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ADAPTING FARMING TO CLIMATE CHANGE IN THE ASIA-PACIFIC REGION

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Adapting Farming to Climate Change in the Asia-Pacific Region

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Abstract

Global consumption of grains is projected to double by 2050 due to projected growth in population and per capita consumption of grains. Additional consumption will be from use of grains in livestock production which is likely to increase as incomes rise. Global food security depends on expanding current farming activities in a sustainable way to meet this demand. Much of this expansion will happen in the Asia-Pacific. A critical part of meeting this challenge will be in provision of appropriate crop nutrition. This will be happening in a background of changing energy availability and prices, different trade arrangements, altered social values including pressure to reduce greenhouse gas emissions and enhance environmental stewardship and improvement in agronomic technologies and practices. Climate variability already has a significant influence on global grain production and fertiliser use and further impacts on production are anticipated as the climate changes. Climate changes are likely to reduce grain yields in tropical and subtropical regions, as well as in regions with 'Mediterranean' climates. Yields could potentially increase in some more temperate regions. The potential for increased climate variability and climate-related disturbances could place downward pressure on the use of fertiliser and other inputs. Adapting to climate change may be effective in lessening the negative impacts of small changes in climate. We briefly cover some of the possible adaptations. However, studies of global food security suggest that the world's population will be exposed to a greater risk of hunger as a result of climate change even with adaptation. In this paper we suggest that these studies may have significantly underestimated the risk to food security. Environmental limitations to grain production, increased variability in production and a range of policy constraints that may affect the fertiliser industry need to be addressed in a systematic and coherent way.

Introduction

Global consumption of grains is projected to double by 2050 due to projected growth in population, per capita consumption and the use of grain to feed animals to meet a growing demand for protein. Consumption increases will vary regionally, with strong demand increases expected as incomes and populations grow, especially in the Asia-Pacific region. Ultimately, the demand for food always equates to its supply, the challenge for food security is at what price to consumers and to the environment? This challenge could be magnified as climate change tends to reduce grain production in the tropics, subtropics and mid-latitudes – the regions where food security has historically been most problematic. In this paper we explore the interactions between climate change and grain production in relation to food security and adaptation.

Climate change and food security studies

Climate change scenarios for the tropics, sub-tropics and mid-latitudes indicate potential reductions in future global grains production. However, these potential reductions have not been fully incorporated in global-scale analyses of food security. These studies have included not only climate change but also demographic and economic changes and, in some cases, climate change adaptations. They conclude that globally, impacts of climate and CO₂ increase are small compared with the positive effects of socio-economic development paths, with substantial regional variation (Easterling et al. 2007). For example, climate change alone is estimated to increase the number of undernourished people in 2080 by 5-10M under the SRES B1 scenario, up to 120 -170M people under the A2 scenario (Fischer et al. 2005) or by \pm 30M (Parry et al. 2005). In terms of regional disparity in food availability, Fischer et al. (2005) noted that for a high-emissions scenario (A1FI), 42 developing countries may benefit from substantial increases in cereal-production (averaging 17%) by 2080. However, 52 countries with a population of up to 3 billion may lose on average 19% of their current yield potential over the same period.

In a review of global food security studies by Schmidhuber and Tubiello (2007) they suggested that the robust economic growth projected for the 21st century will (in all but the SRES A2 scenario) significantly reduce the number of people at risk of hunger in 2080. Their analysis suggested that this was because real incomes are likely to rise faster than real food prices, thereby increasing access to food. Average price variations expected from the effects of global change are much smaller than those from socio-economic development paths. However, even if global food production does not decrease significantly under climate change, the additional transport necessary to compensate for regional disparities in production is likely to increase greenhouse gas emissions and handling costs. These constraints are yet to be fully considered in global analyses of food security. Interestingly, few analyses have flagged in advance the possibility of spikes in food prices like those of 2007-2008, nor the potential consequences of global financial crises like those experienced in Asia in 1998 and globally in 2008.

The positive outlook of most analyses of global food security relates to a projected increase in cropland at higher latitudes (developed countries 160 million ha), and a decline of cropland at lower latitudes (developing countries 110 million ha). The net effect of these changes could be to reduce prime cropping land by 135 million ha, but increase the availability of moderately suitable land by 20 million ha. A problem not usually considered in global food security analysis is that expansion of cropping into grassland or forest areas usually releases vast amounts of carbon dioxide whilst intensification of farming also increases greenhouse gas emissions as well as having other environmental impacts (Gregory et al. 2001). Some of these unwanted impacts arise from increased fertiliser use. It is likely that both national and international policies will emerge that impose significant costs and constraints on emissions of greenhouse gases from land clearing and land-use change as well as from energy use and fertiliser-related emissions amongst others. This will place pressure on the fertiliser industry to develop new technologies and practices to limit their exposure.

Projecting climate changes several decades into the future remains challenging for a range of reasons. There remain large uncertainties in relation to projections of all climate factors (IPCC 2007). Importantly, a significant proportion of this uncertainty stems from the large possible range of emissions scenarios used – ranging from reductions in greenhouse gas emissions to major increases. The current trajectory of increase at or above the worst-case scenarios of the IPCC (see below: Rahmstorf 2007; Canadell et al. 2008) suggests that at this stage we need to be assessing the high end of the spectrum of possible changes. In the Asia-Pacific, the main changes are increased temperatures (ranging from 2 to 6°C by 2100), increased rainfall in north Asia, especially in the cooler months, and decreases in rainfall in south and south-east Asia in the cooler months. In all these regions, there is less clarity in

the rainfall changes in the warmer months of the year due to uncertainty in how the monsoon will change. In the Pacific, there is a general tendency to decreased rainfall except for a band on and just south of the equator, where it may increase. There is likely to be increased variability in rainfall and increased rainfall intensity, possibly increased storms and latitudinally-variable changes in wind speed and sea level may rise from 45 to 140cm by 2100. Water supplies could be reduced in some regions due to lower rainfall and higher temperatures increasing evaporative demand. Cyclones (typhoons) are likely to increase in intensity but there remains uncertainty as to changes in frequency and distribution. There is no firm conclusion as to how El Niño systems may change but the balance of opinion tends towards the mean state of the Pacific being more El Niño-like. It is likely that climate change will enhance the dry conditions associated with El Niño events and enhance the intense rainfall and run-off associated with La Niña events.

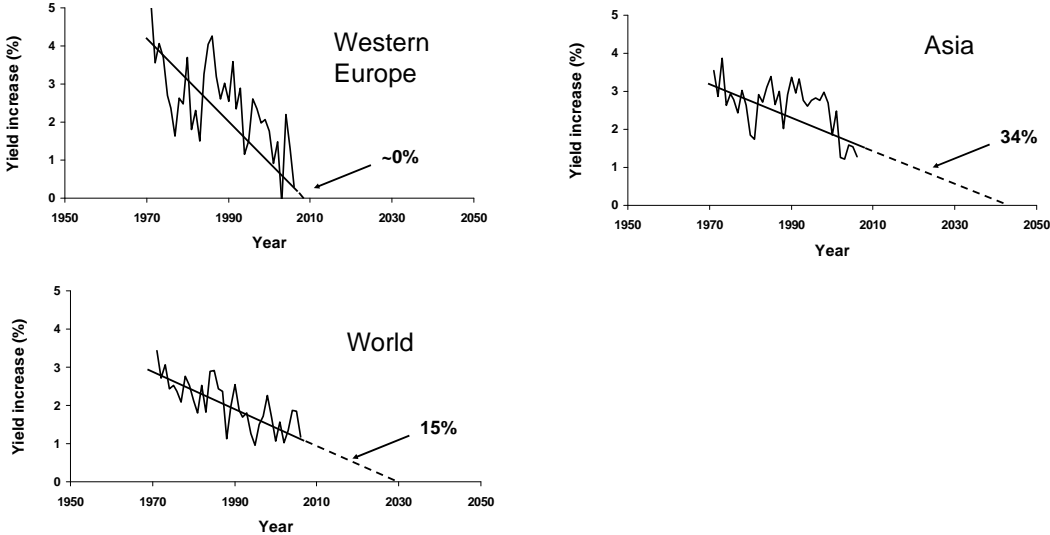
Are climate change impacts underestimated?

Analyses of global food security may significantly understate the challenges arising from climate change. Specific concerns include:

- Climate change is happening faster than expected, with the four key global indicators (greenhouse gas emissions, atmospheric carbon dioxide concentrations, global temperature and sea-level rise) all at or above the 'worst case' scenario developed by the IPCC about a decade ago (Rahmstorf 2007; Canadell et al. 2008);
- Effective adaptation technologies, management options and policies are not yet in place, because of the unexpectedly rapid climate change even though some analyses suggest a very high return on investment if adaptations are implemented (e.g. Howden and Jones 2004);
- Yield growth of the main food crops are declining due in part to a lack of investment in improving crop genetics and crop management, as well as increased bio-security risks;
- The availability of suitable irrigation water for agriculture (surface and groundwater) is likely to decline in some regions due to lower rainfall and higher temperatures, depletion of glacial ice mass (although this may increase availability in the short-term), greater rainfall extremes reducing water quality and increased demand from the non-agricultural industry and urban sectors;
- Increased costs of fossil-fuel-based nitrogenous fertilisers, agri-chemicals and irrigation pumping;
- Reported increases in land degradation which systematically reduce the productive capacity of the land; and
- An increasing number of policy and market constraints to agricultural extensification and intensification including policies to reduce emissions of greenhouse gases, conserve biodiversity and maintain ecosystem services.

A crude way of understanding the urgency with which the implications of climate change for food security need to be addressed is to compare current trends in crop yields against projected demand. We state that it is a crude approach because it fails to consider the substitution possibilities created by new technologies and shifting demand preferences as the relative price of food commodities and inputs to production change. Nevertheless it serves to focus on the challenges ahead. In terms of the demand side of this analysis, year-on-year yield growth of about 1.7% is needed to double food production by 2050. Existing trends in yield growth suggest that this may be difficult to achieve. For example, growth in wheat yields has been strongly downwards globally (Fig 1) and is currently about 1.2% - well short of the 1.7% needed. In the case of Western Europe, the trend in annual growth in yields has already reached zero (i.e. yields have stabilised, albeit at a high level).

Figure 1. Trends in year-on-year growth for wheat from FAO yield data for Western Europe, Asia and globally. The straight line is a linear regression with the dashed part extrapolation of this, the other line is a 5-year running average. The percentage figure is the cumulative increase in yield from now until the extrapolated regression hits the x-axis, representing future yield increases on the basis of current trends only.



In contrast, the same analysis for Asia indicates that yield growth of wheat has declined from about 3% p.a. in 1970 to about 1.5% currently. If current trends continue, yield growth in Asia will be zero by about 2042. Whilst this is more encouraging than the Western Europe situation, the cumulative yield growth implied is about 34% - a long way short of the 100% needed to ensure food security with current patterns of supply and demand. The global picture for growth in wheat yields lies between the Western Europe and Asian trends, with zero growth projected by around 2030 on current trends. The cumulative increase in yield of 15% is even further short of the 100% needed to ensure global food security with current patterns of supply and demand. Importantly, this simple analysis does not include the prospective impacts of climate change as above and so the actual challenge may be even greater. We have yet to implement the same analyses for other crops including rice: the major crop in the Asia-Pacific.

Climate change is also likely to impact on the nutritional quality of food and food safety (Schmidhuber and Tubiello 2007). Experiments with crops grown under elevated CO₂ suggest possible reductions of grain and leaf protein by up to 10%, with health implications in regions and social classes where protein intake is already low (e.g. such as sub-Saharan Africa). This reduction in grain and forage nitrogen (and other nutrients) can be offset by increases in application rates of nitrogenous fertilisers or perhaps by increases in efficiency of uptake or useage of such fertilisers (e.g. Howden et al. 2003). Additionally, the expression of the growth responses to elevated CO₂ is dependent on adequate crop nutrition: in nutrient poor situations there is little crop growth response. Consequently to take advantage of the potential benefits of elevated CO₂, additional fertiliser may be needed.

Variability matters

The volatility in prices due to changes in climate variability that affect food access have been much less studied. Two of the key summary points in the IPCC 4th Assessment Report were that 1) climate variability and climate extremes were likely to increase and 2) changes in climate variability are likely to have greater impacts on agricultural systems than changes in mean climate alone. Historical and current experience informs us that variability is critical to

food prices, availability and access as well as inputs to production. Changes in the volatility of food supplies due to climate change will affect food prices because climate variability has a large impact on grain production and exports. For example, global wheat exports are 50% higher in the El Niño years than in the La Niña years.

Past changes in food prices provide important insights into future volatility with, for example, the FAO food price index increasing by 37% in 2007. These price rises plus various climate-related disasters and several conflicts have resulted in 37 countries currently facing food crises. The FAO reports that the total cost of imported foodstuffs for low-income, food-deficit countries in 2007 was about 25 percent higher than the previous year. This dramatic change in outlook was driven by climate variability (mostly droughts and floods) on several key commodities in a few key exporting nations. For some grains, the availability for human food is also being reduced by increasing demands for grains as animal feed and for biofuel production. This substitution in supply has resulted in record prices and contributed to unprecedented price volatility. Volatility is also occurring because liberalised agricultural commodity markets have resulted in food stocks being kept at historically low levels (lowest since 1983). Greater speculative investment in food markets has followed reductions in trading risks associated with greater market transparency. This has also contributed to recent increases in the volatility of agricultural commodities.

Increased climate variability, price volatility and costs of production inputs such as fertilisers will all tend to reduce the use of high-cost inputs and reduce production – all else being equal. These relationships apply from farm-level to global level. This will place downward pressure on crop production – a problematic response given the food security challenges outlined earlier. One option for the fertiliser industry in response to this may be to increase investment in the research, development and extension that can increase nutrient-use efficiency through improved delivery (e.g. through application of different forms of nitrogen, sub-soil injection, foliar application, split application) and reducing losses (e.g. through nitrification inhibitors, matching crop demand with nutrient supply) and improved tactical use (e.g. through linking nutrient use with climate forecasts at various scales such as the Madden-Julian Oscillation or El Niño).

Adaptation

The anticipated changes in atmospheric and climatic factors outlined in this paper and the potential substantial impacts will likely result in substantial adaptation responses from individual farmers, from industry and from government. Adaptation here refers to the actions of adjusting practices, processes and capital in response to the actuality or threat of climate change, as well as responses in the decision environment, such as changes in social and institutional structures or altered technical options that can affect the potential or capacity for these actions to be realized (Howden et al. 2007). There is a general view that farmers and farming systems are well-adapted to climate variability, price shocks and other disturbances. However, this adaptation is often in terms of fairly well-defined, single factors such as changes in relative price of inputs or outputs, market access or change in consumer preference. In contrast, as indicated in the previous sections of this paper, climate change is, in many respects, highly uncertain in both the nature and degree of the change and has multiple, related dimensions. These are not only through potential climate changes (and hence productivity) at local, regional and global scales, but also through the emerging carbon economy and associated input prices and potential new products such as carbon storage and additionally through its impacts on global food security (Keating et al. 2008). How do farmers and cropping systems in the Asia-Pacific adapt in the face of such uncertainty?

The following is a suggested approach to start dealing with this uncertainty, building adaptive capacity and changing the decision environment to promote adaptation actions (Howden et al. 2007b):

1. To change their management, farmers need to be convinced that projected climate changes are real and are likely to continue. This is more likely to occur if existing trends in climate are consistent with projected changes in climate and where the underlying processes are well understood and communicated. This adaptation element will be facilitated by policies that maintain climate monitoring and communicate this information effectively.
2. Farmers need to be confident that the projected changes will significantly impact on their enterprise and that they understand the range of consequences of different adaptation options singly and in combination. Policies that support the research, systems analysis, extension capacity, industry and regional networks that provide this information could thus be strengthened. Farmers and policymakers also need to understand the limitations of adaptations so that they do not underestimate potential vulnerability. For example, climate changes in excess of 2°C may rapidly increase vulnerability.
3. The technical and other options necessary to respond to the projected changes need to be available. In many cases these will be extensions or intensifications of existing climate risk management or production enhancement activities in response to a potential change in the climate risk profile (e.g. Table 1). Where the existing technical options are inadequate, investment in new technical or management strategies may be required such as developing improved crop germplasm that is more suited to expected atmospheric and climatic conditions. Another example is upgrading climate forecasts in terms of reliability, lead-times and utility so as to allow year-by-year adaptation to a changing climate as first proposed by McKeon et al. (1993)
4. Where climate impacts may lead to major land use change, there may be demands to support transitions such as industry adjustment and enterprise relocation. This may be achieved through direct financial and material support, creating alternative livelihood options with reduced dependence on agriculture, supporting community partnerships, enhancing capacity to develop social capital and share information and re-training. Effective planning for and management of such transitions may result in less habitat loss, less risk of carbon loss and also lower environmental costs compared to unmanaged, ex-post transitions.
5. New infrastructure, policies and institutions could be developed to support changes in management and land and water use arrangements. Options include addressing climate change in terms of sustainable development and natural resource management; enhancing investment in irrigation infrastructure and efficient water use technologies; encouraging appropriate transport and storage infrastructure; and establishing more efficient markets for products and inputs.
6. Importantly, farmers and policymakers in industry and government must maintain the capacity to make continuing adjustments and improvements in adaptation by “learning by doing” via targeted monitoring of adaptations to climate change and their costs, benefits and effects.

Finally, it should be recognised that ‘adaptation’ is an ongoing process that is part of good risk management, whereby drivers of risk are identified and their likely impacts on systems under alternative management are assessed and remedial options implemented. In this respect, adaptation to climate change is similar to adaptation to climate variability, changes in market forces (cost/price ratios, consumer demands etc), institutional or other factors. Isolating climate change from other drivers of risk may be helpful, especially during the initial stages of assessment when awareness of the relative importance of this risk factor is still low (Howden et al. 2007). However, in the long-term, climate change risks and opportunities will need to be integrated into a broader approach to manage risks and opportunities.

Conclusion

The climate and atmospheric changes that could impact the Asia-Pacific over the next decades are likely to be substantial but key aspects of these are highly uncertain such as rainfall change and alteration in cyclones and El Niño. Positive impacts may arise from increases in CO₂, and this will be enhanced by ensuring adequate crop nutrition. However, these positive aspects are likely to be outweighed in some areas by negative impacts from likely reduced rainfall, higher temperatures and a range of possible secondary and tertiary impacts including on water demand. There are potentially significant implications of the above for global food security. We describe an approach to framing adaptation responses and list a small number of the vast array of possible adaptation responses to manage climate changes. These include a range of farm level management responses and several policy options focussed on information, technological and institutional changes that could better support effective adaptation. Enhancing existing climate risk management is likely to be a key part of this adaptation response but this needs to be broadened out into a more comprehensive risk management framework, implemented in a participatory way so as to move from adaptation analysis to adaptation action.

Table 1. A few of the adaptation options available to adapt farming systems to climate changes (Stokes and Howden 2008).

Altering inputs such as varieties/species to those with more appropriate thermal time and vernalization requirements and/or with increased resistance to heat shock and drought, increased responsiveness to CO ₂ , altering fertilizer rates to maintain grain quality consistent with the prevailing climate and to maximise CO ₂ benefits, altering amounts and timing of irrigation and other water management
Wider use of technologies to 'harvest' water, conserve soil moisture (e.g. crop residue retention) and to use and transport water more effectively where rainfall decreases
Water management to prevent water logging, erosion and nutrient leaching where rainfall increases
Altering the timing or location of cropping activities
Diversifying income through altering the integration with other farming activities such as livestock raising
Improving the effectiveness of pest, disease and weed management practices through wider use of integrated pest and pathogen management, development and use of varieties and species resistant to pests and diseases and maintaining or improving quarantine capabilities and monitoring programs
Developing improved climate forecasting and its use to reduce production risk

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