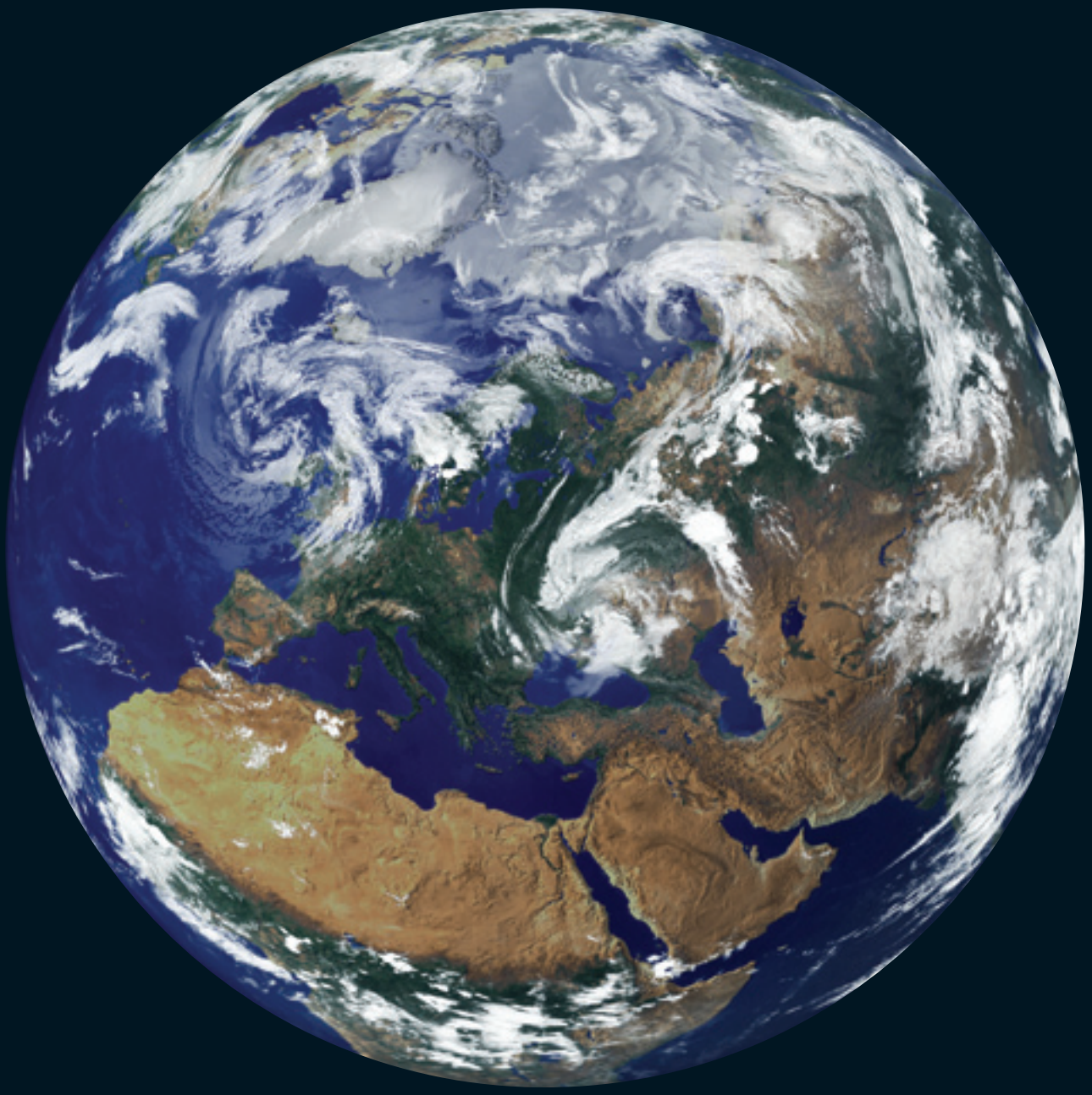
Government Office for Science

Foresight



The Future of Food and Farming:

Challenges and choices for global sustainability

EXECUTIVE SUMMARY

The Future of Food and Farming: Challenges and choices for global sustainability

This Executive Summary is intended for:

Policy makers and a wide range of professionals and researchers whose interests relate to all aspects of the global food system: including governance at all scales, food production and processing, the supply chain, and also consumer attitudes and demand. It is also relevant to policy makers and others with an interest in areas that interact with the food system, for example: climate change mitigation, energy and water competition, and land use.

This Executive Summary should be cited as:

Foresight. The Future of Food and Farming (2011)
Executive Summary.
The Government Office for Science, London.

The Government Office for Science (GO-Science) would like to thank the Project's Lead Expert Group who oversaw the technical aspects of the Project, who were involved in much of the work and in producing the Project outputs. They were led by
Professor Charles Godfray CBE, FRS and are Professor Ian Crute CBE,
Professor Lawrence Haddad, Dr David Lawrence, Professor James Muir,
Professor Jules Pretty OBE, Professor Sherman Robinson and Dr Camilla Toulmin.

GO-Science would particularly wish to acknowledge the contribution of Professor Mike Gale FRS who was also a member of the Lead Expert Group, but who sadly died during the course of the Project.

Thanks are also due to the UK government departments Defra and DFID who provided support throughout the Project, the Project's High Level Stakeholder Group, the Project Advisory Group and the Economics Advisory Group, as well as the many experts and stakeholders from the UK and around the world who contributed to the work, reviewed the many Project reports, and papers, and generously provided advice and guidance. A full list is provided in Annex A of the Final Project Report.

Foreword

The case for urgent action in the global food system is now compelling. We are at a unique moment in history as diverse factors converge to affect the demand, production and distribution of food over the next 20 to 40 years. The needs of a growing world population will need to be satisfied as critical resources such as water, energy and land become increasingly scarce. The food system must become sustainable, whilst adapting to climate change and substantially contributing to climate change mitigation. There is also a need to redouble efforts to address hunger, which continues to affect so many. Deciding how to balance the competing pressures and demands on the global food system is a major task facing policy makers, and was the impetus for this Foresight Project.

Foresight has aimed to add value though the breadth of its approach which places the food system within the context of wider policy agendas. It argues for decisive action and collaborative decision-making across multiple areas, including development, investment, science and trade, to tackle the major challenges that lie ahead.

The Project has brought together evidence and expertise from a wide range of disciplines across the natural and social sciences to identify choices, and to assess what might enable or inhibit future change. Building upon existing work, it has also drawn upon over 100 peer-reviewed evidence papers that have been commissioned. Several hundred experts and stakeholders from across the world have been involved in the work – I am most grateful to them, the core team of lead experts, the group of senior stakeholders who have advised throughout the Project, and to the Foresight Project team.

I am delighted that the findings of all of this work are now published in the Final Report which, together with the supporting papers, is freely available to all. I hope that this will help policy makers and other communities of interest to think creatively and decisively about how to address the challenges ahead in a way that is pragmatic and resilient to future uncertainties.

Professor Sir John Beddington CMG, FRS
Chief Scientific Adviser to HM Government, and
Head of the Government Office for Science

Preface

We are delighted to receive the Final Report of the Foresight Global Food and Farming Futures Project from Sir John Beddington on behalf of Government. Its findings have global relevance and remind us of the scale of the challenge facing us. The Project highlights how the global food system is consuming the world's natural resources at an unsustainable rate; failing the very poorest, with almost one billion of the least advantaged and most vulnerable people still suffering from hunger and malnutrition. Despite the considerable progress made in reducing the proportion of people in Asia and Africa living in hunger and poverty, the overall number affected by chronic hunger has scarcely changed for the past 20 years.

Land, the sea and the actions of food producers not only provide the raw materials to the global food system and deliver a range of crucial environmental services, but are in themselves a source of economic growth in the developed and developing world. The evidence presented in this Report highlights the vulnerability of the global food system to climate change and other global threats and emphasises the need to build in greater resilience to future food price shocks.

In doing so this Report makes a strong case for governments, the private sector and civil society to continue to prioritise global food security, sustainable agricultural production and fisheries, reform of trade and subsidy, waste reduction and sustainable consumption.

Addressing the many challenges facing global farming and food will require decision-making that is fully integrated across a diverse range of policy areas which are all too often considered in isolation, and for action to be based on sound evidence. Building on previous international studies including the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) and the International Fund for Agricultural Development (IFAD) Rural Poverty Report, this Project provides new insight into how different challenges could converge, the strategies and polices needed to address these challenges, and priorities for action now and for the future.

The Report also provides valuable insight into how our farming and food industry in the UK can contribute to the transition to a green economy by increasing sustainability, seizing opportunities and providing innovative solutions for the future.

We will be jointly acting on the Project's findings. And we will strongly encourage others to do the same, as it is clear that concerted efforts at national, regional and global levels of government, and close partnership with the private sector and civil society, will be crucial to address the challenges we face.

We would like to take this opportunity to thank Sir John Beddington for this excellent Report, and also the many individuals and stakeholders who have contributed to the Project.

Rt Hon Caroline Spelman MP
Secretary of State for Environment, Food and Rural Affairs

Rt Hon Andrew Mitchell MP
Secretary of State for International Development

Contents

1	Introduction	9
2	Important drivers of change affecting the food system	13
3	Challenge A: Balancing future demand and supply sustainably	16
4	Challenge B: Addressing the threat of future volatility in the food system	22
5	Challenge C: Ending hunger	24
6	Challenge D: Meeting the challenges of a low emissions world	28
7	Challenge E: Maintaining biodiversity and ecosystem services while feeding the world	31
8	Priorities for action	34
9	Why action is needed now	36
10	Conclusion	37
11	Annex: Project reports and papers	38

Executive Summary – key conclusions for policy makers

1 Introduction[1]

Project aim: to explore the pressures on the global food system between now and 2050 and identify the decisions that policy makers need to take today, and in the years ahead, to ensure that a global population rising to nine billion or more can be fed sustainably[2] and equitably.

The global food system will experience an unprecedented confluence of pressures over the next 40 years. On the demand side, global population size will increase from nearly seven billion today to eight billion by 2030, and probably to over nine billion by 2050; many people are likely to be wealthier, creating demand for a more varied, high-quality diet requiring additional resources to produce. On the production side, competition for land, water and energy will intensify, while the effects of climate change will become increasingly apparent. The need to reduce greenhouse gas emissions and adapt to a changing climate will become imperative. Over this period globalisation will continue, exposing the food system to novel economic and political pressures.

Any one of these pressures ('drivers of change') would present substantial challenges to food security; together they constitute a major threat that requires a strategic reappraisal of how the world is fed. Overall, the Project has identified and analysed five key challenges for the future. Addressing these in a pragmatic way that promotes resilience to shocks and future uncertainties will be vital if major stresses to the food system are to be anticipated and managed. The five challenges, outlined further in Sections 4 – 8, are:

A. Balancing future demand and supply sustainably – to ensure that food supplies are affordable.

B. Ensuring that there is adequate stability in food supplies – and protecting the most vulnerable from the volatility that does occur.

C. Achieving global access to food and ending hunger. This recognises that producing enough food in the world so that everyone can *potentially* be fed is not the same thing as ensuring food security for all.

D. Managing the contribution of the food system to the mitigation of climate change.

E. Maintaining biodiversity and ecosystem services while feeding the world.

These last two challenges recognise that food production already dominates much of the global land surface and water bodies, and has a major impact on all the Earth's environmental systems.

In recognising the need for urgent action to address these future challenges, policy-makers should not lose sight of major failings in the food system that exist today.

Although there has been marked volatility in food prices over the last two years, the food system continues to provide plentiful and affordable food for the majority of the world's population. Yet it is failing in two major ways which demand decisive action:

- **Hunger remains widespread.** 925 million people experience hunger: they lack access to sufficient of the major macronutrients (carbohydrates, fats and protein). Perhaps another billion are thought to suffer from 'hidden hunger', in which important micronutrients (such as vitamins and minerals) are missing from their diet, with consequent risks of physical and mental impairment. In contrast, a billion people are substantially over-consuming, spawning a new public health epidemic involving

1 Note: the contents of this Executive Summary closely follow the findings of the Foresight Project's Final Report, although the emphasis here is on the high-level conclusions and priority actions. All the supporting references for the analysis and figures contained in this Executive Summary are provided in the Final Report.

2 Sustainability implies the use of resources at rates that do not exceed the capacity of the Earth to replace them. A more detailed description of the use of this and other terms is provided in the Final Report.

chronic conditions such as type 2 diabetes and cardiovascular disease. Much of the responsibility for these three billion people having suboptimal diets lies within the global food system.

- **Many systems of food production are unsustainable.** Without change, the global food system will continue to degrade the environment and compromise the world's capacity to produce food in the future, as well as contributing to climate change and the destruction of biodiversity. There are widespread problems with soil loss due to erosion, loss of soil fertility, salination and other forms of degradation; rates of water extraction for irrigation are exceeding rates of replenishment in many places; over-fishing is a widespread concern; and there is heavy reliance on fossil fuel-derived energy for synthesis of nitrogen fertilisers and pesticides. In addition, food production systems frequently emit significant quantities of greenhouse gases and release other pollutants that accumulate in the environment.

In view of the current failings in the food system and the considerable challenges ahead, this Report argues for decisive action that needs to take place now.

The response of the many different actors involved will affect the quality of life of everyone now living, and will have major repercussions for future generations. Much can be achieved immediately with current technologies and knowledge given sufficient will and investment. But coping with future challenges will require more radical changes to the food system and investment in research to provide new solutions to novel problems[3]. This Report looks across all of these options to draw out priorities for policy-makers[4].

The analysis of the Project has demonstrated the need for policy-makers to take a much broader perspective than hitherto when making the choices before them – they need to consider the *global food system* from production to plate.

The food system is not a single designed entity, but rather a partially self-organised collection of interacting parts. For example, the food systems of different countries are now linked at all levels, from trade in raw materials through to processed products. Besides on-farm production, capture fisheries and aquaculture are also important, in terms of both nutrition and providing livelihoods, especially for the poor – about a billion people rely on fish as their main source of animal protein. Many vulnerable communities obtain a significant amount of food from the wild ('wild foods'), which increases resilience to food shocks.

Most of the economic value of food, particularly in high-income countries, is added beyond the farm gate in food processing and in retail, which together constitute a significant fraction of world economic activity. At the end of the food chain, the consumer exerts choices and preferences that have a profound influence on food production and supply, while companies in the food system have great political and societal influence and can shape consumer preferences. All of the above imply the need to give careful consideration to the complex ramifications of possible future developments and policy changes in the global food system.

Policy-makers also need to recognise food as a unique class of commodity and adopt a broad view of food that goes far beyond narrow perspectives of nutrition, economics and food security.

Food is essential for survival and for mental and physical development – nutritional deficiencies during pregnancy and in early growth (especially the first two years) can have lifelong effects. For the very poor, obtaining a minimum amount of calories becomes a dominant survival activity. However, issues of culture, status and religion also strongly affect both food production and demand, and hence shape the basic economics of the food system. Also, food production, cooking and sharing are major social and recreational activities for many in middle- and high-income countries.

3 See Box 1.2 for a brief discussion of the Project's treatment of new technologies in the food system.
4 See Box 1.3 for a list of the Project's high-level conclusions, and Section 8 for a list of priorities for policy-makers.

Box 1.1 The Project's added value

The Project has involved around 400 leading experts and stakeholders from about 35 low-, middle- and high-income countries across the world[5]. Drawing upon the latest scientific and other evidence from many organisations and researchers, it aims to add value by:

- Taking a long-term, strategic outlook at likely challenges over the next 20 years to 2030 and the next 40 years to 2050. It has used futures techniques to embrace the many uncertainties inherent in the future, and to identify choices that are resilient to a range of outcomes.
- Taking a very broad view of the food system and the wider context in which it operates. It has considered the concerns and experiences of many different types of stakeholder, from African smallholder to multinational retailer, from issues of governance to evolving consumer demand.
- Commissioning new economic modelling to explore possible future trends in food prices.
- Involving participants from a very wide range of disciplines: natural and social scientists and experts in risk management, economics and modelling.

The Annex provides an overview of all the Project's evidence and reports. These include commissioned papers and reports synthesising specific aspects of the future challenges affecting the food system.

A word of caution

It is impossible for a broadly scoped project such as this to consider the range of issues and disciplines in the same detail as the more focused work of individual researchers and organisations. Rather, its insights should be seen as complementary, aiming to provide a fresh look and a challenge to existing thinking, as well as providing signposts to the most important issues and promising approaches. It aims to present a framework for thinking about the future, and for more detailed analysis and policy development by others.

Box 1.2 Appraising new technologies in the food system

- New technologies (such as the genetic modification of living organisms and the use of cloned livestock and nanotechnology) should not be excluded *a priori* on ethical or moral grounds, though there is a need to respect the views of people who take a contrary view.
- Investment in research on modern technologies is essential in light of the magnitude of the challenges for food security in the coming decades.
- The human and environmental safety of any new technology needs to be rigorously established before its deployment, with open and transparent decision-making.
- Decisions about the acceptability of new technologies need to be made in the context of competing risks (rather than by simplistic versions of the precautionary principle); the potential costs of *not* utilising new technology must be taken into account.
- New technologies may alter the relationship between commercial interests and food producers, and this should be taken into account when designing governance of the food system.
- There are multiple approaches to addressing food security, and much can be done today with existing knowledge. Research portfolios need to include all areas of science and technology that can make a valuable impact – any claims that a single or particular new technology is a panacea are foolish.
- Appropriate new technology has the potential to be very valuable for the poorest people in low-income countries. It is important to incorporate possible beneficiaries in decision-making at all stages of the development process.

5 See Annex A of the Project's Final Report for a list of experts and stakeholders that were closely involved.

Box 1.3 High-level conclusions

A major conclusion of this Report is the critical importance of interconnected policy-making. Other studies have stated that policy in all areas of the food system should consider the implications for volatility, sustainability, climate change and hunger. Here it is argued that policy in other sectors outside the food system also needs to be developed in much closer conjunction with that for food. These areas include energy, water supply, land use, the sea, ecosystem services and biodiversity. Achieving much closer coordination with all of these wider areas is a major challenge for policy-makers.

There are three reasons why broad coordination is needed. First, these other areas will crucially affect the food system and therefore food security. Secondly, food is such a critical necessity for human existence, with broad implications for poverty, physical and mental development, wellbeing, economic migration and conflict, that if supply is threatened, it will come to dominate policy agendas and prevent progress in other areas. And, thirdly, as the food system grows, it will place increasing demands on areas such as energy, water supply and land – which in turn are closely linked with economic development and global sustainability. Progress in such areas would be made much more difficult or impossible if food security were to be threatened.

However, there is a tension between the Report's identification of five key challenges to the food system and its stress on the importance of considering policy development in the round. The following highlight a number of key themes and conclusions that both summarise the findings and cut across the different challenges, with an emphasis on what needs to be done immediately.

1. Substantial changes will be required throughout the different elements of the food system and beyond if food security is to be provided for a predicted nine billion people. Action has to occur on all of the following four fronts simultaneously:

- More food must be produced sustainably through the spread and implementation of existing knowledge, technology and best practice, and by investment in new science and innovation and the social infrastructure that enables food producers to benefit from all of these.
- Demand for the most resource-intensive types of food must be contained.
- Waste in all areas of the food system must be minimised.
- The political and economic governance of the food system must be improved to increase food system productivity and sustainability.

The solution is not *just* to produce more food, or change diets, or eliminate waste. The potential threats are so great that they cannot be met by making changes piecemeal to parts of the food system. It is essential that policy-makers address all areas at the same time.

2. Addressing climate change and achieving sustainability in the global food system need to be recognised as dual imperatives. Nothing less is required than a redesign of the whole food system to bring sustainability to the fore.

The food system makes extensive use of non-renewable resources and consumes many renewable resources at rates far exceeding replenishment without investing in their eventual replacement. It releases greenhouse gases, nitrates and other contaminants into the environment. Directly, and indirectly through land conversion, it contributes to the destruction of biodiversity. Unless the footprint of the food system on the environment is reduced, the capacity of the earth to produce food for humankind will be compromised with grave implications for future food security. Consideration of sustainability must be introduced to all sectors of the food system, from production to consumption, and in education, governance and research.

3. It is necessary to revitalise moves to end hunger. Greater priority should be given to rural development and agriculture as a driver of broad-based income growth, and more incentives provided to the agricultural sector to address issues such as malnutrition and gender inequalities. It is also important to reduce subsidies and trade barriers that disadvantage low-income countries. Leadership in hunger reduction must be fostered in both high-, middle- and low-income countries.

Though the proportion of the world's population suffering from hunger has declined over the last 50 years, there are worrying signs that progress is stalling and it is very unlikely that the Millennium Development Goals for hunger in 2015 will be achieved. Ending hunger requires a well-functioning global food system that is sensitive to the needs of low-income countries, although it also requires concerted actions that come from within low-income countries.

4. Policy options should not be closed off. Throughout, the Project's Final Report has argued the importance of, within reason, excluding as few as possible different policy options on *a priori* grounds. Instead, it is important to develop a strong evidence base upon which to make informed decisions.

Food is so integral to human wellbeing that discussions of policy options frequently involve issues of ethics, values and politics. For example, there are very different views on the acceptability of certain new technologies, or on how best to help people out of hunger in low-income countries. Box 1.2 both illustrates the need to keep policy options open and gathers together the Report's conclusions about the application of new technologies, such as the genetic modification of living organisms and the use of cloned livestock and nanotechnology. Achieving a strong evidence base in controversial areas is not enough to obtain public acceptance and approval – genuine public engagement and discussion needs to play a critical role.

5. This Report rejects food self-sufficiency as a viable option for nations to contribute to global food security, but stresses the importance of crafting food system governance to maximise the benefits of globalisation and to ensure that they are distributed fairly. For example, it is important to avoid the introduction of export bans at time of food stress, something that almost certainly exacerbated the 2007 – 2008 food price spike.

The food system is globalised and interconnected. This has both advantages and disadvantages. For example, economic disruptions in one geographical region can quickly be transmitted to others, but supply shocks in one region can be compensated for by producers elsewhere. A globalised food system also improves the global efficiency of food production by allowing bread-basket regions to export food to less favoured regions.

2 Important drivers of change affecting the food system

This is a unique time in history – decisions made now and over the next few decades will disproportionately influence the future:

- For the first time, there is now a high likelihood that growth in the global population will cease, with the number of people levelling in the range of eight to ten billion towards the middle of the century or in the two decades that follow.
- Human activities have now become a dominant driver of the Earth system: decisions made now to mitigate their detrimental effects will have a very great influence on the environment experienced by future generations, as well as the diversity of plant and animal species with which they will share the planet.
- There is now a developing global consensus, embodied in the Millennium Development Goals, that there is a duty on everyone to try to end poverty and hunger, whether in low-income countries or among the poor in more wealthy nations.

Threats from interacting drivers of change will converge in the food system over the next 40 years. Careful assessment of the implications of these drivers is essential if major pressures are to be anticipated, and future risks managed. Six particularly important drivers are outlined here. This Project

has considered the combined effect of such drivers on the food system to explore interactions, feedbacks and non-linear effects.

I. **Global population increases.** Policy-makers should assume that today's population of about seven billion is most likely to rise to around eight billion by 2030 and probably to over nine billion by 2050. Most of these increases will occur in low- and middle-income countries; for example, Africa's population is projected to double from one billion to approximately two billion by 2050. However, population projections are uncertain and will need to be kept under review. Factors affecting population size include GDP growth, educational attainment, access to contraception and gender equality; possibly the single most important factor is the extent of female education. Population growth will also combine with other transformational changes, particularly in low- and middle-income countries as rising numbers of people move from rural areas to cities that will need to be serviced with food, water and energy.

II. **Changes in the size and nature of per capita demand.** Dietary changes are very significant for the future food system because, per calorie, some food items (such as grain-fed meat) require considerably more resources to produce than others. However, predicting patterns of dietary change is complex because of the way pervasive cultural, social and religious influences interact with economic drivers.

- *Meat:* different studies have predicted increases in per capita consumption (kg/capita/annum) from 32 kg today to 52 kg by the middle of the century. In high-income countries, consumption is nearing a plateau. Whether consumption of meat in major economies such as Brazil and China will stabilise at levels similar to countries such as the UK, or whether they will rise further to reach levels more similar to the USA is highly uncertain. However, major increases in the consumption of meat, particularly grain-fed meat, would have serious implications for competition for land, water and other inputs, and will also affect the sustainability of food production.
- *Fish:* demand is expected to increase substantially, at least in line with other protein foods, and particularly in parts of east and south Asia. The majority of this extra demand will need to be met by further expansion of aquaculture, which will have significant consequences for the management of aquatic habitats and for the supply of feed resources.

Major uncertainties around future per capita consumption include:

- the degree to which consumption will rise in Africa
- the degree to which diets will converge on those typical of high-income countries today
- whether regional differences in diet (particularly in India) persist into the future
- the extent to which increased GDP is correlated with reduced population growth and increased per capita demand – the precise nature of how these different trade-offs develop will have a major effect on gross demand.

III. **Future governance of the food system at both national and international levels.** Many aspects of governance have a significant impact on the workings of the food system:

- The globalisation of markets has been a major factor shaping the food system over recent decades and the extent to which this continues will have a substantial effect on food security.
- The emergence and continued growth of new food superpowers, notably Brazil, China and India. Russia is already significant in global export markets, and likely to become even more so, with a large supply of underutilised agricultural land.
- The trend for consolidation in the private sector, with the emergence of a limited number of very large transnational companies in agribusiness, in the fisheries sector, and in the food processing, distribution and retail sectors. There is some evidence that this trend may be reversing, with the entry into international markets of new companies from emerging economies.
- Production subsidies, trade restrictions and other market interventions already have a major effect on the global food system. How they develop in the future will be crucial.
- The extent to which governments act collectively or individually to face future challenges, particularly in shared resources, trade and volatility in agricultural markets. The inadequate governance of international fisheries, despite severe resource and market pressures, illustrates in microcosm many of the political and institutional obstacles to effective collective action.

- The adequacy of the current international institutional architecture to respond to future threats to the global food system, and the political will to allow them to function effectively, is unclear.
- The control of increasing areas of land for food production (such as in Africa) will be influenced by both past and future land-purchase and leasing agreements – involving both sovereign wealth funds and business.

IV. **Climate change.** This will interact with the global food system in two important ways:

- Growing demand for food must be met against a backdrop of rising global temperatures and changing patterns of precipitation. These changing climatic conditions will affect crop growth and livestock performance, the availability of water, fisheries and aquaculture yields and the functioning of ecosystem services in all regions. Extreme weather events will very likely become both more severe and more frequent, thereby increasing volatility in production and prices. Crop production will also be indirectly affected by changes in sea level and river flows, although new land at high latitudes may become suitable for cultivation and some degree of increased carbon dioxide fertilisation is likely to take place (due to elevated atmospheric carbon dioxide concentrations). The extent to which adaptation occurs (for example through the development of crops and production methods adapted to new conditions) will critically influence how climate change affects the food system.
- Policies for climate change mitigation will also have a very significant effect on the food system – the challenge of feeding a larger global population must be met while delivering a steep reduction in greenhouse gas emissions (see Section 6 below).

V. **Competition for key resources.** Several critical resources on which food production relies will come under more pressure in the future. Conversely, growth in the food system will itself exacerbate these pressures:

- *Land for food production:* Overall, relatively little new land has been brought into agriculture in recent decades. Although global crop yields grew by 115% between 1967 and 2007, the area of land in agriculture increased by only 8% and the total currently stands at approximately 4,600 million hectares. While substantial additional land could in principle be suitable for food production, in practice land will come under growing pressure for other uses. For example, land will be lost to urbanisation, desertification, salinisation and sea level rise, although some options may arise for salt-tolerant crops or aquaculture. Also, while it has been estimated that the quality of around 16% of total land area including cropland, rangeland and forests is improving, the International Soil Reference and Information Centre has estimated (2009) that of the 11.5 billion hectares of vegetated land on earth, about 24% has undergone human-induced soil degradation, in particular through erosion. In addition, with an expanding population, there will be more pressure for land to be used for other purposes. And while some forms of biofuels can play an important role in the mitigation of climate change, they may lead to a reduction in land available for agriculture.

  There are strong environmental grounds for limiting any significant expansion of agricultural land in the future (although restoration of derelict, degraded or degrading land will be important). In particular, further conversion of rainforest to agricultural land should be avoided as it will increase greenhouse gas emissions very significantly and accelerate the loss of biodiversity.
- *Global energy demand:* This is projected to increase by 45% between 2006 and 2030 and could double between now and 2050. Energy prices are projected to rise and become more volatile, although precise projections are very difficult to make. Several parts of the food system are particularly vulnerable to higher energy costs – for example, the production of nitrogen fertilisers is highly energy intensive: the roughly fivefold increase in fertiliser price between 2005 and 2008 was strongly influenced by the soaring oil price during this period. The financial viability of fishing (particularly capture fisheries) is also strongly affected by fuel price.
- *Global water demand:* Agriculture already currently consumes 70% of total global 'blue water' withdrawals from rivers and aquifers available to humankind. Demand for water for agriculture could rise by over 30% by 2030, while total global water demand could rise by 35–60% between 2000 and 2025, and could double by 2050 owing to pressures from industry, domestic use and the need to maintain environmental flows. In some arid regions of the world, several major non-renewable fossil aquifers are increasingly being depleted and cannot be replenished, for example in the Punjab, Egypt, Libya and Australia. Estimates suggest that exported foods account for between 16% and 26% of the

total water used for food production worldwide, suggesting significant potential for more efficient global use of water via trade, although there is the risk of wealthy countries exploiting water reserves in low-income countries.

VI. **Changes in values and ethical stances of consumers.** These will have a major influence on politicians and policy makers, as well as on patterns of consumption in individuals. In turn, food security and the governance of the food system will be affected. Examples include issues of national interest and food sovereignty, the acceptability of modern technology (for example genetic modification, nanotechnology, cloning of livestock, synthetic biology), the importance accorded to particular regulated and highly specified production methods such as organic and related management systems, the value placed on animal welfare, the relative importance of environmental sustainability and biodiversity protection, and issues of equity and fair trade.

3 Challenge A: Balancing future demand and supply sustainably

Concerted action across several policy domains is essential to address the challenge of balancing supply and demand sustainably over the next 40 years. This section sets out five classes of action, drawing out their potential contribution, and where efforts should best be focused. They relate to the better use of existing knowledge, capitalising on new science and technology, reducing waste, and improving governance and influencing demand.

It is important to stress that action involving difficult decisions is important in all areas. Concentrating on one or a subset of the five classes will not be sufficient and progress in one reduces pressures on the others.

3.1 Improving productivity sustainably using existing knowledge

It has been estimated that the application of existing knowledge and technology could increase average yields two- to threefold in many parts of Africa, and twofold in the Russian Federation. Similarly, global productivity in aquaculture could, with limited changes to inputs, be raised by around 40%. However, in determining where and how much to invest in producing more food, policy-makers will need to consider a range of criteria rather than increases in production alone. These criteria will need to acknowledge the existence of both positive and negative externalities associated with different forms of food production, and the particular needs of poor rural communities whose livelihoods often depend on food production.

Making decisions about different ways of producing more food is difficult because the consequences of different actions may be hard to quantify economically and environmentally. Operational definitions of sustainability are also complicated by issues of geographical scale and levels of uncertainty, as well as by their long-term or inter-generational implications. Equally, it is clear that there are no simple, blueprint solutions that have universal application. Rather, design of these policies involves social and political choices, in a contested space within which different interest groups advance particular arguments that they hope will influence outcomes in their favour.

A wide range of evidence considered by the Project provides support for four classes of intervention aimed at raising agricultural productivity. These relate mostly to middle- and low-income countries because it is here that policy interventions are likely to have the greatest influence in increasing yields sustainably.

- **The revitalisation of extension services to increase the skills and knowledge base of food producers (often women) is critical to achieving sustainable increases in productivity in both low-income and high-income countries.** Recent experience with models for extension that make use of new forms of social infrastructure should be applied to increase producers' knowledge about best practice, and expand the social capital within and between institutions and communities in the food supply chain. The role of women needs particular consideration in view of their often significant role as food producers in lower income countries.
- **Improving the functioning of markets and providing market access, particularly in low-income countries.** In many low-income countries food markets function poorly or only very locally. Business

and financial reform designed to facilitate entrepreneurship in the food production sector can increase food production, household revenue, livelihood diversification and the strength of rural economies. Another possibility includes spreading best practice relating to access to capital – such access enables producers to invest in new and better farming or fishing methods, diversify into new activities such as aquaculture or specialist crops, and access markets.

- **Strengthening rights to land and natural resources, such as water, fisheries and forests should be a high priority.** Uncertainty in such rights is a major disincentive to investment in food production in many low-income countries. They should be strengthened at the levels of individual local producers and communities and should build upon customary rights. Developments in China and Ethiopia provide examples of the effectiveness of such measures.
- **Physical infrastructure must be improved in middle- and low-income countries to facilitate access to markets and investment in rural economies.** Such infrastructure includes roads, ports, irrigation projects, storage facilities and information and communication technology (ICT) systems. The importance of these developments is demonstrated in Africa where, for certain landlocked countries, transport costs can be as high as 77% of the value of their exports. The establishment of development corridors linked to major ports can be a very effective way of stimulating local economies.

3.2 New science and technology to raise the limits of sustainable production and address new threats

The application of existing knowledge and technology has very substantial potential to increase crop yields. Investment in research and development is critical to:

- **producing more food efficiently and sustainably**
- **securing ecosystem services**
- **keeping pace with evolving threats such as the emergence of new and more virulent pests and diseases**
- **addressing new challenges, such as the development of new varieties of crops that are resistant to increased drought, flooding and salinity arising from climate change**
- **meeting the particular needs of the world's poorest communities.**

Looking across the entirety of the evidence reviewed by the Project, the following strategic conclusions on research and development can be drawn:

- There is a strong case for reversal of the low priority accorded to research on agriculture, fisheries and the food system in most countries. Countries such as China have demonstrated the effectiveness of agricultural research in raising productivity.
- Recent scientific and technological advances offer significant new opportunities to address major environmental challenges such as climate change, water scarcity and soil degradation.
- Research on climate change adaptation and mitigation in the food system should be a priority. Agriculture and food production will need to adapt to a changing world with a higher likelihood of extreme weather events.
- Investment in food production research needs to focus on raising yields in conjunction with improving sustainability and maintaining ecosystem services. This shift must recognise that special measures will often be needed to incentivise research that produces public goods.
- A pluralistic research portfolio is essential: the magnitude of the challenges are so large that no single research avenue will address all the new knowledge required.
- New ways are required to incentivise research and development that meets the needs of low-income countries and where at least initial returns on investment will be low. Where incentives do not currently exist for investment in research that provides public goods, new models of delivery are needed to mobilise the considerable strengths of private-sector research and scientific entrepreneurship.
- The contribution of funders to research from the public, private and third sector needs better coordination.

- Investment in research and development is not enough in itself. Communication is critical – not just to spread new knowledge to policy-makers and potential users, but also to the public, specifically to engender trust in new science and its application.

This Foresight Project has commissioned a series of reviews exploring the new science required to meet the challenges of producing more food more sustainably. Important priorities are summarised in the Project Synthesis Report C6. The Final Project Report also concurs with the conclusions of the Royal Society's recent report, *Reaping the Benefits*, which explores in more detail research challenges in crop production. The following suggest general priorities:

- **Development of new varieties or breeds of crops, livestock and aquatic organisms**, capitalising on recent advances in the biosciences.
- **The preservation of multiple varieties, land races, rare breeds and closely related wild relatives of domesticated species.** This is very important in maintaining a genetic bank of variation that can be used in the selection of novel traits.
- **Advances in nutrition and related sciences.** These offer substantial prospects for improving the efficiency and sustainability of animal production (both livestock and aquaculture).
- **Scientific and technological advances in soil science and related fields.** Relatively neglected in recent years, these offer the prospect for a better understanding of constraints to crop production and better management of soils to preserve their ecosystem functions, improve and stabilise output, reduce pollutant run-off and cut greenhouse gas emissions.
- **Targeted research in modern crop and animal science, agro-ecology, agricultural engineering and aquaculture management.** Research across a broad range of subjects, including areas that have received less investment in recent years, is critical to improving yields and sustainability at the same time.

This Project has also considered other more revolutionary advances, such as the development of perennial grain crops, the introduction of nitrogen fixation into non-legume crops, and re-engineering the photosynthetic pathways of different plants. These are important areas for study, although they are unlikely to contribute significantly to raising agricultural productivity until at least the latter end of the 40-year period considered by this Report. In parallel with the development of the science, it will be critical to consider how such advances would be commercially sustainable and hence could be deployed on a large scale.

3.3 Reducing waste

Although global estimates of waste are reliant so far on a weak evidence base, there is little doubt that the scale is substantial. It has been estimated that as much as 30% of all food grown worldwide may be lost or wasted before and after it reaches the consumer. Some estimates have placed it as high as 50%. Addressing waste across the entire food chain will be critical in any strategy to feed around eight billion people sustainably and equitably by 2030, and nine billion by 2050.

Making the food chain more efficient through waste reduction measures will reduce pressure on resources required for food production, lower greenhouse gas emissions and contribute to other policy agendas, such as cutting the need for further space set aside for landfill, which in turn would reduce greenhouse gas emissions.

Food waste is defined here as edible material intended for human consumption that is discarded, lost, degraded or consumed by pests as food travels from harvest to consumer or, as some put it, 'from field to fork'. This definition includes food that is fit for human consumption but intentionally used as animal feed, and spans the entire food supply chain. Whilst such a broad definition is appropriate, it creates problems in gathering accurate estimates of the *total* global food waste. This is because it is difficult to obtain accurate estimates of all the different kinds of waste. This Report focuses primarily on food waste that is either not used at all or not used productively or sustainably or where the resulting benefits are small compared with the value of the original food product.

Halving the total amount of food waste by 2050 is considered to be a realistic target, in view of the evidence reviewed by this Project. If the current global estimate of 30% waste is assumed, then halving

the total could reduce the food required by 2050 by an amount approximately equal to 25% of today's production[6].

Making waste reduction in the global food system a strategic target would be more easily achieved if there was high-level international political support and an international body willing to act as champion. This is because many diverse organisations would need to come together to tackle the highly variable levels of waste that occurs in the food supply chain in different parts of the world.

Rising food prices should themselves act as an incentive for waste reduction. However, there are a number of areas where the market alone will not achieve what is possible, and where other interventions will be required. The following are considered particularly promising.

Reducing post-harvest waste, chiefly in low-income countries:

- **Deployment of existing knowledge and technology in storage and transport infrastructure.** There are many examples of relatively simple and often traditional technologies that can substantially reduce post-harvest waste. One example concerns a Food and Agriculture Organization (FAO) project that provided simple sealed storage drums for grain farmers in Afghanistan and elsewhere.
- **Investment in new, appropriate technology to reduce post-harvest waste.** An example would be the use of modern scientific advances to produce crops that are less susceptible to pests and spoilage, or better fish-smoking kilns that reduce losses and demand less fuel.
- **Infrastructure, financial and market reforms to reduce waste.** The use of ICT (mobile phones in particular) could help improve market information and allow producers to make better decisions about timely supply to markets, avoiding or at least reducing seasonal gluts.

Reducing waste by consumers, and the food service sector, chiefly in high-income countries:

- **Campaigns to highlight the extent of waste and the financial benefits of reducing it.** Specific programmes aimed at consumers, companies in the food supply chain, and those providing meals in restaurants, firms, hospitals, schools and other institutions.
- **The development and use of cheap, mass-produced sensor technology that can detect spoilage in certain perishable foods.** This would allow more sophisticated food management than reliance on estimated 'best before' dates in retail food labelling and have the potential to ensure food quality as well as reduce waste.
- **Productive recycling of surplus food deemed as non-premium quality.** This could be achieved through redistribution of good-quality surplus food to consumers via schemes such as 'Fareshare' in the UK[7] or the use of food no longer fit for human consumption as animal feed or a source of energy through processes such as anaerobic digestion.
- **Spreading best practice.** For example, a project in the Netherlands involving modest funding shows how waste in the supply chain from food processing through to the home can be significantly reduced by a combination of education and simple technology.

3.4 Improving governance of the food system

3.4.1 General conclusions on governance

These are:

- **Food security is best served by fair and fully functioning markets and not by policies to promote self-sufficiency.** However, placing trust in the international system does not mean relinquishing a country's sovereignty, rights and responsibilities to provide food for its population.
- **Greater powers need to be given to international institutions to prevent trade restrictions at times of crisis.** Interventions should include economic incentives and penalties designed to stop the erection of trade barriers that exacerbate price rises. In the absence of new institutional structures it is likely

6 The actual saving will depend upon a number of uncertain factors, not least the size of demand in 2050. However, the figure of 25% is considered to give an approximate estimate of the magnitude of savings that may be achieved.

7 FareShare is an independent UK charity that provides quality food – surplus 'fit for purpose' product from the food and drink industry – to organisations working with disadvantaged people in the community.

that the G20 will play a key role in the short term. Even with this coordinated response, humanitarian reserves and mobilisation capacity may need to be strengthened or introduced in vulnerable regions.

- **In high-income countries, food production subsidies and related interventions act as a disincentive to efficient global food production, raise consumer prices in protected countries, and are ultimately harmful to global food security. The current trend to reduce them [for example in the last decade's reform of the European Union's (EU's) Common Agricultural Policy (CAP)] should be accelerated to encourage the self-sustaining improvements in productivity which are necessary to meet future increase in demand sustainably.** In addition to direct interventions, careful international monitoring and sanctions against the use of sanitary, phytosanitary (SPS) and other standards as deliberate or unintentional non-tariff barriers to trade should continue, with further support for poorer producers to meet the growing and confusing array of these requirements.
- **Where there are strong reasons to support rural communities and the provision of environmental public goods via agriculture, nations should do this in way that does not distort food prices.**
- **Future reform of international institutions such as the World Trade Organization cannot ignore the issues of sustainability and climate change. But there is the risk that allowing sustainability to be reflected in trade rules may lead to environmental protectionism.** Whether or not trade rules eventually do change, reaching agreement between low-, middle- and high-income countries on baseline standards for sustainability in food production and processing that can be implemented at national scale will be an important first step.
- **An essential first step towards a more equitable global trading system for poor agricultural producers is the realisation of a *genuinely* pro-development Doha Development Agenda agreement via the negotiations of the World Trade Organization (WTO).** The principles of special and differential treatment, which allow 'developing countries' and the 'least developed countries' (WTO terminology) to protect vulnerable sectors where they are essential for rural livelihoods, or more generally to liberalise at a slower and less steep pace, are essential.

3.4.2 Governance of capture fisheries

The governance of capture fisheries in inland, coastal or open waters faces particular problems. Fishery resources are commonly held as public goods, at national level or by international treaty, but harvesters have insufficient incentives to resist overexploitation. Regulation is complex, and monitoring, control and surveillance (MCS) is difficult and expensive to implement, and few authorities have the means or sanctions to control over-fishing. Possible improvements include:

- **More effective options built on approaches that link traditional community-shared management of common property with economic arguments of responsible ownership and efficient production.** Using longer term and sometimes tradable allocation of resource rights to individuals or community groups, incentives can be created for reducing effort and building resource value, landing and recording all catches, transparently acquiring and sharing data on resources, improving returns to harvesters, reducing management costs and increasing resource rents. Approaches to adaptive management based on efficient ecosystem-based concepts also need to be adopted, and temporarily or permanently protected areas may be required. As impacts of climate change are likely to become a frequent feature in fisheries, leading, for example, to changes in the spatial and temporal location of fish stocks, these approaches will become even more critical in maintaining resilience.
- **Responsible fishing can also be incentivised by pressures from consumers and retailers, international initiatives for controlling illegal fishing, restricting landing locations and campaigns to sanction non-compliant fleets.**

More broadly, governance approaches in fisheries are strongly connected with those for the food system, in issues such as marketing, government investment, development of new technology and the critical need to improve sustainability. Also, many people gain their livelihoods from a combination of crop production, animal husbandry and in seasonal fishing. However, although the nutritional, social and economic value of the sector is widely recognised, poor levels of support and commitment at national and multilateral levels have compounded the problems of governance and weakened its future potential.

3.4.3 Corporate governance in the global food system

Over the last two to three decades a relatively small number of companies have come to dominate in the global food supply chain. This trend is apparent all along the supply chain, from agri-business (including seeds, crop protection) through to commodity wholesalers, manufacturers and retailers. Concerns have been raised regarding the exercise of this concentration of corporate power, for example in retail markets and purchase contracts with suppliers (particularly smaller farmers); wider public access to agricultural intellectual property and the transparency of governance in the food system.

However, there does not seem to be an argument for intervention to influence the number of companies in each area or how they operate – provided that the current numbers of major companies in each area and region of the food system were not to contract to a level where competition was threatened, and provided that all organisations adhere to high international standards of corporate governance. Governance of the food system should ensure that a global diversity of actors is reflected in healthy competition at local levels.

Continuing open and transparent dialogue, and increased collaboration between governments, the private sector and civil society, with commitments to robust standards of action and performance to achieve this, will be essential to achieving future sustainability in the global food supply chain.

At the workshop Foresight held on developments in the global food supply chain, it was clear that there is very considerable scope for the food industry to play a significant role in facilitating greater sustainability. **Extending best practice in the food supply chain has the potential to make radical improvements in sustainability across the food system. To encourage this shift, food industry leaders have called for a 'level playing field' in standardising best practice in sustainability. These behavioural shifts will entail government support for the development of new metrics of sustainability, strong direction setting and a consensus for action amongst diverse actors.**

3.5 Influencing demand

The balance between supply and demand can also be influenced by measures aimed at influencing demand – changing people's diets. This approach has potential because different foods vary considerably in the resources required for their production[8].

A number of different levers have been identified in the literature. They include:

- economic interventions, including taxing non-preferred food types
- 'choice editing', regulatory or voluntary actions, including purchasing guidelines by retailers and the food service sector to restrict choices by consumers or selectively enhance access to better foods
- campaigns to change individual behaviour involving public education, advertising, targeted programmes in schools and workplaces, and the provision of better labelling to enable the public to make more informed decisions.

Evidence from the health sector shows that changing diets is difficult but not impossible. It requires concerted and committed actions, possibly over long timescales.

However, constraints on modifying consumption can include resistance from consumers, and also from business and producers whose interests may be adversely affected by changing diets. Also, public good campaigns can sometimes be undermined by commercial interests; for example the five-a-day message promoting consumption of fruit and vegetables in the UK has been used to promote foodstuffs that do not belong to these categories and which do not offer the same nutritional benefits. However, dietary change can have multiple benefits, and hence there are some synergies across different areas of policy, such as health and sustainability, which could help achieve action.

If policy-makers decide to seek to influence patterns of consumption, there are a number of guiding principles that should be considered:

- Better decisions are made by an informed consumer.

8 For example, see Box 3.1 for a discussion on policies relating to the production and consumption of meat.

- Simple, consistent and trusted information on food is important.
- Government fiscal and regulatory intervention ideally requires societal consensus.

Box 3.1 Policies on the production and consumption of meat

It has been argued that a reduction in the amount of meat consumed in high- and middle-income countries would have multiple benefits: a reduced demand for grain, leading to lower greenhouse gas emissions, and a positive effect on health. Although this is a complex issue, there are three unequivocally beneficial options for policy:

- There is little dispute about the importance of a balanced diet and the role of a moderate intake of livestock products; communicating this to the consumer should be a priority for public health (recognising the power of vested interests in promulgating contrary messages).
- There should be investment in, and incentives for, production systems that maximise efficiency of inputs such as water and energy and minimise the trade-off between the production of animal feed and crops for human consumption.
- Reducing greenhouse gas emissions (and other negative externalities) from livestock production is an important global good; regulatory frameworks and incentives, and public-funded investment in research and development, aimed at reducing emissions and other environmental harm, is a priority.

However, policy-makers should recognise that more proactive measures affecting the demand and production of meat may be required should current trends in global consumption continue to rise. A discussion of the triggers and options for further actions are provided in the Project's Final Report.

4 Challenge B: Addressing the threat of future volatility in the food system

High levels of volatility in global food markets are an issue because of the adverse effects they have on consumers and producers, because of the disruption they cause to the global food system, and, when particularly severe, because of the general economic and political instability that can occur. These effects will be most severe for low-income countries and the poor, and spikes in food price can be a major cause of increased hunger.

4.1 Volatility in the past and in the future

The pattern of fluctuations in the price of five major food commodities (wheat, rice, sugar, beef and palm) over the last 50 years shows that food prices can be strongly affected by shocks from outside the food system, such as the oil crises of the early 1970s. It also shows that the last 20 years have been a period of relatively low volatility compared with the previous three decades – in particular, the spike in food prices of 2007 – 08, while receiving considerable political and media attention, was relatively small compared with the fluctuations in the 1970s (see Box 4.1 for a discussion of the possible causes).

Box 4.1 The causes of the 2007–08 spike

The most likely contributing factors were a steady increase in global demand, in particular due to economic growth in middle-income countries; an increase in energy prices and regulatory changes encouraging the conversion of agricultural land to the production of biofuels; a series of poor wheat harvests in 2006 and 2007 in agriculturally important regions such as Australia; and a general rundown in commodity stocks. The height of the spike was undoubtedly exacerbated by the introduction or tightening of export restrictions by governments in some important producer countries. It has also been argued that commodity speculation was an important causal factor, but the empirical evidence for this is contested and does not allow the relative importance of the various factors in causing or exacerbating the price spikes to be distinguished.

The number of factors affecting volatility and the levels of uncertainty associated with each make it very difficult to predict whether the magnitude of fluctuations in food prices will fall or rise in the coming decades. Although predicting future volatility is complex, there are several arguments

suggesting that volatility may well increase in the future. Also, at least some food price spikes are inevitable.

A wide range of drivers is likely to affect volatility in the future: non-economic factors such as armed conflict and breakdown of regional or national governance; general economic factors such as globalisation and international trade, and shocks in other commodities particularly in the price of oil; the level of food stocks held by private and public sector agents; how the markets are regulated; continuing improvements in crop protection and biotechnology; subsidies or incentives to biofuels; and for particular commodities the size of the relevant market. The cultural importance of certain foods can also be influential, as this can lead to government interventions to reduce price volatility.

4.2 Policy implications relating to future volatility

While the amount of volatility remains uncertain, price spikes in the future are inevitable.

The key issues for policy-makers are:

- **What levels of volatility are considered 'acceptable', and should governments intervene to attempt to control volatility within defined bounds?**
- **How can the negative consequences of volatility be mitigated, and which interventions would be most effective?**
- **Is it better to develop mechanisms to protect producers or consumers from the effects of volatility and, if so, how?**
- **To what extent should collective action and planning at the international level (for example the G20) occur to protect the poorest from the worst effects of volatility?**

Determining acceptable levels of volatility in food prices is a political judgement that needs to consider the negative effects of volatility, but also the costs of intervention.

Negative implications of volatility include:

- periods of high food prices that particularly have impact on low-income countries, and the poor everywhere
- risks of political and social instability
- distortions of investment decisions by making returns harder to gauge and incurring costs in hedging risk.
- potential to exacerbate problems of macroeconomic and fiscal management.

But the costs to interventions to reduce volatility include:

- high costs: they are expensive and require resources that could be used elsewhere
- risk of distorting markets or of interventions being hijacked for political reasons
- failure to be effective or making problems worse through unintended consequences.

Protection of the most vulnerable groups from the worst effects of food price volatility should be a priority, especially those in low-income countries where market and insurance institutions are weak. This can be done indirectly through intervention to try to influence market prices, but is likely to be more effective through the provision of safety nets for poor consumers or producers that are designed to stabilise real incomes.

It is essential that mechanisms are put in place to give governments the confidence in the global trade system to resist what will often be intense political pressures to impose export restrictions at times of high food prices.

Improving the functioning of commodity markets can reduce the element of volatility that does not reflect underlying market fundamentals.

Well-functioning markets require access to accurate information – information on international production and the size of commodity stocks is generally poor and in some cases deliberately withheld. The incorporation of commodities in more complex markets and over-the-counter traded derivatives,

and the effect of automatic computer trades need to be explored further. Also, the effects of these issues, if any, on excess volatility should be explored to determine if action is needed by policy-makers.

There have been calls for a global system of virtual or actual international grain reserves to help dampen price fluctuations on global markets. The Project did not find the arguments in favour of this strategy to be sufficiently strong to suggest that it be given priority.

In most circumstances the costs and policy risks of using international food reserves, virtual or real, to dampen volatility (as opposed to protecting the poor directly) will tend to outweigh the benefits. Past experience with international agreements, such as those for coffee and sugar following the 1970s price spikes, were not successful – they broke down when divergent interests of the participants emerged as markets recovered. There is a case, however, for higher public stock holding at the national or regional level, as noted below.

Governments and regional systems of support (such as the EU) have a clear role in improving education and awareness of the options available to improve risk management. Special measures for the most vulnerable countries include:

- Targeted food reserves for vulnerable (typically low-income) countries should be considered. There is a strong case for establishing an emergency food reserve and financing facility for the World Food Programme to help low-income countries facing sudden increases in food import bills when price spikes occur.
- The poorest food producers need specific assistance to obtain insurance against risk and volatility.
- Safety nets will be required at times of unusually high food prices.

5 Challenge C: Ending hunger[9]

5.1 Hunger today

Ending hunger is one of the greatest challenges to be considered by this Project. Today, there are an estimated 925 million people who suffer from hunger and perhaps an additional billion who, while having access to sufficient macronutrients, suffer from the 'hidden hunger' of not having enough vitamins and minerals.

This challenge is already recognised in the target of Millennium Development Goal 1. This aims to halve the number of undernourished people from the 1990 level of 16% to 8% in 2015. The current figure is 13.5%. Although China met its target in the early 2000s, many countries in Africa and south Asia are unlikely to succeed by 2015; although there has been a slight fall (from 1,020 million to 925 million over the past 12 months), progress has been slow.

There are substantial difficulties in defining and measuring hunger, undernutrition and food security. This issue contributes to a serious shortfall in the evidence and data available to inform policies. For example, household surveys have demonstrated that, in some countries, FAO data may underestimate the number of people suffering from hunger by as much as a factor of three.

Hunger intersects with food insecurity and undernutrition in complex ways. It is important for policy-makers to take a broad view of the nature and causes of hunger and its many impacts, including the severe and long-lasting nature of the effects that hunger and undernutrition can cause, particularly in children.

Hunger results in increased morbidity and mortality, through diseases caused by nutrient deficiency, and a greater susceptibility to disease more generally. It leads to distress behaviour that undermines development, including the sale of assets, the withdrawal of children from school (particularly girls) and into the labour force, the prompting of outmigration and, at worst, permanent destitution, prostitution and child trafficking. It also contributes to the onset of armed conflict. The food price rises of 2007–08 and their impacts, particularly on the poorest households, highlighted the inability of the current global food system to protect the most vulnerable from volatility in food prices.

9 The emphasis here is on ending chronic hunger.

There is a widespread consensus on the causes of hunger: for people to be free of hunger, there has to be physical, economic and social access to food. However, interventions will require the deliberate generation of a more robust and consistent consensus on tackling hunger. Strong levels of political courage and leadership will be required to carry this through.

Many of the factors that enable poor people to access money and other resources to consume, purchase or grow good-quality food lie from outside the food system. However, there is still much more that national and international actors can do to tackle hunger through the food system itself. These are considered below.

5.2 Making agriculture work harder to reduce hunger

In the countries where hunger is most chronic (south Asia and sub-Saharan Africa) agriculture can make a major contribution to its eradication. For this to occur, agricultural development must be designed and incentivised with hunger reduction as a primary goal. Food production, whether from terrestrial or aquatic sources, has a powerful potential triple role in ending hunger:

- Production is essential for physical access to food. Technologies, institutions, infrastructure and information that support increased, sustainable productivity and which are equitable (i.e. are desirable, available and practical for the poorest farmers to adopt) can increase the supply of a diverse and locally desirable food at affordable prices.
- These technologies, institutions, infrastructure and information sources can improve economic access for all by raising farm income, generating employment on and off farm, and reducing food prices.
- Production can address issues of social access by deliberately empowering women and other socially excluded groups.

In the poorest countries, agriculture provides not only food for households, but also a very important means of broadly based income generation. Recent empirical evidence suggests that, compared with growth from other sources, growth in agriculture generates welfare gains that are much stronger for the poorest parts of the population. Cross-country econometric analysis reported in the 2008 World Development Report shows that a 1% gain in gross domestic product (GDP) originating in agriculture generates a 6% increase in overall expenditure of the poorest 10% of the population, while the equivalent figure for GDP growth originating in non-agricultural sectors is zero growth.

There are grounds for optimism that agriculture can become a more powerful force for the reduction of hunger and poverty in the decades ahead – but agriculture needs to be repositioned within governments as a profession dedicated to multiple ends, of which hunger and poverty reduction are central.

For many governments, the purpose of agriculture is seen primarily as food production. In reality, agriculture requires flexibility to adapt to multiple agro-ecological niches; social analysis to understand issues of equity and exclusion; environmental skills to, among other things, work within the climate change mitigation and adaptation agendas; and political resourcefulness to forge new alliances that enable the sector to leverage additional funds and influence. This means a repositioning of agriculture as a profession dedicated to multiple ends, of which hunger and poverty reduction are central. Food production is the means, not the end. Such a repositioning would mean changing the formal and informal training of professionals in agricultural development, the ways in which Ministries of Agriculture are located, organised and staffed, and how the media perceives agriculture. The following are particularly important:

- Innovation in how to involve producers in improving yields sustainably is as important as innovation in research – there is still a need for far greater participation of producers in defining and monitoring success.
- With much technology development taking place at greater distances from the farmer's plot, stronger mechanisms are needed to ensure that representatives of poor farmers and groups experiencing chronic hunger are included in local and national fora.
- Smallholder farming has been long neglected. It is not a single solution, but an important component of both hunger and poverty reduction.

- Women in low-income countries play a critical role in agriculture, and agriculture plays a critical role in women's livelihoods. Purposively empowering women and focusing on their unique challenges will bring much wider gains in terms of poverty and productivity.

5.3 Measures in the broader food system

Hunger cannot be ended by agriculture alone. Other policies and investments to increase food access, income, reduce differences in gender power and improve nutrition status are vital. Interventions discussed elsewhere in this Executive Summary in the areas of trade, research and development, training and extension have a critical contribution in addressing hunger as well as increasing production of, and access to, food.

- **There has been considerable recent innovation in different forms of social protection to improve access to food.** Cash transfers – with or without conditions –are quickly becoming the main type of programme for social protection to help vulnerable households be less exposed, less sensitive and more adaptive to a range of shocks.
- **However, it is important not to view social protection policies uncritically.** Social protection can compete with agriculture for political support and may only be affordable for the poorest 10% of the population.
- **In addition to placing gender power relations at the heart of the agricultural research and development system, there is a wide range of complementary measures that can be undertaken to promote the agency of women in ways that will accelerate hunger reduction.** They include the eradication of gender-based discrimination (such as land ownership and user rights) and steps to actively promote women's status (such as quotas for representation in agricultural decision-making bodies).
- **Undernutrition needs to be tackled by direct and by indirect interventions.** 'Direct nutrition' interventions focus exclusively on improving nutrition status – for these the main issue has been the challenge of scaling up. 'Indirect' interventions refer to programmes or policies that do not have improvements in nutrition as a core aim, but have the potential to be beneficial – particularly as some draw upon large budgets. Programmes relating to agriculture, social protection and women's status fall within this category. For these, empowering women will help accelerate gains in addressing hunger and undernutrition. But so too will embedding direct nutrition components within larger resource flows – examples of promising innovations include biofortification of staple food crops with micronutrients, and the health conditionalities embedded in cash transfers.

5.4 Efforts to end hunger

A stronger constituency for hunger reduction needs to be built. The international community must challenge itself over the apparent ease with which hunger is ignored and ask why hunger is so easy to neglect. Brazil's experience of the past 10 years shows that if the political will is present, poverty and hunger can be substantially reduced.

Reducing the number of people suffering from hunger rarely receives political priority, since the poorest section of society exercises little leverage, nationally or globally. Arguably agriculture receives even less attention than hunger reduction. In the African context, it is often seen as old-fashioned, and the preoccupation of previous generations[10].

In the donor countries, investment in agricultural development has declined in recent decades because of changing donor fashions.

This is partly because of a shift in focus to social development and governance, and partly because those involved in agriculture did not invest sufficiently in impact analysis to defend it. In the last few years, however, greater attention has been given to agricultural development. For example, the World Development Report in 2008 focused on agriculture, and the aid given to agriculture by the

10 But see Box 5.1 for a discussion of the dynamism in parts of the African food system.

Development Assistance Committee (DAC) of the Organization for Economic Cooperation and Development (OECD) and multilateral agencies has increased.

However, despite this recent surge, the prolonged dip in investment means that agricultural training, infrastructure and research have suffered a 20-year period of underinvestment. There is now a need for a bold and global consensus for tackling hunger and ensuring investment in pro-poor, anti-hunger agricultural growth.

An infrastructure to strengthen commitment to hunger reduction needs to be developed to:

1. Monitor more appropriate outcomes. The FAO and the World Bank should be tasked with working together to develop a new set of hunger outcomes.

2. Monitor outcomes better and raise awareness of hunger. Governments need data on hunger within the year to adjust and respond. New mobile phone and global positioning system (GPS) technologies have the potential to revolutionise the mapping of hunger.

3. Monitor commitments and inputs, levels and perceptions – concerning government action and spending on hunger reduction. Constructing an index for measuring governmental commitment to hunger reduction could provide useful means of comparing the performance of different governments.

4. Strengthen the culture of monitoring, impact and learning in agriculture. Mixed-method approaches to agricultural measurement and evaluation are available. They must be used to understand what works, why, how and when. Agricultural organisations need to be incentivised to use these methods and to learn from them.

5. Enable greater strategic prioritisation and sequencing of actions to address hunger and undernutrition. There is a need to take much better account of the complementarities and interactions between different factors in addressing hunger, rather than focusing on their independent effects. The aim would be to develop and apply a 'growth diagnostics' approach (as currently being used to help policy stimulate economic growth), so that a broad range of factors contribute in concert.

6. Develop a culture that supports the emergence of leaders to champion hunger reduction. Very little is known about how to create leadership for hunger reduction, including the issue of whether such leadership will emerge independently or whether leaders might be encouraged by programmes on leadership for hunger reduction at the community and national levels. The lack of conclusive evidence suggests the need for experimentation and innovation across the field.

7. Mobilise mechanisms for accountability in hunger reduction. At a local level there are many mechanisms for social accountability that have proven to be effective in strengthening service delivery and improving the agency of the poorest. At a global level, the United Nations (UN) is leading a worldwide effort to build enforceable international law recognising the 'right to food'. While this work is welcome in terms of affirming values, it remains to be seen whether it leverages resources to accelerate hunger reduction.

Box 5.1 Agriculture in Africa – the myth and the reality

Agriculture accounts for 65% of full-time employment in Africa, 25–30% of GDP, and over half of export earnings. Perceptions about African agriculture are mixed. It has been called stagnant by some, and assumed to have failed smallholders – per capita production indicates that the amount of food grown on the continent per person has only just recovered today to the 1960 level.

However, when account is taken of the substantial growth in demand from population increases, it can be argued that African agriculture has been dynamic and adaptive over decades. Indeed, net production data show that there has been substantial growth in production across all regions of Africa, with output more than trebling over 50 years (with the greatest growth in north and west Africa), and growing faster than world output. A review commissioned by this Project of 40 African case studies demonstrates where sustainable increases in agricultural yield have been achieved – and the considerable potential that could be realised if these examples can be scaled up and applied elsewhere[11].

Nevertheless, the challenge still remains substantial for African agriculture: continued population growth, rapidly changing patterns of consumption and the impacts of climate change and environmental degradation are driving limited resources of food, energy, water and materials towards critical thresholds.

6 Challenge D: Meeting the challenges of a low emissions world

Greenhouse gas (GHG) emissions from the global food system constitute a substantial fraction of all emissions and need to be a focus of efforts to mitigate climate change. Equally, it will be critically important for policies on climate change mitigation to take full account of their potential impact of the global food system, in view of its vital role in human survival and wellbeing and its influence on wider issues of sustainability.

Developing policies in this area is particularly difficult because in addition to carbon dioxide (CO_2), the food system emits substantial volumes of the more powerful greenhouse gases methane (CH_4) and nitrous oxide (N_2O), which complicates monitoring and regulation. Also, the contribution that the food system makes to greenhouse gas emissions is difficult to measure and depends critically on where the boundaries of assessment are drawn. For example, in recent years the consequences of greenhouse gas emissions from land use change associated with agriculture have been of the same order as the sum of all other agricultural factors.

6.1 The food system and greenhouse gases – past and future

Agriculture itself is estimated to contribute 12–14% of greenhouse gas emissions, including those associated with fertiliser production; the figure rises to 30% or more when costs beyond the farm gate and especially land conversion are added. Moreover, agriculture contributes a disproportionate amount of greenhouse gases with high impact on warming: approximately 47% and 58% of total CH_4 and N_2O emissions respectively. Low- and middle-income countries are currently responsible for about three-quarters of agricultural greenhouse gas emissions with their proportionate share increasing. A study in 2006 estimated that 31% of the EU's greenhouse gas emissions were associated with the food system. The single most important contribution of agriculture to greenhouse gas emissions is through the production and application of nitrogen fertilisers, and the second most significant is from livestock production through enteric fermentation and manure.

These highly aggregated figures contain much variation among food types and across regions. For example, within livestock, ruminants produce significant amounts of methane when compared with monogastrics, while crop production and distribution systems that involve growing under heated glass, air-freighting or refrigerated distribution are particularly energy-intensive. N_2O from soils is the main source of greenhouse gas emissions from industrialised nations as well as in Africa and most of Asia, while CH_4 emissions from livestock dominate from Central and South America, Eastern Europe, central Asia

11 These are reported in a Project paper – see chart of Project outputs in the Annex.

and the Pacific. Wetland rice production and biomass burning are important sources of GHG emissions in south and east Asia and in Africa and South America respectively.

Looking to the future, the EU has enacted legislation to reduce emissions by 20% by 2020 (taking 1990 as the base), while the UK has set the legally binding target of reducing emissions by 34% by 2020 and at least 80% by 2050 (Scotland's targets are 42% and 80% respectively, with the same baseline). These ambitious goals cannot be achieved without the food system playing an important part. At the global level, substantial increases in GHG emissions from agriculture are highly likely in the decades ahead.

Global increases will be especially associated with increased production of artificial fertiliser to serve both an expanded food-production system, and to redress the currently low levels of use in certain parts of the world, notably sub-Saharan Africa. Because agriculture is currently not included in many national greenhouse gas reduction initiatives, the proportional contribution of emissions from this sector is likely to rise.

6.2 The food system in a low-carbon world – policy implications –

There is a clear case for substantially integrating and improving considerations of agriculture and food production in negotiations on global emissions reductions, although the special features of this sector must be taken into account. These include the possible effects on efforts to reduce hunger, and ethical issues concerning which geographical and economic groups should bear the costs of mitigation. Consideration also needs to be given to whether other sectors should set more ambitious emissions reduction targets – so that food production is not constrained, and economic development in low-income countries is not impeded.

Changes in agricultural practices that affect the net flux of greenhouse gases between the land, aquatic margins and the atmosphere could, depending on their direction, have significant positive or negative effects on global warming. There is nearly as much carbon in the organic compounds contained in the top 30 cm of soil as there is in the entire atmosphere and a vast amount of carbon is tied up in land used for food production.

It is desirable to develop smart policies to achieve multiple goals in the food system: There are four main ways in which impetus can be given to emissions reduction in the food system:

- Creation of market incentives to encourage emissions reductions. These might include grants, subsidies, levies, carbon taxes or carbon cap and trade schemes.
- Introduction of mandatory emissions standards or limits by direct regulation.
- Adoption of low-emission strategies through market pressures driven by consumer choice. This requires active and informed consumers, and sources of accurate and trusted information such as labelling for emissions or product certification.
- Voluntary (non-profit driven) measures taken by industry as part of corporate social responsibility.

In designing, encouraging and facilitating such initiatives, it is essential to consider not only their effects on greenhouse gas emissions but how they affect the amount of food produced, the quantity of inputs required, and all the other externalities of the food system from ecosystem services to animal welfare.

The following points should be noted:

- *Reducing emissions can occur without loss of production or productivity.* In some cases, emissions reduction can occur without loss of production or productivity or even with a gain in efficiency. For example, incentives that encourage the more efficient use of water and fertilisers (including recycling) may both reduce emissions and increase value per resource unit, and also have other benefits such as reducing nitrogen leaching and run-off, and pressure on increasingly scarce resources such as energy and water, to the benefit of sectors beyond the food system.
- *Developments in science or technology can influence and increase the efficiency of interventions to reduce greenhouse gas emissions.* For example, precision agriculture with reduced volume of fertiliser

application, breeding for improved nitrogen use by plants, and breeding for reduced greenhouse gas emissions in beef and dairy cattle and via genetic improvements in their fodder.

- *Where emissions reduction affects yield, interventions should be chosen to achieve the greatest greenhouse gas reductions at the least cost.* However, it will be critical to understand how an intervention affects yields and productivity, and whether it will have an impact on the poorest people least able to bear the cost of mitigation. In particular, it will be important to give careful consideration to the consequence of interventions for smallholders and for women, as well as for societies such as many pastoral communities whose culture is intimately connected with agriculture and food production.
- *The need to recognise the importance of land conversion in policies to reduce greenhouse gas emissions.* The single largest way the global food system contributes to greenhouse gas emissions is through land conversion, particularly from forest into farmland. One of the strongest arguments for the Project's conclusion that the global food supply must be increased through sustainable intensification without significant new land being brought into cultivation is the emissions of greenhouse gases that would otherwise result. Emissions policy for agriculture must be developed within the broader context of emissions from all land use types.
- *The importance of the link between mitigation policies, biofuels and the food system.* Though some biofuel systems have net positive effects for greenhouse gas emissions, many first-generation biofuels do not contribute to greenhouse gas reduction but reduce the area available to grow food. The history of the introduction of biofuels illustrates the dangers of not considering all the consequences of a climate change policy, and the way they can be exploited by those with vested interests.
- *Policies to mitigate climate change can incentivise the delivery of multiple public goods associated with the food system.* A theme running through this Report is the importance of internalising within the global food system the negative consequences for the environment of different forms of production. This approach incentivises best practice but also provides the means by which food producers can be rewarded for supplying multiple goods without direct public funding.

Many examples of the application of existing knowledge and technology to increase sustainable food production will also have positive effects on reducing greenhouse gas emissions. The creation of new knowledge to increase current yield ceilings in the most sustainable way will also have the potential to make a contribution. However, measures that are greenhouse gas emission-neutral, but which increase productivity, reduce demand or increase the efficiency of the food system are also beneficial for climate change mitigation because they reduce the pressure on the food system to expand, and therefore help to limit greenhouse gas increases that might otherwise occur.

For measures to reduce emissions, an audit of their consequences for greenhouse gas emissions should be carried out. The results should become part of decision-making processes in allocating funds for interventions and for research.

Particularly promising options for reducing emissions include reducing waste; more efficient use of nitrogen in crop and livestock production; implementing management changes to the cultivation of wetland rice to reduce the amount of anaerobic decomposition (a major source of methane); encouraging agroforestry; reducing CH_4 and N_2O emissions from livestock production; and increasing the efficiency of land use to harvest solar radiation for food and energy through second-generation biofuels and the integration of biomass production. In the future, energy crops based on algae or macroalgae (seaweed) may be cultivated in integrated systems linked to terrestrial or aquatic food production. Increased carbon sequestration through integrated soil and vegetation management is also promising: were the organic carbon pools in the world's soils to be increased by 10% in the 21st century, it would be the equivalent of reducing atmospheric CO_2 by 100 parts per million.

6.3 Enabling greenhouse gas reduction in the food system

Developing better and more comprehensive metrics of greenhouse gas emissions in the global food system should be a priority. Government-backed schemes setting sector-wide sustainability standards would obtain strong support from industry and be a very positive contribution to increasing sustainability.

In measuring how greenhouse gas emissions are affected by different strategies, it is critical to include not only the direct but also the indirect consequences, such as effects on land use conversion and those mediated by global trade. There is also a balance to be struck between comprehensiveness and simplicity that will vary across applications.

Senior representatives of the UK food retail sector gave the clear message that they would welcome government-accredited national schemes that set standards for sustainability. They argued that the key to its success would be in setting a level playing field in this intensively competitive sector, and that it would be important for the definitions of standards to be in place for a sufficient time to encourage investment in sustainability.

7 Challenge E: Maintaining biodiversity and ecosystem services while feeding the world

Until recently, policies in conservation and in food security were largely developed in isolation. However, increasingly and rightly, they are being pursued together, driven by a growing realisation of their interdependence.

There are both economic and non-economic arguments for why ecosystem services and biodiversity should be integral parts of decision-making in the global food system. It is only in the last few decades that the importance of the services provided by different managed and unmanaged ecosystems to food production has been realised, and efforts started to quantify their economic significance. Different national and international 'ecosystem assessments' seek to understand how various drivers of change will affect the provision of ecosystem services in the future.

A key argument of this Report is that the global food supply will need to increase without the use of substantially more land and with diminishing impact on the environment: sustainable intensification is a necessity. Pursuit of this agenda requires a much better understanding of how different policy options, both within and outside the food system, affect biodiversity and ecosystem services.

Box 7.1 What the Project means by sustainability

The principle of sustainability implies the use of resources at rates that do not exceed the capacity of the earth to replace them. Thus water is consumed in water basins at rates that can be replenished by inflows and rainfall, greenhouse gas emissions are balanced by carbon fixation and storage, soil degradation and biodiversity loss are halted, and pollutants do not accumulate in the environment. Capture fisheries and other renewable resources are not depleted beyond their capacity to recover. Sustainability also extends to financial and human capital; food production and economic growth must create sufficient wealth to maintain a viable and healthy workforce, and skills must be transmitted to future generations of producers. Sustainability also entails resilience, such that the food system, including its human and organisational components, is robust to transitory shocks and stresses. In the short to medium term non-renewable inputs will continue to be used, but to achieve sustainability the profits from their use should be invested in the development of renewable resources.

The political reality is that sustainability[12] cannot be pursued in the absence of food security. Nevertheless, it is important for policy-makers to appreciate a range of trade-offs affecting decisions involving the food supply and ecosystem services. Important trade-offs include yield versus ecosystem services; trade-offs between different ecosystem services; land sparing versus wildlife-friendly agriculture; and the relationship between biodiversity and the needs of the poor.

Some of the most threatened and diverse habitats on earth exist in very low-income countries, and interventions to make farming more wildlife friendly, fishing less damaging, or to set land aside as reserves may affect the livelihoods of the very poorest people. Whatever strategies are adopted, the human impacts need to be understood and quantified as there are strong ethical arguments against imposing the costs of protecting biodiversity on those least able to pay them.

12 See Box 7.1 for a discussion of what the Project means by sustainability.

The fact that food production requires ecosystem services provided by both farmed and non-farmed land means that policy in these two areas needs to be developed and properly connected at global, national and landscape scales. Therefore:

- **At global and international levels:** recognise that food security and environmental protection are interdependent; develop mechanisms to reward countries that produce supranational environmental goods – international policy needs to ensure that countries obtain benefits from providing global goods, especially when costs are borne by low-income countries; avoid policies that have negative environmental impacts in other countries; coordinate the protection of biodiversity across administrative or national borders – much significant biodiversity can only be protected with coordinated regional or international action.
- **At national and landscape levels:** make land sparing work; develop new infrastructure sensitively; consider biodiversity in planning at the landscape scale; implement realistic minimum environmental flows; consider setting aside marine and freshwater protected areas; and recognise the importance of 'wild foods' in low-income countries. (See Box 7.2 for a discussion of the particular need to preserve tropical rain forests.)

Box 7.2 The imperative to preserve tropical rain forests

Much of the land that could be brought into agriculture is currently covered by tropical rainforest. Pressure from expanding agriculture has been a major factor leading to recent tropical deforestation, especially in South America (where conversion to soybean and cattle ranching is the greatest pressure) and south-east Asia (owing to oil palm conversion). Such deforestation has a number of very adverse effects:

- The conversion of tropical forests to agriculture releases large one-off amounts of greenhouse gases. It also reduces the land's subsequent ability to take up greenhouse gases.
- Tropical deforestation may have direct and damaging effects on local climate.
- Much of the associated biodiversity can only exist in rainforest, and is lost immediately once the land is converted to other uses.
- Tropical rainforests are home to many indigenous groups.

The Report concludes that there will hardly ever be a case to convert forests, especially tropical rainforests, to food production.

The importance of tropical forests to climate change is the focus of the UN Collaborative initiative on Reducing Emissions from Deforestation and Forest Degradation (REDD) and REDD+, which also includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. An increased focus on aligning REDD+ with agriculture and food security in low-income countries will be essential for its success.

Terrestrial and aquatic ecosystems used in food production need to be managed to achieve multiple goals. Where high levels of productivity are important then sustainable intensification is the key concept. But as explored in a recent Foresight report, land will also need to be managed for multiple functions, for example food production, supporting rural economies, flood management and protection of biodiversity. Aquatic zones, particularly in inland and coastal areas, require similar approaches. The challenges and opportunities of multifunctional uses, integrating land and water systems are critical for policy formulation.

Some ecosystems used primarily for food production have particularly high biodiversity value. Examples include many agro-ecosystems in the Mediterranean basin that have high levels of biodiversity adapted to agricultural practices which have persisted for several thousand years; grassland ecosystems such as the steppes where cattle, sheep and other livestock have replaced natural grazers, some of which are now extinct; wetlands used for rice growing, and coral reef marine ecosystems subject to capture fisheries. For these special agro-ecosystems there will be a strong policy imperative to protect biodiversity even at the cost of reduced yields. But even when such considerations do not apply, it may be possible to improve the provision of ecosystem services or protect biodiversity with relatively modest costs to yields.

- **Evidence-based, wildlife-friendly farming.** Such schemes can potentially be of great benefit to wildlife, but there needs to be a more analytical and evidence-based approach to what works best. For example, in investing to support biodiversity a full range of management options (including setting land aside in reserves) should be considered, and in comparing alternatives, the appropriate spatial and temporal scales should be employed.
- **Biodiversity-sensitive fisheries.** The development of ecosystem approaches for fisheries (EAF) management has potential benefits for both biodiversity and production, and although comprehensive approaches require considerable resources, elements of EAF can be adopted in many fisheries. In the absence of fully developed EAFs, the immediate prospects for protecting or building biodiversity are based on strategic measures such as controlling illegal fishing, reducing by-catch by improving fishing gear, as well as more specific actions such as creating protected zones, defining and protecting endangered species, controlling stock movements, banning destructive fishing methods and restricting predator culls. For aquaculture, measures to avoid the use or release of non-native species, contamination of wild-species gene pools, and the culling of endangered bird, reptile or mammal predator species are important to protect biodiversity.

But it must also be recognised that much biodiversity can only be protected in relatively natural habitats. It is therefore critical to produce enough food from cultivated land to allow land to be spared for wildlife, and for the ecosystem services these habitats provide.

7.1 Strategic policy implications

The arguments presented here and in the Project's Final Report illustrate the benefits of making environmental issues integral to policy making in the food system. Some strategic implications for policy makers concern:

Major knowledge gaps that urgently require further research. They include the ecological basis of many ecosystem services and their resilience to perturbation; the economic assessment and valuation of ecosystem services and biodiversity; the development of a more analytical evidence base to judge amongst different management alternatives.

National and supranational governance. Many of the most critical decisions in this area require decisions at the national level (for example land use policy) or the international level (governance of factors affecting global goods). Environmental issues are being given much higher priority than in the past at all levels, but this must be continued and strengthened.

Negative environmental externalities. There needs to be much greater realisation that market failures exist in the food system that, if not corrected, will lead to irreversible environmental damage and long-term threats to the viability of the food system. Moves to internalise the costs of these negative environmental externalities are critical to provide incentives for their reduction.

Aligning environmental and market incentives. Progress on achieving desirable environmental goals will be most easily achieved when they are congruent with market incentives.

Environmental protection and stewardship. Payments for environmental stewardship are a means of both supporting rural incomes and protecting the environment without distorting agricultural markets. Such schemes should be designed so that they support the long-term maintenance of on-farm biodiversity and are robust to changes in economic and food system conditions. Stewardship schemes are less frequent in low-income countries including those with centres of biodiversity, and should be encouraged.

8 Priorities for action

A key conclusion of this Foresight Project is that no single approach can meet all of the complex challenges that have been outlined above – decisive action is needed across a wide front. This is perhaps unsurprising, given the diversity and scale of the challenges, and the need for the global food system to deliver much more than just food, and food security in the future. The attention of policy makers will therefore shift to the question of prioritisation – where to focus efforts, and how best to deploy scarce resources.

The following 12 cross-cutting actions (Box 8.1 – these are not in any order of importance) are priorities for policy-makers suggested by the wider analysis of the Project.

Box 8.1 Key priorities for action for policy makers

1. Spread best practice.
2. Invest in new knowledge.
3. Make sustainable food production central in development.
4. Work on the assumption that there is little new land for agriculture.
5. Ensure long-term sustainability of fish stocks.
6. Promote sustainable intensification.
7. Include the environment in food system economics.
8. Reduce waste – both in high- and low-income countries.
9. Improve the evidence base upon which decisions are made and develop metrics to assess progress.
10. Anticipate major issues with water availability for food production.
11. Work to change consumption patterns.
12. Empower citizens.

1. Spread best practice

There are major advances to be made using existing knowledge and technologies to raise yields, increase input efficiency and improve sustainability. But this will require significant investment of both financial and political capital to ensure that food producers have the right incentives and are equipped with the necessary skills to meet current and future challenges. This Report has highlighted the following priorities to achieve these ends: improvements in extension and advisory services in high-, middle- and low-income countries; and the strengthening of rights to land and natural resources in low-income countries. Adopting proven models of extension and knowledge exchange to build human and social capital is critical to addressing all aspects of food production from sustainable agronomy to business skills.

2. Invest in new knowledge

There is a consensus among the results of food system models that one of the most critical drivers of future food supply is the rate of growth of yields due to new science and technology. New knowledge is also required for the food system to become more sustainable, to mitigate and adapt to climate change, and to address the needs of the world's poorest. These challenges will require solutions at the limits of human ingenuity and at the forefront of scientific understanding. No one technology or intervention is a panacea, but there are real sustainable gains to be made by combining biotechnological, agronomic and agro-ecological approaches. Because of the significant time lags in reaping the benefits of research, investment in new knowledge needs to be made now to solve problems in the coming decades. Investment needs to occur not only in the important field of biotechnological research but across all the areas of the natural and social sciences involved in the food system.

3. Make sustainable food production central in development

The 'Cinderella status' of primary food production in international development financing has for too long ignored the crucial role that it plays in rural and urban livelihoods. There is evidence from a series of recent initiatives that this neglect is now changing. Such investment is not only about food production but also the web of people, communities and physical infrastructure that surrounds it. Investment in the sector offers a pro-poor model of economic growth with much wider positive impacts on low- and middle-income economies and a means of producing a broader range of public goods. Development trajectories should be chosen to help food producers in low-income countries adapt to the effects of climate change to which they are likely to be disproportionately exposed. Development of sustainable production systems that avoid the mistakes made by countries which moved out of the low-income class in earlier times is required. Investment in infrastructure and capacity is needed at a scale which will be realised only by innovative new partnerships between governments, multilateral bodies and the private sector.

4. Work on the assumption that there is little new land for agriculture

Relatively little new land on a global scale has been brought into food production in the last 40 years. Although modest amounts may in future be converted to agriculture, the Report concludes that major expansion is unwise. In particular, it is now understood that one of the major ways that food production contributes to greenhouse gas emissions is through land conversion, particularly of forests. Only in exceptional circumstances can conversion of forests (especially tropical rainforests), natural grasslands and wetlands to agricultural land be justified. This Report also recognises that while some biodiversity can be maintained on land used for food production, a very significant fraction, especially in the tropics, requires relatively undisturbed non-agricultural habitats. In contrast to land conversion, the restoration of degraded agricultural land can be an important means of increasing the food supply and a good use of international development monies.

5. Ensure long-term sustainability of fish stocks

Very few of the world's wild fish stocks are not currently exploited, with many over-exploited and subject to poor fisheries management. This is exacerbated by illegal fishing which thrives where controls are weak, and by the continued provision of capacity-enhancing subsidies. There is an urgent need to reform fisheries governance at national and international levels to ensure the long-term sustainability of this natural resource and enable it to meet the challenges identified in this Report. The status quo is not an option, as many fish stocks will be more open to overexploitation to meet increasing demand, be less resilient to climate change and at greater risk of collapse. More effective management needs to be put in place, building on examples of best practice around the world and based on long-term allocation of clearer entitlements to fish to incentivise more sustainable use of the resource. At the same time, aquaculture, which will have a major role to play in meeting the supply and resource challenges ahead, will need to produce more with increased sustainability.

6. Promote sustainable intensification

It follows that if (i) there is relatively little new land for agriculture, (ii) more food needs to be produced and (iii) achieving sustainability is critical, then sustainable intensification is a priority. Sustainable intensification means simultaneously raising yields, increasing the efficiency with which inputs are used and reducing the negative environmental effects of food production. It requires economic and social changes to recognise the multiple outputs required of land managers, farmers and other food producers, and a redirection of research to address a more complex set of goals than just increasing yield.

7. Include the environment in food system economics

The food system relies on a variety of services that are provided without cost by the environment – what are now called ecosystem services. The food system may negatively affect the environment and hence harm the same ecosystem services it relies upon, or affect those that benefit other sectors. Understanding the economics of ecosystem services is a very active area of current research and incorporating the true costs (or benefits) of different productions systems on ecosystem services is a powerful way to incentivise sustainability. It also helps identify situations where moves to increased sustainability impact upon the poorest people who will require help and support.

8. Reduce waste – particularly in high- and low-income countries

Food is wasted at all stages of the food chain: in high-income countries waste tends to be concentrated at the consumer end and in low-income countries more towards the producer's. Reducing food waste is an obvious priority and this Report supports earlier analyses in according it very high priority. It is also an area where individual citizens and businesses, particularly in high-income countries, can make a clear contribution.

9. Improve the evidence base upon which decisions are made and develop metrics to assess progress

This Report makes specific recommendations for the creation of a global, spatially explicit, open-source data base for the analysis of agriculture, the food system, and the environment, and the setting up of an International Food System Modelling Forum to enable a more systematic comparison of different models, to share results and to integrate their work better to meet the needs of policy-makers.

10. Anticipate major issues with water availability for food production

While this Report has highlighted a series of issues concerning competition for the inputs for food production, it is growing pressure on water supplies that is likely to be experienced first. The dangers come from higher demand for water from other sectors, the exhaustion of aquifers, and changes in precipitation patterns, higher sea levels and altered river flows caused by climate change. Incentives to encourage greater efficiency of water use and the development of integrated water management plans need to be given high priority.

11. Work to change consumption patterns

The informed consumer can effect change in the food system by choosing to purchase items that promote sustainability, equitability or other desirable goals. Clear labelling and information is essential for this to happen. Governments are likely to need to consider the full range of options to change consumptions patterns including raising citizen awareness, approaches based on behavioural psychology, voluntary agreements with the private sector, and regulatory and fiscal measures. Building a societal consensus for action will be key to modifying demand.

12. Empower citizens

Investment is needed in the tools to help citizens hold all other actors (and themselves) to account for their efforts to improve the global food system. Examples include the better provision and publication of information on the commitments of different groups, the extent to which they have acted on their commitments, and through information on a food system 'dashboard' a measure of their effectiveness. Modern ITC needs to be mobilised to provide, for example, real-time hunger surveillance and to allow farmers and consumers to give feedback on what is working and not working in hunger reduction efforts.

These priorities, together with the many other more detailed actions that are set out in this Executive Summary, will need to be pursued by a wide range of actors in the global food system, often acting in concert. These include UN and other international organisations, governments, the private sector, non-governmental organisations and the research community. Indeed, individual consumers could also play an important role, as outlined above. A broad range of actions that these various actors should consider are described in more detail in the concluding chapter of the Final Project Report.

9 Why action is needed now

There is urgency in taking what may be very difficult policy decisions today relating to the diverse challenges facing the global food system, and also to address the present levels of hunger – 925 million people suffer from hunger and perhaps a further billion lack sufficient micronutrients. It is imperative that the need for rapid action is realised by all concerned. This task is difficult because, not withstanding recent volatility in food prices, the food system is working for the majority of people. Also, those suffering or at risk from hunger generally have the least influence on decision-making in the food system.

Besides the unacceptability of the present levels of hunger, some of the main arguments for immediate action are:

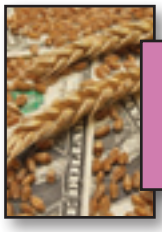
- The lack of sustainability in the global food system is already causing significant environmental harm, for example through nitrogen pollution, food production's contribution to greenhouse gas emissions, and the drying up of rivers and lakes. Many marine ecosystems are damaged by unsustainable fishing.
- There is increased competition for, and scarcity of, inputs into food production. Of these, as discussed above, water is the most pressing with significant effects on regional productivity likely to occur by 2030. Competition for land has also emerged as a significant factor in many countries.
- Some effects of climate change are now inevitable and the food system must prepare for them and adapt.
- The food system is a significant producer of greenhouse gases and must contribute to global mitigation efforts; immediate action on climate avoids the necessity of more radical measures in the future.
- There is the risk of negative irreversible events if action is not taken; this includes the loss of biodiversity, the collapse of fisheries and the loss of some ecosystem services (for example the destruction of soils).
- There is substantial evidence for increasing global demand for food (which probably contributed to the recent food price spike).
- Food security in 2030 and out to 2050 will require new knowledge and technology, and the basic and applied research underlying this needs to be funded now; there is evidence of a slowdown in productivity gains today correlated with a reduction in research and development (R&D) investment in many countries over the last two decades.
- The absence of food security will also make it much harder or impossible to pursue a broad range of other policy goals. It may also contribute to civil unrest or to failed states; it may stimulate economic migration or fuel international tensions.
- Actions taken in the near future can address problems that, if allowed to develop, will require much more difficult and expensive measures later on.

10 Conclusion

Despite inevitable uncertainties, the analysis of the food system presented in this Report makes clear that the global food system between now and 2050 will face enormous challenges, as great as any that it has confronted in the past. The Report carries a stark warning for both current and future decision-makers on the consequences of inaction – food production and the food system must assume a much higher priority in political agendas across the world. To address the unprecedented challenges that lie ahead the food system needs to change more radically in the coming decades than ever before, including during the Industrial and Green Revolutions.

Although the challenges are enormous there are real grounds for optimism. It is now possible to anticipate a time when global population numbers cease to rise; the natural and social sciences continue to provide new knowledge and understanding; and there is growing consensus that global poverty is unacceptable and has to be ended. However, very difficult decisions lie ahead and bold actions by politicians, business leaders, researchers and other key decision makers will be required, as well as engagement and support by individual citizens everywhere, to achieve the sustainable and equitable food system that the world so desperately needs.

Annex: Project reports and papers



Assessment of Future Challenges

- **C1:** Demand, Production and Prices
- **C2:** External Pressures on the Food System
- **C3:** Governance
- **C4:** Modelling and Scenarios

Challenge A: Sustainable Supply and Demand

- **C5:** Better Use of Existing Technology
- **C6:** New Science and Technology
- **C7:** Addressing Waste
- **C8:** Modifying Demand
- **C9:** Sustainable Intensification in African Agriculture

Challenge B: Volatility

- **C10:** Addressing Future Volatility

Driver Reviews

- **DR1:** Population
- **DR2:** Climate change and its effect on agriculture
- **DR3:** Consumption and consumer attitudes
- **DR4:** Energy and agriculture
- **DR5a:** Production possibilities: crops
- **DR5b:** Production possibilities: livestock
- **DR7a:** Ecosystem services
- **DR7b:** Competition for land
- **DR8:** Agricultural investment, research, extension and development
- **DR10a:** Review of existing modelling and scenarios
- **DR10B:** Economics of globalisation, specialisation and trade
- **DR12:** Competition for water
- **DR13:** Urbanisation, megacities and de-urbanisation
- **DR14:** Marine fisheries
- **DR15:** Freshwater fisheries
- **DR16:** Aquaculture
- **DR17:** Production to plate
- **DR18:** Volatility
- **DR19:** Income distribution
- **DR20:** Waste
- **DR21:** Wild foods
- **DR22:** Health

Regional Reviews

- **R1:** U.K. – Sustainably increasing productivity
- **R2:** China – Investment in agricultural research and development
- **R3:** Africa Nile catchment – Trans-national water sharing
- **R4:** India – Determinants of demand for food
- **R5:** Brazil – Competition for land in the face of increasing food production
- **R6:** Mekong – Inland fisheries and aquaculture
- **R7:** Eastern Europe – Production possibilities

Additional Reviews

- **WP1:** The relationship between agriculture and health
- **WP2:** Moderating consumer behaviour and demand
- **WP5:** 100 questions – overview
- **WP6:** Food Security, Farming, and Climate Change to 2050
- **WP9:** Physical resources and commodities and climate change

Working Papers

- **WP10:** New pathways to innovation
- **WP8:** Governance
- **WP13:** International Aid for Agricultural Development

Sustainable Intensification in African Agriculture – case examples

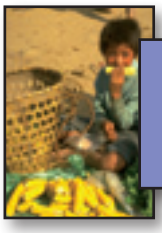
(see next page)

Project reports and papers can be found on the Project's CD and are freely available to download at http://www.bis.gov.uk/Foresight.

Note: some report numbers were initially allocated but were not subsequently used.

Executive Summary

Final Report



Challenge C: Hunger

- **C11:** Addressing Hunger

Challenge D: Climate Change Mitigation

- **C12:** The Food System in a Low Emissions World

Challenge E: Maintaining Biodiversity

- **C13:** Maintaining Biodiversity and Eco-system Services

Workshop Reports

- **W2:** The global food supply chain
- **W3:** Difficult to imagine drivers
- **W4:** The reduction of food waste
- **W5:** Sustainable livestock production
- **W6:** Food system ethics
- **W7:** Modelling the food system

State of Science Reviews

- **SR1:** Biotechnology in crops
- **SR2:** Biotechnology in livestock
- **SR3:** Biotechnology in aquaculture
- **SR4:** Advances in plant disease and pest management
- **SR5:** Advances in weed management
- **SR6:** Advances in animal disease management
- **SR7:** Integrated soil management
- **SR8:** Modern aquaculture
- **SR9:** Management in capture fisheries
- **SR10:** Novel crop science to improve yield and resource use efficiency
- **SR12:** Societal attitudes to food production
- **SR13:** Climate change and trade in agriculture
- **SR14:** Modifying crops
- **SR15:** Postharvest losses and waste
- **SR16b:** Education, training and extension
- **SR17:** The social structure of food production
- **SR19:** Urban and periurban food production
- **SR20:** Long-range meteorological forecasting
- **SR21:** Alternative mechanisms to reduce food price volatility
- **SR22:** Latest developments in financial risk management
- **SR23:** Governance of international trade in food
- **SR24:** The sustainability and resilience of global water and food systems
- **SR25:** Helping the individual: education, extension services, and land rights
- **SR27:** Developing national food security strategies
- **SR30:** A review of hunger indices
- **SR31:** Fertiliser availability in a resource-limited world
- **SR32:** Opportunities for reducing greenhouse gas emissions in the food system
- **SR33:** Options of reducing greenhouse gas emissions from agricultural ecosystems
- **SR34a:** The new competition for land
- **SR34b:** Competition for land from biofuels
- **SR35:** Engineering advances for input reduction
- **SR36:** Minimising the harm to biodiversity
- **SR37:** Ecosystem services and sustainable agriculture/ aquaculture
- **SR38:** Climate change and the loss and gain of marine fisheries
- **SR39:** Valuation of ecosystem services
- **SR45:** Recent developments in intellectual property
- **SR46:** Funding research on the food system
- **SR48:** Gender in the food system
- **SR49:** Children in the food system
- **SR55:** Arid agriculture in Australia
- **SR56:** Global food waste reduction

Sustainable Intensification in African Agriculture – case examples

- **AA1:** Agriculture service provision: Oxfam's strategic cotton programme: Mali
- **AA2:** Indigenous vegetable enterprises and market access: East Africa
- **AA3:** Fertiliser tree systems: Southern Africa
- **AA4:** Conservation agriculture: Zimbabwe
- **AA5:** CARBAP and innovation in plantain banana: West and Central Africa
- **AA6:** Livestock research for sustainable disease management: Mali and Burkina Faso
- **AA7:** Conservation agriculture: Tanzania
- **AA8:** Focal area approach: agricultural extension and market developments: Kenya
- **AA9:** Focal area approach: agricultural extension and market developments: Kenya
- **AA10:** Growing sustainable tea: Kenya
- **AA11:** Harnessing sustainability, resilience and productivity: Likoti in Lesotho
- **AA12:** Meru dairy goat and animal healthcare
- **AA13:** On-farm biological control of the pearl millet head miner: Mali, Burkina Faso and Niger
- **AA14:** Breeding and dissemination of improved sweet potato varieties
- **AA15:** Promoting smallholder seed enterprises (SSE): Cameroon
- **AA16:** Push-pull technology: a conservation agriculture approach
- **AA17:** Quncho: the first most popular tef variety in Ethiopia
- **AA18:** The adoption of fodder shrub innovations in East Africa
- **AA19:** Revival of cassava production: Nakasongola District, Uganda
- **AA20:** Sharing ideas between cultures with videos
- **AA21:** Soyabeans and sustainable agriculture: Southern Africa
- **AA22:** Sustainable crop production intensification: Senegal and Niger River Basins of Francophone West Africa
- **AA23:** The Ghana Grains Partnership
- **AA24:** The Malawi Agricultural Input Subsidy Programme: 2005/6 to 2008/9
- **AA25:** The Rakai Chicken Model: Uganda
- **AA26:** The rise of peri-urban aquaculture: Nigeria
- **AA27:** The System of Rice Intensification (SRI) as a sustainable agricultural innovation: Timbuktu region of Mali
- **AA28:** Trees, agroforestry and multifunctional agriculture: Cameroon
- **AA29:** Soil and water conservation techniques to rehabilitate degraded lands: North western Burkina Faso

Working Papers

- **AWP1:** Designing innovative: Small-scale organic agricultural technologies
- **AWP2:** Diffusion of tissue culture banana technology to smallholder farmers: Kisii District
- **AWP3:** Egyptian aquaculture sector overview
- **AWP4:** Orange-fleshed sweet potatoes for food, health and wealth: Uganda
- **AWP5:** Partnership in managing bean root rots: Eastern and Central Africa
- **AWP6:** Pigeonpeas for prosperity: East and Southern Africa
- **AWP7:** Institutional collaboration in the development of rice production: Kpong Irrigation Project, Ghana
- **AWP8:** Zooming-in Zooming-out: Videos to scale up sustainable technologies and build livelihood assets
- **AWP9:** Experience du Projet de Conservation des Eaux Et Des Sols

This report has been commissioned as part of the UK Government's Foresight Project: Global Food and Farming Futures.

The views do not represent the policy of the UK or any other government.

Printed in the UK on recycled paper with a minimum HMSO score of 75
First published January 2011.
The Government Office for Science.
© Crown copyright. URN 11/547.