsidising insurance in a riskier environment is more cost-effective than investing in research and uptake of risk-reducing adaptation. Moreover, there may be a danger that insurance subsidies distort incentives in favour of maintaining the status quo even when greater risk has made it uneconomic, rather than taking adaptive measures.

There was scepticism that farm insurance, whether subsidised or not, could play a significant role in developing countries.

6.2. What can be done *only* by governments

Governments have a crucial role to play in maintaining a coherent policy environment that sends clear signals such that the goals of individual farmers and society are aligned, and so that synergies between climate change adaptation and other related or potentially conflicting goals can be recognised and exploited.

Food security and climate change goals are too often considered separately from each other, with responsibilities divided between (non-cooperating) ministries or other bodies, and with potentially perverse outcomes. Moreover, in many countries, adaptation, mitigation and food security programmes have separate policy and/or financing channels. Nowhere is this partitioning more apparent than at international level, where three different international conventions deal separately with food security, climate change and biodiversity, although

[19] The controversy over use of agricultural land to produce biomass for fuel was mentioned here as a relevant issue.

[20] Italy, Spain and the USA described their experiences. In all three countries, governments subsidise insurance to farmers, in coordination with the private sector, and with farmers bearing some of the risk themselves to reduce moral hazard. The *average* rate of subsidy is 'up to 80%' in Italy and about 60% in the USA. The US government also gives subsidies to companies operating these schemes, and provides reinsurance.

these issues are intimately linked. When a holistic approach exists at national and sub-national levels, governments are in a better position to exert the necessary pressure on international organisations to operate in a more coherent framework.

Governments need to review all relevant policies with the aim of removing impediments to productivity growth, climate change adaptation and increased resilience, and to apply a 'climate lens'[21] to all new and existing policies. Institutions and allocation of administrative capacity, not to mention government education and training programmes, need to be reviewed from the same perspective.

Furthermore, governments can provide positive stimuli for growth and adaptation by, for example, more direct public sector involvement in stimulating the development of new technologies unlikely to attract private corporations (lack of commercial spin-off) or donor organisations (scale) but which have large potential social benefits.

It is within the domain of policy to stimulate the provision of public goods related to climate change and environmental sustainability, using targeted payments or other measures. Only governments can correct market failure situations where, if self-interested actors are left to maximise according to the signals they receive, perverse outcomes will occur.[22]

6.3. Pitfalls to be avoided

There were strong warnings about the potential conflict between adaptation that is optimal in the short run but not in the long run, and the resulting risk of maladaptation. Adaptation is *not* synonymous with adjustments that help to maintain status quo practices. For example, if rainfall decreases in areas where agriculture is mainly rain-fed, investment in costly irrigation structures may help in the short run; however, if in the medium term these systems themselves will be starved of the water resources they need, effort would be better spent on changing cropping systems, devising drought management strategies, and investing in infrastructure and know-how for water harvesting and recycling.

Clearly, maladaptation is not specifically due to *policies* designed for the short term. It may result from independent decisions by farmers in the absence of any policy signal[23]. However, in this case, it usually needs over-riding government action to deal effectively with the clash between short- and medium-term optimality.

In short, governments *must* take a longer-term perspective in order to prevent unsustainable adaptation that will otherwise lead to discontinuities or inefficient later reversals of adaptation initiatives. Since there are always stakeholder groups with a vested interest in the status quo, this issue highlights the need to adopt a longer term horizon not only regarding technical solutions but also in relation to the political trade-offs involved.

Concern was also expressed by some delegates about the danger of governments over-regulating farmers' adaptation to climate change. The costs of over-regulation (stifling of individual initiatives, frequent inappropriateness of standardised or 'one-size-fits-all'

[21] Each policy should be evaluated according to whether climate change risks have been taken into account in formulating the measure, and whether the measure could lead to increased vulnerability or to maladaptation. Pre-existing strategies and policies need to be amended in order to address climate risks and opportunities.

[22] For example, rather than building flood barriers to protect individual agricultural holdings, coordinated controlled flooding of a number of holdings could prevent major consequences incurring far greater social costs downstream.

[23] Maladaptation specifically concerns the conflict between short- and long-term objects, exacerbated by the uncertain dynamics of climate change effects. It should not be confused with the situation described in footnote 22, which is due to externalities imposed by one group on another in the same time period.

solutions, potentially high policy transaction costs etc) have been well rehearsed in many other contexts. As regards climate change adaptation, at one end of the spectrum the appropriate area for government action was seen by some participants as confined to supplying improved and relevant information, providing incentives for sustainable adaptation and stimulating public goods. The other end of the spectrum – how far some other governments might be prepared to intervene with regulation – was left undefined.

7. Conclusions and recommendations

The new elements in the climate change challenge are its dynamic, ongoing nature, and the uncertainty surrounding many aspects of the process. Recognising this, the workshop emphasised the need to increase resilience and to build adaptive capacity, not just at farm level but at multiple levels in the system comprising agriculture, the natural environment, food production and delivery, and rural communities.

To ensure that adaptation results in an efficient, productive and resilient agriculture, a strong stimulus to advanced, science-based research and development is needed. To what extent governments should themselves become directly involved in this effort was not explored in depth; nonetheless, there is clearly a major role for governments in setting priorities, stimulating research initiatives, filling gaps in research coverage and, working with other main players, improving the delivery of new technologies to farmers.

Governments have a crucial role to play in maintaining an appropriate institutional infrastructure and a coherent policy environment. Given the closely interlinked goals facing agriculture, which leave it little margin for manoeuvre, it is important for governments to adopt a holistic approach that can identify and exploit synergies between these goals wherever possible, remove bottlenecks and avoid perverse, costly outcomes.

It is also important to set objectives and frame measures in a longer-term perspective, in order to minimise the risk of maladaptation. This means avoiding short-term solutions that will prove unsustainable as climate change continues. It also implies continuing to support the various initiatives (scenario modelling, environmental indicators, early warning systems) that are trying to shed light on longer-term developments, despite the current shortcomings and huge challenges inherent in these methodologies.

Because climate-change impacts and hence successful adaptation strategies are specific to particular circumstances, there is a need for governments to concentrate on creating the right enabling institutional and policy environment for agriculture as a whole, whilst closely monitoring local developments and scientific advances. This will enable them to identify as soon as possible those winning strategies that might be generalised to form the basis for formalised policy measures, and to recognise opportunities for stimulating public goods and dealing with emerging externalities.

Countries are not in the same state of readiness. There is huge variation across and within countries in the adaptive capacity of agriculture and the resilience of farmers. Building resilience is not specific to climate change issues. In developing countries, it is hard to separate out core development challenges from climate change adaptation needs. This is not, however, an obstacle to action. On the contrary, climate change needs to be built into development planning at multiple levels, ranging from legislation and regulatory frameworks to the promotion of local coping strategies, and mainstreamed across large areas of policy.

Climate change will impinge on agricultural production, the natural environment and rural communities in complex ways. Many stakeholders are involved, and successful solutions

require contributions from various players. Partnerships are crucial, especially those between developing and developed countries, the public and private sectors, farmers and research scientists.

At international level, governments need to act together more purposefully in coordinating programmes related to these interlinked goals, allocating tasks over institutions effectively according to their comparative advantage in dealing with them.