Climate change, agricultural growth and poverty reduction

Draft, May 2007

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3

Background and Acknowledgements

Over the last few years, our understanding and certainty about how the climate is changing and the possible impacts this could have has grown hugely. In response there are increasing efforts to 'mainstream' what we know about these impacts into development policy and planning processes. Given the fundamental links between agriculture and poverty reduction and agriculture's dependence on the climate, understanding in more detail about linkages between agricultural policies and climate change is important and urgent.

This paper is one of a series of five outputs produced under a small project for the Renewable Natural Resources and Agriculture Team of the UK Department for International Development (DFID). The objective of the project was to identify the implications of climate change for key areas of DFID's Agricultural Policy and the Renewable Natural Resources and Agriculture (RNRA) Team portfolio and to produce a series of practical outputs to assist the RNRA team in programme implementation and communication.

The five papers are as follows:

1. A rough guide to climate change and agriculture
2. Climate change: Implications for DFID's Agricultural policy
3. Climate change, agricultural growth and poverty reduction
4. Climate change and agriculture: Agricultural trade, markets and investment
5. Access to assets: Implications of climate change for land and water policies and management

The papers are written by a team of researchers from ODI's Rural Policy and Governance and International Economic Development Groups. The authors are grateful to DFID for their funding of this project. The arguments presented in the papers are those of the authors and do not necessarily reflect the policy position of DFID.

Table of Contents

1. Executive Summary 4
2. Introduction 7
3. Key debates in agricultural policy 9
   3.1 Small farms versus large farms 9
   3.2 Cash crops versus food crops 10
   3.3 High-potential versus low-potential areas 11
4. Modelling the impact of climate change on agriculture and agricultural growth 13
   4.1 Impacts on agriculture 13
   4.2 Impacts on agricultural growth 15
5. Implications of climate change for agricultural policy debates 18
   5.1 Small versus large farms 19
   5.2 Cash crops versus food crops 21
   5.3 High potential versus low potential 22
6. Policy implications and conclusions 25
7. References 29

Boxes

Box 2.1: Five connections between climate change and agricultural productivity 8
Box 4.1: Likely impacts of climate change on agriculture 13
Box 4.2: Food first, agricultural growth second 15
Box 4.3: Modelling techniques 16
Box 5.1: Definitions 18
Box 5.2: Small farmer responses to climatic and other risks in South Africa 21

Abbreviations

CDM Clean Development Mechanism
IPCC Inter-governmental Panel on Climate Change
ODA overseas development assistance
RRAs Remote Rural Areas

1. Executive Summary

The contribution of agriculture, specifically growth in agriculture, to poverty reduction is increasingly recognised by donors and developing country governments. Whilst different agricultural growth policies have different visions of precisely how agricultural growth contributes to poverty reduction, there are a set of critical debates regarding:

(i) under what circumstances small or large farms are likely to offer optimal combinations of growth and poverty reduction in agriculture;

(ii) whether investments in high potential or low potential areas offer the best prospects for growth and poverty reduction in agriculture, and;

(iii) whether a focus on cash or food crops will offer the best prospects for growth and poverty reduction in agriculture.

This paper explores what we know about the impact of climate change on each of these three debates and, more broadly, on agricultural growth and poverty reduction. It then reviews what the subsequent implications for the agricultural policies of donors and developing countries might be.

Whilst climate change is recognised as a significant potential barrier to achieving agricultural growth, debates about climate change and agriculture tend to take place somewhat separately from prevailing debates about patterns of agricultural growth and poverty reduction. There are three main approaches to modelling impacts of climate change on agriculture: *agronomic*, *agroeconomic*, and *Ricardian*.

Agronomic and agroeconomic models prevailed in the 1990s and are relatively good at identifying likely patterns of crop yields but weaker at incorporating likely adaptation by farmers to changing climate and more extreme weather events. More recently, Ricardian models have enabled the incorporation of autonomous adaptation by measuring the contribution of different factors (land, labour, infrastructure etc.) to farm productivity and performance. Evidence is now slowly emerging about the potential impacts of climate change on small and large farms, high and low potential areas, and on cash and food cropping. However, the evidence base remains thin, geographically patchy and still focuses more on the impacts on agriculture than the impacts on agricultural growth.

In the case of large and small farms, there are two prevailing views. The first is that small farms have shown remarkable resilience and capacity for adaptation in the face of significant environmental (and economic) change relating to agriculture. Climate change is just an additional challenge to which small farmers will respond. The second view is that small farms are able to cope with risk and uncertainty in the short-term, for example by drawing on temporary measures such as entering the casual labour force or delaying planting, but that they cannot adapt in the longer-term unless they can access state or private initiatives to support adaptation (micro-insurance, credit, new technology, market information). In contrast, large farms are more likely to benefit from many of the current government programmes that will enable risk-taking (such as producer subsidies, tax breaks, market information systems and export support) and from new modes of transportation required by mitigation policies and changing consumer demands. Timescales are important and whilst small farmers have good, autonomous adaptation potential in the short-term, supporting small farmer adaptation through longer-term policies is more difficult.

The evidence about cash and food cropping is scant, particularly because often models (agronomic, agroeconomic and Ricardian) tend to focus on grain production. However, it is known that coffee and other perennial crop producers find it more difficult to respond to changing temperature and precipitation patterns and price signals because of the associated costs of uprooting, replanting and waiting associated with change. Cash crop producers can also be mal-adaptive as in the face of climate change they respond in ways which reinforce the problems they face from climate change rather than reduce them. Examples of this include continuing to produce crops that are unsustainable in the long-term but in the short-term can generate high incomes. Food crop producers' adaptation strategies are concerned with reducing risk. They withdraw from markets and spread risk by staggering planting, diversifying their range of crops and switching to drought-resistant crops. In the future, carbon sequestration may create a new dimension in cash cropping whereby farmers produce not solely for sale in commodity markets but also for income from carbon markets. This may imply a shift towards tree crops and/or agro-forestry, or possibly new cropping systems, such as reduced tillage.

In terms of high and low potential areas, the prevalent view is that low potential areas are highly vulnerable to climate change and significant investments will be needed to maintain production there. There are two alternative sets of policy responses in this view. One is to invest in agriculture in low potential areas as a way of sustaining vulnerable households – agriculture as a social investment. A second policy response is to build on existing risk responses by farmers – these include supporting diversification into the rural non-farm economy and enabling migration and mobility through good land administration. An alternative view to the prevalent focus on low potential areas uses evidence about the impacts of climate change on rain-fed single cropped areas versus double or triple cropped areas in the developing world. Evidence has shown that the greatest losses in the developing world will be in double or triple cropped areas. Where national level food supply is at risk, or where export earnings are threatened, governments may choose to focus on protecting existing high potential areas in order to protect food supply and export income rather than investing in marginal areas.

In conclusion, the paper finds that climate change is not currently the greatest challenge in achieving agricultural growth. However, the climate change impact and adaptation debate remains largely disconnected from these other challenges and from existing agricultural policy and programmes. This suggests a need for improved coordination of research and policy between climate change modellers, agricultural economists and agricultural policy-makers.

In the future, mitigation in developing countries will be an emerging issue. At present, most mitigation policies and programme, for example, the Clean Development Mechanism (CDM), do not include agricultural practices. However, there will be an increasing need to measure the carbon balances of both agricultural and wider development programmes and create synergies between mitigation and adaptation programmes in the agriculture sector.

Whilst the evidence base is still patchy, it is possible to draw out policy implications. However, it is important to note that current policy challenges – for example improving access to markets, information (weather, prices) and technology – should remain at the top of the agenda. Notwithstanding increases in extreme weather events, the longer-term impacts of climate change will probably not be felt severely for at least another two decades (IPCC 2007). This provides a window of opportunity to invest in agricultural growth, stimulate linkages and multipliers in the wider economy and enable farmers to become more resilient.

2. Introduction

The importance of agriculture in development is widely recognised and although overseas development assistance (ODA) in agriculture has fallen over the last few decades, recent policy statements from various donors, and the fact that the World Development Report (WDR) 2008 will focus on agriculture, suggests renewed interest in the role that agriculture can play in poverty reduction. The focus of most recent policy statements about agriculture by both donors and governments level has been on the importance of agricultural growth (DFID 2005, OECD POVNET 2006, Government of Malawi 2006 and IFAD 2007).

In each of these cases, the identified pathways by which growth in agriculture will contribute to poverty reduction are different. DFID (2005) argues that increased productivity, in combination with lower food prices, will provide increased incomes for net producing farm households whilst providing cheaper food for urban dwellers and net consumers of food in rural areas. In contrast, IFAD in Malawi (see IFAD 2002 and 2007 for broader policy statements) have argued for higher producer prices to support the incomes of small farmers. The policy positions that emerge from these alternative perspectives are largely an outcome of policy-makers' views on three specific debates:

- under what circumstances small or large farms are likely to offer optimal combinations of growth and poverty reduction in agriculture;
- whether investments in high potential or low potential areas offer the best prospects for growth and poverty reduction in agriculture, and;
- whether a focus on cash or food crops will offer the best prospects for growth and poverty reduction in agriculture.

It is also recognised that there are significant challenges or obstacles to achieving growth in the agricultural sector including

- declining ODA to the agricultural sector;
- long-term degradation of the natural resource base;
- poorly functioning and highly volatile markets, and;
- changing value chain governance that makes it difficult for small farmers to participate on good terms in supply chains.

Climate change raises an additional challenge to the agricultural sector (see below) and agriculture receives significant attention in climate change discourse and research because:

- output in the agriculture sector is heavily dependent on climate (see Box 1);
- agriculture can contribute a significant amount of total global CO2 emissions[1] but can also play a role in moderating global warming, and;
- agriculture will play an important role in debates about adaptation to climate change.

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[1] Agriculture, in combination with deforestation, accounts for nearly one third of global greenhouse gas emissions (Fritschel 2006)

Box 2.1: Five connections between climate change and agricultural productivity

1. Average temperature increases
2. Changing rainfall amounts and patterns
3. Rising atmospheric concentrations of CO_2
4. Pollution levels (for example, tropospheric ozone)
5. Changing climatic variability and extreme events

Source: USEPA (2006)

There is a rapidly emerging literature about the impact of climate change on agriculture and adaptation by farmers, most of it in journals, with a focus on climate change and on natural resources. However, debates on the climate change agenda regarding future adaptation in the agricultural sector appear to currently take place separately from existing agricultural policy debates. Within the climate change literature, evidence about agriculture focuses on agriculture and output, identifying implications for food supply and food insecurity, and pays much less attention, if any, to the implications for agricultural growth as a pathway towards poverty reduction.

This paper is the third in a series of five papers that seeks to explore the impact of climate change on agriculture and suggest what the policy implications of these impacts might be for agricultural policies. In this paper, we focus specifically on agricultural growth and its role in poverty reduction. We seek to make connections between climate change and agricultural policy discourses and ask:

- what do we know about the impact of climate change on agricultural growth and poverty reduction? and;
- what does this imply for agricultural policies on the parts of governments and donors?

We begin the paper by exploring the main dimensions of three critical debates around agricultural growth (small versus large farms, high versus low potential areas, food versus cash crops). We then review evidence about the impact of climate change on agriculture in relation to each of these three debates. We conclude by identifying what the policy implications for existing and future agricultural policies might be.

3. Key debates in agricultural policy

3.1 Small farms versus large farms

Debates regarding the relative merits of small farm and large farm production focus mainly on four main issues: *productivity*, *efficiency*, *rural growth linkages* and *poverty-alleviating effects* (see Ellis and Biggs 2001). Broadly speaking, for the past three decades or so 'small farm' arguments have been dominant.

Supported by the experience of 'Green Revolution' productivity gains in South and South-East Asia, and based on empirical observation of the inverse relationship between farm size and productivity, proponents of small farm systems point to how labour-intensive smallholder-led increases in yields can directly (through income increases) and indirectly (through increased employment and demand for goods and services) lead to broad-based agricultural growth and poverty reduction (Hazell et al 2006). The crucial element to 'small farm' arguments is that they address both growth and equity goals simultaneously (Ellis and Biggs 2001). Small farms are generally owned and operated by the poor, often use locally-hired labour, and distribute income within nearby locales, creating multipliers (Hazell et al 2006). Small farms also have more advantages over large firms in certain types of transaction costs: the supervision of labour, local knowledge, and food purchases and risk management (Hazell et al 2006).

Proponents of 'large farm' systems point to the capital constraints of smallholders, and the lack of capacity to adopt technological innovations, and manage contracts with agri-businesses (Ashley and Maxwell, 2001). In addition, the limited economies of scale on small farms for certain types of transaction costs increase the cost of inputs, and decrease output prices (Ashley and Maxwell, 2001). Indeed, large farms have certain further advantages as well: market and technical knowledge, finance and capital, land, product traceability and quality (Hazell et al 2006).

Recent global shifts have lent some weight to 'large farm' arguments (DFID 2004). The increasing importance of non-farm and off-farm income streams to household portfolios in southern Africa (see Ellis 2000) has brought into question the 'full-time farmer' assumption inherent within the 'small-farm-first' paradigm. Moreover, the rise in importance of non-traditional export crops, and non-tariff import criteria in the North (see Dolan et al 1999) have increased the capital and quality requirements for primary commodity exporters. Poorly educated smallholders may find it hard to reliably produce standardised products for these markets.

Further challenges to small farmers include changes in trade regimes leading to domestic markets for key crops being flooded by cheap imports, the lack of investment in rural extension and research, environmental degradation, climate change and HIV/AIDS (Hazell et al 2006). Supporting small farms no longer appears to be a generic recommendation, and is now more dependent on context, particularly in light of the multiple and diverse livelihood strategies pursued by rurally-based populations (Scoones *et al* 2005).

3.2 Cash crops versus food crops

Acrimonious debates around the relative merits of cash crop and food crop production have centred on five issues: *growth*, *income distribution*, *food security*, *dependency*, and the *environment* (Maxwell and Devereux 2001). Advocates of cash cropping focus on the first two arguments: that labour-intensive agricultural growth using growers' comparative advantage directly (via increasing agricultural production and incomes) and indirectly (via employment and backward and forward linkages) contributes to poverty alleviation and equity goals (Maxwell and Devereux 2001, DFID 2003).

Sceptics focus on the dependency and environmental dimensions: respectively, that cash cropping can increase risk through a reliance on imperfect and volatile markets; and that it encourages monoculture production, land pressure and soil erosion. Moreover, further arguments revolve around potential changes in the intra-household distribution of labour/income.

The distinction between food and cash crops is, though, flawed: the potential impact of food and cash cropping depends, of course, on the type of crop being grown, the most obvious example being when the cash crop is also a food crop. Further parameters include: What are the market conditions? What is the labour requirement? How frequent are returns to the crop, and what is the gestation period? What is the relative role of men and women in the production and marketing process? (von Braun and Kennedy 1994).

The last issue – food security – is the most contentious. There are two widely cited summaries. The earliest of these was the review by Maxwell and Fernando (1989) who found that the consequences of cash cropping depended strongly on the type of farming system, the crops in question, and, crucially, the policy context. Moreover, Maxwell and Fernando (1989) recognised both short- and long-term impacts of cash cropping: such that short-term costs for the poor may need to be off-set by some form of social protection (DFID 2003).

Such arguments were eclipsed in the 1990s by a highly detailed and comprehensive collection of case studies by von Braun and Kennedy (1994), the main findings from which were:

- That cash croppers sold an increased proportion of food crops vis-à-vis non-adopting households. Cash croppers were therefore more integrated with both input and output markets.
- Increased income effects for cash croppers.
- Cash cropping led to a large increase in demand for labour, especially amongst the poor, and increases in rural wage rates.
- Substantial forward and backward linkages in the rural economy

These findings led von Braun and Kennedy (1994) to be very optimistic about the ability of cash cropping to increase household welfare and food security in all settings. However, in the face of repeated food crises and chronic hunger in sub-Saharan Africa in recent years and the difficulties for small producers accessing supermarket value chains, the debate about the role of cash and food crops remains unresolved.

3.3 High-potential versus low-potential areas

Economic growth in the South has been most concentrated in areas with rich natural resources, or close to cities, ports and transport routes. Areas with low-potential have, overall, grown at a much slower rate, and have a much greater concentration of poverty (Wiggins and Proctor 2001). These areas, termed less-favoured areas (ibid.) not only suffer from high transaction costs with urban locations, but a multitude of further disadvantages: lack of good quality infrastructure, relatively low levels of human capital and institutions to foster it, often a lack of governance, poorly functioning markets including credit. This is not to say that remote rural areas are only blessed with disadvantages. Advantages of such locations include: enjoying first-stage processing of many agricultural commodities; low wages and low opportunity cost of off-season labouring; specialist skills; tourism and aesthetic value; possibilities for straddling urban and rural spheres (Wiggins and Proctor 2001).

However, despite these caveats, fostering agricultural growth and poverty reduction in less-favoured areas is challenging. Whilst such areas will benefit from urban growth (through increased demand for staple foods, cheaper manufactured goods, possibly more investment in infrastructure, technology transfer), such chances diminish with distance (Wiggins and Proctor 2001). Notwithstanding variations in different contexts, one general consequence of the confluence of these factors may be increasing levels of out-migration from these locations – the corollary of this argument is that remittances will be invested into rural locations, if not to stimulate growth, at least to play a socially protective function. Again, the extent to which this occurs is dependent on context, particularly where there is a long history of out-migration from an area (Wiggins and Proctor 2001).

The high-potential versus low-potential debate is also closely linked to food security arguments, and, as such, is underpinned by differing understandings of the problem of food production and distribution (Maxwell 1996). On the one hand, those who subscribe to neo-Malthusian standpoints view population growth and environmental degradation as limiting the supply of food (globally as well as nationally) and subsequently tend to promote increasing productivity in areas of high agricultural potential (Maxwell 2001). On the other hand, those who understand food shortages and hunger as stemming from the poor's lack of entitlements to access food, the demand-side argument, tend to encourage livelihood-enhancing measures in areas of low agricultural potential (Maxwell 2001).

There are, of course, synergies to be found by focusing on both high- and low-potential areas within a country. For example, Devereux and Maxwell (2001) highlight how productivity losses incurred by investing in low-potential areas can be outweighed by reduced expenditure on food relief operations. Moreover, considering the lack of non-farm employment opportunities in Remote Rural Areas (RRAs), investment in agriculture (and the income and employment effects this generates) in these locations can be viewed by some as a social protection policy instead of growth policy (DFID 2004). Such investments should be accompanied with efforts to support the entitlements of the poor through stimulating non-farm and off-farm income sources (ibid.).

4. Modelling the impact of climate change on agriculture and agricultural growth

4.1 Impacts on agriculture

Output 1 of this series of papers identifies what we know about the impacts of climate change on agriculture. Mendelsohn and Dinar (1999) note that evidence from developing countries is much more limited than from more temperate latitudes. However, existing scenarios tell us about the impacts on agriculture at a global level with some more detailed regional analysis. They focus on:

- changes in yields due to changes in seasonal climates;
- changes in production potential in relation to factors such as yields, available land suitable for agriculture and lengthened/shortened growing seasons;
- responses of crops to changes in atmospheric composition, such as concentrations of carbon dioxide;
- changes in the price of cereals resulting from climate change;
- changes in patterns of trade resulting from climate change;
- changes in the number of people at risk of hunger as a result of climate change, normally measured as the number of people whose incomes allow them to purchase cereals, and;
- water runoff and related water stress, normally measured in terms of the number of litres of water available per person per year

(Source: Peskett 2007)

Peskett (2007) identifies the key impacts of climate change on agriculture of which there is some certainty (Box 4.1). There remain significant areas of uncertainty though, such that the only certainty in climate change is that there will be increased uncertainty. This suggests a need for flexible programming that can respond to changing knowledge about impacts. Finally, whilst the latest IPCC assessment (2007) stresses that extreme weather events will become commonplace relatively quickly, and indeed are already being felt, in general the impacts will not begin to be felt in earnest until after 2020. This has implications for the timelines over which agricultural policies are made.

Box 4.1: Likely impacts of climate change on agriculture

1. **Current scenarios predict that global cereal production could continue to increase up to 4.3 gigatonnes depending on the scenario and model used** (Fischer 2005). When climate change is factored in, global cereal production could be within 2% of reference scenarios. This implies that climate change is unlikely to result in large-scale collapse of food production at the global level under all but the most extreme scenarios. This aggregated trend masks potentially large regional variations.

2. **At a regional level, most models predict greater differences in cereal production between developed and developing countries by 2080 with increases expected in developed countries and decreases in developing countries** (Parry et al 2005, cited in Stern 2006). In general increases are expected in potential agricultural land in high latitudes, particularly North America (20-50%) and the Russian Federation (40-70%). Production in China is also expected to increase. Decreases are expected in low latitudes and up to 9% in Africa (IPCC 2007a). Sub-regional variations are masked by these figures, with some short term increases possible in areas of overall decrease (e.g. Africa). For example, tropical highlands where current low temperatures prevent planting of certain crops, new land could become suitable for agriculture.
3. **Related to the projected regional differences in production, most scenarios project that tropical developing countries could increase cereal imports from developed countries and temperate areas.** Some models indicate that the influence of climate change on agricultural imports of developing countries could be between 10 and 40% (e.g. Fischer 2005).
4. **Comparisons between scenario studies suggest that the impacts of climate change on agriculture could diverge over time.** Few differences between current scenarios can be discerned over the next 20 years. This may be due more to the large uncertainties in predictions making trends more discernable at the extremes. In addition, in the short term, the frequency and severity of extreme events is also likely to increase, so more localized effects may be much more severe than indicated by the scenarios. As a very general rule, these changes will occur in areas that are already most susceptible to these events. This may have implications for those policy responses aimed at supporting agricultural growth compared to those aimed at helping the poor to cope with extreme events.
5. **CO_2 'fertilisation' effects have a major impact on future yield predictions.** These are complicated to model, but most recent estimates suggest that the benefits of this effect are less than assumed in most climate models to date. The beneficial effects of CO_2 for plants are different for different types of crop. Crops such as rice, wheat and soybean could increase yield by 8-15% for a doubling of CO_2, whereas little change is expected in crops such as maize, sugarcane and sorghum (Long et al 2006 cited in Stern 2006). This implies that some crops will be more resilient in future climates, in terms of their response to CO_2 levels. Complex interactions of other factors such as levels of water availability and responses to ozone at ground level complicate the relationship.
6. **Climate change could increase the number of people at risk of hunger by up to 600 million by 2080, and particularly in Africa** (Warren 2006). It should be noted that the number of people at risk of hunger bears a large relation to levels of economic growth in the modelling studies, so most future worlds show fewer people at risk of hunger compared to today despite climate change.
7. **Temperature increases could be beneficial for cereal crop yields in temperate regions for moderate warming (2-3°C).** In tropical regions, temperature increases are likely to have negative effects because crops are already near to their threshold temperatures. Above 3°C warming, negative impacts of temperature could occur in most areas (Stern 2006).
8. **Extreme events such as floods and droughts are likely to become much more severe and frequent over the next century under all scenarios and for most land areas.** The most recent IPCC predictions for example indicate over a 90% probability that the frequency of warm spells and heat waves and heavy precipitation events could increase in most land areas. Whilst the exact changes in different scenarios and their relationship to impact on crops are hard to predict, the general trend indicates that areas where agriculture is already at risk from such events, might be more severely impacted in future worlds with climate change.
9. **All climate change models project that the hydrological cycle could intensify with**

increased warming. This is likely to lead to increased frequency and severity of droughts and heavy precipitation events. However, projections in precipitation can be very uncertain. There are much higher levels of certainty in projections of changes in seasonal levels of stream flow in areas dependent on snow pack melting for water resources. This implies that policy responses focusing on climate-related water resource issues in these areas (e.g. large scale water storage) might have more guaranteed success than responses in areas not dependent on snow melt.

Source: Peskett 2007

4.2 Impacts on agricultural growth

The climate change and adaptation literature does not tell us much about agricultural growth. There are three reasons for this.

First, with current scenarios and models, it is very difficult to distinguish between the effects on both different farming and cropping systems, and on socio-economic groups. Thus, O'Brien and Leichenko (2000: 225) note that

> *In considering the linkages between climate change and socioeconomic conditions, Parry and Carter (1998, p. 24) note that* 'the effects of any climate change in the future will be influenced by concurrent economic and social conditions and the extent to which these create a resiliency or vulnerability to impact from climate change'*. Nevertheless, most impact analyses consider only crude socioeconomic scenarios, developed from baseline scenarios representing* 'the present state of all the non-environmental factors that influence the exposure unit' *(Parry and Carter, 1998, p. 75). Most socioeconomic scenarios involve a simple extrapolation of present-day trends, such as population and economic growth rates.*

Second, it tends to focus on agricultural production and the implications for food supply and food security, and pay much less attention to the wider ways in which agricultural growth can contribute to poverty reduction. Food supply and food security is almost always seen as the primary goal of agricultural policies and even where the importance of agricultural growth for wider poverty reduction objectives is discussed (see Box 4.2) the actual effects of climate change on growth are rarely articulated, nor are the ensuing policy implications (Rosenzweig and Hillel 1995).

Box 4.2: Food first, agricultural growth second

The central challenge of sustainable agriculture is to meet the **food demand** *of the present generation without sacrificing the needs of future generations. This cannot be achieved without the systemic integration of the social, economic, and environmental pillars of agriculture and rural development. Sustainable agricultural development is essential for economic growth, which creates employment opportunities in non-agricultural rural sectors, which in turn reduce* *poverty. Policies that reduce pressure on resources, improve management of environmental risks, and increase the welfare of the poorest members of society can simultaneously advance sustainable development and equity, and enhance adaptive capacity and coping mechanisms. The inclusion of climate-change impacts in the design and implementation of national and international development initiatives can reduce vulnerability to climate change (*Fischer *et al* 2002: 116-117*)*

People's ability to ***grow enough to feed themselves*** *and their animals is determined to a large extent by the weather - by temperature, light and water.* FAO (http://www.fao.org/News/1997/971201-e.htm)

Third, and linked to the previous two points, is the fact that the earliest models that have been used for analysing impacts have focused on production and yields, rather than production systems, capacity and policies.

Agronomic approaches were prevalent in the 1990s and draw on agronomic economic models and agroecological zone analysis (Box 4.3). They address adaptation by stimulating change in the growth parameters of various crops but they fail to take into account economic considerations and human capital limitations (Mendelsohn and Dinar 1999). For this reason they may overestimate the impact of climate change and are not very helpful in understanding the implications of climate change for the behaviour of different kinds of farmer or for different farming systems. In agroeconomic approaches a less pessimistic view emerges that adaptation will reduce damages from climate change.

Box 4.3: Modelling techniques

Agronomic economic techniques draw on controlled experiments where different temperature, precipitation and CO2 levels produce different yields which are then entered into an economic model to predict aggregate crop outputs, prices and revenues.

Agroecological zone techniques are developed by assigning crops to zones and using these to predict yields. As climate changes, crop zones change and so it is possible to predict the effect of alternative climate scenarios on crop yields. Inter- and intra-national zones can be calculated but large shifts within zones have no effect on the model whereas small shifts between zones have very large effects. It is not clear how well the zones predict what should be grown compared to what is grown.

Both models attempt to incorporate adaptation but this is done largely on an *ad hoc* basis.

(Mendelsohn and Dinar 1999)

Ricardian models are better able to incorporate adaptation because they work by regressing farm performance (based on land value or net income) against a set of environmental factors, inputs (such as land or labour) and support systems (infrastructure). In doing so, it is possible to measure the contribution of each factor to farm performance and identify the impact of climate change on farm value (Mendelsohn and Dinar 1999). If the right variables are identified, Ricardian models can be highly effective at incorporating adaptation and compared with other approaches, Ricardian models have been used to show how much of the negative impact of climate change can be overcome through adaptation. As a result, the findings from Ricardian models are far less pessimistic about the impacts of climate change and, in combination with improved understandings of CO_2 fertilisation effects, have been critical in showing that in some areas CO_2 will result in increased agricultural productivity. For example, Mendelsohn and Dinar show how:

> *Comparing the damages predicted by the agronomic simulations with the results of the cross-sectional studies provides an estimate of the importance of adaptation. In India, for example, the agronomic approach predicts damages of about 28 percent for severe warming, whereas the cross-sectional results predict damages of between 15 and 23 percent. If this difference is due to adaptation, private* [autonomous] *adaptation could reduce potential climate damages by between one-fourth and one-half* (1999: 288).

Cross-sectional Ricardian models can also help to understand seasonal climate change. In vulnerable, rain-fed farming areas, this is particularly important for understanding impacts. However, like other models, Ricardian models also focus on major grains and thus, understandings of adaptation resulting from diversification into other cash crops, or risk spreading by moving into more drought resistant staples, remain poorly understood.

As a result of Ricardian techniques, evidence is now slowly emerging about the impact of climate change on small and large farms, high and low potential areas, and on cash and food cropping. However, the evidence base remains thin and geographically patchy and still focuses more on the impacts on agriculture than the impacts on agricultural growth.

5. Implications of climate change for agricultural policy debates

Drawing on the models identified above, our review of existing literature and evidence finds very few pieces of research that make linkages between climate change impacts and adaptation and questions about the roles of small and large farms. Links regarding cash versus food crops and high versus low potential areas are even fewer. A critical reason for this lack of linkage is that there is a different but overlapping language used to describe climate change impacts and response which fails to sit well within the language of development policy. The definitions in Box 5.1 are those that are used in the climate change literature and are drawn from the Inter-governmental Panel on Climate Change (IPCC). As can be seen from the box, the language is very narrowly focused on climatic systems and tends to ignore other kinds of economic or social risks and shocks. When comparing languages, it is clear that the same terminology is often used to describe different processes. The best example of this is the use of the terms 'mitigation' and 'adaptation'. In the development literature, households mitigate risk when they change their behaviour or activities to deal with risk (see for example Holzmann and Jorgenson 2000). In the climate change literature uses the term 'adaptation' to refer to the same behaviour, whilst 'mitigation' is instead used to describe efforts to reduce carbon emissions.

Box 5.1: Definitions

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass all the elements of climate change, including mean climate characteristics, climate variability, and frequency and magnitude of extremes. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed as well as the system's sensitivity and adaptive capacity.

Source: IPCC

Despite the lack of a coherent language and common policy concerns, two things are clear from the evidence about climate change and adaptation in agriculture. First, climate change is by no means the most important issue currently facing the agricultural sector. Adaptation and changing agricultural strategies are driven more by other factors, including price volatility and variation, access to supply chains, HIV/AIDS, micro-finance

(Kurukulasurya and Ajwad 2007, O'Brien and Leichenko 2001, Hageback *et al* 2005). Second, the wider agricultural policy environment is important (particularly given the rapid increase in demand for biofuels) but rarely discussed in the adaptation literature. One important exception to this is work by Eakin which stresses the importance of changing terms of trade for small maize producers in Mexico following the introduction of NAFTA (2000).

5.1 Small versus large farms

Understanding the impact of climate change on the productivity and profitability of small and large farms is critical for understanding how different pathways for agricultural growth and poverty reduction are likely to be affected. Whilst the evidence base is weak and patchy, there appear to be two predominant views.

The first view is that small farms have been remarkably resilient in adapting to environmental and economic change for millennia and that current rapid climate change presents an additional layer of risk to which they must respond. For example, Eakin notes that

> *Through centuries of experience and knowledge derived from formal research, small-scale farmers of diverse cultures and histories have developed coping strategies unique to the environmental conditions they confront. The flexibility of these strategies is central to their effectiveness, as farmers are not only constantly adapting to constraints posed by the physical environment but also to dynamic social and institutional circumstances.*

At the same time, O'Brien and Leichenko (2000) suggest that climate change in India may create similar challenges for small farmers that emerge as a result of globalisation, but that the addition of climate change creates a 'double exposure'[2]. Less clear is the extent to which small farmers can continue to be efficient in the face of double exposure or whether their farming systems will be unable to remain efficient and profitable.

Timescales are important. In rain-fed farming systems in Rajasthan in India, evidence from TERI suggests that medium scale farmers can respond to drought through the sale of stocks. Small/marginal farmers rely on distress sales of cattle, switching to different crops and the sale of labour/seasonal migration. However, as TERI (2003) note, these are only temporary coping measures. *Options that enhance longer-term adaptive capacity (such as institutional credit, crop insurance, and use of drought-resistant varieties) are*

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[2] *Double exposure refers to the fact that certain regions, sectors, ecosystems and social groups will be confronted both by the impacts of climate change, and by the consequences of globalization. By considering the joint impacts of the two processes, new sets of winners and losers emerge* (O'Brien & Leichenko 2000: 221)

not used by small farmers due to procedural complexities and stringent eligibility criteria, compounded by lack of awareness (TERI 2003: 20).

In Karnataka, one of a series of sites where TERI have tested their double exposure theory, there are examples of how adaptation can be successful. Where farmers are encouraged through state government and private initiatives to cultivate alternative crops, such as areca nut, pomegranate, and banana they have successfully adapted to new markets. New markets require new farming systems and export companies in Karnataka have entered into out-grower contracts with small farmers producing gherkins for European markets:

> *The economics of gherkin cultivation mean that small and marginal farmers with small landholdings and family labour that are most able to benefit from such contract farming.* Kisan kendras *(farmer centres) set up by corporates also provide scientific soil testing services, market information, and transport facilities to cultivators of horticultural crops, in return for a subscription fee* (2003: 21).

However, other government and private initiatives are less pro-poor:

> *It is the larger farmers who tend to benefit from government subsidies (for drip irrigation, sericulture rearing houses, and other production technologies), formal bank credit, crop insurance, and access to larger markets. Smaller farmers are disadvantaged due to lack of information and dependence on local merchants for credit* (2003: 21).

The second view is that, in contrast to small farms, large farms may be significantly less flexible as they have greater capital outlays but again, the timescale over which adaptation takes place is important. In the short-term, larger farms may not respond to signals and even be maladaptive. The case for large farmers being maladaptive is based on the fact that they have the capacity to respond to market opportunities which are not 'climate-proofed' options. However, given that the impacts of climate change will generally not be felt severely for around another two decades, and given that even highly capital intensive farms turn around capital investments in a number of decades, large farms may not be inflexible in the longer-term. Other factors associated with climate change may also be more beneficial to larger than smaller farms, for example, transportation costs increasing and modes of transport changing due to mitigation policies and consumer preferences changing in response to climate change. Ludi *et al* (2007) argue that the likely shift to sea freight for agricultural commodities will alter the structure of production between small and large farmers because it will require large volumes of identical items that ripen uniformly en route and this will favour large producers.

In sum, timescales are critical when evaluating the implications of climate change on large and small farmers. Climate change will affect both, in different ways and over different timescales. This has implications for the capacity of agricultural policies to respond, given that they are largely made for periods of around five years. States will have an important role in enabling non-autonomous adaptation and different types of instrument affect small and large farmers differently.

5.2 Cash crops versus food crops

There is very little empirical evidence about cash versus food crops under different climate change scenarios and modelling (agronomic, agroeconomic and Ricardian) tends to focus on grain production at the expense of other crops. An example from South Africa is given in Box 5.2. Some findings can be drawn from other evidence regarding large and small farms and high and low potential areas including:

i) coffee and other perennial crop producers find it more difficult to respond to changing temperature and precipitation patterns and price signals because of the associated costs of uprooting, replanting and waiting associated with the maturation of perennial crops (Gay *et al* 2006);

ii) cash crop producers can be 'maladaptive'. Rather than adapt to make their production sustainable in the long-term, they seek to make short-term gains from continuing with the same production methods;

iii) cash crop producers are more likely to mono-crop. By not planting a range of crops, their risk spreading options are reduced;

iv) in contrast, food crop producers have adaptation strategies that are more concerned with reducing or managing risk. They withdraw from markets and spread risk by staggering planting, diversifying their range of crops and switching to drought-resistant crops, and;

v) in the future, energy crops and carbon sequestration programmes may create new dimensions in cash cropping (Worldwatch Institute 2006).

Box 5.2: Small farmer responses to climatic and other risks in South Africa

Ziervogel *et al* (2006) find that different small farmers using weather forecasting have different responses.

> *For example, it appears that poorer households are more likely to stagger their planting. This is a risk-coping strategy that suggests that these households would rather increase their chances of having some yield than investing everything in planting when the first rains come and risk losing it all if the rains do not continue. Similarly, hiring transport is restricted to average and better-off farmers. This strategy is effective in dealing with variable market demand. These individuals are able to take a bulk-load of produce to markets further afield where there may be higher demand and thus they are also able to secure higher prices away from the community garden. Female farmers appear to prioritise crops for home consumption more than men, yet they are aware of market demand so they plant both marketable and home consumption products. Although climate information is often not used directly, it is seen as an additional source of information that contributes to their knowledge about the 'risky' environment in which they operate.*

5.3 High potential versus low potential

It is now well established that, whilst at a global level climate change is likely to result in gains in potential agricultural land, there will be substantial regional losses – particularly in Africa. Agronomic models, for example, suggest that the vulnerability of farmland in less productive tropical climates will increase and that there is a high likelihood that warming will push more farmland into this zone (Rosenzweig and Parry 1994, Reilly *et al* 1996, Mendelsohn and Dinar 1999).

Various perspectives can be drawn out from the climate change literature. Much of it shows that practising agriculture in low potential areas will become even more difficult. The already fragile productivity of marginal lands will be further undermined by increased temperature and greater variation in precipitation. There are concerns regarding the capacity of poor farmers on marginal lands to respond to increased climatic variability and falling yields. All the models referred to above – agronomic, agroeconomic and Ricardian – draw this kind of conclusion.

Evidence from India, for example, suggests that, in the face of drought in low potential areas – notably those weakly-integrated into marketing systems – farmers' options for adaptation are fewer (TERI 2003: 20):

> *In Anantapur district in Andhra Pradesh, groundnut is the principal crop but farmers are now facing a crisis due to growing import competition and stagnating market prices, which have coincided with a multi-year drought. Although free market economics would predict that farmers in Anantapur should respond to price stagnation by shifting to production of more profitable crops, our case study results indicate that there is a lack of alternative, drought-tolerant, and economically viable crops because institutional barriers have made them unprofitable. Rainfed crops (such as different fruit varieties), which could be economically viable, either require too much capital or do not have long enough shelf lives to be marketable under current circumstances. Without irrigation, water harvesting systems, or alternatives to groundnut, dry land farmers in Anantapur are highly vulnerable to both climate change and trade liberalization* (TERI 2003: 20).

The focus on vulnerable areas and the argument that the greatest losses of land and most of the increased variability will be found on marginal lands currently occupied by poor farmers has rarely been questioned. However, Fischer *et al* (2002) provide two particularly important insights that call this finding, and subsequent policy implications, into question. They begin by differentiating between areas of single, double and triple cropping in their analysis and find that:

> *In developing nations and in particular sub-Saharan Africa, the overall contractions in potential cultivatable areas are mainly at the cost of double- and triple-cropping areas, where losses are above average. Although the area for single cropping increased in sub-Saharan Africa at the expense of double- and triple-cropping areas, considerably more is lost to the category where cropping is not possible.*

They then also stress that in both Africa and South America, any decrease in suitable land is relatively small when compared to the remaining balance of unused potential cultivable land.

Whilst multi-annual cropping provides only a rudimentary proxy for the lower and higher potential farming systems (for example it is not just natural resources that define the potential of an area – roads, proximity of markets and consumers, etc are also important) this evidence does lead us to question the assumption inherent in much of the literature – that it will be land in low potential areas, currently cultivated by poor small farmers, that will be lost to agricultural production as a result of climate change. From the evidence of Fischer *et al*, production from high potential areas are equally, or not more, threatened.

There are three alternative sets of policy options that emerge from these different views:

i) *Support the agricultural sector in low potential areas, particularly small marginal farmers **in situ***. Policy options here focus on investments in agriculture in low potential areas to maintain some level of income from agriculture for poor farmers. The TERI evidence from section 4.1 points to some policy options for doing so. Another alternative is to increase the use of social protection to support poor rural households whose livelihoods are under threat. These policies are not necessarily a sub-optimal choice in terms of maximising agricultural growth. Evidence described in section 3 suggests that investing in less productive agriculture in marginal areas will not necessarily be a net sub-optimal investment in terms of productivity because of the other costs that may be avoided. In a climate change context, these costs become more important and include costs of food aid and other emergency responses to support the most vulnerable as they face increased and potentially devastating weather shocks.

ii) *Support the existing adaptive strategies of farmers in low potential areas to reduce dependence on marginal agriculture*. The second set of policy options focuses on the many different ways that farmers respond to global environmental change and other risks in agriculture. These include activities in the agricultural sector, such as crop diversification and use of drought resistant varieties, but not solely in agriculture. Wider options include investments to support migration and labour mobility, improved flexible land administration and diversification into the rural non-farm and urban economies.

iii) *Investments to protect existing production in high potential areas* including protection of natural resources in high potential but threatened areas (flood defences, more efficient irrigation techniques) and investments to open up new high potential areas that are currently unused.

Decisions about the three options outlined above depend on existing priorities in agricultural policy and the extent to which the geography of climate change impacts is known. Sanghi, Mendelsohn and Dinar (1999) also find winners and losers in different parts of India where there is different cropping intensity – in this case though, it is not easy to discern a clear pattern between higher and lower potential areas. West Bengal, which produces three rice crops in succession throughout the year, is predicted to benefit from increased temperatures but other major food-producing regions (Punjab, Haryana and western Uttar Pradesh will be negatively effected (TERI 2003). Combining evidence from Africa and India suggests that there are no simple conclusions to be drawn about whether climate change will affect high or low potential areas but that incorporating climate change models with better understanding of existing farming systems and challenges is critical if agricultural policies are to reduce the negative impacts of climate without jeopardising agricultural growth.

6. Policy implications and conclusions

i) There is relatively little evidence about the impacts of climate change on agricultural growth and the prospects for small and large farms, high and low potential areas, and cash and food crop systems.

In the case of large and small farms, there are two prevailing views. The first is that small farms have shown remarkable resilience and capacity for adaptation in the face of significant environmental (and economic) change relating to agriculture. Climate change is just an additional challenge to which small farmers will respond. The second view is that small farms are able to cope with risk and uncertainty in the short-term, for example by drawing on temporary measures such as entering the casual labour force or delaying planting, but that they cannot adapt in the longer-term unless they can access state or private initiatives to support adaptation (micro-insurance, credit, new technology, market information). In contrast, large farms are more likely to benefit from many of the current government programmes that will enable risk-taking (such as producer subsidies, tax breaks, market information systems and export support) and from new modes of transportation required by mitigation policies and changing consumer demands. Timescales are important and whilst small farmers have good autonomous adaptation potential in the short-term, supporting small farmer adaptation through longer-term policies is more difficult.

The evidence about cash and food cropping is scant, particularly because many models (agronomic, agroeconomic and Ricardian) tend to focus on grain production. However, it is known that coffee and other perennial crop producers find it more difficult to respond to changing temperature and precipitation patterns and price signals because of the associated costs of uprooting, replanting and waiting associated with change. Cash crop producers can also be mal-adaptive – in the face of climate change they respond in ways which reinforce the problems they face from climate change rather than reduce them. Examples of this include continuing to produce crops that are unsustainable in the long-term but in the short-term can generate high incomes. Food crop producers' adaptation strategies are concerned with reduce risk. They withdraw from markets and spread risk by staggering planting, diversifying their range of crops and switching to drought-resistant crops. In the future, carbon sequestration may create a new dimension in cash cropping whereby farmers produce not solely for sale in commodity markets but also for income from carbon markets. This may imply a shift towards tree crops and/or agroforestry.

In terms of high and low potential areas, the prevalent view is that low potential areas are highly vulnerable to climate change and significant investments will be needed to maintain production there. There are two alternative sets of policy responses in this view. One is to invest in agriculture in low potential areas as a way of sustaining vulnerable households – agriculture as a social investment. A second policy response is to build on existing risk responses by farmers – these include supporting diversification into the rural non-farm economy and enabling migration and mobility through good land administration. An alternative view to the prevalent focus on low potential areas uses evidence about the impacts of climate change on rain-fed single cropped areas versus double or triple cropped areas in the developing world. Evidence has shown that the greatest losses in the developing world will be in double or triple cropped areas. Where national level food supply is at risk, or where export earnings are threatened, governments may choose to focus on protecting existing high potential areas in order to protect food supply and export income rather than investing in marginal areas.

ii) Climate change and agricultural economics literature, research and policy are poorly linked.

Thus, as Ziervogel *et al* note: *people respond to stresses for different reasons; some to survive and others to succeed* (2006: 302). Responses to stresses are differentiated – socially and by farming system.

The way in which the climate change literature discusses agriculture is largely out of sync with current agricultural policies of governments and donors and with development more generally. With the aggregate global impacts of climate change being better understood than localised impacts, the discussion of agriculture in the climate change literature focuses on impacts of yields and subsequent implications for food supply and food security, rather than dissecting the impacts on the efficiency of different farming systems and different socio-economic groups.

The priority must be to establish research partnerships between climate change modellers and agricultural economists to improve the linkage between climate change scenarios and the socially and economically differentiated farming systems. Ricardian approaches to modelling, which incorporate adaptation, may offer one opportunity for comparing different farming systems (small/large, high/low, cash/food).

iii) Climate change is not the most critical challenge that faces poor farmers in the developing world.

Ziervogel *et al* (2006) note that:

> *The recent focus on adaptation to climate change could divert attention from more urgent development needs as it emerges that climate is not necessarily the key driver of change, although it is one important driver among many (Gregory et al., 2005; Reid and Vogel, 2006; Scholes and Biggs, 2004). It is therefore imperative that policies aimed at supporting adaptation to climate change are clear on what type of adaptation is being supported and who within the chosen target group will benefit, recognizing that very few groups will be homogeneous.*

Again, better linking climate change and development research and policy will enable climate change to be placed in context and appropriately prioritised in wider development policy.

iv) Agricultural and climate change policies need to address the risks that farmers face if they are to be effective.

Eakin draws on evidence from Mexico to show how farmer behaviour in the context of climate change makes them increasingly risk averse.

> *This was effectively illustrated in the Plan Puebla program that introduced hybrid corn to smallholders in Puebla in the 1970s. In years of poor rainfall – 1973-1974, 1978-1979, 1982-1983, and 1987-1988 – the yields of the hybrid seed varieties were not significantly different from that of the non-program participants who planted primarily local varieties. The same input and management recommendations to farmers that were responsible for boosting production among the program participants in good years proved to be harmful to maize yields in years of poor rainfall. Many of the promoted hybrid varieties also depended on costly applications of chemical inputs and irrigation that encouraged farmers to go into debt, thus increasing their vulnerability by jeopardising their economic security … small-scale producers are still reluctant to adopt hybrid varieties for these reasons. (*p.23)

v) Existing agricultural policy priorities remain largely unchanged in the context of climate change

After linking the climate change and agricultural policy discourses, it appears that most policy implications relating to climate change adaptation are already priorities in development. These include access to markets, to information (especially weather forecasting and prices) and technology. With the exception of a very small number of countries, the impacts of climate change will not be felt severely for about two decades (IPCC 2007). For policy-makers in the agriculture sector, this provides a window of opportunity to invest in agricultural growth, to stimulate linkages and multipliers in the wider economy and to enable farmers to become more resilient.

vi) States will play a critical role in supporting adaptation

At present, the climate change literature focuses on autonomous or private adaptation by individual farmers and farm enterprises, and on international level policy processes. In between the households/enterprise and international level, other actors, particularly national and state levels, are largely ignored.

Evidence from TERI work in India shows the importance of state interventions in enabling small farmers to access new market opportunities but also demonstrates that different interventions will be appropriate for small farmers whilst others are likely to be captured by larger, wealthier farmers.

vii) Beyond adaptation, future agricultural policy will need to incorporate new objectives

One objective is likely to relate to the potential impacts of agricultural as well as wider development, policies and programmes on climate change. As concerns about climate change increase, agricultural policies and programmes might have to incorporate assessments in areas such as greenhouse gas quantification that are not part of most existing policies.

A related objective is likely to surround potential new markets that will emerge due to climate change. Carbon markets and certain forms of renewable energy, such as biofuels could be particularly important. At present most agricultural practices are not included in the largest carbon markets, such as the CDM, although this could change in future commitment periods of the Kyoto Protocol after 2012. Interest in biofuels is increasing rapidly and is already a substantial part of the agriculture sector in certain developing countries. These new markets are likely to add an additional dimension to cash crop systems as farmers attempt to realise the potential of agro-forestry and new cropping systems to access income under mitigation programmes.

These new objectives also have implications for agriculture and climate change research that support policy making. Climate change response policies are currently not well integrated into models of potential climate change impacts on agriculture. As the policy responses to climate change become larger and the rate of policy making increases these factors are likely to become more important in our understanding of the effects of climate change on agricultural growth.

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