Policy for climate change adaptation in agriculture

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Abstract

A number of Australian governments have established or planned programs to assist farmers in adapting to climate change. This paper considers a potential range of policy responses that may be appropriate for climate change adaptation in agriculture. It discusses the extent to which different policy responses may be justified on the basis of market-failure and the likelihood of positive net benefits. While research and extension have the potential to generate significant benefits, there is a need to carefully consider their rationales and emphases. Given the characteristics of climate change (slow, highly uncertain, small relative to climate variability, spatially heterogeneous), the value of information from research and extension to guide farmers' decision making about adaptation is likely to be low for decisions about farming practices and land uses. Such information would be more valuable for decisions that are larger and indivisible, such as land purchase or the decision to exit from agriculture. Policy options that appear likely to generate relatively large benefits are technology development, quarantine/eradication/containment of pests and weeds, and water market reform. This assessment is not consistent with the emphasis of existing government programs.

Introduction

Consideration of climate change policy in Australia has predominantly focused on mitigation of climate impacts (e.g. Garnaut 2008; Anonymous 2008). Yet, arguably, adaptation is much more important than mitigation. At present it appears that there may not be a very substantial global mitigation response, and even if there is, it is predicted that climate will continue to change to a significant extent (Garnaut 2008). Thus, in either case, adaptation is an unavoidable requirement. Current predictions indicate that Australian agriculture is likely to differ from most other developed countries in that it faces net costs from climate change (Garnaut 2008) whereas other developed countries may have net benefits (Tol 2002; FAO 2007; Antle 2009). Sound adaptation responses have the potential to reduce the costs (or, in some cases, increase the benefits) of climate change.

The importance of climate change adaptation has been noted in a number of reports (e.g. Garnaut 2008; Lim and Spanger-Siegfried 2004; Burton et al. 2006), including some that focus on agriculture (Ash et al. 2008; FAO 2007; Antle 2009). Some governments have already developed policies and programs in the area (see below).

The aim of this paper is to evaluate whether governments should intervene to facilitate farmer adaptation to climate change, and if so, why and how. It discusses a number of factors that influence farmers' management decisions. It explores a range of policy options that have been adopted or proposed or which could be adopted for addressing climate change adaptation in agriculture. It examines their likely justification, considering the nature of climate change in agriculture, and a set of accepted principles for assessing government intervention. It identifies those policy responses that may generate net benefits overall, and those which are not likely to.

Current Australian government thinking and action on adaptation

The debate about policy for climate change mitigation is prominent, multifaceted and controversial. It has tended to dominate the public debate, with climate change adaptation receiving relatively little public attention. Ironically, there may be greater scope to generate net benefits from adaptation than from mitigation, particular given the obvious difficulty of establishing effective international agreements that would substantially cut emissions of greenhouse gases (Brennan 2009; Nordhaus and Shellenberger 2009) and the technical difficulty of preventing climate change even if such agreements could be established. Thus, adaptation to climate change will be required irrespective of what happens in relation to policy for climate change mitigation.

The Australian Government House of Representatives Standing Committee on Primary Industries and Resources has been conducting an inquiry addressing:

- "Current and prospective adaptations to the impacts of climate change on agriculture and the potential impacts on downstream processing.
- The role of government in:
  - augmenting the shift towards farming practices which promote resilience in the farm sector in the face of climate change;
  - promoting research, extension and training which assists the farm sector to better adapt to climate change.
- The role of rural research and development in assisting farmers to adapt to the impacts of climate change."
  (http://www.aph.gov.au/house/committee/pir/australianfarmers/tor.htm, accessed 1 Feb 2010)

At the time of writing, the report from this inquiry is not yet published. A number of Australian governments have prepared, or are preparing, reports, policy documents or reviews on climate change adaptation, or have established programs to address it. Overall, the emphasis of these public interventions is on creating and distributing information. Nationally, the Council of Australian Governments (2007) agreed on a "National Framework for Climate Change Adaptation", which emphasises the need to build understanding and adaptive capacity, mainly based on strategies related to information provision.

A number of the 73 submissions to above-mentioned inquiry are from governments, including one from the Australian Government Department of Agriculture, Fisheries and Forestry, which states that,

> "The Australian Government's response to climate change adaptation in agriculture is therefore to focus on providing fundamental information and knowledge, and the decision support tools that will allow farmers and rural industries to manage the risks of climate change.

> This reflects the government's preference for markets to operate with minimal intervention, concentrating its role on situations where there is market failure, where there is a clear need to intervene to protect or maintain a public good, or where there is a high risk to assets of national significance." (DAFF 2009, p.2).

The state government of Victoria, Department of Primary Industries, has the "Victorian Climate Change Adaptation Program". "The aim in this research program is to increase the knowledge and capabilities of government, the agriculture sector and farming businesses to undertake sound and informed planning and policy decisions that maximise the benefits and minimise the economic, social and environmental costs of climate change" (Sandall 2009, p. 1). Essentially, it is generating, collating and distributing information about climate change and its predicted impacts on agriculture.

The South Australian government has prepared two reports discussing climate change adaptation in agriculture and laying out potential adaptation responses (Rebbeck and Dwyer 2007; Dwyer et al. 2009).

New South Wales has a "Greenhouse Plan" (New South Wales Government 2005) and has been developing a new "Climate Action Plan". The Greenhouse Plan includes research, monitoring, and a variety of "capacity building" measures, which are essentially information-related strategies.

In addition, there is a growing number of research programs related to climate change adaptation, including the Future Farm Industries Cooperative Research Centre, The Climate Adaptation Flagship of the CSIRO and the Bureau of Meteorology. The Australian Government's rural research and development corporations and companies (RDCs) also fund a range of research relevant to climate adaptation. They are explicitly guided by a set of government priorities, which include "building resilience to climate variability and adapting to and mitigating the effects of climate change".

Adaptation in agriculture

Adaptation by farmers is normal and is constantly happening. Over coming decades, farmers will adapt their production decisions in response to many different factors. As well as adapting to climate change, farmers will respond to changes in product prices and input costs, to new technologies and, possibly, to the requirements of climate mitigation policies. Other factors, such as demographic changes in their region, the availability of skilled farm labour, and change in the pattern of farm inheritance, will also probably influence their decisions (Kingwell and Pannell 2005; Pannell et al. 2006). Climate change in other parts of the world could influence Australian farmers via changes in market prices (FAO 2007). For example, Tol (2002) predicts that, once allowance is made for adaptation, the overall effect of climate change on world agriculture is likely to be positive. This suggests that international prices for agricultural products could fall, a change to which farmers would, of course, adapt.

Across a population of farmers there is a great deal of individual variation in the adaptation responses they make, even where they face the same exogenous changes. Their responses vary depending on individual farm characteristics and farmer preferences or goals. Advice from public agencies to farmers tends to be based on only a subset of the issues that are relevant to farmers, and to be somewhat generic. We would have to expect any advice on climate change adaptation to follow this pattern.

How might farmers adapt to climate change? By doing the same sorts of things they currently do in response to weather, markets and technology change. That is, by changing any or all of the following: their mix of farm enterprises; risk management strategies; usage of farm inputs; farm infrastructure; use of new technologies; mix of on-farm and off-farm income; business structure; the location where they farm; or whether they continue to farm at all.

With responses like these, most farmers are likely to cope with climate change within levels currently predicted. Antle's observation for U.S. agriculture is just as relevant to Australia: "experience suggests that that the U.S. agricultural sector is capable of adapting to a wide range of conditions and adopting new technologies as they become available. As long as the rate of climate change is relatively slow, we can expect the same to be true with future climate change." (Antle 2009, p.21). Indeed, with the lack of agricultural protection in Australia, its farmers are likely to be even better able to adapt than their U.S. counterparts.

Justifications for government intervention

Later I will discuss the potential use of a range of government policy measures in the light of standard rationales for government intervention. Here I outline those rationales. Circumstances in which government intervention can be justified from a social welfare point of view (rather than for political reasons) include the following.

To address information asymmetries or information failures

If government has information about climate change adaptation that (a) is not known to farmers, (b) would be of significant benefit to them if it was known to them, and (c) has a sufficient level of confidence behind it, then it could potentially justify spending money on extension activities, including education, awareness raising, training and support for rural networks. Many of the existing or planned government actions identified above would be motivated by this sort of rationale.

To address public good issues

It may be that there is information or technology that publicly funded research could beneficially provide that would not be provided by the private sector. Differences in public and private decision making may be due to economies of scale, non-rival goods or non-price-excludable goods (Randall 1987).

To address externalities

It may be that changes in climate result in an increase in negative externalities arising from farm land. For example, if the intensity of rainfall increases in a region, this may lead to increased movement of sediment into waterways, potentially justifying increased government action to reduce that impact.

Actions that farmers take to adjust to climate change may also have spin-off effects that result in external costs or benefits. For example, climate change may cause the public or private benefits of perennial-based farming systems to increase relative to annual-based farming systems, such that it becomes worthwhile for governments to provide positive incentives for adoption of perennials to capitalise on spin-off external benefits to the environment.

Figure 1 shows how this might occur, using the Public: Private Benefits Framework of Pannell (2008, 2009). The framework shows how the optimal policy mechanism depends on the levels of public net benefits and private net benefits (for a particular set of assumptions about lags to adoption, impacts of extension, and transaction costs, and assuming that policy makers require a threshold benefit: cost ratio of 2.0). Suppose that, prior to climate change, a strategy of switching from annual to perennial production in a particular location is located at point A, with somewhat positive public net benefits but large negative private net benefits. The recommended policy mechanism at point A is no action.

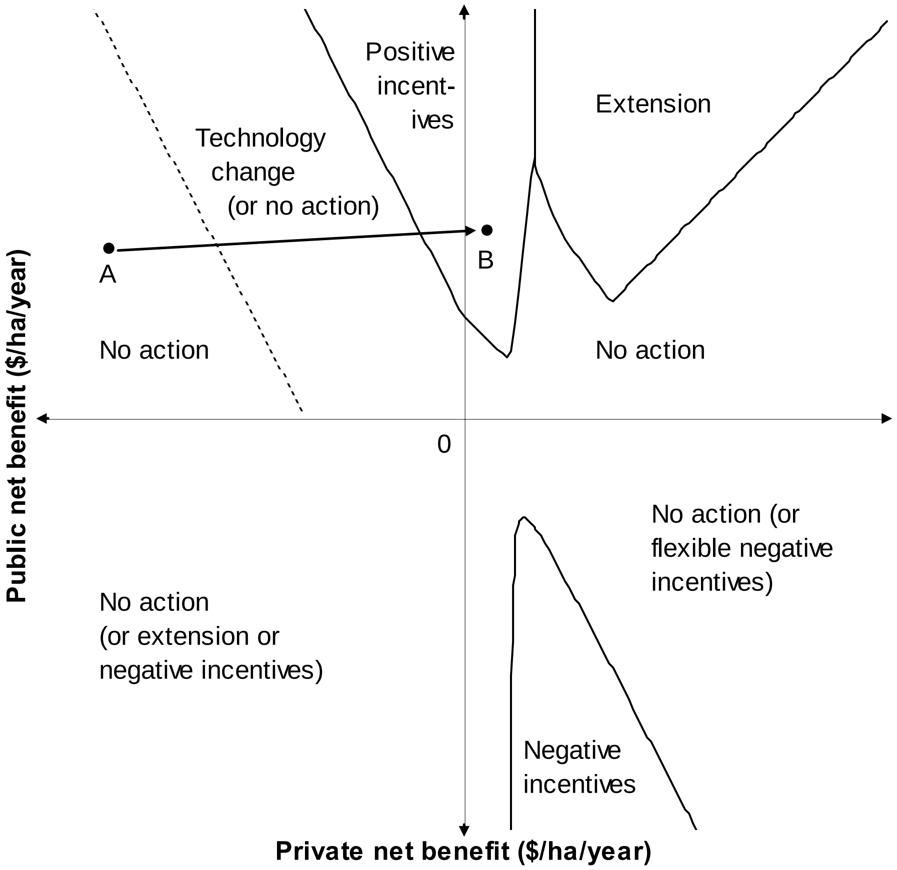

Figure 1. Public: Private Benefits Framework, showing how climate change might alter the justification for government intervention to promote on-farm actions that generate positive externalities (Source: based on Pannell 2008, 2009).

Following climate change, the private net benefits of those perennials increases so that the strategy moves to point B. At this new point, the recommended policy mechanism is positive incentives, to encourage landholders to adopt the perennials. Positive incentives are financial or regulatory instruments that potentially include polluter-pays mechanisms (e.g. command and control, pollution tax, offsets), beneficiary-pays mechanisms (e.g. subsidies, conservation auctions and tenders), and mechanisms that can work in either way depending on how they are implemented (define and enforce property rights, such as through tradable permits) (Pannell 2008).

For interventions intended to address information failures, public goods or externalities, an essential additional criterion is that the overall benefits of the intervention should outweigh the costs. Given the characteristics of climate change (see below), this becomes an important limit on the justification of a number of the proposed policy responses.

Addressing issues of disadvantage

Governments use a variety of mechanisms to protect people from hardship or disadvantage. If climate change causes hardship for certain farmers, government intervention to protect their welfare may be justified.

One of the most prominent welfare-related policies in agriculture has been drought policy. Although the National Drought Policy of 1992 was based on a philosophy of self reliance and risk management, governments have repeatedly provided *ad hoc* assistance to drought-affected farmers, ostensibly for welfare reasons (Botterill 2003). With predictions of increasing drought frequency in Australia (CSIRO 2007), pressures on drought policy may intensify.

Like drought policy, “rural adjustment” policy in Australia has a troubled and controversial history (e.g. Musgrave 1990). Elements of this policy have, at times, been intended to assist struggling farmers to transition out of agriculture, or to assist viable farmers to ride out short-term difficulties so that they can remain in agriculture (Cockfield and Botterill 2006). These interventions might have dual benefits, in reducing hardship, as well as increasing the economic efficiency of agricultural industries. If climate change causes an increase in the number of farmers facing hardship, an increased emphasis on rural adjustment policy might potentially be justified.

These examples highlight that, even if a government intervention is justified to assist farmers adapt to climate change, it does not necessarily follow that a new policy mechanism or program is required. Existing government program for family welfare or drought may potentially provide appropriate support (provided that they are implemented as intended and not overwhelmed by *ad hoc* political responses). Similarly, existing government research bodies and research funders may be able to provide new research needs.

Characteristics of climate change

Before considering the merits of various policy responses, it is worth noting some of the distinctive characteristics of climate change that will influence the benefits and costs of those responses. The following four features of climate change are of particular relevance.

Climate change is slow

Notwithstanding constant media attention to current extreme weather events and speculation that they are caused by climate change, the Intergovernmental Panel on Climate Change (IPCC) predicts that climate change will occur slowly over the coming century and beyond (IPCC 2007). Slow onset of climate change has a number of implications. It means that farmers will have time to adapt as required. It means that there is time to develop farming technologies, plants and systems that are better adapted to the new climate[1].

Climate change is highly uncertain

McKibbin and Wilcoxen (2002, p.37-38) propose that, "Uncertainty is the single most important attribute of climate change as a policy problem." The uncertainties are pervasive, large, and unlikely to be resolved.

To illustrate the degree of uncertainty facing agriculture when it comes to climate change adaptation, Figure 2 shows a chain of uncertain variables and relationships influencing the merits of future farm management alternatives. Starting at the top of the figure:

- *Level of economic activity* over the coming century is highly uncertain.

- The success of future efforts to develop new *Energy technologies* is highly uncertain.

- The existence and effectiveness of *Global climate policy* over the coming century are uncertain.

- Even if the above three factors were known with certainty, there would still be uncertainty about future levels of *Greenhouse gas emissions*. Given that these three factors are far from known with certainty, combined uncertainty about greenhouse gas emissions is very high.

- There is uncertainty about the relationship between greenhouse gas emissions and *Global climate*. For one thing, factors other than greenhouse gases also factor affect climate (e.g. volcanic activity). The correlation between carbon dioxide concentrations and global average temperatures over the past century is only moderate. Historically, climate has changed without changes in atmospheric carbon dioxide concentration, or has changed prior to changes in carbon dioxide (Monnin et al. 2001). Prediction of global climate depends solely on computer models, which, of course, are highly imperfect. Different computer models differ significantly in their predictions (IPCC 2007).

- Predictions of *Regional climate* are dependent on predictions of global climate, and are considered to be more uncertain than the global predictions on which they are based (Mitchell and Hulme 1999).

- *Local climate* is imperfectly related to regional climate. Predictions are provided at the regional level, but not at the local level.

- Farm production and farm management decisions depend on *Local weather,* which is uncertain in any period, even if local climate were stable and fully understood.

- As well as weather, farm management will be influenced by a host of other factors, including *Market prices*, the availability of *New farming technologies*, and the

[1] Given that farmers are unlikely to adopt new practices until climate change has proceeded to the extent that those practices are beneficial to adopt (Pannell et al., 2006), benefits from R&D could be very drawn out.

requirements for agriculture to comply with *Local climate policy*, each of which is also subject to considerable uncertainty, especially on a decadal time scale.

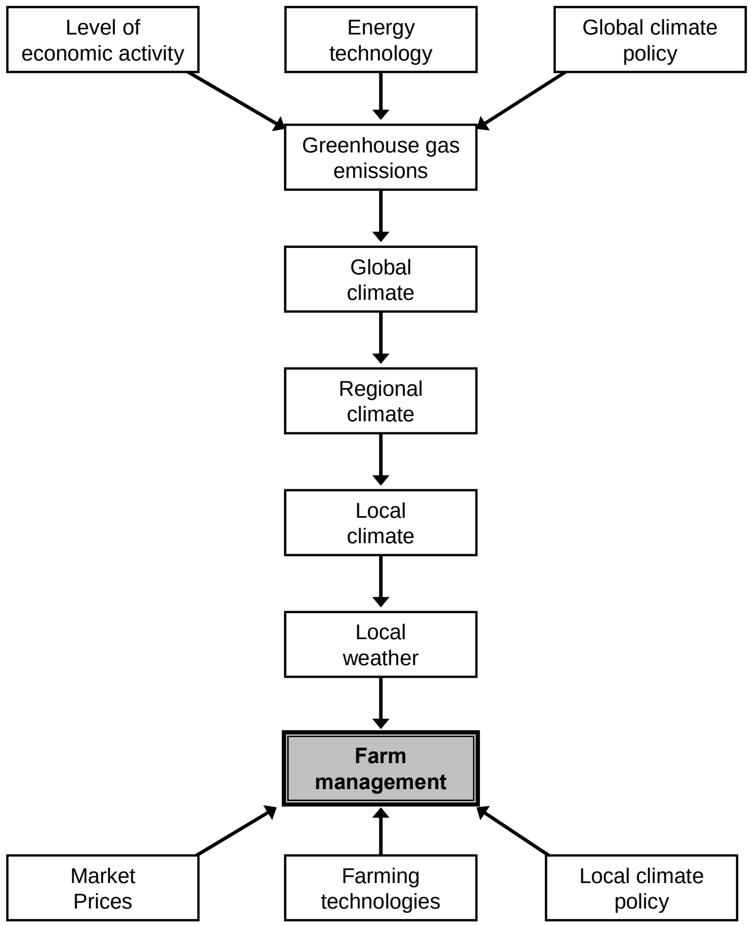

Figure 2. Climatic and other factors influencing farm management.

It is true that, over the next two or three decades, uncertainty about climate change is lower than for later in the century (CSIRO 2007), but in that shorter time frame, if climate predictions are accurate, the degree of climate change will be relatively minor, and adaptation to it will not be problematic. If climate predictions are not accurate, this further accentuates the level of uncertainty affecting the issue.

For most Australian farmers, precipitation is a much more important driver of farm incomes than is temperature. It is believed that there is greater uncertainty in the prediction of rainfall than of temperatures. For example, CSIRO (2007) observes that, "Regional precipitation variations can be quite sensitive to small differences in the circulation and other processes," and that, "it will not be possible to make definitive statements on the direction of precipitation change in many cases." (CSIRO 2007, p. 65).

Uncertainty is important because it affects the value to farmers of predictions about future climate change, the expected benefits and costs of pre-emptive adaptations, and the ability to interpret information from observations of climate and weather in the short term.

Climate change is small relative to climate variability

Especially in the short term, the predicted degree of climate change is small relative to year-to-year weather variations or medium-term cycles. Even in the long term, the predicted degree of climate change would not stand out from historical weather patterns when viewed at time frames of, say, a decade or less. This adds to the difficulty of interpreting information from observations of climate and weather, and so will delay the ability of farmers to reach confident conclusions about climate change. Conceivably there may be a threshold of CO2 concentration beyond which climate changes markedly, making it easy for farmers to detect climate change at that time, although existing models do not predict this.

Climate change is spatially heterogeneous

Climate change is predicted to be quite different in different parts of Australia (CSIRO 2007), to the extent that it may be adverse in some areas but beneficial in others. This interacts with uncertainty and slowness to increase a farmer's difficulty in interpreting the extent to which climate change is actually occurring at his or her location.

Policy options

Many options for government to support climate change adaptation in agriculture have been proposed. A broad selection of proposals is collected in Table 1. The following subsections will discuss these options, including whether they are likely to be advisable strategies given the earlier discussions of the requirements for government intervention to be justified, and given the characteristics of climate change. The question of whether these options should be implemented pre-emptively or after climate change has occurred is also considered.

Extension

A number of the options in Table 1 involve delivery of information to farmers: options 2, 3, 4, 5, 6 and 9. This is consistent with what Australian governments are actually doing, as noted earlier. Assuming that governments have better information about climate change than farmers do, this strategy may generate benefits for some decisions. However, there is a need to carefully consider the rationales and emphases for extension to deliver information.

For information to have value to decision makers, it needs to lead to changes in management decisions. For this to happen, the decision maker needs to have sufficient confidence that the information is accurate, and the information needs to cause a reassessment of management options such that an option that did not appear worth adopting now does appear worth adopting.

In my judgement, in most cases, farmers would be highly ill-advised to alter their short-term farm management (e.g. crop choices, input usage, hedging) in response to predictions of climate change prior to those changes actually occurring. Reasons for this have been identified earlier: the huge uncertainty surrounding predictions of climate change; the slow rate of climate change, which means that there will be time to adapt later; the fact that weather and climate are not the only factors that drive farmer decision making, and that responses to predicted climate change may lead farmers in directions that conflict with more important changes in response to other factors; and the fact that, in their year-to-year management, farmers respond to weather, not climate, so that, for some decades at least, changes in climate will be small relative to annual variations in weather. Furthermore, farmers know that they are much better able to judge which management strategies best suit their own farms and their own goals than are distant researchers or government officers. For this reason, while information about climate *per se* may be of value, information about the optimal farming strategy is of limited value.

Table 1. Options for government actions to support climate change adaptation in agriculture.

1.	Collect information about climate change (e.g. data bases of weather information, analysis of trends in weather, regional predictions of climate change).
2.	Communicate the information to stakeholders in agriculture.
3.	Evaluate and extend the benefits and costs of farm-level adaptation strategies.
4.	Extension to encourage adoption of new technologies (e.g. water-saving technologies for irrigators).
5.	Enhance landholders skills and capacities (e.g. to deal with uncertainty, to manage reduced water availabilities).
6.	Help agribusinesses identify where changes may be needed to their longer-term strategies.
7.	Undertake analysis and planning to determine which areas may no longer be climatically suitable for current agricultural activities, considering climate predictions, social and economic vulnerability, adaptive capacity of farmers, likely availability of new technologies, governance systems, and policies such as structural adjustment.
8.	Research to develop plant or animal types better suited to the predicted climate. Enhance genetic resource infrastructure to support this research.
9.	Provide technical support during transitions to new systems that are more adapted to the emerging climate.
10.	Provide financial support during transitions to new systems that are more adapted to the emerging climate.
11.	Monitoring and quarantine services to contain pests, diseases and weeds that are suited to the new climate.
12.	Improve water distribution systems (e.g. reduce leakage and evaporation).
13.	Construct new infrastructure, such as dams.
14.	Ensure that there are efficient and effective water markets in place to facilitate efficient adaptation.

Sources: Adapted from Ash et al. (2008), Stokes and Howden (2008), Howden et al. (2007), Smith and Lenhart (1996), COAG (2007).

Note: Some publications on this topic list policy options that seem of peripheral relevance to climate change adaptation. The list in this table is limited to directly relevant option.

Some authors are optimistic about the potential for farmers to act pre-emptively in response to predictions of climate change (e.g. Ash et al. 2009), but the discussion above highlights that, in many cases, it is unlikely to be in farmers' interests to do so. The high uncertainty about future climate combined with slow onset of climate change means that is little benefit in either government or farmers attempting to evaluate many types of adaptation strategies for farmers in advance of climate change. For most farm-management decisions, it is hard to see how pre-emptive changes could reduce future risks. At any point in time, farmers will use those practices that suit current perceived conditions. Farmers would respond to change as it occurred, rather than responding to predicted changes. Even for adaptations that would take some years to implement, the pace of climate change is predicted to be easily slow enough for pre-emptive action to be unnecessary in many cases.

Exceptions to this generalisation may include large indivisible decisions. These might include, for example, decisions about whether to stay in farming, decisions about where to farm, and decisions about the placement of a farm house given a possible increased risk of bushfires. Another exception could be changes in management that would help with climate adaptation but which are also beneficial in the current climate. While these practices may be adopted rapidly, this does not really constitute a pre-emptive response to climate change because they would be adopted for their benefits under current climate conditions.

An area of research and extension for climate adaptation that may be beneficial is extension to advise and support farmers who are in the learning process involved in adoption of new farming technologies, such as new perennial crops and pastures (option 9), which might be completely novel, or just new in a regional context. This policy option would be beneficial in cases where the opportunity or need for change in farming practices would be relatively clear. If this opportunity or need was driven by climate change, then this implies that climate change would be well progressed. Like a number of other policy options discussed later, it would be difficult (and probably unwise) to separate out climate change as a driver of change in this case. There are many factors that drive changes in farming practices (e.g. drought, markets, new technologies), and climate change would need to be considered within the context of all of those things. If climate change predictions are accurate, then climate change would be a minor contributor to such changes in land use for some decades.

Research and extension to examine alternative drought-tolerant farming systems in regions that are currently drought stricken have been initiated in recent years. The benefits of this as a policy response depend on whether the observed drought conditions are predominantly due to climate variability or are in fact the first stage of long-term climate change. While the latter may be possible, it is worth noting that such a dramatic step change in climate would be at odds with all quantitative climate predictions. If the observed drought conditions are temporary, the benefits of this policy option depend on how long they will last, how frequently they will occur in future and on the on the performance of the alternative drought-tolerant farming systems when applied in non-drought circumstances.

The proposition that farmers need assistance to develop skills to deal with uncertainty (option 5) seems naïve given the extent of uncertainty that farmers deal with routinely and, generally, with success. Theoretical techniques for decision making under uncertainty, while involving high costs in terms of farmer time, seem highly unlikely to outperform the intuitive decisions of an experienced farmer (Malcolm, 1990). Musgrave (1976) argued that, despite a strong emphasis on analysing uncertainty in farm management research in the 1960s and 1970s, this effort did not lead to useful applied techniques. Anderson and Hardaker (1979) suggested that the scope for intuition will always be high in farm management.

Planning

Ash et al. seem too optimistic about the potential for governments to plan (and thereby enhance) the process of adaptation to climate change. “Transformational change to address these climate changes need to be developed with a full systems understanding of the climatic, economic and social forces at work” (Ash et al. 2009, p.4). The capacity for planning implied in this statement is highly demanding. The poor track record of governments making planning decisions about complex environmental problems, such as salinity (Pannell and Roberts 2010), does not give confidence that such a difficult planning task is likely to be delivered successfully, even if it made sense theoretically. In any case, the previous discussion about the uncertainty of climate change and the long time scales involved indicate that the benefits of planning may be limited in many circumstances.

Given the slow onset of climate change, for many issues, it may be possible to plan in an adaptive way as climate change unfolds. For example, if drought conditions in the Murray-Darling Basin continued for another 10 years, this might give confidence that climate change was a significant contributor, rather than it being predominantly due to climate variability. Changes in government plans for infrastructure development, regional land use or environmental interventions may then be justified.

Research and development

Options 1, 3, and 8 from Table 1 relate to various forms of research and development. I have argued above that *ex ante* assessments of the benefits and costs of farm-level adaptation strategies (option 3) are likely to be of little value to farmers. General information about climate change trends and predictions may perhaps be of some value to them, in that it may prime them to be alert to the potential need for adaptive responses and prompt them to trial new technologies and systems, although I expect that most farmers would respond to actual weather and climate changes *ex post* with or without provision of such predictive information.

By contrast, option 8 provides a strategy that could potentially provide major benefits to farmers by providing them with additional and superior adaptation strategies than would otherwise have been available. It involves development of improved plant or animal species or varieties and novel farming systems that may be better adapted to changed climate conditions. Given the very high uncertainty we have about future climate conditions, such research needs to increase resilience across a range of potential climate conditions, rather than attempting to respond to any particular climate prediction. To be adopted quickly, the technologies produced by this research will need to outcompete current options under current climatic conditions, and to avoid being disadopted they will need to outcompete other options under future climate conditions. Many plant improvement efforts in Australia have stated objectives of improving drought tolerance and water-use efficiency. which will deliver general benefits as well as some adaption to climate change. The main research organisation undertaking this role in a systematic way in Australia is the Future Farm Industries Cooperative Research Centre. Notably, the perennial farming systems it is developing are potentially of benefits to farmers with or without climate change. Other government programs for climate change adaptation put little emphasis on this strategy.

A feature of this type of research is that it has long lead times. It may take 10 to 20 years for commercially viable varieties of novel plant species to reach the stage of widespread availability. Substantial changes to known species allowing novel applications (adaption to a new regional setting) can usually be achieved more rapidly, but rarely in less than a decade. However, given the predicted slowness of climate change, this is not a severe problem. Notwithstanding the long time frames that are often required for this type of research, it does have a strong track record of delivering successful new crops and pastures in Australia and elsewhere (e.g. new varieties of major crops, the development of canola and white lupins as major crops, and a range of new pasture species including annual and perennial grasses, legumes and shrubs)

Research to examine alternative drought-tolerant farming systems in drought stricken regions, or research into the performance of existing technologies that are novel in the target region were discussed above, in the extension section.

Incentive mechanisms

Option 10 involves farmers receiving public funding to influence their decisions about adapting to a changed climate. Figure 1 illustrates that there may be some projects such as project B, where such a payment could be justified on the basis that it results in high public net benefits (i.e. positive externalities), such as benefits to biodiversity or a waterway. These public benefits may or may not be related to climate change. For example, climate change may make little or no difference to the public net benefits of a farming practice but increase the private net benefits such that an incentive mechanism becomes warranted (as in Figure 1).

Incentive payments should not be used as a blanket measure. They need to be targeted to projects that had passed a comprehensive and rigorous assessment showing that they did indeed generate high public net benefits and an appropriate level of private net benefits. If they were used to promote adoption of projects far to the right of point B, the funds would be wasted as the project would be adopted even without payments due to its high private net benefits. Projects too far to the left of point B would require payments that were too large to be worthwhile – the payments would exceed the public net benefits.

Whether incentive payments were justified would be independent of whether the management changes involved were beneficial from a climate adaptation point of view. What matters is their private net benefits overall, and their public net benefits. Thus, a separate program of payments to promote climate adaptations *per se* would not be justified. Any payments should be made as part of a general environmental management program, which should not be targeted specifically to climate change adaptation. It should target the best-value public investments, irrespective of considerations of climate change adaptation.

Quarantine, eradication and containment

Climate change may result in changes in the spatial ranges over which some weeds or pests are well adapted, creating a risk of weed or pest spread into new environments. Given that prevention of weed or pest spread can generate substantial external benefits (Grimsrud et al., 2008), and given that such spread is largely irreversible, it can make sense for governments to intervene, as in option 11. However, as with incentive payments (above), it is hard to see why a special program particularly linked to climate change would be required. It would be preferable to expand the budget for existing programs and relevant agencies to accommodate the increased need for quarantine, eradication and containment activities.

A potential climate-related element of this could be research to identify particular weeds or pests that pose high risks of spread given new climate conditions. For analysis at the level of individual species, it would make sense for this mainly to be conducted *ex post* (i.e. after climate change, but before pest spread), so that it reflected actual climate change rather than highly uncertain future climate change. Given climate change's high uncertainty and slow onset, *ex ante* assessment of individual species would not be of high value. On the other hand, *ex ante* analysis of this issue may help to evaluate the overall need for additional resources for quarantine, eradication and containment, which would need to be in place prior to the increased threat of pest spread.

Infrastructure

Climate change may prompt a need for investment in infrastructure, as in options 12 and 13. In relation to agriculture, the most commonly discussed type of infrastructure in this context relates to water storage and delivery. As with a number of other options discussed above, such investment may be justified even without climate change. For additional investment to be justified, beyond what would be needed already, climate change would need to lead to an increase in the shadow price of water. This could occur through reductions in the supply of water (e.g. due to reduced rainfall) or increases in demand (e.g. due to higher temperatures).

Again, given the uncertainty about climate change, a responsible government would not make additional climate-motivated investments until after climate change had occurred, to avoid the risk of making poor investments. Challen (2000) emphasised the quasi-option value of deferring decisions about investment in water infrastructure until improved information is available. This quasi-option value arises due to the irreversible nature of the investment.

Water market reform

Prior to investing in water infrastructure, it may be preferable to improve the efficiency of water markets, such as through reducing existing limits on trade, and developing improved systems to facilitate inter-regional trade, and trade between agriculture and the domestic water sector. This too makes sense even without climate change, and indeed has been a focus for much debate and reform over the past two decades. Conceivably, climate change may increase the unmet gains from trade that are currently inhibited by inefficient water markets, although I suspect that this increase is likely to be small relative to existing unmet gains.

Discussion

Table 2 provides a summary of the key conclusions and observations about each of the policy options. As noted earlier, the main activities currently being undertaken or planned by Australian governments are in the areas of extension or research to provide information for farmer decision making. My conclusion is that, if the aim is to inform farmers about the merits of existing technologies as pre-emptive adaptation strategies, this policy options is not likely to generate large benefits. While the approach potentially addresses issues of market failure, it probably would fail a benefit-cost test because a rational farmer would not respond to the information provided. Given the characteristics of climate change (slow, highly uncertain, small relative to climate variability, spatially heterogeneous), the value of *ex ante* information provided to farmers would be very low for many types of farm management decisions, at least in respect of its contribution to improved management decisions related to pre-emptive adaptation. At best, it might contribute to large strategic decisions, particularly those that are indivisible, such as whether to remain in farming or which region to buy a farm in, but even there the very high uncertainty around regional predictions would limit the value of such information. Extension is likely to provide worthwhile benefits after climate change has actually occurred to the extent that it can be detected with some confidence and farmers are responding by adopting new practices. In coming decades, adoption of new practices due to climate change *per se* is unlikely to be a major feature of agriculture, unless existing climate change predictions are dramatically wrong.

There are three strategies that appear likely to provide worthwhile and widespread benefits in relation to climate adaptation in agriculture: research and development to create new technology options; quarantine, eradication and containment; and market reform. It is notable that each of these strategies is likely to generate substantial net benefits even in the absence of climate change, and indeed each has been subject to attention and resources independent of the climate change issue. They may warrant some increase in resourcing as a result of the expectation that climate change will occur, but climate change is far from being the only reason why they would be of benefit. At the moment, none of them features as a prominent element of climate adaptation programs or plans in Australia.

Two strategies seem likely to generate net benefits in very targeted situations: incentive mechanisms and infrastructure. As a blanket measure, incentive mechanisms to encourage farmers to adapt their farming practices in particular ways would be a very bad policy. However, highly targeted incentive measures may help to reduce external costs arising from climate change, or to capitalise on opportunities to increase external benefits. Such incentive payments may not necessarily encourage changes to practices that are beneficial to farmers. Indeed, they may be designed to inhibit the extent of climate adaptation that farmers undertake, in order to reduce external costs associated with the practices that farmers would wish to adopt.

Some commentators have emphasised the importance of farmers and policy makers taking pre-emptive adaptive actions (e.g. Burton et al., 2006; Ash et al. 2008). However, my assessment is that the scope for pre-emptive analysis is limited. It may be warranted for technology development provided that the technologies being developed are sufficiently flexible or provided that the research generates a sufficiently wide range of technologies to be able to accommodate a range of potential future climates. Pre-emptive action is relevant to quarantine, eradication and containment activities, in that these capabilities need to be operating prior to pest spread in order to prevent that spread. For the other options, either the options themselves are not warranted, or their pre-emptive application is not necessary.

This assessment raises doubts about whether specialised public programs focusing on adaptation to climate change in agriculture are justified. The three policy options that are most likely to generate positive net benefits (technology development, quarantine, water market reform) are all options that will probably generate benefits irrespective of the existence of climate change, and there has been investment in all three areas primarily for reasons other than climate change adaptation. In my judgement, the most valuable role for a climate change adaptation program would be to examine whether existing resources in these three areas is sufficient to meet the needs of agriculture for adaptation to climate change, and to facilitate the allocation of additional resources to them if appropriate. In addition, the long-term nature of technology development opportunities highlights the need to provide continuity of funding beyond the 2-5 year funding cycle in common use. Notably, the current emphasis by Australian governments on "providing fundamental information and knowledge, and … decision support tools" is a concern, especially the expectation is that this information and tools will assist farmers to adapt their farm management practices pre-emptively.

The issue of disadvantage and social welfare has not featured in the discussion of the policy options. Conceivably, any of the policy options discussed could contribute to reducing hardship and increasing the welfare of farmers. However, I am not convinced that these policy responses could be justified on that basis. Rather, welfare support is better met through welfare programs, provided that they are designed in consideration of the circumstances of farmers, such as high wealth but low income in some years.

Table 2. Summary of conclusions about policy options for adapting to climate change in agriculture.

Policy option	**Potential justification**	**Positive net benefits?**	**Justified without climate change?**	**Pre-emptive action justified?**
Extension	Information failures, information asymmetry, technology transfer	No, except to support transition to new farming systems.	n.a.*	No
Planning	Public goods, externalities	Unlikely	n.a.	Limited
Research and development	Public goods	Very limited for information Yes for technology development	n.a. for information Yes for technology development	Yes
Incentive mechanisms	Externalities	Potentially in very targeted locations	Some that would not be justified without climate change may become justified	Potentially in very targeted locations
Quarantine, eradication and containment	Externalities, public goods	Yes	Yes, although climate change may justify a larger budget	Yes
Infrastructure	Public goods	Perhaps in certain locations	Yes, to a large extent	No
Water market reform	Improved market efficiency	Yes	Yes	Not for reasons of climate adaptation, but it should happen anyway

*n.a. = not applicable. The details of this policy option are specific to climate change and would not be relevant in its absence.

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