The Feeding of the Nine Billion

Global Food Security for the 21st Century

A Chatham House Report

Alex Evans

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Executive Summary and Recommendations

The challenge

Global food prices have eased significantly from their record highs in the first part of 2008. As a worldwide economic downturn has gathered pace, commodity markets have weakened significantly. By October 2008, the UN Food and Agriculture Organization's Food Price Index stood at 164, the same level as in August 2007, and 25% lower than the Index's high of 219 in June 2008.

However, this does not mean that policy-makers around the world can start to breathe a sigh of relief. For one thing, even at their somewhat diminished levels current prices remain acutely problematic for low-income import-dependent countries and for poor people all over the world. The World Bank estimates that higher food prices have increased the number of undernourished people by as much as 100 million from its pre-price-spike level of 850 million.

Looking to the medium and longer term, moreover, *food prices are poised to rise again.* Although many policy-makers have taken a degree of comfort from a recent OECD/FAO report on the world's agricultural outlook to 2017, which argued that food prices would shortly resume their long-term decline (even if they remained on average higher than their pre-spike levels), it largely overlooked the potential impact of long-term resource scarcity trends, notably climate change, energy security and falling water availability.

This Chatham House Report, by contrast, argues that these trends – together with competition for land and higher demand resulting from increasing affluence and a growing global population – represent a major challenge for global food security.

- ***Climate change*** will result in an increase of 40–170 million in the number of undernourished people worldwide, according to the Intergovernmental Panel on Climate Change. While higher average temperatures may lead to yield increases in higher latitudes, lower latitudes – where most developing countries are located – will start to see negative impacts immediately. Increases in the frequency and severity of extreme weather and climate-driven water scarcity will also affect food production, as will the need to reduce greenhouse gas emissions from agriculture, which accounts for as much as 32% of emissions if deforestation is included.
- ***Energy security*** affects food prices in multiple ways, from fertilizer prices, on-farm energy use and transport costs to the more recent trend of using crops to produce biofuels – the single most important driver of food price increases in recent years. While oil prices have collapsed dramatically since the summer of 2008 (from a peak of $147 in July to around $40 in December 2008), the ongoing lack of investment in new oil production, coupled with accelerating declines in existing oil fields, suggest that prices are set to rebound sharply when the world emerges from the downturn – pulling food prices up with them.
- ***Water scarcity*** is already becoming a major problem as population grows and per capita consumption rises. Half a billion people live in countries chronically short of water; by 2050, the number will rise to more than four billion, not only because of climate change but also as a result of unsustainable extraction from rivers, lakes and groundwater. Agriculture, which accounts for 70% of global fresh-water use, will be particularly vulnerable.
- ***Competition for land*** is likely to become a major problem in the future. To meet rising global demand for food, yield increases alone may not be enough;

increased acreage is likely to be needed as well. However, demand for land from other uses – such as biofuels, timber, carbon sequestration, forest conservation and the world's growing cities, which tend to expand on some of the most productive land – is also intensifying. A significant proportion of land used to grow food now is already degraded.

- ***Demand for food*** will rise over coming decades as world population increases towards 9.2 billion in 2050 (although the rate of growth has slowed significantly since the 1960s, so that on current trends global population will stabilize in the year 2200 at ten billion people). At the same time, growing affluence and rising expectations mean that ever more people are eating resource-intensive 'Western' diets rich in meat and dairy products, increasing demand for crops as animal feedstocks. The World Bank projects that by 2030 worldwide demand for food will increase by 50%, and for meat by 85%.

There is therefore a real risk of a 'food crunch' at some point in the future, which would fall particularly hard on import-dependent countries and on poor people everywhere. But this outcome is not inevitable – and it would be a grave error to fall into a Malthusian determinism, or to assume that the path ahead must lead to endless competition for ever scarcer resources.

> "Policy-makers should use the current period of easing in food prices as a moment of opportunity in which to identify and agree the key elements of a global food security strategy"

Instead, *policy-makers should use the current period of easing in food prices as a moment of opportunity in which to identify and agree the key elements of a global food security strategy*. They should start by bringing greater clarity to the question of what they are seeking to achieve. Many recent policy statements have emphasized the need to increase world food production dramatically. While this objective is critical, it will also be essential to make the world's food systems for producing and distributing food:

- ***more resilient***, given that the next few decades will be characterized by pronounced turbulence as the result of *shocks* (such as extreme weather events or spikes in oil prices), slower-onset *stresses* (such as land degradation or steady price inflation), *accident or ignorance* (such as the unintended consequences of food export restrictions) or *malicious action* (such as intentional attacks on food systems by terrorists or guerrilla insurgencies);
- ***more sustainable***, given that food production is as often a driver of scarcity issues as a victim of them – whether through poor husbandry (such as over-grazing or over-ploughing), inefficient use of resources (such as water, fertilizers or energy), or in its contribution to climate change (for example through on-farm energy use, transportation, meat production and deforestation); and
- ***more equitable***, given that the reason why almost one billion people go hungry today is not that there is insufficient food to go around (a point also implied by the fact that about the same number of people globally are overweight) – but rather that poor people lack *access* and *entitlement* to food.

To meet these objectives, a comprehensive global strategy for global food security is needed. This report makes ten key recommendations – five for action in developing countries, and five for action internationally.

What needs to be done: a ten-point agenda for international action

Action in developing countries:

1. ***Spend more on food and agriculture***. The last twenty years have seen a disastrous decline in the proportion of foreign aid that goes to agriculture, from 17% in

1980 to 3% in 2006. Total aid spending on agriculture fell 58% in real terms over the same period. Today, developed-country donors urgently need to reverse this trend, and to start plugging the gap left by years of under-investment. The need to increase spending on agriculture also applies to developing-country governments, which have similarly overlooked rural sectors in recent years (despite the fact that three-quarters of the world's poor people live in rural areas). In Africa, for example, governments spend on average only 4.5% of their budgets on agriculture – despite an African Union target of allocating 10% of public spending to agriculture by 2008.

2. ***Invest in a 21st-century Green Revolution.*** The 20th-century Green Revolution achieved astonishing yield increases. Now, a 21st-century equivalent is needed – one that not only increases yields, but that also moves from an agricultural model that is *input*-intensive (in water, fertilizer, pesticide and energy) to one that is *knowledge*-intensive. Genetically modified crops may have a role, but ecologically integrated approaches – such as integrated pest management, minimum tillage, drip irrigation and integrated soil fertility management – often score higher in terms of resilience and equitability, as they put power in the hands of farmers rather than seed companies. Additional funds for public research and development are also vital: the budget of the Consultative Group on International Agricultural Research has fallen by 50% over the last 15 years, for example.
3. ***Get the basics in place.*** In order to thrive, farms in developing countries need access to five key resources: *assets* (such as land, machinery, or renewable resources such as water); *markets* (for example adequate infrastructure, communication networks that give farmers access to up-to-date price information, or the capacity to meet supplier standards for supermarkets); *credit* (to prevent small farmers from falling prey to predatory lending, and to improve access to inputs such as fertilizers); *knowledge* (where there is an urgent need to invest in agricultural extension services to help disseminate R&D findings in the field); and *risk management tools* (for example through social protection systems, mechanisms for hedging against bad weather, and improved crop storage systems). Developing-country governments and donors alike need to focus on supporting these outcomes.
4. ***Focus on small farmers.*** 1.5 billion people live in households that depend on small farms. While arguments for supporting small farms are sometimes dismissed as based on a romantic attachment to peasant agriculture, the evidence shows that, with the right policy framework, small farming can be a viable route out of poverty. In Vietnam, for instance, small farmers have been able to benefit from high food prices through accessing export markets and thus to share in the country's impressive growth. A key part of the puzzle is establishing mechanisms that can aggregate small farmers' output and help them to meet supplier standards for supermarkets and other large buyers. In the past, this role was often played by government-run marketing boards, many of which were dismantled in the 1980s and 1990s. Today, the gap they left needs to be filled – but private companies, NGOs or farmers' organizations may be just as capable of fulfilling the role as government agencies.
5. ***Improve access to social protection.*** Many poor countries have tried to deal with high food prices through subsidies or price controls. Both approaches come with a cost: the former can wreck government budgets, while the latter reduces farmers' incentive to produce more. Social protection systems represent a better alternative, but only 20% of the world's people have access to them. Although more experimentation is needed on what kinds of system work where, the main obstacles are political rather than technical: affluent groups in developing countries often oppose social protection systems for fear they will encourage dependency (although the evidence suggests the opposite). In these circumstances, the challenge for foreign aid donors is to support local advocates of pro-poor change seeking to open up political space – a challenge that is more about *influence* than about spending money.

Action internationally:

6. ***Consider an IEA for food.*** After the first oil shock in 1973, the International Energy Agency (IEA) was created. Its core mission: to coordinate collective action in future oil crises, above all through an emergency response system based on strategic oil reserves in member countries. Today, an equivalent function is needed for food. Part of the reason for the recent food price spike is that worldwide food stocks had fallen to unsustainably low levels: the recent easing in prices gives governments an opportunity to rebuild those reserves. A global system of food reserves need not entail the creation of a new agency, but to be credible the system would need to be overseen by a disinterested party, such as the World Food Programme (WFP). It would also be essential to specify that the role of any system of reserves would be limited to emergency assistance – *not* to act as a price support for producers or a permanent system for managing food aid.
7. ***Improve technical assistance on long-term 'security of supply' agreements.*** The trend for major food importers such as China, South Korea and a number of Gulf countries to seek long-term food purchase agreements, land leases or land purchases in other countries risks disadvantaging poor countries that lack the capacity to negotiate a fair deal. (Madagascar, for example, is reported to have leased half its arable land to a South Korean company for 99 years with no compensation other than jobs created on the farms.) Yet such agreements could in principle provide a benefit for both sides, allowing import-dependent countries to increase their security of supply at the same time as bringing much-needed capital, infrastructure and know-how to countries that have the potential to produce much more food than they currently do. In order to move towards this more positive scenario, developing countries need better technical assistance in negotiating these complex and innovative deals. International donors should gear up to provide such advice as a matter of urgency.
8. ***Push ahead with developed-country agricultural liberalization.*** Although agricultural liberalization may have the effect of raising food prices in the short term, the underlying fact remains that reform of United States farm support and the European Union's Common Agricultural Policy is essential for improving poor countries' food security. By subsidizing food production and then exporting food, developed countries introduce in the world trade system a dynamic that structurally disadvantages developing countries by eroding the capacity of their agricultural sectors to compete. Accordingly, reform of developed-country agricultural support remains essential. On the same basis, developed countries should move towards giving food aid in cash (which can then be used to purchase food in developing countries, thus investing in their agricultural sectors at the same time) rather than in food (a form of tied aid that subsidizes producers in the donor country). Countries with support regimes for biofuels (above all those for corn-based ethanol in the US and biodiesel in the EU) also urgently need to review those policies in the light of their impact on food security.
9. ***Integrate security of supply into global trade rules.*** A lapse into protectionism would be a serious step back for global food security. But after recent convulsions in agricultural trade (above all the export restrictions introduced by more than 30 countries), many governments are unsure whether they can trust world markets – to the extent that some of them are even flirting with autarky, despite warnings from the UN High Level Task Force on the Global Food Crisis that self-sufficiency and food security are not the same. For liberalized trade in agricultural goods to command support, importers' legitimate security-of-supply concerns need to be addressed. Policy-makers should use the Doha Round as an opportunity to explore the potential for new World Trade Organization rules on export suspensions on food, as already exist in the context of the North American Free Trade Agreement.
10. ***Agree a comprehensive global deal on climate change.*** The projected impacts of climate change alone mean that a global plan for stabilizing greenhouse gas

concentrations is a *sine qua non* for future worldwide food security – but they are not the only reason. Analysts from Goldman Sachs, the World Bank and the International Monetary Fund now agree that biofuels have been one of the most important (if not *the* most important) driver of rising food prices in recent years. If oil prices resume their volatile upward trend – as recent analyses from Chatham House and the IEA suggest they will – then food prices risk being pulled up with them. The best way of avoiding this scenario is through greatly increased investment in new oil production infrastructure, which in turn depends on a more stable and predictable outlook for oil prices. By limiting future carbon emissions, a global deal on climate change would also provide predictability on the shape of future oil demand – allowing oil producers to invest with more confidence while at the same time reconciling this goal with the need to tackle climate change seriously.

1. Introduction

Between mid-2007 and mid-2008, the issue of rising global food prices moved to the very forefront of the international political agenda. Tens of millions more people were pushed into hunger and poverty as a result; civil unrest flared up in locations all over the world; over thirty countries introduced export restrictions on food, even as many importing countries attempted to tackle the issue through subsidies and price controls.

This report – a longer follow-up to an April 2008 Chatham House Briefing Paper entitled *Rising Food Prices: Drivers and Implications for Development* – sets out to look beyond the immediate causes and impacts of the global food price crisis of recent months, towards the medium and longer term. In particular, it aims to assess:

- The *outlook* for global food prices, where the report argues that despite the sharp falls in food prices during the autumn of 2008 and the sanguine tone of a recent OECD/FAO report on the agricultural outlook to 2017, a range of long-term scarcity trends suggest that food prices may soon start to rise again; and
- What *action* policy-makers need to take now to ensure global food security in the future – particularly in developing countries and in the context of international collective action on trade in agricultural goods and related areas such as climate change and energy security.

The scale of the challenges that the world's policy-makers and peoples will face in the decades ahead is daunting. Addressing them will entail considerable risk, uncertainty and turbulence. Yet with timely and decisive action, there is every prospect of attaining the long-delayed goal of a world in which all enjoy food security.

2. How Prices Rose

A brief chronology

The story of food prices' recent rise begins in around the year 2000, when global grain stocks began to decline steeply – from over 110 days' worth of food before the turn of the century to just over 60 days' worth just half a decade later in 2004.[1]

Part of the reason for the fall in stock levels was simply that global use of grains and oilseeds had overtaken production – a factor that has continued to hold for seven of the eight years since 2000.[2] In part, this was the intended result of policy: a long-term slump in the price of commodities, together with improved trade logistics and apparently abundant supplies on world markets, helped to convince many governments (including China's) that large buffer stocks had become an expensive encumbrance.[3]

In 2002 the US dollar also began to depreciate. As the dollar fell, the price of oil increased – a trend that accelerated from 2004 onwards.[4] With oil prices increasing, the cost of agricultural inputs (especially fertilizers) rose too.[5] Transport costs also went up, creating severe problems for humanitarian agencies as well as companies engaged in trade.[6] The rising price of oil also helped to increase the attractiveness of biofuels as a substitute for oil in the United States, the European Union, Brazil and elsewhere – although subsidy and regulatory regimes were probably the more important drivers here.[7]

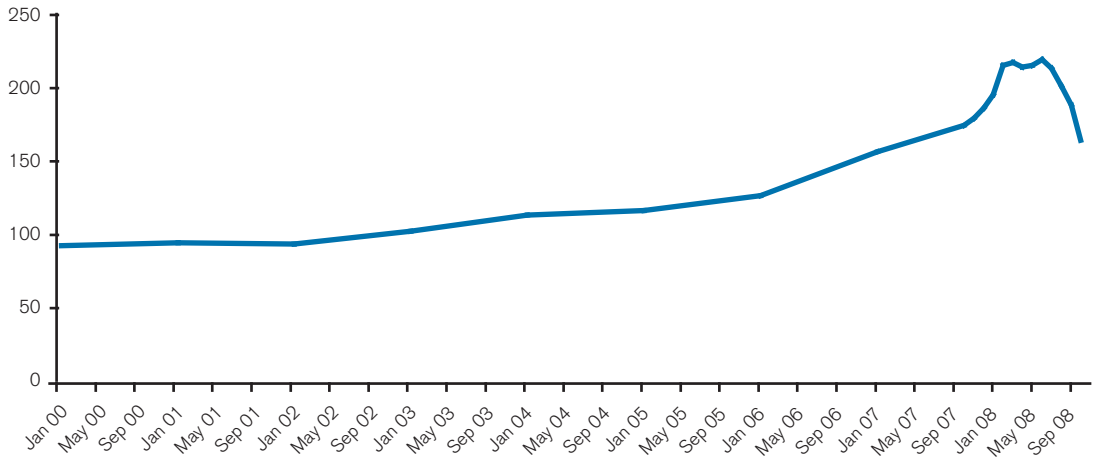
From around 2006, investors, especially those in hedge funds and sovereign wealth funds, began to seek more exposure to commodities, including food. Ronald Trostle, an economist at the US Department of Agriculture's Economic Research Service, notes that these new investors were 'not so much interested in agricultural commodities as they were in using commodities to diversify their financial portfolios', and observes that while it is difficult to lay the blame for higher prices squarely at the door of speculators, investment funds' use of automated trend-following trading practices may well have served to increase price volatility.[8]

A more tangible upward effect on prices was felt in 2005 when extreme weather in a number of major food-producing countries caused world cereal production to fall by 2.1% in 2006.[9] Australia was particularly affected, suffering its worst multi-year drought in a century. Russia and Ukraine, meanwhile, entered a two-year drought in 2006, and 2007 saw further impacts including a dry spring followed by harvest-time floods in Northern Europe, a hot and dry growing season in Canada with lower yields for wheat, barley and rapeseed, and droughts in Southeast Europe, Turkey, Northwest Africa and Argentina.[10]

'Part of the reason for the fall in stock levels was simply that global use of grains and oilseeds had overtaken production – a factor that has continued to hold for seven of the eight years since 2000'

From 2006 onwards, food prices began to rise more sharply. The United Nations Food and Agriculture Organization (FAO) Food Price Index rose by 9% during 2006, 24% during 2007 and 51% during the 12 months to July 2008.[11] Corn prices were among the first to take off, in September 2006 – a trend that led several months later to riots in Mexico City over the price of tortillas, the first major incident of civil unrest over food prices to receive widespread international media coverage.[12] Soya bean prices were next, in May 2007, followed by those of wheat in August, and rice later in the year.[13]

Figure 1: FAO Food Price Index, January 2000 to October 2008



Source: http://www.fao.org/worldfoodsituation/FoodPricesIndex/en/

The second half of 2007 also saw the first impositions of export restrictions as a means of curbing domestic food-price inflation in exporting countries. By early 2008, this new trend was under way in earnest and was being matched by moves by importing countries to reduce their trade barriers to try to increase imports, build stocks and control inflation.[14] The net effect of both sets of actions, however, was to increase world prices still further as increased demand met reduced supply.

By the middle of 2008, the FAO index had risen by more than 50% in 12 months, and protests and riots were taking place in numerous countries. By this point, the multilateral system was moving into action. In April, UN Secretary-General Ban Ki-moon had set up a UN High Level Task Force on the Global Food Crisis, headed by UN Emergency Relief Coordinator Sir John Holmes. Unusually for a UN task force, the World Bank and the International Monetary Fund (IMF) were represented among its members, and it appeared that old inter-agency rivalries were being put aside in favour of an effective joint approach.[15] At the end of May, World Bank President Robert Zoellick published a ten-point plan for tackling the food crisis, which set out key actions in an analysis developed more fully by the UN task force's draft report, published in June.[16] The World Bank also committed $1.2 billion for immediate needs.[17]

Even as Zoellick's ten points were being published, the first of them – calling for full funding of the World Food Programme's immediate emergency needs – was unexpectedly heeded. In the first quarter of the year, WFP Executive Director Josette Sheeran had been engaged in an urgent search for an additional $755 million in funding just in order to continue feeding the 73 million people already dependent on the WFP. At the end of May, this gap was plugged, largely thanks to a surprise $500 million donation from the government of Saudi Arabia.[18] Meanwhile, the US administration requested $770 million in emergency assistance, and Congress subsequently enacted supplemental assistance for the current financial year by allocating over $1.8 billion in emergency food assistance.[19]

In June 2008, the FAO held a major summit on food prices in Rome at head-of-government level. A month later, at Toyako in Japan, food prices were firmly at the top of the agenda for the 2008 G8 summit. While neither summit produced much in the way of concrete outcomes (most notably in rolling back any of the key export bans or showing signs of any kind of global rethink on biofuels), both underlined the degree of high-level attention focused on the issue.

Which drivers mattered most?

At the time of the first flurry of concern about rising food prices, many initial estimates (including this author's) suggested that their most important driver was rapid

income growth in emerging economies, notably China and India, leading to a shift towards a more grain-intensive 'Western' diet, rich in meat and dairy products.[20] However, in recent months this argument has been challenged by analyses suggesting that biofuels have been the single most significant driver of higher prices.

The World Bank, for example, argued in July 2008 that of the various factors that have contributed to upward prices, 'the most important was the large increase in biofuels production in the US and EU in response to policies that subsidized production of biofuels, restricted their imports, and mandated their use'.[21] This analysis follows the reasoning set out in an internal World Bank discussion paper by economist Don Mitchell, subsequently leaked to *The Guardian*, which controversially argued that no less than three-quarters of the 140% increase in the Bank's food prices index from January 2002 to February 2008 was caused by biofuels and related effects.[22]

Mitchell's analysis did allow that, aside from biofuels, higher energy and fertilizer costs would still have had an effect, as would the decline of the dollar. But, as the Bank's published analysis continued,

> Back-to-back droughts in Australia, and growing global demand for grains (excluding for biofuel production) have been modest contributors and on their own would not have led to large price increases. Commodity investors and hedge fund activity also seem to have played a minor role.[23]

Of particular significance are data suggesting that while global demand for cereals is increasing, this is only true as long as biofuels are included – and that once they are taken out, global demand growth is actually slowing down. For example, data from Goldman Sachs show that while historically global demand growth for food crops has been around 1.5% a year, the figure is now 2.0% (and likely to rise to 2.6% within a decade).[24] Yet the World Bank data show that with biofuels excluded, global grain demand increased by only 1.3% a year between 2000 and 2007 – and in East Asia (including China) by just 0.3% a year over the same period.[25] Goldman Sachs's analysis also suggests that biofuels have been the principal driver of rising food prices in recent years.[26] The IMF's *World Economic Outlook 2008* also echoed the World Bank's finding, observing that

> Although biofuels still account for only 1.5% of the global liquid fuels supply, they accounted for almost half the increase in the consumption of major food crops in 2006–07, mostly because of corn-based ethanol produced in the United States.[27]

Ultimately, however, while biofuels may well have been the straw that broke the camel's back and the role of changing diet patterns in emerging economies may have been overestimated, the underlying point is that a concatenation of trends on both the supply and demand side was involved creating a situation in which global consumption outstripped production for several years in succession. The phrase 'perfect storm' has become over-used in recent years; in this case, it was justified.

Impacts of rising food prices

The effects of this perfect storm were felt worldwide, including in developed economies. In industrialized economies, *inflation* edged upwards even as growth slowed, raising concerns about a return to 1970s-style 'stagflation'.[28] In emerging markets, meanwhile, headline inflation indices rose more markedly given stronger demand growth and the greater weight of energy and (in particular) food in consumption baskets.[29] The IMF estimated in April 2008 that food prices represented 44% of global inflation in 2007, and as much as 67.5% in Asia.[30]

In numerous countries, the combination of food and fuel inflation has emerged as a highly contentious political issue, and in many, dissatisfaction has led to violence or *civil unrest*. West Africa has been a particular hotspot, but violence has also flared up in low-income countries elsewhere in Africa (Ethiopia, Mozambique), Asia (Bangladesh, Yemen) and Latin America (Haiti), as well as in a range of middle-income countries around the world (Egypt, Indonesia, Mexico, Morocco, the Philippines, Thailand and Uzbekistan).[31]

For security analysts, food prices are becoming a significant factor in assessing *state fragility*: in Pakistan, for example, polls show that 70% of people perceive inflation to be the country's biggest challenge, while 86% of people believe that the country is heading in the wrong direction.[32] The US-based Center for Strategic and International Studies notes that fragile states such as Pakistan, Egypt, Ethiopia and Afghanistan are especially at risk from high food prices, and observes that this helps to make the issue a strategic threat as well as a moral, humanitarian and developmental imperative.[33]

> "The World Bank estimates that between 73 and 105 million more people may have become poor solely as a result of increases in food prices between 2005 and 2007"

Faced with these kinds of political risks, many developing-country governments have urgently sought policy responses to defuse tension. As already noted, *export restrictions* have been one widely used response: as at July 2008, the World Bank counted 31 countries that had reduced or suspended their exports.[34] Many importing countries, meanwhile, have sought to tackle rising prices by *reducing taxes* on food grains (49 countries) or by introducing or extending economy-wide *price controls or consumer subsidies* (46 countries).

However, for many importing countries these economy-wide measures have come at considerable cost. Unplanned contingency measures are having a major impact on *public-sector budgets*, particularly in West Africa.[35] In addition, some countries (particularly those with low foreign exchange reserves or without exports whose prices are also rising) have seen a significant deterioration in their *balance-of-payments* position.[36]

Above all, however, the issue of rising food prices matters for international development and *poverty reduction*, given that the most pressing impact of these price rises has been felt, predictably enough, by the world's poorest people – who spend a much higher proportion of household income on food (typically between 50% and 80%) than average.[37]

Globally, some 854 million people worldwide were estimated to be undernourished before the latest food price spike.[38] With the impacts of higher prices factored in as well, the World Bank estimates that between 73 and 105 million more people may have become poor solely as a result of increases in food prices between 2005 and 2007.[39]

In assessing the impact of rising food prices on poverty, it is important to differentiate between urban and rural contexts. Three-quarters of the world's poor people live in rural areas; most of them, including smallholder farmers, are net food buyers.[40] Many small farmers have also been affected by the fact that the price of fertilizers and other inputs has risen faster than food prices, further diminishing opportunities for them to profit from the latter.[41] Even more vulnerable than small farmers are poor people with no land of their own, who work as rural labourers and who are unlikely to be compensated fully by additional employment as agriculture grows, or by higher wages.[42]

However, poor people in cities have also been hard hit by rising food prices. WFP head Josette Sheeran pointed out the nature of the problem in early 2008. 'There is food on shelves but people are priced out of the market. There is vulnerability in urban areas that we have not seen before.'[43] This vulnerability is compounded by a lack of access to social protection systems such as welfare safety nets, food assistance or cash transfers: 80% of the world's population lacks access to social protection systems of any kind.[44]

Finally, it is worth restating the obvious but often overlooked point that the impacts of high food prices have been felt by poor people everywhere – not just those who live in poor countries. While popular conceptions of poverty (such as Paul Collier's idea of the 'bottom billion') centre on the fact that poverty is relatively concentrated in low-income countries, there are also large 'tails' of poverty in many middle- and even upper-income countries.[45] In the United States, the number of citizens receiving benefits under the Food Stamp Programme reached 31.5 million in September 2008, breaking the previous record of 27.4 million in 1994.[46]

In wealthier countries as in low-income countries, poverty needs to be understood not just in terms of economic statistics – growth rates, GDP per capita, people on less than a dollar a day – but also (and perhaps more fundamentally) in terms of political economy, social exclusion and power. This theme is explored more fully later in this report.

Signs of relief?

As already noted, the headline FAO Food Price Index peaked in March 2008 and was then virtually unchanged between May and July, before falling significantly over the course of the autumn.[47] At the time of writing in December 2008, the most recent FAO figures available showed the overall Food Price Index back at its lowest level since June 2007 as the effects of the global economic slowdown fed through to commodity prices (notably oil, which collapsed from a peak of $147 a barrel in July 2008 to $40 in December).[48]

Is it therefore time to start breathing a sigh of relief? Certainly not yet for poor people in developing countries. Even at August 2007 levels, many poor people were struggling to cope with the level of food prices. That remains the case today, even if prices have eased from their peak and even if higher food prices present a development opportunity over the long term. But what of the long-term trend? Now that prices have reached a short-term peak, can they be expected to resume their decline of recent decades?

Even before the credit crunch spread from the US to the rest of the world, and from credit markets to equity markets, commodity prices and the real economy, some analysts were already forecasting exactly that. An OECD/FAO report on the agricultural outlook to 2017, for example, argued in May 2008 that record prices 'will not last and … will gradually come down because of the transitory nature of some of the factors that are behind the recent hikes'.[49] Although the report conceded that 'once they have fallen from their current peaks … prices will remain at higher average levels over the medium term than in the past decade', it continued that

> the underlying forces that drive agricultural product supply (by and large productivity gains) will eventually outweigh the forces that determine stronger demand, both for food and feed as well as for industrial demand, most notably for biofuel production. Consequently, prices will resume their decline in real terms, though possibly not by quite as much as in the past.[50]

Others take a more pessimistic view. With the world's population still rising fast and looming 'scarcity trends' such as climate change, reduced water availability, high oil prices and competition for land likely to play an increasingly significant role, recent months have seen the re-emergence of themes and narratives that had been largely dormant since the 1970s. The then Japanese Prime Minister, Yasuo Fukuda, surprised many at the FAO summit in June 2008 when he said in his address:

> Thirty years have passed since the Club of Rome issued the [Limits to Growth] report. We are finally hearing the scream of the earth, and we now realize [that] the Cassandra's prophecy was right.[51]

Some have even suggested that high food prices could potentially herald 'the return of Malthus': former Northern Foods chairman Chris Haskins argued at the beginning of 2008 that 'the Malthusian predictions were wrong for 200 years, but might prove right in the next 50' if evasive action is not taken in time.[52]

So what *is* the outlook for food prices? The next chapter looks for lessons from history before turning to the future in an attempt to evaluate these competing claims.

3. Past Successes, Future Challenges

Ten thousand years ago, humans began deliberately cultivating plants. Not a lot was needed, beyond the seeds themselves: an axe, a digging stick and the capacity to make fire comprised humanity's agricultural arsenal. At the time, the Earth's population numbered around 5 million people.[1] Today, it has increased over a thousand-fold to around 6.7 billion.[2] What part did agriculture play in this remarkable development?

Part of the answer, of course, is a relentless process of *technological innovation*. From the first prototype plough more than 4,000 years ago, humanity has proceeded through terraced cultivation, the horse collar and heavy plough, crop rotations, the manufacture of inorganic fertilizers and the tractor, to name just a few – all the way to the high-yielding hybrid crop strains of the Green Revolution and the genetically modified crops of the 21st century.[3]

Another part of the story is *social innovation*. The process of enclosure of the commons that took place in England from the 16th to the 18th centuries, during which the population of the country trebled, allowed the introduction of revolutionary new techniques that had been impossible under the old system of open-field strips.[4]

Throughout the process, these different innovations have often arrived in *synergistic clusters*. During England's agrarian revolution, for instance, enclosure was part of a much bigger process of change – one that included a doubling of the productivity of farm labour through more efficient management practices; the arrival of new crops, including turnips (which were fed to livestock, which then also provided manure for cereal crops); and the famous 'Norfolk four-course rotation' (wheat-turnips-barley-clover), which avoided the need for land to lie fallow between crops by replacing nutrients through both manure and the nitrogen-fixing properties of clover, and increased cereal yields by 50% by the end of the 18th century. These changes on the land were in turn synchronous with changes in wider society: industrialization, population growth and rising food demand.

The Green Revolution and its limitations

Notwithstanding the importance of the innovations discussed above, until the first part of the 20th-century the most important means of increasing global food production was simply to increase the amount of land under cultivation. As the world's population doubled to two billion between 1825 and 1927, for example, the area of land cleared of forests and prairies to make way for agriculture doubled too, especially in the new frontier lands of Russia and North America. Even as humanity reached its third billion between 1927 and 1960 – a period during which mechanization began to replace human and animal labour – it was still expansion of global arable land from 1 billion to 1.4 billion hectares that was the real motor for feeding this increased population.[5]

From the 1960s onwards, however, the net amount of arable land levelled off; new land brought into production was offset by that lost to urbanization or environmental degradation. So while the earth's population is today more than double its 1960 level, the key driver for ensuring that the world's food supply has kept pace has been yields rather than acreage, as Table 1 overleaf illustrates.[6]

The process that delivered this progress – the 'Green Revolution'[7] – began in Mexico in 1943. To support the search for ways to increase Mexico's low grain yields, the country's Ministry of Agriculture and the Rockefeller Foundation set up a new venture, the Office of Special Studies.[8] It succeeded. Whereas Mexico had to import half its wheat requirements in the year of the OSS's founding, by 1956 it was self-sufficient; and in 1964, it exported half a million tonnes of wheat.[9]

Table 1: Selected innovations in agriculture and food supply, 8000 BC–AD 1975

Population size	Period	Innovations
First fifty million	8000 BC–2000 BC	• Cultivation (deliberately growing useful plants) • Axe, fire, digging stick • Domestication of key staples, including wheat, rice, maize, beans, squash, sorghum, millet, teff, yam
First half billion	2000 BC–AD 1500	• Clearing forests, ploughing grassland • Terraced cultivation on hills • Heavy plough and horse collar • Two-and three-course crop rotation
First billion	1500–1825	• Extension of arable area • New crops (e.g. potato in N Europe, maize in S Europe, both in China) • More frequent cropping • Enclosure of the commons in England • Four-course crop rotation (e.g. wheat, turnips for feed, barley, clover) combines nitrogen fixing with more animal manure: yields up 50% in England and Low Countries • Drilling crops in rows (rather than scattering seed) • More productive farm labour management systems
Second billion	1825–1927	• Doubling of area of land cleared of forests and prairies for agriculture • Beginning of agricultural research (e.g. von Liebig discovers nitrogen to be an essential plant nutrient) • Introduction of fertilizers (e.g. Chilean nitrate, Peruvian guano, German potash) • Research on pesticides (e.g. verdigris, Paris green) • Botanical gardens propagate new crops • Plant hybridization, Mendel's laws of genetic segregation
Third billion	1927–1960	• Global arable area extended from 1.0 to 1.4 bn hectares • Rising dependence on off-farm inputs • Mechanization; liquid fuel and electricity replace men and horses • Cheap nitrogenous fertilizers replace compost and manures; mixed crop / animal husbandry increasingly abandoned • Breeding of hybrid maize
Fourth billion	1960–1975	• Green Revolution: yield increases replace acreage increases as principal means of increasing production (see below)

Source: Adapted from Evans (1998).

The Green Revolution had three central elements. First, new *seed varieties* were developed that matured early, were insensitive to day length, and above all that produced high yields. An important element of progress was the 'dwarfing' of wheat and rice: reducing the height of the plant in order to allow it to concentrate its energy on growing in the grain rather than the stem.[10]

Fertilizers provided the second element. Inorganic fertilizers were not new: nitrogen, phosphate and potash had all shown their capacity to increase yields in experiments at the Rothamsted agricultural research station in England in the second half of the 19th century. But until the introduction of dwarf varieties, the additional yield provided by applying fertilizers could cause long-stemmed cereals to 'lodge' – fall over – under their own weight.[11]

Irrigation was the third element that, with new crop strains and inorganic fertilizers, completed the virtuous circle. Most developing countries have a wet and a dry

season, and while dry season yields are much higher than those in the wet season, lack of rainfall can mean that crops are lost to water stress. Without proper irrigation, crop yields tend to be low and unpredictable – whatever the level of fertilizer application.

In the background of these three core trends was a fourth innovation that had begun a few decades earlier: the *mechanization* of agriculture, replacing human and animal labour with power from fossil fuel combustion instead. Horse-drawn combine harvesters had been around since the early 19th century, but the real leap forward came with the internal combustion engine and its arrival in fields in 1892 in the form of the gasoline tractor. By 1925, Fordson tractors had captured three-quarters of the American market, and the horse was on its way out (freeing up more arable land in the process).

These, then, were the key elements of the Green Revolution. From the 1960s onwards, major effort focused on rolling them out across much of the developing world. Agricultural research institutes such as the International Centre for the Improvement of Wheat and Maize (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines were central players. In 1971, the Consultative Group on International Agricultural Research (CGIAR) was established to coordinate the growing number of research centres. International donors provided massive financial flows: World Bank lending for agriculture and rural development rose from around 1% of its loans in 1959 to almost 40% in 1979.[12]

By 1970, dwarf varieties accounted for nearly a quarter of the area given over to wheat in the developing world (not including China); the figure rose to 40% in 1975 and around 70% by the late 1990s. Rice followed a similar path. Together with fertilizer and irrigation use, yields increased steadily – in the case of rice, by about 3% a year. Worldwide, as the fifth billion was added to global population between 1975 and 1986, rice yields grew by 32% and wheat by 51%. The area under irrigation in developing countries grew by 82% over the same period.[13]

Even as the world's population has more than doubled over the half-century since 1960, global aggregate food production has kept pace – an astonishing achievement. However, the Green Revolution has not been without its drawbacks and limitations. Three areas in particular are worth highlighting.

The first is that the Green Revolution, and 'industrialized' agriculture more generally, has often been associated with problems of e*nvironmental degradation and pollution.*

Up to 70% of fertilizer applied to crops can be lost, rather than taken up by crops, polluting both groundwater sources (one study in India found a fifth of wells sampled to contain nitrate concentrations in excess of the World Health Organization limit) and rivers, lakes and coastal zones (where fertilizers can stimulate algae or phytoplankton that then starve water, and the species that inhabit it, of oxygen). Today, significant areas of the world's oceans are classified as 'dead zones' because of this problem, primarily related to agriculture in developed countries, but also around developing countries including Brazil, Mexico and China.[14]

"Even as the world's population has more than doubled over the half-century since 1960, global aggregate food production has kept pace"

Intensive farming practices have also been accused of contributing to falling biodiversity, a charge that first broke into widespread public consciousness in 1962, with the publication of Rachel Carson's *Silent Spring*.[15] Carson's book triggered a widespread debate about pesticides and agrichemicals, and contributed directly to the development of compounds that were more specific in their targets and less persistent in the environment.[16]

Intensive agricultural practices are, in addition, a major emitter of greenhouse gases. Depending on how emissions are counted (whether deforestation for agriculture is included, for example), global food and agriculture contributes between 17% and 32% of total global greenhouse gas emissions, with a particularly large share of nitrous oxide (owing to fertilizer use) and methane (particularly from livestock).[17]

As we shall see in later sections, modern agricultural methods have also been criticized for inefficient use of resources, notably energy and water.

The second limitation of the Green Revolution is that its benefits have been *unequally shared*. As Gordon Conway, the Chief Scientific Adviser at DFID, the UK Department for International Development (and former head of the Rockefeller Foundation), has shown, application of Green Revolution technologies has tended to be concentrated mainly on the best agricultural lands, making less impact on more marginal areas such as unirrigated lands or those with problematic soils or difficult topographies. Moreover, some developing countries benefited more than others: while almost all countries saw a growth in per capita food consumption during the 1960s, the 1970s saw a major divergence, with only modest growth in South Asia and little to no growth in sub-Saharan Africa.[18]

The benefits of the Green Revolution for poor people have also been varied. While small farmers have benefited from its innovations, large farmers have been the biggest beneficiaries – partly because of their greater political clout in arguing for subsidies, credit and investment.[19] While rural landless labourers have benefited from cheaper food and (in some situations) rising wages, they have also often lost out to mechanization: one Indian study found that the use of combine harvesters led to a 95% decrease in rural employment, for example.[20] And in rural areas that were largely bypassed by the Green Revolution, especially in Africa and South Asia, poor farmers and landless people have suffered reductions in real income, and increased hunger.

Ultimately, while the Green Revolution has allowed world aggregate grain yields to keep pace with population growth, the fact that today 950 million people are undernourished is the clearest illustration that not everyone has benefited. Conway summarizes:

> Technologies are by themselves not enough … Too often the new technologies have been injected into communities with rapidly growing populations already dominated by excessive inequalities where, in the absence of countervailing policies, the powerful and better-off have acquired the major share of the benefits.[21]

The third drawback is that in recent years, the Green Revolution has shown signs of falling prey to the law of *diminishing returns*. Between 1970 and 1990, productivity growth (measured in global average aggregate yield) rose by an average of 2.0% each year. This declined to an average of 1.1% between 1990 and 2007, however, and is projected by the US Department of Agriculture to continue to fall over the next decade.[22] Total global production growth for grains and oilseeds has followed a similar trajectory, from an average 2.2% annual rise in the 1970s and 1980s to 1.3% from 1990 to 2007, and a projected 1.2% from 2009 to 2017.[23]

These global totals do need to be treated with a degree of caution. Land in developed countries that was 'set aside' during years of surplus can be brought back into production, for example. Nonetheless, the fact that world production has been falling even as population continues to rise, while consumption has outstripped supply for several years in a row, is a cause for concern. The World Bank forecasts that global demand for food will rise by 50%, and for meat by 85%, by 2030.

Future challenges

What are the prospects, therefore, for achieving such massive increases in the supply of food? The following sections examine six key trends that are relevant in evaluating the competing claims of agricultural optimists and Malthusian pessimists.

Land

As already noted, until the 20th century increases in world food production were achieved principally through increasing the amount of land under cultivation, as opposed to boosting crop yields per hectare. So if Green Revolution yield increases really are running out of steam, can acreage be increased again?

In theory, there is plenty of land that could be converted to agricultural use. Only around one-tenth of the world's land surface – approximately 1.34 billion hectares – is used to grow crops.[24] Two-tenths is grassland (with considerable variation in quality). The next two-tenths is accounted for by

forest cover. The remaining half of the planet's land surface is taken up by mountains, ice or deserts.[25] As the plant physiologist L.T. Evans notes, 'the recent stasis in arable land is not because the world has run out of potentially arable land'; instead, he suggests, part of the reason at the global level (although not in Africa) is that once world average cereal yields began to keep pace with population growth, there was simply less need to bring new land into cultivation.[26]

However, estimates of how much additional land *is* actually available vary enormously. One suggests that there is at most 12% more arable land available worldwide that is not either forested or subject to erosion or desertification.[27] On the other hand, Buringh and Dudal estimated in 1987 that only 77% of potentially arable land in developed countries is already cultivated, and as little as 36% in developing countries (ranging from 15% in Latin America and 21% in Africa to more than 90% in Asia).[28]

One part of the reason for the high degree of divergence between these figures is whether or not the world's forests are counted as available for arable land. But there is also a lack of clarity over how much the world's currently cultivated land is degraded. One 1992 estimate, for instance, suggested that since the Second World War two billion hectares – 22.5% of the world's agricultural land, forest, pasture and woodland – have been degraded, on which basis as much as 80% of land in developing countries would fall into this category. A 1996 analysis, meanwhile, put the figure at 38%; the FAO and UN Environment Programme (UNEP) estimate is 16%.[29] Yet as Conway notes, other analysts have strongly criticized estimates of land at risk from desertification in particular, arguing that they

> … often [rely] on snapshot assessments, comparing drought with wet years, ignoring the often temporary nature of vegetation change, the capacity of dryland ecological systems to recover and the ability of farmers and pastoralists to adapt to the climatic cycles. What may seem to be a desert one year is a productive tract of land the next.[30]

However, while there are disagreements over the extent of degraded arable land, there is consensus that the problem is real and significant, and that poor agricultural practice (such as overgrazing, overploughing and exposure of topsoil to water erosion through deforestation) can be a major contributor.

Haiti, one of the countries where food prices have already triggered civil violence, is an extreme example of what can happen when land degradation is allowed to run out of control. Haitians largely depend on wood and charcoal for cooking fuel. To meet this demand, woodcutters have largely denuded the country of forest: today, less than 4% of Haiti's forests remain, and in many places the topsoil has vanished altogether as a result. While this is partly attributable to lack of awareness among woodcutters, the more fundamental issue is that of perverse incentives. The long-term issue of topsoil loss is less urgent than the immediate problems of hunger and poverty facing woodcutters. Furthermore, they have little incentive to replace the trees they cut down since for the most part they do not own the land.[31]

Another significant source of cropland loss is the growth of cities and infrastructure (especially roads). Cities are mushrooming, especially in the developing world; during 2008, the world's urban population was, for the first time, larger than the number of people living in rural areas.[32] Moreover, urban growth tends to be on the best agricultural land: one 1987 estimate found that while 4% of potentially productive agricultural land would be lost to urbanization between 1975 and 2000, it would include a full quarter of the most productive land.[33]

In the future, new land uses are likely to compound further the problem of competition for land resources. One likely source of new demand for land is carbon sequestration. Existing international carbon trading rules already allow for afforestation projects to qualify for emissions trading permits under Kyoto's Clean Development Mechanism, although the volume of such projects has so far been relatively limited.[34] Another is the growing significance of global biofuels production (discussed earlier, and also in the section on energy below).

Thus while increasing the amount of land under cultivation is one means of producing more food, in practice this option will often be constrained by land degradation and

by demand for land from other uses, notably urbanization, biofuels and (potentially) carbon sequestration. As well as limiting the aggregate amount of land available for food production, it is also worth noting that rural poor people – who may not own land, lack formal tenure over land that they do own, or indeed lack access to land altogether – are likely to be among the most vulnerable.

Fisheries

While global demand for fish and seafood is rising swiftly, catches of wild fish have remained largely stable since the mid-1980s. In 2005, the world's capture fisheries (i.e. not including aquaculture) produced 93.8 million tonnes of food, of which the great majority (84.2 million tonnes) was from marine rather than inland fisheries.[35]

However, there is significant regional variation within this overall global picture. In some regions, catches are increasing: both the Eastern Indian Ocean and Western Central Pacific show long-term increases, and the Northwest Atlantic and Northwest Pacific both show increases after recent troughs in production (which the FAO correlates with the tight regulation in place in these areas). Elsewhere, however, the news is less positive: Northeast Atlantic catches recently fell below 10 million tonnes for the first time since 1991, and Southwest Atlantic catches are at their lowest level since 1984.[36]

As implied by the fact that demand for fish is rising (especially in China) even as wild catches remain level, aquaculture has become an increasingly important source of fish and seafood. In 2005, aquaculture added another 47.8 million tonnes of food to the 93.8 million tonnes from capture fisheries – bringing the total to 141.6 million tonnes and aquaculture's share to more than a third of the total.[37]

The rate of growth in output from aquaculture is little short of extraordinary. Between 1990 and 2003, world production of beef grew by 0.8% per annum, pork by 2.5% and poultry by 4.9%; production from aquaculture, by contrast, grew by as much as 9.7% per annum, and is set to overtake global beef production within the next few years.[38] Much of this increase has been in China, where production of carp and shellfish in particular has been scaled up massively in recent years.

In principle, aquaculture has a potentially great contribution to make to providing protein sustainably and efficiently. For cattle in feedlots, around 7 kg of grain are needed to produce a 1 kg gain in live weight; for pork, 4 kg are needed. By contrast, for poultry just over 2 kg are required; and for herbivorous species of farmed fish (such as carp or tilapia), less than 2 kg are needed; of all farmed animals, fish demonstrate the highest conversion ratios.[39]

However, an important part of the global picture is that growth in aquaculture appears to be showing some signs of slowing down.[40] Aquaculture can also contribute to the depletion of oceanic fisheries: farmed fish that are carnivorous or omnivorous are often fed fishmeal from wild fisheries. There are also other real and potential constraints to aquaculture. One is the vulnerability of intensive aquaculture sites to disease: this caused the halving of Ecuadorian shrimp production in the 1990s, for example. Another is that farmed fisheries that are not well managed can lead to degradation of the ecosystem.[41]

"In principle, aquaculture has a potentially great contribution to make to providing protein sustainably and efficiently"

In addition, there is a range of social issues involved in aquaculture. Fish farming has frequently created social tensions among poor segments of the community or indigenous groups when these communities have not stood to benefit from new developments, or when pollution or other environmental externalities from fish farming have wider negative social effects. Another social dimension is that while aquaculture can potentially be used by smallholders, very small farms can present difficulties to purchasers in terms of quality management, regulation and securing additional volumes.[42]

Finally, the UK-based Sea Fish Industry Authority notes the risk that high demand – and prices – for fish and seafood in developed countries 'may divert material from

the poor in developing countries': if producers in developing countries focus on high-value products for export then this may have a negative impact on lower-value species that could otherwise be produced for domestic consumption, while in the future limited availability of fishfeed could also reduce the amount of fish and seafood available to low-income consumers in poor countries.[43]

In practice, then, there are constraints and important variations in performance between best and worst practice in aquaculture. Nonetheless, aquaculture shows great potential as a food source for the 21st century if these challenges can be managed effectively.

Water

Only a tiny fraction of the world's water is available for human use. Just 2.5% of the world's water is fresh, and two-thirds of this is inaccessible (locked away instead as glaciers, snow, ice and permafrost). Of the remainder, the vast majority is groundwater, so that just 0.4% of the world's total freshwater is available at the surface as lakes, soil moisture, air humidity, marshes, wetlands, rivers and in biomass.[44]

During the 20th century, the world's demand for water rose sharply. In 1900, on average, each person used 350m^3 of water. By 2000 this had risen to 642m^3, while total annual water withdrawal grew from 579 to 3,973 cubic kilometres over the same period. In the future, the impact of water stress and water scarcity is likely to grow significantly. In 2000, half a billion people lived in countries that were chronically short of water, out of a global population of around six billion. By 2050, however, the number of people living in such conditions is projected to grow to four billion, out of a global population of around nine billion.[45]

This has particularly important implications for agriculture, which is by far the most significant user of water, accounting for 69% of world water use by sector in 2000 (the figure was 90% in 1900, but since then the share of water going to industry and municipalities has risen steeply).[46]

Overall, the problem is simply a larger world population consuming more water per capita even as freshwater availability remains constant or declines. As with land degradation, urbanization is an important part of the story. But a number of changes in the food and agriculture sector are highly significant too.

One is the growth of *irrigation*. As noted earlier, irrigation was one of the three core planks of the Green Revolution. Between 1961 and 1999, the amount of land under irrigation rose at an astonishing rate – above all in West Asia, where the increase was 256%, but it also rose by at least 140% in all other regions. More recently, the rate of growth in irrigation has slowed, both because of lack of suitable land and water resources, and because of the high capital costs involved (up to $10,000 a hectare).[47] Another problem is that poorly implemented irrigation schemes can damage the land on which they are situated. If irrigated fields are not properly drained, they can become waterlogged, allowing salts to build up in the soil which reduce its fertility. The problem of salinization has affected around 30% of all irrigated land.[48]

Increasing the amount of land under irrigation may well be a crucial part of the challenge of feeding a world population due to exceed nine billion by mid-century, especially in parts of the world that missed out on the Green Revolution first time around.[49] Irrigation can undoubtedly increase the productivity of land: while only 17% of the world's arable land is irrigated, that land produces over one-third of the world's total food supply, largely thanks to irrigation's capacity to enable two or even three crops a year.[50] However, irrigation is also often inefficient. While surface water irrigation efficiency is as high as 50–60% in Israel, Japan and Taiwan, it is only 40–50% in Malaysia and Morocco, and as low as 25–40% in India, Mexico, Pakistan, the Philippines and Thailand.[51] Perverse subsidies and a lack of pricing mechanisms are often important enabling factors.

Another important shift in food and agriculture is *changing diet patterns*. On average, it takes as much as 2,000 litres of water to produce the amount of food consumed by one person in one day – 500 times as much as that person will drink directly.[52] However, this total masks huge divergences in the amounts of water needed to produce different kinds of food (and hence the water intensity of the diets of different people around the world). A kilogram of potatoes, for instance, is relatively water-efficient, requiring 500 litres of water to produce, while a kilogram of rice grown in paddies is much thirstier, requiring 1,900 litres. But these disparities are as nothing compared to those involved once meat – especially red meat

– is taken into consideration: a kilogram of poultry needs 3,500 litres, while beef needs 15,000.[53]

The impacts of unsustainable water use are already becoming clear in many parts of the world. One obvious impact is on *surface* water, for instance rivers that run dry before they reach the sea. Two often-cited cases are the Colorado River in the southwestern US and the Yellow River in northern China. Others that either run dry or become a trickle during the dry season include some of the world's most important, including the Indus, the Nile and the Ganges.[54]

Another, less visible impact is on the world's *groundwater* stocks – both aquifers and water tables – many of which are being depleted rapidly. With river water now close to being fully exploited in many of the world's key farming regions, groundwater is the default source of additional supply. In South and West Asia, groundwater has become increasingly important for irrigation: 34% of groundwater was used for this purpose in Pakistan in 2000, 50% in Iran, 53% in India and 69% in Bangladesh.[55]

Today, water tables are falling in most states in India (where well drillers are now using modified oil-drilling technology to find water, sometimes drilling a whole kilometre underground) and throughout northern China, as well as in many other parts of the world.[56] Falling water tables are a relatively new phenomenon, but now threaten the security of water (and hence food) supplies in countries that are home to 3.2 billion people.[57]

In all, then, water scarcity is already poised to be a significant limiting factor on agricultural production capacity in the 21st century – above all once climate change is taken into account (see below). Experts suggest that changes in water availability are likely to be among the most important impacts of climate change in developing countries.[58] As with land scarcity, water scarcity is likely to affect poor people most: equity in sharing water is frequently a highly contentious issue in irrigation management, corruption is widespread, and farmers without political power or money for bribes often find that they lose out.[59]

Energy

As discussed earlier, the 20th century saw a major shift in agriculture towards off-farm inputs. Mechanization and pesticides replaced human and animal labour; inorganic fertilizers replaced manure and compost. In each case, there was also an underlying shift towards reliance on fossil fuels. Longer food supply chains were also enabled by fossil fuels. As vast tracts of new arable land in North America and Russia were opened up in the 19th century, it was railways and ocean-going steamships that shipped their produce to market.

Today, the links between the world's food and energy economies are stronger than ever. As well as fuels used in producing inputs such as fertilizers, in freighting and distributing food to market and in processing, refrigerating and cooking foods, the more recent development of biofuels adds another degree of complexity to an already confusing web.

The volatility in oil prices over the last decade is therefore highly significant for food and agriculture. Demand for oil is likely to remain weaker during the period of economic downturn that the world has entered. In the background, though, a longer-term set of considerations remains relevant. Even as demand exploded in recent years, supply struggled to keep pace, stubbornly remaining at around 85 million barrels a day.[60] Part of the reason is simply that developing new supplies takes many years. But new oil supplies are also hard to get at – either geographically, or because of the expenditure of money or energy needed to access resources such as oil shales or tar sands. People, equipment and engineering skills are all in acutely short supply.[61]

These supply-side factors are likely to become increasingly relevant in future. The International Energy Agency warned in its 2008 *World Energy Outlook* that observed decline rates for existing oil fields were likely to accelerate in the long term even as 64 million barrels a day of additional gross capacity (equivalent to nearly six times Saudi Arabia's current output) needs to be brought on stream.[62]

Accordingly, the IEA estimates that a cumulative investment of $8.4 trillion (in 2007 dollars) in upstream oil and gas production is needed by 2030, but this is 'significantly less than is currently being spent'. Looking to the future, the IEA concludes that

> It cannot be taken for granted that [resource-rich countries] will be willing to make this investment themselves or to attract sufficient foreign capital to keep up the necessary pace of investment.[63]

As a result of the problem of under-investment, a 2008 Chatham House report found that 'unless there is a collapse in oil demand within the next five to ten years, there will be a serious oil "supply crunch" – not because of below-ground resource constraints but because of inadequate investment by international oil companies and national oil companies'. The report concluded that 'a spike of over $200 is possible', and suggested that this could happen as early as 2013.[64] The IEA's conclusion is more cautious, but along the same lines: 'there remains a real risk that under-investment will cause an oil-supply crunch between now and 2030'.[65]

So what would a return to higher oil prices mean for food? One part of the answer lies with *fertilizers* – which in recent months have risen even more sharply in price than has food. Between May 2006 and May 2008, prices for wheat rose by 61%; for maize, 108%; and for rice, 185%. Over the same period, the price of urea – a major nitrogenous fertilizer – rose by 160%, while that of DAP (diammonium phosphate) rose by 318%.[66] High energy prices (in particular for natural gas) are a major reason for the rises, especially in the case of nitrogen fertilizers, as are capacity limits to fertilizer production coupled with high demand for fertilizers driven by food prices and biofuel production.

The impact of these price rises on farmers has been significant. In developed-country agriculture, fertilizers usually account for the single largest use of energy: one study of Canadian farms, for example, found that inorganic fertilizer manufacture accounted for 31% of energy use in corn production.[67] A 2004 study of direct and indirect energy use on US farms found a similar ratio: 29.0% of energy use was represented by fertilizer use, with another 8.3% accounted for by pesticides.[68] In Africa, meanwhile, high prices make fertilizers less affordable, and their use less profitable: a 2008 study found that 'in the many African countries that are heavily dependent on agriculture the impacts of high fertilizer prices will extend beyond farmers to affect consumers, export earnings from cash crops, exchange rates, and the whole economy'.[69]

Another dimension of food sector energy use is fuel for *transport*, where the effects of rising energy prices have been similarly pronounced. One of the most striking illustrations of this was a paper published in May 2008 by CIBC, a Canadian investment bank, which argued that high transport costs could 'reverse globalization' by 'effectively offset[ing] all the trade liberalization efforts of the last three decades'. The report continues:

> Back in 2000, when oil prices were $20 per barrel, transport costs were the equivalent of a 3% US tariff rate … at $200 per barrel, we are back at 'tariff' rates not seen since prior to the Kennedy Round GATT negotiations of the mid-1960s.[70]

In sum, the paper concluded, 'globalization is reversible'. However, it is important to be clear that in fact only a small proportion of food is traded internationally: only 12% of the world's grain production is traded between countries, for example.[71] The proportion also varies widely between crops, so while 27% of sugar and more than 20% of wheat are traded internationally, with rice the figure falls to just 2–3%.[72] Most agricultural trade is also regional rather than intercontinental: the UK's eight largest suppliers of imported food by value are the Netherlands, Ireland, France, Germany, Spain, Denmark, Belgium and Italy, which between them account for nearly two-thirds of the UK's food imports.[73]

However, even where crops are not traded internationally, *domestic distribution networks* are still exposed to rising fuel costs. Data on the energy required to move 1 tonne of cargo for 1 kilometre illustrate the relative energy intensities of different transport modes (see Table 2).

Table 2: Energy use and CO_2 emissions by transport node

	Energy (kWh)	CO_2 emissions (grammes)
Container ship (3,700 TEU)	0.026	12.97
Rail (diesel)	0.067	17
Road (heavy truck)	0.18	50
Air (Boeing 747-400)	2.0	552

TEU = Twenty-foot equivalent unit.
Source: Container Shipping Information Service (2008).

The food and agriculture sector is a highly intensive user of road transport: a 2005 study of 'food miles' in the UK found that agriculture and food produce accounted for

as much as 28% of goods transported on roads, imposing externalized costs of £2.35 bn a year. Yet transport remains a relatively small proportion of the food costs paid by consumers in the developed world.[74]

In addition to inputs and transport, there are many other significant uses of energy in the food value chain. On farms, there is the energy needed to extract water for irrigation, dry crops, heat greenhouses and livestock sheds and fuel tractors; further down the value chain, there is the energy needed to process crops and foods, to provide power for refrigeration and ultimately to cook food in the home.

This complexity can lead to analytical squabbles over which elements of food and agriculture use are most significant. L.T. Evans, for example, argues that

> Modern agriculture is not prodigal of input energy, and next time you eat a slice of bread, please remember that much less energy was used in growing the wheat for it than in processing and distributing it for your convenience.[75]

On the other hand, the climate change analyst Benito Müller notes that in other contexts – fruit and vegetables grown in heated greenhouses, for example – the opposite may be true:

> It is not necessarily true … that the carbon footprint of strawberries grown in Kenya is higher than that of out-of-season strawberries grown in the UK, even if air freight emissions are included.[76]

Some analysts, especially those in the 'peak oil' community, have argued from this observation that a world of tighter energy supplies would need to rely on locally sourced, organically grown food.[77] Others, though, are sceptical that a population approaching ten billion could be sustained without modern agricultural approaches: a 1977 study by Buringh and Van Heemst, for instance, found that if the world used only traditional subsistence, labour-oriented agriculture, *all* of the land available for cultivation would be insufficient to feed the four billion people then alive.[78]

Finally, it is important to note the rapidly growing role of *biofuels*. If the use of fossil fuels to produce crops became a fundamental part of modern agriculture over the 20th century, the 21st century has made the reverse true as well: crops can also be used to produce fuel. This evolution enables an arbitrage relationship between food and fuel, creating what has been termed 'bushel-to-barrel convergence'.[79]

As noted in Chapter 2, increasing global biofuel production is already a significant contributor to rising global food prices. A number of studies into higher food prices have already called for reconsideration of existing biofuel support policies, in particular for biodiesel in the EU and corn-based ethanol in the US.[80]

However, the political prospects for a fundamental re-evaluation are not good. In the EU, the Directorate-General for Agriculture and Rural Development bluntly denies responsibility for the problem, arguing that 'there are strong indications that current EU biofuel production has little impact on global food prices, as biofuels use less than 1% of EU cereal production'.[81] In the US, meanwhile, proponents of corn-based ethanol have become a powerful part of an already powerful agricultural lobby; during the presidential election campaign of 2008, Barack Obama used John McCain's opposition to biofuels as the basis for an attack on his opponent during his acceptance speech at the Democratic National Convention.[82]

As these examples show, there are already real signs of 'policy lock-in' in biofuels, particularly as, notwithstanding the gross inefficiencies of turning maize into fuel, corn-based ethanol has contributed to a reduction in US dependence on imported oil. In May 2008, the US reported that oil imports fell from 58.2% of total US demand last year to 57.9% in the first three months of 2008 – a small decline, but one that allowed the Bush administration to claim that it was beginning to deliver on its pledge to break US dependence on imported oil.[83] The International Energy Agency, meanwhile, has also noted that biofuels will represent almost 75% of the increase in non-OPEC oil production in 2009.[84] In the longer term, if oil prices resume their upwards march then this could lead to a situation in which many biofuels became competitive even without any subsidies or other policy support, raising the even more politically challenging issue of whether

policy-makers would be likely to tax them in order to protect food security.[85]

In sum, then, while it is clear that food prices and oil prices are linked increasingly closely, it is no easy task to draw a comprehensive map of all of these linkages. Even if it is becoming clear that oil prices are likely to rise in the long term, it is much harder to say exactly what this means for food. One can only note that higher oil prices will tend to contribute to higher food prices. More research is needed to identify the specific impacts of a world of higher energy prices for food production, and what needs to be done to prepare for it.

Climate

For most of humanity's time on earth, wild swings in the planet's climate have been the norm. The last major swing was 11,500 years ago when average surface temperatures rose abruptly by about 7°C. Since then, however, humans have lived in unusually stable times, which have proved highly conducive for agriculture. Even during the 'little Ice Age' from AD 1350 to 1850, the global average was only 0.5°C cooler than in preceding years, for instance.[86]

> 'According to the IPCC, the earth is likely to warm by 0.2°C per decade for the next two decades, and to rise by between 0.6° and 4.0°C by the end of the century, depending on future emissions. What would this mean for food production?'

Today, however, human agency risks ending this period of relative stability. According to the Intergovernmental Panel on Climate Change (IPCC), the earth is likely to warm by 0.2°C per decade for the next two decades, and to rise by between 0.6° and 4.0°C by the end of the century, depending on future emissions.[87] What would this mean for food production?

Start with *temperature increase*. Experiments undertaken 'on the ground' show that higher temperatures can be seriously detrimental to agricultural productivity: a major study undertaken at the International Rice Research Institute in the Philippines in 2004, for example, found that 'grain yield declined by 10% for each 1°C increase in growing-season minimum temperature'.[88]

On the other hand, the 2007 IPCC *Assessment Report* suggested that 'on the whole' global food production would increase with temperature increases of between 1° and 3°C, but decrease beyond this. However, there were significant differences between latitudes. In low-latitude regions (such as the Philippines), 'even moderate temperature increases (1–2°C) are likely to have negative yield impacts for major cereals'.[89] By contrast, effects on crop yields could be positive in higher latitudes: in North America, for instance, 'in the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5–20%'.[90]

William Cline, of the Center for Global Development, presents a valuable synthesis of findings from both climate models (such as those used by the IPCC) and field experiments (such as that undertaken at IRRI). He cautions against focusing too much on the next few decades:

> A small amount of warming through, say, the next two or three decades might provide aggregate global benefits for agriculture (albeit with inequitable distributional effects among countries). But policy inaction premised on this benign possibility could leave world agriculture on an inexorable trajectory toward a subsequent reversal into serious damage … by late in this century unabated global warming would have at least a modest negative impact on global agriculture in the aggregate, and the impact could be severe if carbon fertilization benefits (enhancement of yields in a carbon-rich environment) do not materialize, especially if water scarcity limits irrigation.[91]

As Cline implies, one of the most significant unknowns in the interface of agriculture and climate change is the extent to which increased concentrations of CO_2 in the atmosphere will cause a '*carbon fertilization*' effect that could increase crop yields – both because CO_2 is used in

photosynthesis, and because higher CO_2 levels reduce plants' water loss through respiration.[92] It is known that some plants ('C3' crops, including wheat, rice, soybeans, legumes and most trees) benefit substantially from higher CO_2 levels; 'C4' crops including corn, millet, sorghum and sugarcane, on the other hand, derive much more limited benefits.

Cline's study – which gives country-specific estimates for the effect of climate change in 2070–99 under the IPCC's 'A2 scenario' of CO_2 concentrations at 735ppm in 2085 – highlights how important uncertainties over carbon fertilization effects are in practice. In the United States, for example, crop yields rise by 8% with best-guess carbon fertilization effects; but when these effects are taken out of the equation, the yields fall by 6% instead. Similar results are shown for China: +7% with carbon fertilization, but -7% without. However, for most developing countries, Cline finds unambiguously negative results: Africa faces 17% lower yields with carbon fertilization and 28% without; Latin America, 13% lower with and 24% without; in India, the range of possibility is between -30% and -40%.[93]

Another highly significant impact of climate change on agriculture will be changes in *water availability*, which will expose hundreds of millions of people to additional water stress during the course of the 21st century.[94] More than a sixth of the world's population live in river basins fed by glaciers or snowmelt – including the Indus, Ganges, Mekong, Yangtze and Yellow, all of which rely on the Himalayas – and are likely to see more flow in winter and less in summer.[95] Sea-level rise will reduce freshwater availability in coastal areas through salinization of groundwater and estuaries. Increased variability and intensity of precipitation will increase the risk of floods and droughts.[96] As with changes in temperature, latitude will be a major variable: current models predict more precipitation at higher latitudes, and less in the tropics.[97]

The impacts of these changes will vary widely around the world. In Australia – one of the top ten wheat producers in the world – the IPCC projects that by 2030 crop yields will decline in much of the country owing to drought and wildfires. In Africa, between 75 million and 250 million people are likely to be exposed to additional water stress by 2020, and yields from rain-fed crops in some countries could be reduced by up to 60%.[98] By the 2050s, freshwater availability in Central, South, East and Southeast Asia is projected to decrease.[99] Sea-level rise will increase the risk of flooding in densely populated megadeltas, especially in Asia.[100]

Yet another set of impacts is the unpredictable *sudden onset weather shocks* that climate change will drive. Principal among these will be extreme weather events, such as hurricanes and floods. There were plenty of examples during 2008 of how such events can impact on agriculture: Cyclone Nargis destroyed 7% of Burma's rice crop, for example, while floods in the Midwestern US caused major damage to US corn and soybean crops.[101] These impacts are often omitted in quantified projections of how agriculture will be affected by climate change – the IPCC's estimate of the potential for growth in world yields under moderate temperature increase overlooks extreme weather impacts, for instance – but as events such as Cyclone Nargis show, these can have a major impact on yields.

Finally, it is important to note that if climate change will be decisive for agriculture in the century ahead, the converse is also true given *agriculture's own emissions*. As noted earlier, food and agriculture are responsible for up to 32% of man-made greenhouse gas emissions; given that total emissions will need to fall by as much as 85% by 2050 (even more in developed countries, under an equitable global regime), agriculture will have an indispensable contribution to make.[102]

As part of this process, agriculture is likely to need to become a net sink for emissions rather than a net source of them: in other words, it must move beyond reducing its contribution to the problem to becoming part of the solution by removing surplus CO_2 from the atmosphere. Planting trees is one way of doing this. Improving land and soil management is another critically important way (see below).

In summary, the effects of climate change on agriculture are highly uncertain. Over the next few decades (with the important caveat noted above about the impact of extreme weather), IPCC data suggest there will be winners and losers, with relative winners concentrated in higher

latitudes and vice versa. Over the longer term, the outlook for aggregate global yields is more uniformly negative under 'business as usual' emission scenarios, underscoring the extent to which the outlook for global food production is contingent on the agreement and implementation of a comprehensive global deal to stabilize greenhouse gas concentrations at a safe level.

A second key message on climate change and agriculture is about the outlook for developing countries. Many highly populous developing countries face strongly negative impacts on agriculture over even just the next few decades, and catastrophic impacts over the longer term. In the short term, adaptation to climate change will be crucial for agriculture. But unless adequate emissions reduction is undertaken early enough, there is a real long-term possibility of climate change impacts being so severe that adaptation *in situ* becomes effectively impossible for the majority of people in these countries.

Lastly, agriculture will also face a significant challenge in the need to reduce its *own* emissions, and – if the world decides not only to stabilize emissions but also to remove increasing amounts of CO_2 from the atmosphere – to become a net 'negative emitter'. Achieving these demanding goals will require major shifts in the practice of agriculture.

Population

The world's population reached six billion people just before the turn of the millennium, and best estimates for 2008 place the level at approximately 6.7 billion. The most up-to-date estimates suggest that global population will increase by another 2.5 billion to a total of 9.2 billion in 2050. Most of this increase will be in less developed regions of the world, where population is projected to rise from 5.4 billion now to 7.9 billion in 2050.[103]

An important contextual factor, however, is how much the rate of global population increase has slowed from its peak during the 20th century. Population growth reached its fastest rate in 1963, at 2.19% a year. Today, the growth rate has almost halved, to 1.15%. It continues to decline, and is projected to fall below 1% in 2020, and to less than 0.5% by 2050. Long-term projections now suggest that the world's population will stabilize at just above ten billion in the year 2200.[104] The global picture, then, is not, as popularly imagined, the Malthusian nightmare of exponential growth. The long-term outlook is perhaps less one of constant 'running to stand still' on food production than a case of 'one last push'.

But this is not to overlook the real demographic challenges that still lie ahead, even leaving aside the impact of the scarcity issues examined above. Principal among these is that while the global picture shows population growth slowing down significantly, almost all of the remaining projected growth will take place in developing countries – the very countries which are likely to be most severely affected by scarcity trends despite having the least capacity to adapt. A comparison of the world's most populous countries in 2007 and as projected in 2050 illustrates the point (see Table 3).

Table 3: The world's 20 most populous countries, 2007 and 2050

2007		2050	
Country	Population (m)	Country	Population (m)
China	1,329	India	1,658
India	1,169	China	1,409
USA	306	USA	402
Indonesia	232	Indonesia	297
Brazil	192	Pakistan	292
Pakistan	164	Nigeria	289
Bangladesh	159	Bangladesh	254
Nigeria	148	Brazil	254
Russia	142	DRC	187
Japan	128	Ethiopia	183
Mexico	107	Philippines	140
Philippines	88	Mexico	132
Vietnam	87	Egypt	121
Ethiopia	83	Venezuela	120
Germany	83	Russia	108
Egypt	75	Japan	103
Turkey	75	Iran	100
Iran	71	Turkey	99
Thailand	64	Uganda	92
DRC	63	Kenya	85

Source: UN Department of Economic and Social Affairs (2006).

In many of the least developed countries on this list, this degree of population growth implies real risks of exceeding the sustainable yield threshold of the ecosystem depended on for food, be that cropland, rangeland or fishery. In many African countries, average farm size is falling steadily as land continues to be subdivided; political tension over access to land and water rights is already discernible in a range of countries including Sudan and Kenya (where land was a significant issue in the violence that followed the election at the beginning of 2008). Moreover, many of these countries also face the additional challenge of high HIV infection rates coupled with low access to treatment, which means that while the population is rising, the number of adults available to produce food is disproportionately affected. (In Burkina Faso, for example, a study of two villages found that HIV and AIDS reduced income from agriculture by 25–50%.[105])

> "Many African countries also face the additional challenge of high HIV infection rates coupled with low access to treatment, which means that while the population is rising, the number of adults available to produce food is disproportionately affected"

The positive dimension of the population issue, however, is that the means of stabilizing national population levels is well known. The core elements are access for all to primary education (already enshrined as the second of the eight UN Millennium Development Goals), basic health care (covered under MDG4 and MDG5 of reducing child and maternal mortality, respectively), access to family planning and reproductive wealth services (MDG5 again), and overall simply reducing poverty (MDG1).

This point is important, as it effectively rebuts some of the more draconian arguments put forward by Malthusian thinkers during the 1970s. For example, the controversial ecologist Garrett Hardin, best known for his 1968 paper *The Tragedy of the Commons*, followed it up with an even harder-hitting paper in 1974 entitled *Lifeboat Ethics: The Case Against Helping the Poor* in which he argued that countries and their resource endowments were in effect 'lifeboats' that would sink if they attempted to carry too many people, and that aid should therefore not be given to developing countries unless they were taking aggressive measures to reduce population.[106] In fact, the evidence shows that such hardline approaches are not needed. What *is* needed, however, is success in the process of development, especially in rural areas given the already acute problems of land degradation and water depletion.

Conclusion

Chapter 2 noted the divergence between optimistic views of the future, which suggested that food prices would soon resume their long-term decline (even if at higher levels than before), and more pessimistic – or even Malthusian – views of the future. What conclusions can be drawn from the evidence discussed above?

First, it is important to note the high degree of uncertainty across all of the issues considered above. Quantitative estimates of the amount of arable land that is either available or degraded vary enormously; no one can be sure how water availability will be affected by climate change; methodologies for assessing energy use in agriculture and the broader food value chain differ extensively, and there is also no certainty over the outlook for the oil price; the effects of climate change are uncertain at the global level and even more so at more granular levels of focus; there is a broad range of possible outcomes on population projections to 2050.

The extent of uncertainty in analysing scarcity issues is further compounded by the high degree of interconnection between them. As discussed above, food production is not only vulnerable to climate change: it is also a major contributor to the problem. While food production depends on energy inputs, food itself can now be turned into energy through biofuels. Water extraction depends on

significant energy inputs, and in the process helps to cause climate change, which in turn worsens the future outlook on water availability. Here too, there is a high degree of uncertainty: future interactions between scarcity issues will be shaped by complex feedback loops and by human attempts to mitigate them, making it difficult or impossible to predict how these linkages will play out in future.

With these caveats stated, however, it is clear from the evidence set out above that scarcity issues are likely to make for a bumpy ride in world food and agriculture over the next decade and beyond. Perhaps the single most important impact in the near term will be declining water availability, as the last few decades' trend of unsustainable use in many parts of the world converges with the additional water stress imposed by a changing climate. As Lester Brown points out, while substitutes can be found for oil, the same cannot be said of water.[107]

The reliance of modern agriculture on fossil fuel inputs at so many points in its lifecycle also represents a significant source of vulnerability. Anecdotal evidence suggests that some international supply chains are already being reconfigured to reflect new differentials in the relative cost of transport versus labour; if (as the evidence cited earlier implies) oil prices resume a significant upwards trend, these trends may accelerate markedly.[108]

Across all the scarcity issues discussed above, a common theme is that the poorest countries stand to be affected most seriously – not only because of their more limited capacity to adapt to the effects of scarcity issues, but also because of geographical variations inherent in the problems themselves.

Population growth is heavily concentrated in developing countries. Land degradation is most extensive in Africa and Latin America.[109] South and West Asia are most exposed to groundwater depletion, and Africa as a whole to changes in water availability driven by climate change. High energy costs impact most heavily on poor, import-dependent countries (a 2007 International Energy Agency study of 13 non-oil producers in Africa found that increased oil costs since 2004 accounted for 3% of their GDP – more than the total of all aid and debt relief they had received over the same period).[110] Above all, negative impacts driven by climate change will be felt sooner, and more severely, in lower latitudes and above all by poor countries: the IPCC estimates that in all, there will be between 40 million and 170 million more undernourished people as a result of climate change.[111]

At the same time, scarcity issues have the potential to be a serious obstacle to the application of Green Revolution approaches in locations that missed out on them first time around, during the second half of the 20th century. Fertilizer use and irrigation were two of the three main planks of the Green Revolution; yet the capacity of poor countries to use both technologies (as well as the additional enabling technology of mechanization) will be limited if land, water and energy all become more scarce. As the UN's High Level Task Force on food prices noted in its *Comprehensive Framework for Action*,

> While there is scope in some developing countries for bringing new land into cultivation and ... intensifying land use through irrigation, these options are costly, have potentially adverse environmental consequences, and will not be feasible on the scale required to resolve the massive problem of accelerated soil productivity decline.[112]

Do the issues discussed above imply, then, that humanity is inevitably heading for a Malthusian 'overshoot and collapse' scenario as global population rises towards ten billion? No. As discussed above, history shows how exponential rises in population have been matched by extraordinary innovation. But at the same time, there is no room for complacency. The coupling of scarcity trends with a rapidly expanding world population makes for a highly precarious situation that is full of risk – so global strategies on food and agriculture need to start with clear recognition of that risk.

Unfortunately, not all multilateral work on these issues appears to do so. The OECD/FAO report, for example, found that 'the underlying forces that drive agricultural production … will eventually outweigh the forces that determine stronger demand', and further that 'prices will resume their decline in real terms, though possibly not by quite as much as in the past.'[113] What account does this analysis take of scarcity issues?

In fact, very little. The report admits that 'any possible impacts of climate change and water shortages are not

considered', and allows that 'deviations from these assumed conditions would lead to potentially much different market outcomes'. On energy prices, meanwhile, the report assumes that oil prices 'slowly increase over the outlook period from US$90 per barrel in 2008 to US$104 per barrel by 2017' – an arguably optimistic assumption, given that oil prices already exceeded $145 in 2008 and, as argued earlier, may well resume their upward trend if the world emerges from the economic downturn without any alteration of underlying oil supply fundamentals in the meantime.

Or take the World Bank's ten-point plan, first set out by Robert Zoellick in an op-ed in the *Financial Times* and later elaborated in a paper prepared by the World Bank for the July 2008 G8 meeting. In his article, Zoellick writes:

> … there should be greater collective action to counter global risks. The interconnected challenges of energy, food and water will be drivers of the world economy and security.[114]

Admittedly, Zoellick offered little specificity on what should be done to deal with these risks (suggesting instead the need for a system of global food stocks), but he was right to highlight their fundamental significance to food and agriculture. Oddly, however, by the time of the World Bank's fuller G8 paper, these issues had largely disappeared: while there was still a ten-point plan, climate, energy and water scarcity were not referred to anywhere within it. Indeed, climate change was mentioned *nowhere* in the document; nor was there any substantive mention of water scarcity.

Scarcity issues suggest that the current signs of relief on food prices may be no more than a temporary lull before they resume their upward trend. This lull presents policy-makers with an important moment of opportunity. The easing of the acute concerns that led many countries towards counter-productive, short-term pursuit of the national interest – through export restrictions, for instance – means that high-level political attention on the issue can now be channelled towards longer-term action than it was possible to consider even just a few months ago. It is essential that policy-makers seize this opportunity, before the risk that renewed upward lurches in price could close down political space once more.

So what would be the core planks of a global strategy for food security in the face of scarcity issues? The next chapter sets out an agenda for action – starting with food *production*, before turning to questions of *access* to food supplies.

4. Towards an Agenda for Global Food Security

Innovations in agriculture and food supply have tended to come in clusters that are together much more than the sum of their parts, as the previous section of the paper set out. As the world's human population moves towards ten billion people, what might its latest such cluster consist of – and what actions do multilateral agencies and aid donors need to take to expedite the process?

Objectives for 21st-century food and agriculture

Before starting to answer that question, it is important to step back and ask what this new round of innovations will need to achieve. The Green Revolution's central achievement was to boost global crop yields sufficiently to enable them to keep pace with population. As the number of people in the world continues to rise, as demand increases by a projected 50% by 2030, and as competition for land resources grows too, it is already clear that yields per hectare will need to grow dramatically as well. Yet the challenge facing the world is not just to increase yields by this substantial proportion, essential though that task is. Three other objectives must also be taken into consideration in order to deliver real global food security for the 21st century.

First, *resilience*. The next few decades are likely to be a period of pronounced turbulence, caused by a range of drivers. One set will be the increased prevalence of *shocks*: sudden onset crises, such as extreme weather events driven by climate change, or sharp spikes in the price of energy. Another will be *stresses*: slower onset impacts such as land degradation or gradual price inflation that risk being overlooked by short-term policy or investment planning. Then there is the risk caused by human action through *ignorance or accident*: think of the positive feedback loop caused by one set of countries suspending exports while another attempts to build up imports. Finally, the food system could be disrupted by *malicious action* – for example during conflicts or through intentional systems disruption by terrorists or insurgent groups.

While not all of these risks to food security can be prevented, a strong focus on resilience in food supply systems can help to mitigate their impact when they do occur. Resilience is an attribute that is relevant throughout the food value chain: from evaluating crops for their resilience to droughts or pests to assessing the vulnerability to disruption of trade relationships and domestic-level supply chains. In all of these contexts, the question of the resilience or vulnerability of poor people and poor countries – typically those most exposed to risks – needs to be a prime concern for domestic and international policy-makers.

The second additional objective for 21st-century food supply must be *sustainability*. Chapter 3 argued that food supply is not only vulnerable to scarcity issues; it is also often a *driver* of them. Poor husbandry, such as overgrazing or overploughing, can be a major contributor to land degradation. Inefficient and wasteful use of fertilizers or water contributes directly to demand for energy resources against a backdrop of tight supplies. Profligate use of water for irrigation depletes water tables and aquifers even as it can cause salinization in the soil. Agriculture and food supply chains are highly significant emitters of greenhouse gases.

Minimizing the exposure of food systems to scarcity issues through enhanced resilience is only half of the story, therefore: food and agricultural systems also need to be part of the solution, both through reducing their environmental impact and (wherever possible) through contributing actively to environmental restoration.

Finally, the experience of the Green Revolution also shows that *equity and poverty reduction* should be a core objective in 21st-century food supply. Today, the reason why nearly a billion people are undernourished is *not* that there is insufficient food to go round. If the world's food production were added up and then divided equally between the world's population, then each person would have 2,700 calories a day – an average easily sufficient to eradicate hunger.[1] In reality, the number of undernourished people is almost perfectly mirrored by the billion who are overweight or obese – primarily in developed countries, but also (increasingly) among new middle classes in emerging economies.[2]

As the economist Amartya Sen has observed, 'Starvation is the characteristic of some people not *having* enough to eat. It is not the characteristic of there not *being* enough to eat.'[3] For Sen, the real problem is therefore one of lack of *access* and *entitlement* to food, which results from a number of causes: people may be unable to grow enough food on land that they own, let or can access; or they may be unable to buy enough, because their income is too low, or they cannot get the money needed; or they cannot acquire enough food as gifts or loans from relatives or neighbours, or through entitlement to government rations or aid programmes.[4]

Yield increases on their own are not enough: resilience, sustainability and equitability are vital too. If, moreover, scarcity issues mean that agriculture struggles to deliver yield increases on the scale needed, then these three other policy objectives assume an even greater importance. So what are the contexts in which these objectives will play out?

Food production in conditions of scarcity

Finding solutions on the supply side – agriculture and aquaculture – will be fundamental to achieving food security for all, across all four of the objectives identified above. These solutions will have to be identified in a range of areas, as outlined here.

Finance and investment

As a result of the long-term commodity slump of the last two decades, agriculture has often been forgotten by aid donors and developing-country governments alike. The proportion of official development assistance aid going to agriculture fell precipitously between 1980 and 2006, from 17% to 3%; in real terms, the total amount of aid spent on agriculture fell 58% over the same period.[5] Many developing-country governments have also scaled back public support to agricultural extension services over the past two decades: in Africa, for instance, only 4.5% of public spending goes to agriculture (despite an African Union target of 10% by 2008), making the total for the whole of Africa just $13 billion.[6]

Meanwhile, the amount spent on agricultural research and development has fallen dramatically too: the budget for the Consultative Group on International Agricultural Research (CGIAR, the key coordinating body for public investment in agricultural R&D) has fallen by around 50% over the past 15 years.[7]

There is already widespread consensus on the need to reverse these trends, although estimates of how much money is required vary widely. FAO Director-General Jacques Diouf has put the figure at $30 billion a year, although the derivation of this figure is unclear; the World Bank has argued that $5 billion is needed now for rapid-response agricultural investment, plus an additional $9 billion for medium-term agricultural and rural investment; and the UN has called for the percentage of official development assistance spent on food and agriculture to rise from 3% now to 10% within five years.[8] The World Bank has also called for an incremental $1 billion to be spent on CGIAR (twice as much as its current budget of around $450 million a year).[9] However, as this section explores, while greater financial commitment is essential, it is also not sufficient.

Research and development

Start with R&D, which was a central element of the Green Revolution's success. The rates of return on investment in this area are well established: a study by Yale University, for example, found that crop yields in developing countries would have been 19.5% to 23.5% lower without CGIAR investment. A Dutch study, meanwhile, gives an idea of how individual countries have benefited, as Table 5 shows.

Table 5: Returns from publicly funded agricultural research and extension

Country	Research target	Years	Rate of return (%)
Bangladesh	Wheat and rice	1961-77	30-35
Brazil	Soybeans	1955-83	46-69
Brazil	Irrigated rice	1959-78	83-119
Chile	Wheat and maize	1940-77	21-34
Colombia	Rice	1957-64	75-96
Mexico	Wheat	1943-63	90
Pakistan	Wheat	1967-81	58
Peru	Maize	1954-67	50-55
Philippines	Rice	1966-75	75
Rwanda	Potato seed	1978-85	40
Senegal	Cowpeas	1981-87	63

Source: Echeverria (1989).

Public investment in agricultural R&D is especially important for poor countries and poor farmers given that private-sector R&D tends to focus on the major high-value crops, on labour-saving technologies and on the needs of capital-intensive approaches to farming. Research focused on the needs of poorer people, on the other hand, involves long lead times, will involve more marginal lands where outcomes are less assured, and above all benefits people who are less able to pay for the research to be undertaken.[10]

What should the priorities be for a renewed focus on agricultural R&D? One obvious place to start is with improving yields. Here, though, there may be limits to how much further new seed varieties can take us. Before plant hybridization got under way in earnest, domesticated cereals devoted only a small proportion of their energy from photosynthesis (i.e. light) to seeds: in the case of wheat, for example, the figure was around 20%.[11] Today, plant breeding has raised this proportion – the 'Harvest Index' – to around 50% for wheat, rice and corn, through 'dwarfing' the length of the straw.

However, given plants' requirements for the supporting infrastructure of roots, leaves and stems, there is a limit to how high the Harvest Index can go; the estimate is around 60%.[12] One of the 'holy grails' of agricultural R&D is therefore to move beyond increasing the share of photosynthate that goes to seed towards the more fundamental innovation of improving the efficiency of photosynthesis itself. As yet, however, this goal remains a distant prospect.

Much recent media commentary has focused on the potential of genetically modified crops to 'feed the world'. The chief executive of Monsanto, for example, has pledged to develop seeds that will double yields of maize by 2030. However, while genetically modified crops may have an important contribution to make on the resilience and sustainability fronts (discussed below), the track record to date of GM technologies does not show a significant contribution to raising the yield potentials of the world's main cereal crops – wheat, rice and maize.

None of this means that further yield increases are off the table. As L.T. Evans notes, the history of agriculture '[shows] us over and over again that there are no grounds for assuming there will not be further advances in yield just because we cannot foresee a route to them'. Admittedly, he continues, the particular context that gave the world the extraordinary yield growth of the Green Revolution 'may prove to be unique'. However, he concludes, real world crop yields rarely reach their yield *potential*, because of constraints such as water, nutrients, imperfect adaptation to local environments, and pests, diseases and weeds.[13]

Here, GM crops *have* shown potential to deliver improvements. The first generation of GM technologies has focused on improving the resistance of crops to so-called 'biotic stresses', such as weeds and pests: either through building defences against pests into the plant itself (as with crop varieties that contain a gene from the *Bacillus thuringiensis* microbe, which produces a toxin to protect against pests such as corn borers), or through allowing plants to work with herbicides (as with 'Roundup Ready' crop strains). Meanwhile, abiotic stresses – too much or not enough water, extremes of temperature, salinized or acidified soils – are becoming the focus of R&D on the next generation of GM crops. Research has also shown that plants can be engineered to over-express the gene that allows roots to absorb more nitrogen, thus allowing crops to produce the same yield with a 50% or even two-thirds reduction in the amount of nitrogen fertilizer needed.[14]

These advances have the potential to deliver a double win against the objectives identified earlier, improving

both the resilience of crops to climate change and land degradation and their sustainability (in particular by making them more efficient in their use of water). At the same time, however, there is also the risk of pests and weeds emerging that will be resistant to GM technologies. The experience of the Green Revolution gives considerable grounds for caution on this front: as early as 1993, excessive application of new insecticides and herbicides meant that 700 pests, 200 pathogens and 30 weeds had already developed resistance to agrichemicals.[15]

Ecologically integrated approaches

However, if improving the resilience and resource-use of individual crops through biotechnology is one avenue for exploration, another is to achieve the same results through working with whole *systems* rather than just with individual crops, in particular through integrating natural biological and ecological approaches – such as soil regeneration, predation and parasitism – into food production.

One example of this is *Integrated Pest Management* (IPM), first set out in a seminal 1959 paper entitled *The Integrated Control Concept*.[16] The hallmark approach of IPM is to control pests through the influence of natural predators and parasites that prey on them, so reducing the need for pesticides. Massive amounts of research are needed to establish which strategies will work for different crops and in different contexts, and great expertise is also required on the part of the farmers implementing the approach on the ground.[17] Even today, with the concept of IPM nearly half a century old, usable programmes for many important crop pests are still lacking, even in developed countries: much remains to be done.

Another example is *Integrated Soil Fertility Management* (ISFM), an approach that combines the use of both inorganic fertilizers and organic approaches such as composts, manures and nitrogen-fixing plants in order to increase yields at the same time as rebuilding depleted soils, improving moisture retention and protecting the natural resource base.[18] The Alliance for a Green Revolution in Africa, whose research on soil is based on this approach, argues that together, organic and inorganic approaches offer the prospect of a virtuous spiral: 'organic methods increase the efficiency of fertilizer and fertilizer helps increase the returns on organic methods through positive interactions on soil biological, chemical and physical properties'.[19] Like IPM, ISFM is typically highly adapted from place to place, and relies heavily on farmers' knowledge as well as on access to inputs.

A related approach to soil quality is '*minimum tillage*' (also called 'conservation tillage'). Although the plough is a traditional feature of agriculture, there is increasing recognition that tilling the land as little as possible can have benefits for the soil, for minimizing energy and pesticide use, and in reducing erosion. Under minimum tillage systems, crop residues are left on top of the soil as a mulch, and new seeds are simply drilled through them into undisturbed soil. Weeds are controlled by herbicides rather than ploughing; this reduces soil erosion and improves the soil's capacity to sequester CO_2. However, implementation is concentrated in a handful of countries: 24 million hectares are under no-till irrigation in the US, 22 million in Brazil, 16 million in Argentina, 13 million in Canada and 9 million in Australia; no other countries have more than 2 million hectares under no-till systems.[20]

> 'More integrated approaches to livestock management can also produce dramatic improvements in the sustainability of agriculture, either through reducing the grain intensiveness of meat production or through easing the pressure of grazing on rangelands'

Because heavily ploughed soil releases carbon dioxide and methane as once buried organic matter is exposed, techniques such as minimum tillage can play a significant role in tackling *climate change* – an important point given that organic matter contained in soil is the single largest terrestrial pool of carbon.[21] In the future, attention is likely

to be focused not only on minimizing emissions from soil, but also on using soil actively to sequester carbon. 'Terra preta' soils found in the Amazon basin, for example, have an unusually high charcoal content that means their carbon content is 10–20 times as high as typical tropical soils.[22] Johannes Lehmann, an associate professor at Cornell University, estimated in an article in *Nature* in 2007 that converting residues from forestry, fallow farm fields and annual crops to charcoal could offset around one-third of US fossil fuel emissions.[23]

Water use is another area ripe for more sustainable approaches. At present, most of the world's irrigation is under the highly inefficient flood-or-furrow system, but water productivity can be increased substantially through using overhead sprinkler irrigation (which can reduce water use by 30% below flood-or-furrow systems) or drip irrigation (which typically halves water use).[24] At present, only a handful of countries use drip irrigation extensively (90% of the irrigated area in Cyprus, 66% in Israel, 55% in Jordan and 17% in South Africa and Spain; but only 4% in the US, and less than 1% in China and India).[25] Water 'harvesting' and storage systems are also likely to be increasingly important if, as expected, climate change leads to greater seasonal variability in precipitation and water availability, but many developing countries have minimal capacity: Ethiopia, for example, has 38 cubic metres of water storage capacity per inhabitant, as opposed to more than 5,000 in Australia.[26]

More integrated approaches to *livestock* management can also produce dramatic improvements in the sustainability of agriculture, either through reducing the grain intensiveness of meat production or through easing the pressure of grazing on rangelands. One example already in widespread use is the incorporation of soya meal into feed rations, which produces enormous increases (in some cases a doubling) in the efficiency with which grain is converted into animal protein.[27] In India – home to the world's largest dairy industry – cattle are fed almost entirely on roughage such as wheat and rice straw or corn stalks; China is successfully using a similar model in the eastern provinces of Hebei, Shangdong, Henan and Anhui, which now produce more beef than the grazing provinces in the northwest.[28]

Finally, as noted in the previous section, *aquaculture* is also emerging rapidly as a high potential element of the sustainable agriculture toolkit. Global aquaculture production has expanded rapidly in recent years, and in principle this trend has the potential to deliver great efficiencies in protein production as compared to meat. This is especially important in the context of strong demand growth for protein in developing countries: seafood currently represents 20% of global animal protein consumption, and this share is rising.[29]

Contrasting paradigms in agricultural innovation …

Perhaps the most striking feature of both recent and current agricultural innovations is the extent to which they represent a gradual shift from the input-intensive model of the Green Revolution towards an approach that is instead knowledge-intensive.[30] All of the approaches above share the trait that through application of R&D, science, innovation and local knowledge, agriculture can be highly intensive in output terms while treading more lightly in terms of fertilizers, pesticides, water, energy and soil stress.

At the same time, it is also possible to contrast two different poles within the broad sweep of knowledge-intensive approaches. One is more high-tech, and relies on life sciences and biotechnology to deliver increased yields, crop resilience and sustainability; the other is focused more on whole systems than on individual crops.

These two approaches show a marked difference in the implied distribution of knowledge and power. In the life sciences approach, knowledge is heavily concentrated at the 'top' of the process – in the laboratories of biotechnology companies and seed companies – and then moves 'downwards' to farmers who apply the technologies in the field. The biotech companies who own the patents to engineered crop strains (and may enforce them through technologies to ensure that crops do not produce new seed) are also in a powerful economic position if farmers depend on their seeds for future crop plantings.

In more ecologically integrated approaches, by contrast, research is heavily adapted to local context, the line between 'laboratory' and 'field' becomes much more permeable, and the approach is more participative. (As one of the pioneers of Integrated Pest Management puts it, the

promise of ecologically integrated approaches is to 'replace investment in chemicals and their associated pest-surveillance systems by investment in people'.[31])

In this regard, while both approaches can help to deliver resilience and sustainability, the latter arguably scores better on equitability. Ecologically integrated approaches ultimately distribute power and autonomy outwards, to individual farmers, while life sciences approaches empower seed companies while introducing the potential for a dependency relationship among farmers. As noted in the section on the Green Revolution, it is always essential to test agricultural innovations not only on their technical merits but also in terms of who will benefit and how they will change distributions of power.

… and production

The same distinction – between large-scale, high-tech, centralized approaches and smaller-scale, labour-intensive approaches – can also be seen in the context of farms themselves. Most of the world's farms – 85% of them, around 450 million in total – are less than two hectares in size, and the average area is getting smaller; most of these farms are not very productive.[32] To some analysts, the implication of these observations is clear. Paul Collier, for example, argued in April 2008 that

> The remedy to high food prices is to increase supply. The most realistic way is to replicate the Brazilian model of large, technologically sophisticated agro-companies that supply the world market. There are still many areas of the world – including large swaths of Africa – that have good land that could be used far more productively if it were properly managed by large companies. To contain the rise in food prices we need more globalization, not less.
>
> Unfortunately, large-scale commercial agriculture is deeply, perhaps irredeemably, unromantic. We laud the production style of the peasant: environmentally sustainable and human in scale. In respect of manufacturing we grew out of this fantasy years ago, but in agriculture it continues to contaminate our policies. In Europe and Japan huge public resources have been devoted to propping up small farms. The best that can be said for these policies is that we can afford them.
>
> In Africa, which cannot afford such policies, the World Bank and the [UK] Department for International Development have orientated their entire efforts on agricultural development to peasant-style production. Africa has less large-scale commercial agriculture than it had 60 years ago. Unfortunately, peasant farming is not well suited to innovation and investment. The result has been that African agriculture has fallen farther and farther behind.[33]

Is he right? Start with some context. As noted earlier, three-quarters of the world's poor people live in rural areas. Agriculture is central to their prospects: of the three billion rural people in developing countries, 2.5 billion are in households involved in agriculture, and 1.5 billion of them are in smallholder farmer households.[34] The fact that most of them are net food buyers rather than net sellers, together with other trends examined earlier in the report such as the sharp increase in fertilizer prices, means that they are some of the people most severely affected by the recent spike in food prices.

But the immediate challenge with agriculture is not so much to increase the supply of food – a longer-term goal – but to improve poor people's access to it. Is moving off the land and into cities the best way of achieving this goal? In fact, the data suggest otherwise. Between 1993 and 2002, the number of people living on less than a dollar a day declined from 28% to 22% of people in developing countries. The principal driver for this improvement has been falling poverty in *rural* areas (from 37% to 29% over the same period) – and 80% of the decline in rural poverty was due not to migration to cities, but simply to better conditions in rural areas.[35] As the 2008 *World Development Report* concludes, 'agriculture alone will not be enough to massively reduce poverty, but it has proven to be uniquely powerful for that task'.[36]

Collier's argument is also dubious in that it lumps small farms together as a homogeneous mass under the heading 'peasant-style production'. In reality, it is useful to distinguish between a range of different kinds of small farms, which may employ quite different strategies. One recent study distinguishes between three distinct livelihood strategies for small farmers, termed as:

- '*Hanging in*', where activities are undertaken to maintain livelihood levels at a 'survival' level;
- '*Stepping up*', where investments are made in existing activities in order to increase their returns; and
- '*Stepping out*', where existing activities are engaged in to accumulate assets as a basis for investment in alternative, higher-return livelihood activities.[37]

In other words, while it is certainly true that some smallholder farming never gets beyond subsistence levels (if that), it is also possible for it to become a highly viable livelihood strategy, either in itself, as part of a broader portfolio, or as a springboard for an exit from agriculture by choice. Moreover, as an International Food Policy Research Institute paper published in 2007 found, at their best small farms can also deliver wider local economic benefits:

> Smallholdings are typically operated by poor people who use a great deal of labour, both from their own households and from their equally poor or poorer neighbours. Moreover, when small farm households spend their incomes, they tend to spend them on locally produced goods and services, thereby stimulating the rural non-farm economy and creating additional jobs.[38]

The paper concludes emphatically that, with regard to equity and poverty reduction, 'small farms are preferred to large'.[39] Moreover, there is also evidence that small farms can become significant export earners, given adequate functions to aggregate their output. Vietnam, for example, has gone from being a food-deficit country to being a major food exporter, largely as a result of improvements in smallholder farming.[40] As a result, Vietnam's experience of rising food prices has been more positive than that of many other countries: the effect of costlier food in rural areas has been largely offset by increased incomes.[41]

Conditions for success in smallholder production

It seems clear, then, that there is at least the *potential* for small farms to act as the driver of a broad-based form of growth that contributes to poverty reduction not only for the people living on them, but for wider rural economies as well. This leads on to the question: what do developing-country governments, aid donors and the wider private sector need to do to create the conditions for smallholder farming to flourish? While the answer is more complex than the question, it can usefully be organized into a few broad areas.

"Vietnam has gone from being a food-deficit country to being a major food exporter, largely as a result of improvements in the smallholder farming"

First, and most obviously, smallholder farmers need *access to assets*. These may be hard, tangible assets (farm machinery, buildings, land) or they may be environmental assets (water, fisheries or forests), but in all cases, the underlying economic and political questions involved are similar. Who owns the assets? Who has usufruct of them? Who enjoys the right to trade them, and what rules govern this trade?[42]

Of the various assets that small farmers depend on, the most obvious is land. Research undertaken by the World Bank shows that more equitable land distribution tends to go together with higher economic growth, in addition to the obvious benefits for poor farmers.[43] In practice, however, a range of factors often undermines small farmers' access to land. One is that as land gets divided through inheritance, so farms become smaller, as declining average farm sizes in many parts of Asia and Africa show.[44] Insecure property rights and illegal seizures of land coupled with corruption in law enforcement or local government are also often factors. Women, in particular, often have unequal access to land or have insecure tenure.[45] Land reform to address these problems can have major benefits for poor people, especially landless people who are among the most vulnerable of the rural poor. At the same time, by providing long-term security, such policies have the effect of encouraging farmers to look at

the long-term sustainability of their land management practices.

Access to water is another area where effective and equitable governance mechanisms are essential. As noted earlier, groundwater depletion and unsustainable levels of water extraction from rivers and lakes are problems that require immediate action, even before the projected impacts of climate change are added to the equation. Today, though, the lack of property rights and/or pricing mechanisms – together with frequently perverse subsidies for water use or energy for water extraction – means that farmers and other water users often lack the incentives to use water efficiently. Small farmers and/or poor people are often the ones who lose out from unsustainable water use, especially given the extensive corruption frequently associated with water use and irrigation.

Fisheries are yet another area where resource governance is crucially important. As noted above, some wild catch fisheries remain in serious decline even as others remain sustainable or are in the process of recovering. Here too, the evidence shows that equitable and properly enforced rules of access, such as 'individual transferable quotas', can play an important role in making fisheries management sustainable.[46]

Second, small farmers need *access to markets*. The most obvious and tangible need here is for infrastructure such as rural roads, but other kinds of infrastructure – such as communication networks that allow farmers access to up-to-date market and price information – are essential too. Improving the operation of markets themselves, and the ways in which smallholders access them, is also important.

A related question has to do with *which* markets small farmers are able to access – and in particular whether they can successfully break into markets for higher value added products such as fruits, vegetables, fish, nuts, spices and flowers, which now account for more than half of all developing-country agricultural exports (outstripping more traditional 'cash crops' such as tea and coffee).[47]

In all of these cases, the advance of globalization means that small farmers are increasingly finding that their sales avenue is less through traditional markets and more through large purchasers such as multinational food companies and supermarkets (which account for rapidly growing market shares in many developing countries). Typically, large firms will want to source larger volumes of produce than many small farmers can manage, and they will also often want assurance that the produce meets exacting standards for quality assurance, product safety and traceability.[48]

However, these challenges do not necessarily mean that small farmers must find themselves out of the picture. If they have access to an intermediary that can provide the functions of aggregating produce (playing a quality assurance role at the same time), then they can potentially achieve the double win of ensuring that the required standards are met at the same time as redressing what would otherwise be a very imbalanced negotiation.[49]

In the past, this aggregating role was often played by 'parastatal' public-sector bodies such as marketing boards, but in many developing countries these were rolled back or abolished under structural reform programmes mandated by international financial institutions in the 1980s and 1990s. While in many cases these bodies were corrupt and inefficient, many countries now find themselves facing a gap where they used to be. Today, the options for plugging this gap will vary from place to place, from the public sector through cooperatives and public/private partnerships all the way to private companies. In all cases, the *form* that the aggregating function takes is less important than ensuring that the *function* is delivered.

A final point in the context of access to markets is ensuring that small farmers do not find themselves having to compete with highly subsidized exports from developed countries in a battle they will almost certainly lose. This point is discussed more fully in the section on trade below.

Third, small farmers need *access to credit*. When they lack access to loan facilities on reasonable terms, they typically become more vulnerable in a range of ways: their ability to invest in new technology and innovation is diminished (eroding their capacity to compete with larger farmers), their capacity to cope with peaks and troughs in prices is reduced, and by default they become susceptible to often predatory forms of lending (as for example in India, where suicide among heavily indebted farmers has become a major problem and a salient election issue).[50]

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Once again, part of the picture here is the rollback in recent decades of agricultural services that used to be provided by developing-country governments during the heyday of aid investment in agriculture. In some cases, international companies such as seed and fertilizer companies have stepped into the gap, providing small farmers with inputs, finance and extension services, and sometimes also agreeing contracts for small farmers' produce.

At their best, these arrangements can put small farmers on a more level playing field with larger players, and help them to achieve significant increases in productivity. However, as Duncan Green notes, the power imbalance between small farmers and large companies means that such arrangements can be predatory too, for example through extortionate interest rates or by leaving small farmers bearing all of the risk of crop failure (together with the attendant vulnerability to falling into debt).[51]

As with access to markets, small farmers can improve their relative position if they can aggregate themselves into larger units, which will (in turn) be able to access credit, inputs and other services on more preferential terms. Organized groups of small farmers can also improve their political power relative to large companies and landowners, allowing them to pursue lobbying strategies with a greater chance of success. The case of Malawi – where targeted subsidies to help farmers to cope with high input costs (especially for fertilizers) have proved highly cost-effective – is a useful example of how the capacity of state can be brought in to provide support to small farmers if the political will needed is there.[52]

Fourth, smallholders depend on *access to knowledge*. Innovation will be fundamental in enabling farmers to deliver rising yields in at the same time as using more resilient and sustainable practices. During the 20th-century Green Revolution, however, smallholder farmers often struggled to access more capital-intensive innovations, and consequently often lost out on the so-called 'innovators' rent' – a point that re-emphasizes the need for access to credit.[53] However, credit is just one part of the story.

To propagate these highly knowledge-intensive techniques in smallholder farming sectors, governments – or the private sector – need to invest in extension services that can bring research findings to farmers and share best practice between them.[54] Once again, in many developing countries these services were significantly rolled back under structural adjustment programmes and the long period of donor and developing-country government neglect towards agriculture, and they need significant investment to be rebuilt. Here too, delivering the function is more important than organizational form.[55]

Finally, smallholders need *access to risk management mechanisms*. Part of the picture here is social protection systems, which although often associated primarily with protecting consumers can also be used effectively by producers.[56] Another important part of the toolkit is crop insurance, access to which remains relatively rare in the smallholder sector, but which can help smallholders to reduce their exposure to both commodity prices and weather-related risks.[57] Effective crop storage systems can also reduce farmers' exposure to price fluctuations at the same time as reducing post-harvest losses.[58]

In a larger sense, many of the tasks associated with climate change adaptation also come under the broad heading of risk management. The range of actions that may be necessary to adapt to a changing climate is immense, and will differ dramatically across geographical contexts, from different crop strains to mechanisms for harvesting and storing rainwater for use during dry spells or droughts. Ensuring that innovative ways of adapting to climate change are disseminated as widely as possible re-inforces the importance of access to knowledge.

Across all of these areas, a common thread is the underlying *significance of politics*, and the fundamental necessity for small farmers to organize themselves to form a more substantial political and economic force. As an International Food Policy Research Institute study of smallholder farms warns,

> Political will is a fundamental precondition for agricultural investment and policy reform, and it has been lacking in many of today's poorest countries, particularly in Africa. Even Asian countries that have consistently shown strong political commitment to small farm-led agricultural development now face major political economy challenges to

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> cutting back subsidy support to agriculture in the Green Revolution heartlands and redirecting some of those resources to investments in public goods that can expand future small farm opportunities. Vested interests and widespread opposition in rural areas, among large farmers and the fertilizer and seed industries, have become major impediments to adapting the policy agenda to changing economic conditions.[59]

Social protection

If food supply is one half of the story, the other half is all about *access* to food: who gets to buy it, and how it is traded.

High food prices hurt poor consumers hardest, whether urban or rural. In addition to increasing the number of people who are undernourished by around 10% worldwide, thus moving away from the Millennium Development Goal on hunger, food prices have contributed in many countries to civil unrest, violence and concerns for state fragility. In many countries, the concurrent effect of rising fuel prices has worsened the problem.[60]

At least 46 developing-country governments have attempted to address these problems through introducing price controls or economy-wide subsidies.[61] However, these policies come at a cost. In addition to the impact on government budgets of such contingency measures, subsidies can themselves contribute to inflation, and price controls can have the perverse effect of removing incentives for producers to supply more food. Subsidies and controls are blunt instruments that fail to direct assistance to where it is needed most.

Because of these problems, many aid donors and multilateral agencies have suggested that a better alternative would be for developing countries to use social protection systems.[62]

Within the broad term 'social protection', there is an enormous diversity of mechanisms and approaches. In acute crises, emergency safety nets such as food aid or humanitarian relief are a form of social protection.[63] But social protection approaches are also used in much longer-term contexts: for example, cash transfers (which may be unconditional, or linked to conditions such as school attendance, working or accessing healthcare); asset transfers, vouchers, pensions, transfers of inputs such as fertilizers, and so on.

Even before the food crisis emerged as a first-rank issue, social protection systems were already gaining significant attention among donor agencies. Part of the reason for their growing salience is an increasing recognition that the chronically poor tend not to have access to the benefits of private social protection systems (such as remittances) or to private insurance markets. A number of highly publicized success stories, such as the 'Oportunidades' conditional cash transfer scheme in Mexico, have also contributed to their growing profile.[64]

Now, policy-makers are increasingly interested in the potential of social protection systems to protect chronically poor people from spikes in food prices triggered by drivers on the other side of the world, as well as other new global risks. The 2008 *Chronic Poverty Report* identifies five 'poverty traps' against which social protection systems can move poor people towards greater resilience:

- ***Insecurity***, which can result from shocks such as conflicts and violence, economic crises or natural hazards;
- ***Limited citizenship***, where chronically poor people lack a political voice, and hence do not have power, or effective or legitimate political representation;
- ***Spatial disadvantage***, which can be through geographical remoteness, poor natural resource endowments, political disadvantage or weak integration;
- ***Social discrimination***, where chronically poor people are 'trapped' by their positions within households, communities and countries;
- ***Poor work opportunities***, either where employment opportunities are limited, or where the employment available is exploitative or of low return.

All of these factors need to be taken account of in a politically rooted assessment of how the impacts of high food prices have been distributed among poor people.

The success of existing social protection approaches, where they have been put in place, shows that, if well designed, they can achieve their aim of building resilience to shocks at individual, household and community level.[65] If food prices do indeed resume their rise in the medium to long term, social protection systems are likely to have an important contribution to make. However, there is a long way to go: despite calls for universal access to social protection systems by 2020, the fact remains that four-fifths of the world's people lack access to any form of social protection.[66]

What international action is required to build up the capacity of social protection systems? First, a note of realism is important. Apart from the sheer number of people who have access to social protection, there is also the point that the international development sector's enthusiasm for social protection systems is relatively new. Much more evidence is needed about which forms work best in which contexts; as the *Chronic Poverty Report* puts it, the period up to 2010 'must be treated as a genuinely experimental phase'.[67]

> "If higher food prices are here to stay, and risk rising still further, then continuing to feed the 73 million people who currently depend on the WFP for assistance is likely to be just the beginning of the challenge"

Second, significant investment – of time and political will as well as money – is needed to reform and increase the capacity of international humanitarian relief systems, especially the World Food Programme. As noted in Chapter 2, the WFP successfully managed to raise the $755 million of additional finance that it needed in early 2008 to meet the higher cost of its existing relief work. But if higher food prices are here to stay, and risk rising still further, then continuing to feed the 73 million people who currently depend on the WFP for assistance is likely to be just the beginning of the challenge.[68]

What this implies in financial terms is open to question. The UK House of Commons International Development Committee has assessed that in financial terms, the WFP's normal requirement of $3 billion a year in voluntary contributions may need to double to $5–6 billion; and this is before other humanitarian agencies are taken into account.[69] On the other hand, the fact that food and transport account for so much of the WFP's budget means that a move towards providing assistance in the form of cash or vouchers might create efficiency savings, allowing social protection to be scaled up without additional overall resources. In the end, so much will depend on how successful policy-makers are at tackling the root causes of food insecurity that accurate assessments of future funding needs at this stage are simply impossible – but if recent trends are anything to go by, there is every chance that the world's humanitarian system may need to be scaled up rapidly in the not-too-distant future.

In any case, funding alone is not enough: more integrated ways of working are also needed. In addition to the need for better coordination between humanitarian donors (an agenda explored by the UN's 2006 High Level Panel on System Coherence), better integration is needed between humanitarian relief agencies and donors focused on development more broadly. At present, humanitarian relief and development assistance are often seen as largely discrete spheres by practitioners in both areas. Social protection, on the other hand, blurs the line between the two.

In the context of fragile states with limited capacity where poverty reduction and political stability are threatened by spikes in food prices, it is essential that the international donor system is able to move from rapid reaction to investment in longer stability without tripping itself up. The WFP's move towards administering cash transfers as well as traditional food aid has the potential to represent an important step towards this more integrated approach, but the issue transcends the work of one agency. The UN High Level Task Force on the Global Food Crisis, which has already proved its value in its initial assessment of the issue, would be potentially well placed as a forum for

working out the operational implications of a more seamless approach to social protection.

But above all, moving to this more integrated approach requires donors to work with developing-country governments, at both national and local levels. As the *Chronic Poverty Report* notes, social protection systems can at their best have a transformational political impact, both through progressive social change and through building a social compact in which the state acts to reduce people's risks in return for their commitment *to* the state.[70] If, on the other hand, overseas donors allow themselves to fall into the very real trap of supplanting states' responsibilities, then that impedes this process of evolution towards greater state accountability and legitimacy.

As this observation implies, a commitment to increasing access to social protection implies that donors need to be willing to think *politically* about their work in developing countries. In many of these countries, the most significant barriers to implementation of social protection systems are often political rather than technical or related to capacity limits: social elites may critique social protection systems for promoting dependency (in fact the evidence suggests that poor people tend to use social transfers as small investments), while government officials may be worried about the fiscal sustainability of the long-term financial commitment involved.[71]

Donors can help to answer and allay these concerns, for example through providing predictable financing (where their record falls far short of their rhetoric), but resource transfer and technical assistance on their own are not enough. Donors also need to think intelligently about *influence*: about their own position as *de facto* political players, the nature of drivers of change in wider society that open up opportunities for pro-poor change, and how donors can partner with other progressive political actors in promoting social protection provision.

Trade

Some of the most significant impacts of rising food prices have been in the context of agricultural trade, most obviously in the case of export restrictions, which by July 2008 had been implemented in at least 31 countries.[72] As the UN's food task force noted,

> The worldwide reduction of national grain stocks in recent years was the result of increasing confidence that prices would remain relatively stable and that global trade would permit countries to rapidly acquire grain in international markets when needed. The recent combination of export restrictions and severed access to existing food stocks, compounded by subsidy and biofuel policies of major exporters, has contributed to undermining that confidence.[73]

Since then, the outlook has become gloomier for advocates of free trade. Although some countries that imposed export restrictions have now begun to roll them back, this development has been overshadowed by the failure of trade talks held in Geneva in late July 2008 which had been intended to resurrect the ailing Doha trade round. Significantly, the issue that led to the talks' collapse was in the agricultural arena (see below).[74] In the US protectionist sentiment appeared to be increasing during the 2008 presidential election campaign. France's farm minister has suggested that developing countries should adopt their own versions of the EU's Common Agricultural Policy as a response to rising food prices. Rising transport costs had the effect of reimposing costs that had been eliminated in past tariff reductions, and may do so again if oil prices resume their upward march.[75]

Even the autarkic idea of self-sufficiency appears to be becoming more popular. 'Peak oil' theorists have begun to argue that more local self-sufficiency in food production is a necessary response to a world of tighter oil supplies.[76] A range of developing countries that had placed their trust in world markets to meet their food needs appear to be reconsidering their dependence on external suppliers – most dramatically in the case of the Philippines, a major importer of rice, which in 2008 announced its intention to become self-sufficient in rice in just three years.[77] Such policies prompted a warning note from the UN food task force, which noted that such policies 'in the past have generally undermined agricultural growth and have had limited success in actually addressing the desired national food security objectives'.[78]

Behind the headlines and short-term reactions, the underlying story is of a gradual shift away from market access as states' prime concern in agricultural trade, and towards *security of supply*. The World Trade Organization (WTO) and its binding dispute settlement system are essentially designed to resolve arguments about market access and dumping: the kind of disputes that one might expect in a long-term buyer's market, of the kind that prevailed until recently. Today, however – as the trends already discussed amply demonstrate – trade in food has become a seller's market, and many importing states are acutely concerned about the extent to which they can rely on overseas suppliers.

The collapse of the July 2008 trade talks in Geneva arguably demonstrated the extent of this shift. At issue was a measure known as the Special Safeguard Mechanism, which allows developing countries to increase tariff levels temporarily when threatened by either a sharp increase in import volumes or a sharp fall in prices; the talks collapsed when the United States suggested a much higher threshold for application of the measure than either China or India was willing to accept.[79] Despite the apparent irony that the talks should have foundered on a measure designed to protect developing countries from too many *imports* when it was *export* restrictions that were furrowing most brows, in fact China and India's stance made sense. If future import surges or price falls were to lead to significant portions of their agricultural capacity going under in the face of cheap imports, only for prices subsequently to rise again, then these countries' higher import dependence would leave them even more vulnerable than before.

So how should aid donors and multilateral agencies make sense of this changing context for trade and development?

Food reserves and stocks

First, *all* countries ought to be able to agree on the basis of recent experience that, whatever their stance on the degree of openness or protection that they favour, volatility is a common enemy. Sudden swings in markets and changes in trading conditions can create political contexts in which political constituencies find themselves suddenly disadvantaged, and are as such fertile ground for the outbursts of violence, civil unrest or conflict that a range of countries have already experienced as a result of the food price spike. During 2009, therefore, policy-makers should examine options for creating buffers in the international trade system, to make it more resilient to shocks and stresses.

The 'traditional' approach has been for governments to hold food stocks at the national level, and with adequate oversight this approach can deliver benefits. The Chinese government, for example, holds significantly higher grain stocks than many other countries, and argues that this has helped it to mitigate the impact of global turbulence on Chinese consumers.[80] In many other countries, however, government-held grain stocks have been much less effective, in particular when their management has been politicized or captured by interest groups, or has fallen prey to outright corruption.

However, stocks can still be held at levels other than the national, and by agencies other than central governments. In many cases, the local or community level can work well; aid agencies such as Oxfam have for many years invested in community grain banks that protect farmers and consumers alike against market fluctuations through buying just after harvest (when prices are low) and then selling stocks during lean seasons, at a price below market cost but with sufficient margin to cover management costs.[81] Similarly, regional-level stocks can also make sense: the Southern Africa Development Community (SADC), for example, recently announced its intention to create a regional stock of 500,000 Mt.[82]

Given the extent of global interdependence in agricultural trade today, is a more coordinated approach to grain reserves needed? Since 1974, OECD member states (which at the time still represented all of the world's principal consumers of oil) have through the IEA had a system for emergency management of coordinated oil reserves. Today, policy-makers could consider whether a similar model is needed to provide countries dependent on food imports with more security.

The most obvious approach to the problem might be to create a physical, public, globally managed grain reserve. As the International Food Policy Research Institute points out, however, there are potential disadvantages to such an

approach, in particular its high storage costs and slow transactions. IFPRI proposes instead a two-pronged approach: a decentralized emergency reserve of grain for humanitarian donors, and a *virtual* reserve and intervention mechanism based on coordinated commitments by participating countries.[83] The latter idea would work through each participating country undertaking to supply funds, if needed, for intervention in world grain markets. The commitments would be promissory rather than actual budget expenditures; the system would also be able to intervene in futures markets to try to stabilize markets.

One potential drawback of this approach as compared to traditional grain reserves, however, is that it would still leave import-dependent developing countries reliant on the goodwill of exporters, with no cast-iron guarantee that the system would work during a serious crisis. Similarly, regional food stocks controlled by the World Food Programme would also rely on exporters who in the end have an interest in maintaining their trading partners' reliance on their produce. (This reflects an often-cited problem of the Food Aid Convention – namely that while food aid ought in theory to be counter-cyclical, it is in fact strongly pro-cyclical, and highly correlated with grain prices and the size of US harvests.[84])

In either case, however, it would be important for policymakers to specify clearly exactly what the system's objectives would be. In particular, they should stipulate that the system was *only* designed to cope with emergencies and shocks – and hence by extension that the mechanism was not designed to provide price support to food producers, nor to provide an ongoing welfare system that would replace current financing streams for humanitarian aid and development assistance spending. The credibility of the system would be further enhanced by ensuring that oversight of it rested with a disinterested, expert international agency such as the World Food Programme.

Improved technical assistance on long-term security of supply agreements

The second area for immediate action by international donors should be a rapid, clear-headed assessment of whether, and in what circumstances, large-scale investment projects in low-income countries by overseas purchasers looking to boost the security of their food supply will actually deliver development benefits.

Such deals are already becoming a significant feature of the global food landscape. For example, China is reported to have acquired the ownership or leasehold of 1.24 million hectares of land in the Philippines and 700,000 hectares in Laos; and the United Arab Emirates to have acquired 900,000 hectares in Pakistan and 378,000 in Sudan. South Korea is also reported to have acquired 690,000 hectares in Sudan.[85] China's Ministry of Agriculture has proposed acquiring offshore land as a central policy objective similar to the country's existing stance on purchasing rights to overseas energy resources.[86] More recently Daewoo, a South Korean conglomerate, has agreed a lease agreement with Madagascar to acquire 1.3 million hectares there (fully half of that country's arable land).

At best, such partnerships could help to deliver capital investment in infrastructure, technology and productivity gains while also driving poverty reduction through rural growth. But there is no guarantee that they will do so, and real risks that the benefits could be highly concentrated among a few landowners without achieving wider wins for poor people – replicating problems that are well chronicled in other commodity sectors such as oil and mining. The case of the South Korea/Madagascar land deal cited above appears to show a case in point: reports in the *Financial Times* suggest that Daewoo expected to pay nothing for the deal, with the benefits for Madagascar limited instead to employment creation.[87]

The problem of limited developing-country governmental capacity reinforces the potential for poor deals. Consequently, international donors should urgently undertake a review of third-country investment programmes and the circumstances in which they can deliver development wins, which would bring valuable additional analytical capacity to bear on an important immediate-term issue.

In particular, international donors such as the World Bank and the Food and Agriculture Organization should move quickly to offer producer countries technical assistance in negotiating these complex and innovative deals, and ensure that countries are aware that this support is available.

Bringing security of supply into the Doha round

In the wider context, the increase in food prices and the prospect of security of supply concerns becoming still more acute over time raise some fundamental questions about the future shape of global agricultural trade.

Proponents of liberalization need to recognize that policy prescriptions that made sense in a long-term buyer's market may need to be re-evaluated in the altogether different context of a seller's market animated by fears over scarcity and security of supply. While economic models will still prove that the optimal outcome for all countries is to liberalize and pursue their respective comparative advantage, the political reality is that after the shock to the system of the last few months, importers may well be unwilling to take the risk of becoming more dependent on overseas suppliers. Furthermore, poorer countries are likely to be mindful of the fact that if in the future scarcity trends lead to supplies of food falling further behind demand, then a liberalized trade regime will enable richer countries simply to outbid them.[88]

In view of this, advocates of liberal trade must ensure that countries' concerns about security of supply are taken seriously, and as far as possible integrated into trade rules to avoid the much worse alternative of an uncoordinated lapse into protectionism in which poor countries would stand to lose out heavily.

The WTO has in some ways been left on the sidelines of recent controversies over export restrictions, built as it is to mediate disputes between states about market access and unfair dumping, rather than security of supply and unfair suspensions of supply. Yet there is nothing to say that WTO rules could not be amended to seek to prevent sudden export restrictions; some analysts argue that the North American Free Trade Agreement (NAFTA) sets out a more restrictive approach to export restrictions than do the equivalent WTO rules, for example.[89]

If amending trade rules to punish sudden export restrictions is one option, then another might be to amend trade rules to allow import-dependent countries more leeway in retaining some endogenous production capacity, as a hedge against potential turbulence in the future. The Special Safeguard Mechanism, discussed earlier, is arguably a case in point: Chinese and Indian insistence on having the flexibility to safeguard their farmers from sudden import surges can be seen as protectionism pure and simple, or it can be seen as a relatively benign kind of protectionism that ultimately supports liberal markets by enabling countries to feel that they can rely on them.

A third way of building security of supply concerns into trade reform is simply through pushing forward with existing development priorities in agricultural trade – above all reform of US farm support and the EU Common Agricultural Policy. As the Center for Strategic and International Studies notes, the current global agricultural trade system 'structurally favors production among wealthy countries and disadvantages producers in poor developing countries'; redressing that balance needs to become a strategic priority in the years ahead.[90]

The problem applies not only to developed-country trade barriers that discriminate against imports from developing countries, but also to dumping of developed-country exports on developing markets – including through food aid (the key reason why it is so crucial for the incoming US administration to continue to move away from food aid and towards providing cash instead to humanitarian agencies such as the WFP).

Integrating multilateral approaches on food and related issues

Lastly, it is worth pausing to recognize the need for international action on food to be reconciled with action on other, related issues. The boundaries between different global risks and areas of foreign policy are becoming increasingly blurred: the issue of biofuels, which straddles the line between food, climate and energy policy, is a case in point. Another current topical example is illustrated by a comparison between attempts to coordinate international collective action on the financial crisis and on climate change. Both areas of policy are at the top of the international agenda; major summit meetings are planned on both of them during the course of 2009 (notably the G20 meeting to be held in London in April and the Copenhagen climate summit in December); both have the potential to drive a major restructuring in the operation and regulation of the global economy – and yet there is so far no real attempt to reconcile the two processes with each other and move towards a more joined-up approach.[91]

A comprehensive discussion of how to make the international system's approach to global (and especially resource scarcity) issues more coherent is beyond the scope of this report.[92] However, it is possible to flag up two key links between food and other areas of international concern.

The first is the overriding need for a comprehensive global framework on climate change to be agreed as soon as possible. In one way, the reason why food security depends on such a framework is obvious, given the extent to which projected climate change impacts will damage agricultural production (especially in developing countries) and increase the number of undernourished people worldwide. Yet there is also a second, more subtle, reason why a global deal on climate change is required: the link between energy security and food security.

As already argued, some biofuels (especially corn-based ethanol) have rapidly become significant problems for global food security. Countries with support regimes for biofuels (especially corn-based ethanol in the US and biodiesel in the EU) therefore need to review their policies urgently. Yet the prospects for such a re-evaluation are not encouraging. Notwithstanding the effect of biofuels on food prices, the fact remains that even very inefficient biofuels like corn-based ethanol can contribute to improving producer countries' energy security; the International Energy Agency, while acknowledging that first generation biofuels can compete with food for land, has argued explicitly that biofuels are crucial to meeting current and future demand.[93]

In the longer term, the development of second-generation biofuels such as cellulose holds out the possibility of coexistence between food and biofuel production that moves beyond the current zero-sum game. But for now, the problem remains that the more energy insecure oil importing countries feel about their ability to source energy reliably and at stable prices, the more attractive biofuels will be.

In this sense, collective action taken to improve countries' energy security has the potential to improve global food security too, by providing more predictability and less need for the more inefficient kinds of biofuel as a hedge. The key need here is for massive investment in new oil production: the IEA estimates that cumulative investment of $8.4 trillion (in 2007 dollars) is needed between 2008/9 and 2030 in upstream oil and gas production. However, investment in new oil production currently remains far below this level – in large part because of the wild fluctuations in oil prices, which significantly increase the risk premium in oil-sector investment.

If a clearer signal about the outlook for future oil prices were available, this would make for a better investment climate in this sector. Ironically, although a global climate framework would reduce demand for oil in line with the overall emissions reduction targets agreed, it would also dramatically improve predictability about the shape of future demand for oil – for the very same reason. It would also achieve an integration of energy security and climate change concerns that is currently notable by its absence in international discussions.

5. Conclusion

This report has suggested that the outlook for global food security over the coming decades will be characterized by turbulence, uncertainty and risk. As the world's population rises, as the material demands of an affluent 'global middle class' increase, as scarcity trends such as climate change, energy security, water scarcity and competition for land make themselves felt and as a major global redistribution of power proceeds, so the challenges faced by the world's food system multiply and interact in new, unpredictable ways.

As this process of change rapidly unfolds, the need for further work on the nature of the challenge and what needs to be done to meet it will remain acute. In particular, one area that this report has investigated less than is needed is the extent to which international trade – including, and perhaps especially, in food – will be constrained in the context of a future in which climate change is being addressed successfully.

In concentrating on international action, the report has also said much less than is warranted about the importance of individual consumers' decisions in developed countries. People in developed countries need to recognize the huge impact that their lifestyles have on the rest of the world, especially in the context of global food markets. In addition to the growing use of biofuels, Western diets – full of meat and dairy products – are massively inefficient in terms of water, energy and grain use, and produce more CO_2 as well. This is not to say that consumers must all become vegetarians; but they do need to realize the global impact of what is on their plates and in their car engines. Fundamental questions of fairness are at stake; Gandhi's observation that there is enough for everyone's need, but not for everyone's greed, is becoming truer all the time.

While blind optimism would certainly be unwise, there are certainly grounds for hope. The story of human history since prehistoric times can in one way be seen as the dynamic interaction between rising population, growing social complexity and increasing agricultural innovation – for it is the last of these that has enabled the first two. The human race has an extraordinary track record in creativity in food production, and will need to call on that creativity again in the years ahead.

At this point, the prospects for a 21st-century Green Revolution of the kind called for in this report look positive – *if* certain conditions are satisfied. Collective action between countries in pursuit of common interests will be essential, as will timely action in developing countries. A full summary of recommendations is set out in the Executive Summary at the beginning of this report.

Steady nerves will be essential, given the high risk that kneejerk policy measures will result in unintended consequences or make matters worse. But perhaps the most fundamental requirement is for policy-makers to remember that innovation on its own is not enough. The benefits of the 20th-century Green Revolution were often slow to reach poor farmers; some countries missed out on it altogether. This time around, innovation will need to be married with commitment to social justice and political sophistication.

Notes

Chapter 2: How Prices Rose

1. Trostle (2008).
2. Ibid.
3. Alexandratos (2008).
4. Since oil is denominated in dollars on the world market, as the purchasing power of the dollar falls relative to other currencies, purchasers in other countries are able to buy more oil for the same price, leading to inflation in energy prices.
5. Trostle (2008).
6. Sheeran (2007).
7. Alexandratos (2008).
8. Trostle (2008).
9. FAO (2008a).
10. Ibid.
11. UN High Level Task Force on the Global Food Crisis (2008).
12. Buchanan (2007).
13. Trostle (2008).
14. A comprehensive list of export restrictions imposed by countries is provided in World Bank (2008b).
15. Personal communications with Task Force members.
16. Zoellick (2008); UN High Level Task Force on the Global Food Crisis (2008).
17. CSIS Task Force on the Global Food Price Crisis (2008).
18. World Bank (2008b).
19. CSIS Task Force on the Global Food Price Crisis (2008).
20. For example Evans (2008); von Braun (2007); see also Alexandratos (2008).
21. World Bank (2008b).
22. Mitchell (2008).
23. World Bank (2008b).
24. Currie (2007).
25. World Bank (2008b). Mitchell's leaked internal discussion paper (Mitchell, 2008) gives the slightly different figures of 1.7% growth in world grain consumption excluding biofuels from 2000 to 2007 as compared to yield growth of 1.3% and area growth of 0.4% over the same period, but the underlying point still holds.
26. Dart (2008).
27. IMF (2008). See also Alexandratos (2008) for a detailed discussion of the relative weight of different price drivers.
28. For example, Wolf (2008); Economist (2008a).
29. IMF (2008).
30. Ibid.
31. Trostle (2008).
32. International Republican Institute (2008).
33. CSIS Task Force on the Global Food Crisis (2008).
34. World Bank (2008b).
35. Fletcher (2008).
36. UN High Level Task Force on the Global Food Crisis (2008).
37. Evans (2008).
38. Conway (1995) provides a succinct definition of undernutrition as opposed to malnutrition: 'Chronically undernourished people are short of the calories needed for their daily energy needs. Malnutrition results from lack of proteins, vitamins, minerals and other micro-nutrients in the diet.'
39. World Bank (2008b).
40. Evans (2008).
41. Dorward and Poulton (2008).
42. Maxwell (2008).
43. Quoted in Borger (2008a).
44. UN High Level Task Force on the Global Food Crisis (2008).
45. Collier (2007).
46. US Department of Agriculture (2008).
47. FAO (2008b).
48. Blas (2008b).
49. OECD/FAO (2008).
50. Ibid.
51. Fukuda (2008).
52. Haskins (2008).

Chapter 3: Past Successes, Future Challenges

1. Evans (1998).
2. UN Department of Economic and Social Affairs (2006).
3. Ibid.
4. A point made forcefully by Arthur Young in his 1808 *General Report on Enclosures*: 'what a gross absurdity, to bind down in the fetters of custom ten intelligent men willing to adopt the improvements adapted to enclosures because one stupid fellow is obstinate for the practice of his grandfather!'. Young (1971).
5. Evans (1998).
6. Ibid.
7. The term is from William Gaud, the then administrator of the US Agency for International Development.
8. Conway (1997).
9. Dewar (2007).
10. Conway (1997).
11. Evans (1998).
12. Ibid.
13. Ibid.
14. Handa (1983); Dewar (2007).
15. Carson (1962).
16. Evans (1998).
17. Garnett (2008); IPCC (2007a).
18. Conway (1997).
19. Ibid.
20. Laxminarayan et al. (1981).
21. Conway (1997).
22. Trostle (2008).
23. Ibid.
24. Area estimate: Evans (1998).
25. Brown (2005).
26. Evans (1998).
27. FAO/UNEP (1997).
28. Buringh and Dudal (1987).
29. Oldeman (1992); Scherr and Yazav (1996); FAO/UNEP (1997).
30. Conway (1997).
31. Bourne (2008).
32. UNFPA (2007).
33. Buringh and Dudal (1987).
34. Aukland et al. (2002).
35. FAO (2006).
36. Ibid.
37. Ibid.
38. FAO figures, cited in Brown (2005).
39. Brown (2006); Sea Fish Industry Authority (2008).
40. FAO (2006).
41. Sea Fish Industry Authority (2008).
42. Ibid.
43. Sea Fish Industry Authority (2008).
44. Clarke and King (2004).
45. Ibid.
46. Ibid.; Evans (1998).
47. Clarke and King (2004).

48. Ibid.
49. Evans (1998).
50. Ibid.
51. Postel and Vickers (2004).
52. Kijne (2003).
53. Clarke and King (2004).
54. Brown (2005).
55. Clarke and King (2004).
56. Brown (2005).
57. Ibid.
58. Parry (2008).
59. Conway (1997).
60. IEA (2008a).
61. Yergin (2008).
62. IEA (2008c).
63. Ibid.
64. Stevens (2008).
65. IEA (2008c).
66. Dorward and Poulton (2008).
67. McLaughlin et al. (2000).
68. Miranowski (2004).
69. Dorward and Poulton (2008).
70. Rubin and Tal (2008).
71. Evans (1998).
72. Ibid.
73. Department for Environment, Food and Rural Affairs, UK (2008).
74. Pretty et al. (2005).
75. Evans (1998).
76. Müller (2007).
77. For example Hopkins (2008); Pfeiffer (2006).
78. Buringh and Van Heemst (1977).
79. Currie (2007).
80. For example, World Bank (2008b); CSIS Task Force on the Global Food Crisis (2008).
81. European Commission (2008).
82. Schor (2008); Obama (2008).
83. Hoyos (2008).
84. Blas (2008c).
85. See Alexandratos (2008).
86. Evans (1998).
87. IPCC (2007b).
88. Peng et al. (2004).
89. Easterling et al. (2007).
90. IPCC (2007b).
91. Cline (2007).
92. Ibid.
93. Ibid.
94. Parry (2008).
95. Kundzewicz et al. (2007).
96. Ibid.
97. Ibid.
98. IPCC (2007b).
99. Ibid.
100. Ibid.
101. World Bank (2008b).
102. IPCC (2007a).
103. UN Department of Economic and Social Affairs (2006).
104. UN Department of Economic and Social Affairs (1999).
105. UN Department of Economic and Social Affairs (2004).
106. Hardin (1974).
107. Brown (2005).
108. Rohter (2008).
109. Evans (1998).
110. Crooks and Wallis (2007).
111. Easterling et al. (2007).
112. UN High Level Task Force on the Global Food Crisis (2008).
113. OECD/FAO (2008).
114. Zoellick (2008); World Bank (2008b).

Chapter 4: Towards an Agenda for Global Food Security

1. Alexandratos (1995).
2. World Health Organization (2008).
3. Sen (1981).
4. Ibid., as summarized in Conway (1995).
5. Diouf (2008).
6. UN High Level Task Force on the Global Food Crisis (2008).
7. Lumpkin and Ziegler (2008).
8. Diouf (2008); World Bank (2008b); UN High Level Task Force on the Global Food Crisis (2008).
9. World Bank (2008b).
10. Conway (1997).
11. Brown (2005).
12. Sinclair (1998).
13. Evans (1998).
14. Biello (2008).
15. Thacker (1993).
16. Stern et al. (1959).
17. Evans (1998).
18. Alliance for a Green Revolution in Africa (2008).
19. Ibid.
20. Brown (2006).
21. Kern and Johnson (1993).
22. Mann (2008).
23. Lehmann (2007).
24. Brown (2006).
25. Postel and Vickers (2004).
26. Economist (2008b).
27. Brown (2005).
28. Ibid.
29. Rabobank (2008).
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32. World Bank (2008b).
33. Collier (2008).
34. World Bank (2008a).
35. Ibid.
36. Ibid.
37. Dorward et al. (2006).
38. Hazell et al. (2007).
39. Ibid.
40. International Fund for Agricultural Development (2008).
41. Von Braun et al. (2008).
42. Hamilton (2006).
43. Quoted in Green (2008).
44. World Bank (2008a).
45. Ibid.
46. Arnason (2002).
47. World Bank (2008a).
48. Green (2008).
49. Hazell et al. (2007); Green (2008).
50. Leahy and Chopra (2008).
51. Green (2008).
52. Dorward et al. (2008); Green (2008).
53. Conway (1998).
54. World Bank (2008a).

55. Green (2008).
56. Dorward et al. (2006).
57. World Bank (2008b).
58. Hazell et al. (1997).
59. Ibid.
60. Fletcher (2008).
61. World Bank (2008b).
62. UN High Level Task Force on the Global Food Crisis (2008); World Bank (2008b); Zoellick (2008).
63. World Bank (2008b).
64. For example Jack (2008), *Economist* (2005).
65. Chronic Poverty Research Centre (2008).
66. Ibid.; UN High Level Task Force on the Global Food Crisis (2008).
67. Chronic Poverty Research Centre (2008).
68. UN News Service (2008).
69. House of Commons International Development Committee (2008).
70. Chronic Poverty Research Centre (2008).
71. Ibid.
72. World Bank (2008b).
73. UN High Level Task Force on the Global Food Crisis (2008).
74. International Centre for Trade and Sustainable Development (2008).
75. Hall (2008); Rubin and Tal (2008).
76. For example Heinberg (2007).
77. Landingin (2008).
78. UN High Level Task Force on the Global Food Crisis (2008).
79. International Centre for Trade and Sustainable Development (2008).
80. Liu (2008).
81. Frederic Mousseau, personal communication.
82. IRIN (2008).
83. Von Braun and Torero (2008).
84. Hoddinott and Cohen (2007).
85. Borger (2008b).
86. England and Blas (2008); Kerr and Bokhari (2008); Anderlini (2008).
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