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Climate Change: The Future of Cropping Systems

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Climate Change: The Future of Cropping Systems

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Global consumption of grains is projected to double by 2050 due to projected growth in population and per capita consumption of grains directly and also in livestock production as incomes rise. Global food security depends on expanding current farming activities in a sustainable way to meet this demand. Climate variability already has a significant influence on global grain production and further impacts on production are anticipated as the climate changes. Grain yields are likely to decline in tropical and subtropical regions, as well as in regions with 'Mediterranean' climates. They could potentially increase in more temperate regions. Adapting to climate change may be effective in lessening the negative impacts of small changes in climate. Studies of global food security indicate, however, that the world's population will be exposed to a greater risk of hunger. 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 need to be addressed in a systematic and coherent way.

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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 in the world's poorer nations. Ultimately, the demand for food always equates to its supply; the challenge for food security is at what price to consumers? This challenge could be magnified as climate change reduces 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 as they are expected to impact on the four dimensions of food security: availability, access, stability and utilisation.

Climate change and food security studies

Climate change scenarios for the tropics, subtropics 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 5–10 million under the SRES B1 scenario, up to 120–170 million people under the A2 scenario (Fischer *et al.* 2005) or by ± 30 million (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, Schmidhuber and Tubiello (2007) suggested that the robust economic growth projected for the 21st century will (in all but 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 socioeconomic 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. 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.

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 *et al.* 2007; Canadell *et al.* 2008)
- effective adaptation technologies, management options and policies are not yet in place (Howden *et al.* 2007) 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 is 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 irrigation water suitable 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
- 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 changes. 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).

In contrast, the same analysis for Asia indicates that yield growth 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.

Climate change is also likely to affect 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 where protein intake is low such as sub-Saharan Africa. Warmer conditions could potentially increase the incidence of salmonella and diarrhoeal diseases, and increase the frequency and distribution of the tropical reef-fish disease ciguatera. Water-borne diseases such as cholera may also become more prevalent if extreme rainfall events increase. However, there remain large gaps in the understanding of the implications of climate change for food safety.

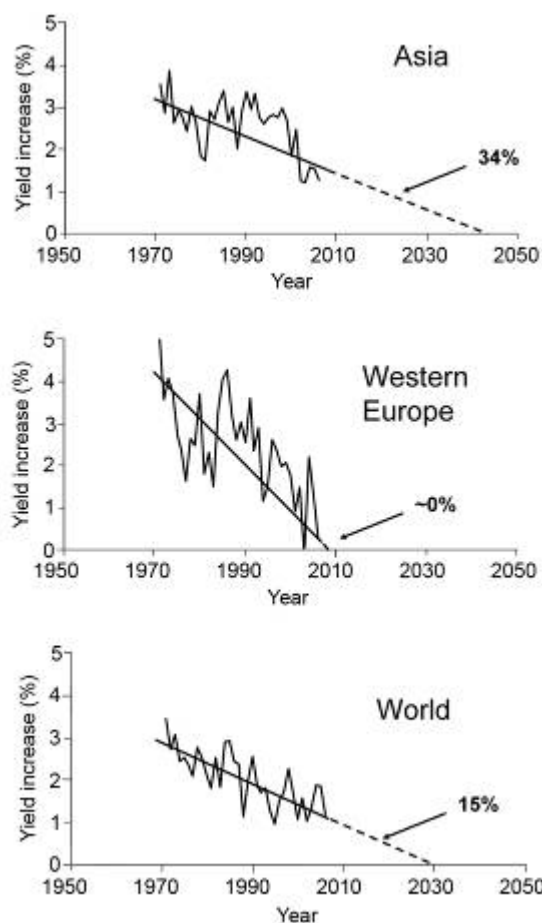


Figure 1. Trends in year-on-year growth for wheat from FAO yield data for Western Europe, Asia and globally. The straight line is a linear regression with the dashed part an extrapolation of this; the other line is a 5-year running average. The percentage figure is the cumulative increase in yield from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

Variability matters

The volatility in prices due to changes in climate variability that affect the ability particularly of poor people to access food have been much less studied. Two of the key summary points in the IPCC 4th Assessment Report were that:

- climate variability and climate extremes were likely to increase
- 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. 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. Analyses of global food systems to date have tended to concentrate on food availability.

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% higher than in the previous year. This dramatic change in outlook was driven by the effects of 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.

Pathways ahead

The volatility of production and prices should be a core part of future assessments of global food security alongside more traditional analyses of food availability. This raises the question as to whether new assessment methods are needed. For example, partial equilibrium economic models could be used instead of general equilibrium models to incorporate the impact of climate variability on food production. There is a clear need to increase investment into research of the biophysical, economic and institutional factors limiting growth in grain yields. More integrated systems research that includes genetics, management, policy and communication could open pathways to yield improvements that are closed to more traditional reductionist approaches. This could enable research to transcend the

natural limits of single-factor research. These new integrated methods for assessing global food security need to be able to incorporate the new policies, constraints and opportunities associated with climate change, such as emissions restrictions and the emerging carbon economy. This may require more of a bottom-up approach including social, economic and cultural dimensions, and scaling these up to regional level. A stronger focus on managing climate variability is likely to deliver useful information and technologies at farm and community scales that can reduce supply and price fluctuations and be transferred between regions. Lastly, consideration needs to be given to collective action to build the livelihood options and risk management capacity of vulnerable groups to deal with climate change (Howden *et al.* 2007).

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