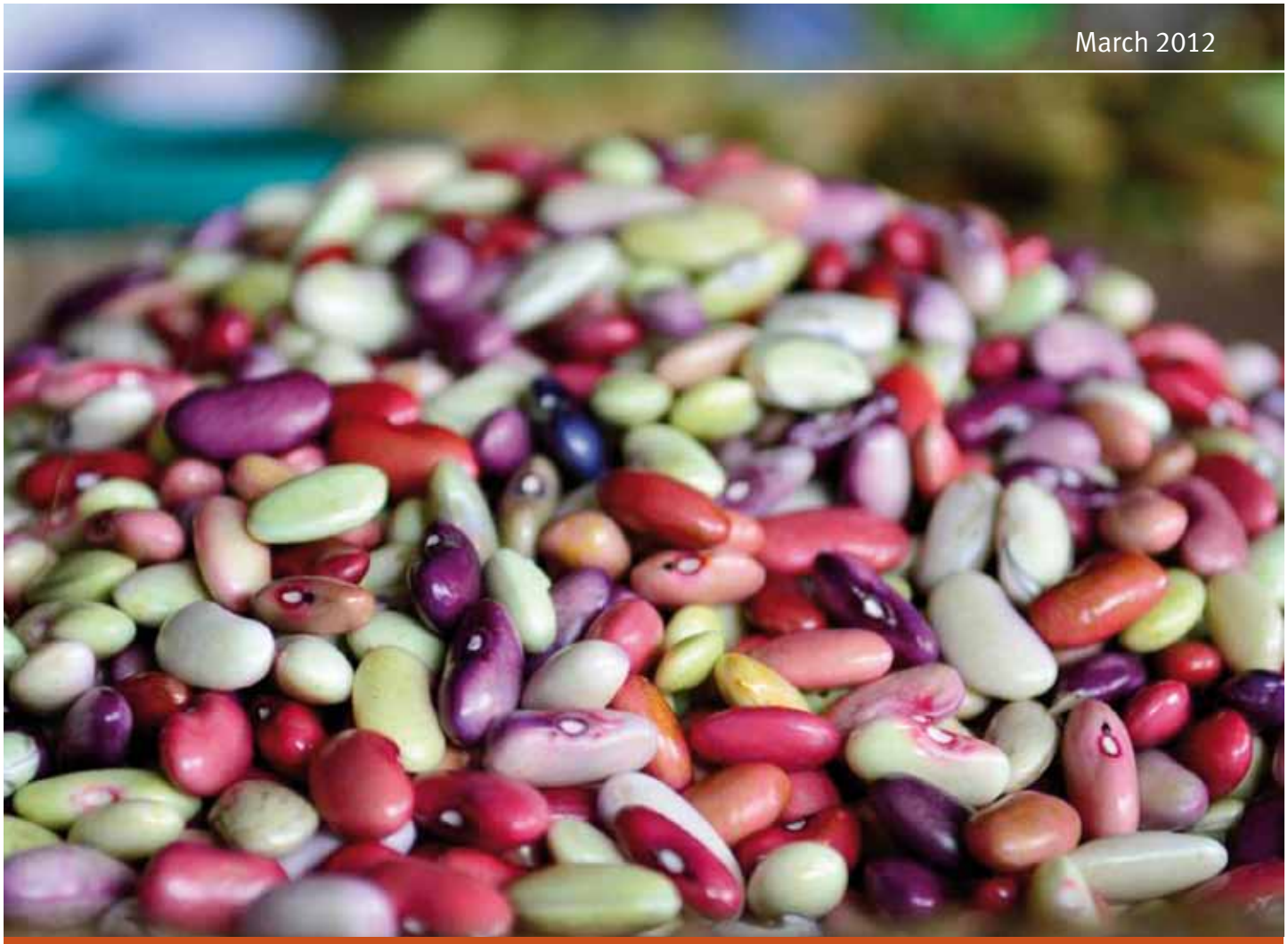
March 2012



Achieving food security in the face of climate change

Final report from the Commission on Sustainable Agriculture and Climate Change

Commissioners

Professor Sir John Beddington, Chair, United Kingdom
Dr Mohammed Asaduzzaman, Bangladesh
Dr Megan Clark, Australia
Dr Adrian Fernández, Mexico
Dr Marion Guillou, France
Professor Molly Jahn, United States
Professor Lin Erda, China
Professor Tekalign Mamo, Ethiopia
Dr Nguyen Van Bo, Vietnam
Dr Carlos A Nobre, Brazil
Professor Robert Scholes, South Africa
Dr Rita Sharma, India
Professor Judi Wakhungu, Kenya

Commissioners

- Professor Sir John Beddington, Commission Chair, United Kingdom
- Dr Mohammed Asaduzzaman, Bangladesh Institute of Development Studies, Bangladesh
- Dr Megan Clark, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Dr Adrian Fernández, Metropolitan University, Mexico
- Dr Marion Guillou, French National Institute for Agricultural Research (INRA), France
- Professor Molly Jahn, University of Madison-Wisconsin, United States
- Professor Lin Erda, Chinese Academy of Agricultural Sciences, China
- Professor Tekalign Mamo, Ministry of Agriculture, Ethiopia
- Dr Nguyen Van Bo, Viet Nam Academy of Agricultural Science, Viet Nam
- Dr Carlos A Nobre, Ministry of Science, Technology and Innovation, Brazil
- Professor Robert Scholes, Council for Scientific and Industrial Research (CSIR), South Africa
- Dr Rita Sharma, National Advisory Council, India
- Professor Judi Wakhungu, African Center for Technology Studies (ACTS), Kenya

Commission Secretariat

- Commission Coordinator: Dr Christine Negra
- Communications Manager: Ms Vanessa Meadu
- Events Coordinator: Ms Ratih Septivita
- Research Assistants: Ms Cecilia Schubert, Ms Helena Wright

Acknowledgements

- Mr Odd Arneson, Norwegian Agency for Development Cooperation (Norad)
- Dr Andrew Ash, CSIRO
- Dr Marie-Caroline Badjeck, WorldFish Center
- Mr Paul Barnett, CSIRO
- Mr Mario Boccucci, United Nations Environment Programme (UNEP)
- Dr Ademola Braimoh, World Bank
- Dr Bruce Campbell, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)
- Mr Volli Carucci, World Food Programme (WFP)
- Ms Isabelle Coche, Farming First
- Ms Béatrice Darcy-Vrillon, INRA
- Dr Peter Dewees, World Bank
- Ms Anette Engelund Friis, Danish Agriculture and Food Council
- Professor Alex Evans, New York University
- Ms Rebecca Fisher-Lamb, United Kingdom Government Office for Science
- Professor Charles Godfray, Oxford University
- Mr Elwyn Grainger-Jones, International Fund for Agricultural Development (IFAD)
- Dr Herve Guyomard, INRA
- Dr Stefan Hajkowicz, CSIRO
- Ms Tanja Havemann, Beyond Carbon GmbH
- Dr Mario Herrero, International Livestock Research Institute (ILRI)
- Dr Ulrich Hoffmann, United Nations Conference on Trade and Development (UNCTAD)
- Mr David Howlett, UK Department for International Development (DfID)
- Dr Andy Jarvis, International Center for Tropical Agriculture (CIAT)
- Dr Brian Keating, CSIRO
- Dr David LeZaks, University of Wisconsin
- Dr Leslie Lipper, UN Food and Agriculture Organization (FAO)
- Mr Danny Martinez, CIAT
- Mr Hayden Montgomery, Global Research Alliance on Agricultural Greenhouse Gases (GRA)
- Dr Lou Munden, Lou Munden Associates
- Mr Musa Muwanga, National Organic Agricultural Movement of Uganda (NOGAMU)
- Dr Gerald Nelson, International Food Policy Research Institute (IFPRI)
- Dr Henry Neufeldt, World Agroforestry Centre (World Agroforestry Centre)
- Mr Randall Purcell, WFP
- Rockefeller Foundation's Bellagio Center
- Mr Scott Ronchini, WFP
- Professor Cynthia Rosenzweig, Columbia University
- Dr Marie Russel, INRA
- Dr Sara Scherr, EcoAgriculture Partners
- Professor Tim Searchinger, German Marshall Fund/Princeton University
- Ms Emmy Simmons, Meridian Institute AGree initiative
- University of Minnesota's Institute on the Environment
- Dr Egizio Valceschini, INRA
- Dr Sonja Vermeulen, CCAFS
- Dr Elizabeth Warham, United Kingdom Government Office for Science
- Dr Paul West, University of Minnesota
- Dr Lini Wollenberg, CCAFS

Financial support
CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Global Donor Platform for Rural Development (GDPRD)

Published by
The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Contact information
CCAFS Coordinating Unit, Department of Agriculture and Ecology, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark

Tel: +45 35331046

Email: ccafs@cgiar.org

Online: www.ccafs.cgiar.org/commission

Correct citation
Beddington J, Asaduzzaman M, Clark M, Fernández A, Guillou M, Jahn M, Erda L, Mamo T, Van Bo N, Nobre CA, Scholes R, Sharma R, Wakhungu J. 2012. *Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)*. Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission.

Front cover photo
N. Palmer (CIAT)

Design Concept
Scriptoria Communications

Editorial and Layout
Stairway Communications

A Summary for Policy Makers and more information is available at www.ccafs.cgiar.org/commission

Contents

Tables, figures and boxes

Tables

Figures

Boxes

Foreword

Humanity faces difficult tradeoffs in producing sufficient food to feed our growing population and stabilizing our climate system. Globally our food system is not sustainable, does not provide adequate nutrition to everyone on the planet and, at the same time, changes to our climate threaten the future of farming as we know it. Agriculture is both part of the problem and part of the solution to climate change. We must seize every opportunity to shift away from inefficient farm practices, supply chains and diet choices towards long-term sustainability, profitability and health.

To bring our interconnected food and climate systems within a 'safe operating space' for people and the planet, the Commission on Sustainable Agriculture and Climate Change has outlined seven major areas for policy action. Over the past year, I have worked with my colleagues on the Commission to harvest the practical solutions detailed in the many recent authoritative reports on food security and climate change. By combining this thorough review of the substantive evidence base with the diverse perspectives and disciplinary expertise of the 13 Commissioners, we have crafted a succinct roadmap for policy makers. We offer no 'one-size-fits-all' solutions, but rather point the way forward to foster national, regional and sectoral innovation that can aggregate up to meaningful global change.

Responsibility for action lies with us all. We offer our recommendations to the global community of policy makers who, collectively, can create an enabling environment for a sustainable global food system. There is much that can be done to advance these recommendations by policy makers working under the mandates of the United Nations Framework Convention on Climate Change, the Rio+20 Earth Summit and the Group of 20 nations. We also look to initiatives such as the United Nations High-Level Taskforce on the Global Food Security Crisis and the Global Agriculture and Food Security Program.

It is my sincere hope that this report will accelerate our shared global commitment to the fundamental well-being of current and future generations through decisive policy action.

Professor Sir John Beddington

Chair, Commission on Sustainable Agriculture
and Climate Change

Photo: N. Palmer (CIAT)

Chapter I: Introduction

Widespread uptake of sustainable practices in agriculture and food supply chains is essential to meet current and future threats to food security and environmental resilience. The global food system does not yet provide adequate calories or nutrition to everyone on the planet, yet it enables some populations to overconsume. In the coming decades, global agriculture must produce more food to feed a growing population while adapting to climate change, an increasing threat to agricultural yields.[1]

Extreme weather events such as droughts and floods are predicted to become more frequent, adding to the global burden of hunger caused by poverty, weak governance, conflict and poor market access.[2] In agricultural production, greenhouse gases (GHGs) contributing to climate change originate from fertilizers, ruminant digestion (cattle, sheep and goats), rice cultivation and fuel use. Land clearing for agriculture, particularly deforestation, can also contribute significantly to GHG impacts.[3] But this is not inevitable. Alternative agricultural practices, suitable in different regions, can reduce net GHG emissions while maintaining or improving yields and adapting to more extreme weather.[4]

A host of recent assessment reports make compelling arguments for urgent action to transform the global food system.[5] A range of solutions has been proposed to meet the challenges of providing food security while adapting to climate change and reducing the environmental footprint of agriculture. It is important that global bodies such as the United Nations Framework Convention on Climate Change (UNFCCC), the Group of 20 nations (G20) and the United Nations Convention on Sustainable Development (the organizing body of the Rio+20 Earth Summit to be held in June 2012) adopt appropriate policy and financial actions to support implementation of these solutions on a global level.

The Commission on Sustainable Agriculture and Climate Change was convened in February 2011 to identify practical, evidence-based policy actions to achieve food security in the context of climate change. The Commission has reviewed the scientific evidence to identify a set of clear decisions and actions to be undertaken by key stakeholders and institutions (see Figure 1). The recommendations presented in this report encourage transformational investments that will increase human capacity to navigate current and emerging trade-offs and to capitalize on synergies between food security and adaptation and mitigation of climate change.

While critically important actions will be taken at national and sub-national levels, the Commission has focused on the leadership needed within international institutions and policy processes.

[1] Foresight 2011; INRA/CIRAD 2011; IAASTD 2009; Lobell et al. 2011; The Hague Conference 2010.
[2] Beddington et al. 2012; IPCC 2007.
[3] Smith et al. 2007.
[4] Pretty et al. 2011.

[5] The findings and recommendations presented here rely heavily on a comprehensive survey of 16 recent major assessment reports including: Foresight 2011; The Hague Conference 2010; IAASTD 2009; IFAD 2011; INRA/CIRAD 2011; Lipper et al. 2010; MEA 2005; NAS 2010; Nelson et al. 2011; Parry et al. 2009; Royal Society 2009; Vermeulen et al. 2012; World Bank 2010a; World Bank 2010b; World Bank 2008; Worldwatch 2011.

Commission on Sustainable Agriculture and Climate Change

What: The Commission on Sustainable Agriculture and Climate Change was established by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) with support from the Global Donor Platform for Rural Development (GDPRD) to identify the policy changes and actions that are needed now to help the world achieve food security in the context of climate change.

Who: The Commission brings together senior natural and social scientists working in agriculture, climate, food and nutrition, economics and natural resources in governmental, academic and civil society institutions in Australia, Brazil, Bangladesh, China, Ethiopia, France, Kenya, India, Mexico, South Africa, the United Kingdom, the United States and Vietnam.

How: To provide a clear and authoritative set of policy findings based on science, the Commission has undertaken a synthesis of major assessment reports to clearly articulate scientific findings on the potential impact of climate change on agriculture and food security globally and regionally. These recommendations highlight the actions and pathways that policy makers across the globe should be addressing in order to support sustainable agriculture and food systems that contribute to food security in the context of climate change.

This report seeks to elevate discussion of the interconnected dimensions of sustainable agriculture, food security and climate change, and to communicate the importance of investments in self-sustaining rural development, as well as in new tools and information systems to support governance of sustainable agriculture and the food system. In addition, it emphasizes the need for a revitalized global architecture for agreeing and delivering essential investments in sustainable agriculture and food systems; an architecture that incorporates lessons learned about the importance of 'bottom-up' approaches with strong connections to global policy development. This means striving to move beyond 'silos' and building linkages among policy processes.

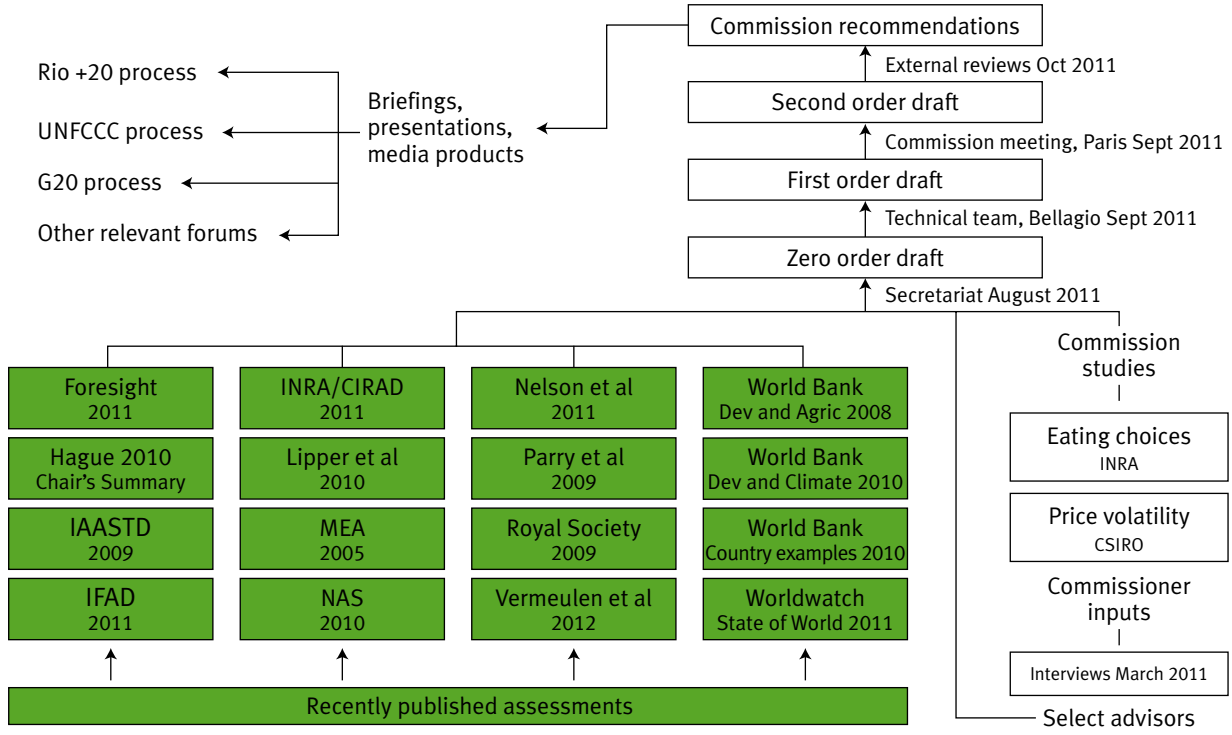


Figure 1. Development process for the Commission's recommendations. This report represents the expert opinion of thirteen Commissioners, drawn from all parts of the world and several disciplines. Their evaluation is based on their experience, informed by synthesized findings of sixteen recent, authoritative assessments of climate change and food security (which draw, in turn, on thousands of peer-reviewed scientific studies), and by selected advisors. Targeted studies on food price volatility and on eating patterns were produced to further inform the Commission. The report was developed over a period of 12 months, with iterative review by Commissioners and final external review. It is intended to inform global policy processes.

Figure 2. Regional examples of threats from climate change, population growth and unsustainable resource use.

6 National Academy of Sciences. 2010.
7 Nelson et al. 2011.
8 Cabinet Office. 2008.
9 WRAP. 2008.
10 FAO Country Profiles: France; Etilé. 2010; Reardon et al. 2003.
11 World Bank. 2010a.
12 Foresight. Migration and Global Environmental Change. 2011.
13 Foley et al. 2011.
14 FAO Country Profiles: China
15 World Bank. 2010a.
16 Laborte et al. 2011.
17 Choudhury. 2006.
18 Mittal. 2007.
19 Prosser. 2011.
20 FAO. 2011a.
21 World Bank. 2010a.
22 FAO. 2011b.
23 FAO Country Profiles: South Africa
24 World Bank. 2010b.
25 World Bank. 2010a.
26 FAOStat: Mexico.

Sustainable agriculture

Agriculture is at the nexus of three of the greatest challenges of the 21st century – achieving food security, adapting to climate change, and mitigating climate change while critical resources such as water, energy and land become increasingly scarce.

Sustainable agriculture[27] simultaneously increases production and income, adapts to climate change and reduces GHG emissions, while balancing crop, livestock, fisheries and agroforestry systems, increasing resource use efficiency (including land and water), protecting the environment and maintaining ecosystem services. The goal for sustainable food production systems is to maximize productivity of both land and seascapes within humanity's 'safe operating space' for the planet[28] – 'safe' from the perspective of achieving food security within the planet's safe environmental boundaries. Contexts will vary in different geographic regions and locations. Improvements to agricultural production systems should allow more productive and resilient livelihoods and ecosystems, contributing to a more secure, sustainable and safe food system and providing access to adequate food and nutrition, and allowing poor rural people to escape from and remain out of poverty. Sustainable agriculture lies at the heart of delivering poverty reduction.

Food insecurity and climate change are already inhibiting human well-being and economic growth throughout the world and these problems are poised to accelerate.[29] Countries vary in their vulnerability to climate change, the amount and type of GHGs they emit and their opportunities to reduce GHG emissions and improve agricultural productivity.[30]

Threats from climate change, population growth and unsustainable resource use are affecting different regions of the world (see Figure 2). Trends in population, diet, resource degradation and climate change impacts on productivity indicate that there is a real risk of global food shortfalls as the century progresses (see Figure 3).

Difficult trade-offs will need to be considered when addressing current and future challenges for the global food system. Decisions taken today will have a profound effect not only on agriculture and the global food system, but also on our landscape and ecosystem services. The benefits of strategic action taken now will be long-lasting, satisfying the needs of a growing world population while critical resources are efficiently managed. However, if there is a delay in serious commitment and action, hunger will continue to prevail and probably intensify, and environmental damage could be irreparable, compromising the world's capacity to produce food in the future.

Climate change adaptation and mitigation

The challenges of adaptation to climate change for agriculture in many parts of the world are enormous. The process of adaptation begins with an assessment of the different dimensions of vulnerability and of the appropriateness of a range of potential options for action, including their costs and benefits. In practice, adaptation is a collection of coping strategies, with each strategy focused on a particular threat. Some of these actions may be taken by individuals or communities reacting to climate change hazards as they occur; others may be more planned, depending for their initiation on government policies and institutions.

Despite the many examples of successful attempts to reduce GHG emissions in agriculture within different environments, overall the potential for implementing large-scale mitigation measures has seen relatively little progress. Barriers include limited access to finance, technology and resources and lack of appropriate political, institutional and economic policies, as well as the possibility of short-term yield losses followed by long-term gains with some types of mitigation practices. A whole systems approach, incorporating both large-scale and locally specific economic, development and environmental conditions and their interactions with different mitigation measures, will be essential to minimizing the potential trade-offs.

[27] According to the National Academy of Sciences' report, *Toward Sustainable Agricultural Systems in the 21st Century*, "Agricultural sustainability is defined by four generally agreed upon goals: Satisfy human food, feed, and fibre needs, and contribute to biofuel needs. Enhance environmental quality and the resource base. Sustain the economic viability of agriculture. Enhance the quality of life for farmers, farm workers, and society as a whole."

[28] Rockstrom et al. 2009.

[29] Nelson et al. 2011.

[30] The Hague Conference 2010.

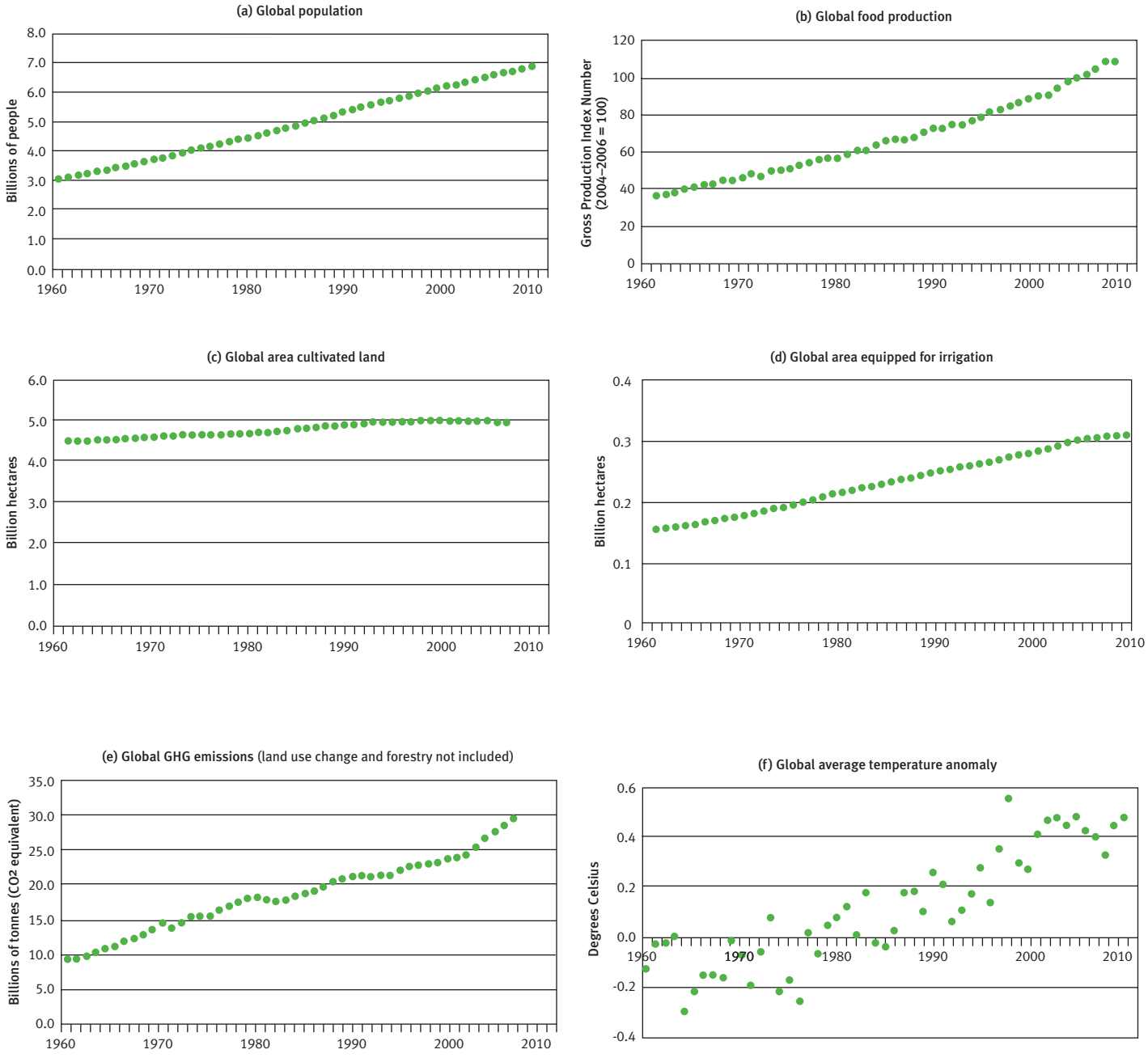


Figure 3. A synthesis of several key trends in the food and climate systems. (a) Global population estimates based on medium-fertility variant. Source: UN DESA's World Population Prospects: The 2010 Revision. (b) Global food production estimated as annual volume of agricultural production compared with the base period 2004–2006, FAO Gross Production Index Number. Source: FAO. (c) Global area of cultivated land. Estimates from 1960 to 2007: Annual FAO land resource questionnaire for country land-use data supplemented with information from official secondary data sources. Source: FAO's ResourceSTAT-Land-use domain. (d) Total land area (global) equipped for irrigation. FAOStat. http://faostat.fao.org. (e) GhG emissions. Total annual GhG emissions excluding land use change and forestry. Estimates for 1960 to 2007: Cumulative Emissions indicator expresses a country's total emissions across a specified range of years. Source: CAIT (Climate Analysis Indicators Tool). (f) Global average temperature anomalies. Estimates for 1960 to 2010: Anomalies from 1961 to 1990 for the combined global land and marine surface temperature record. Source: Climate Research Unit (CRU) and UK Met. Office Hadley Centre.

Photo: C. Isenberg

Chapter II: Understanding the current food system in the context of climate change — major components and drivers

'Business as usual' in our globally interconnected food system will not bring us food security or environmental sustainability. Several converging threats — from population growth, climate change and the unsustainable use of resources — are steadily intensifying pressure on people and governments around the world to transform the way food is produced, distributed and consumed.[31]

II-A. Demography, development and diets

On a planet with sufficient food for all, a billion people go hungry.[32] Another billion overconsume, increasing risks from chronic diseases.[33] The food system faces additional pressure as the global population grows, to around 9 billion by 2050,[34] and as diets shift towards higher consumption of calories, fats and animal products (see Figure 4). Food insecurity afflicts communities throughout the world wherever poverty prevents assured access to food supplies. As well as causing widespread human suffering, food insecurity contributes to degradation and depletion of natural resources, migration to urban areas and across borders, and political and economic instability.

Most of this century's growth in world population will occur in low-income countries. For example, Africa's population is projected to double from just over 1 billion in 2010 to about 2 billion by 2050.[35] More people means more total food demand. Projections suggest that demand for cereals will increase by 70% by 2050, and will double in many low-income countries.[36]

For low-income populations, food insecurity negatively affects future livelihoods through the forced sale of assets that are difficult to rebuild, and through reduced expenditure on education.[37] In addition, a reduction in consumption can lead to long-term health issues. In sub-Saharan Africa, poor health reduces agricultural productivity, and some agricultural practices contribute to health problems such as malaria, pesticide poisoning and disease transmission from animals to humans.[38] The global population is increasingly urban; this has implications for land use, food production systems, access to food — and potentially civil unrest.[39] In crowded cities, food security is weakened by the lack of suitable, nutrient-rich soil as well as growing space available for local families.[40]

The proportion of people of working age in low-income country populations is increasing.[41] Agriculture currently engages 2.6 billion people.[42] Non-farm employment is limited in many low-income countries yet the viability of subsistence agriculture is decreasing given small-scale land holdings, low prices for agricultural products (exacerbated, in some cases, by subsidised imports), high input costs and small surpluses.

31 The Hague Conference 2010.
32 FAO 2010.
33 Foresight 2007; World Health Organization 2011.
34 United Nations Population Division 2010.
35 UNDP 2006.
36 FAO 2009a.
37 FAO 2010.
38 World Bank 2008.
39 Chen 2007; UN 2009.
40 Worldwatch 2011.
41 IFAD 2011.
42 IAASTD 2009.

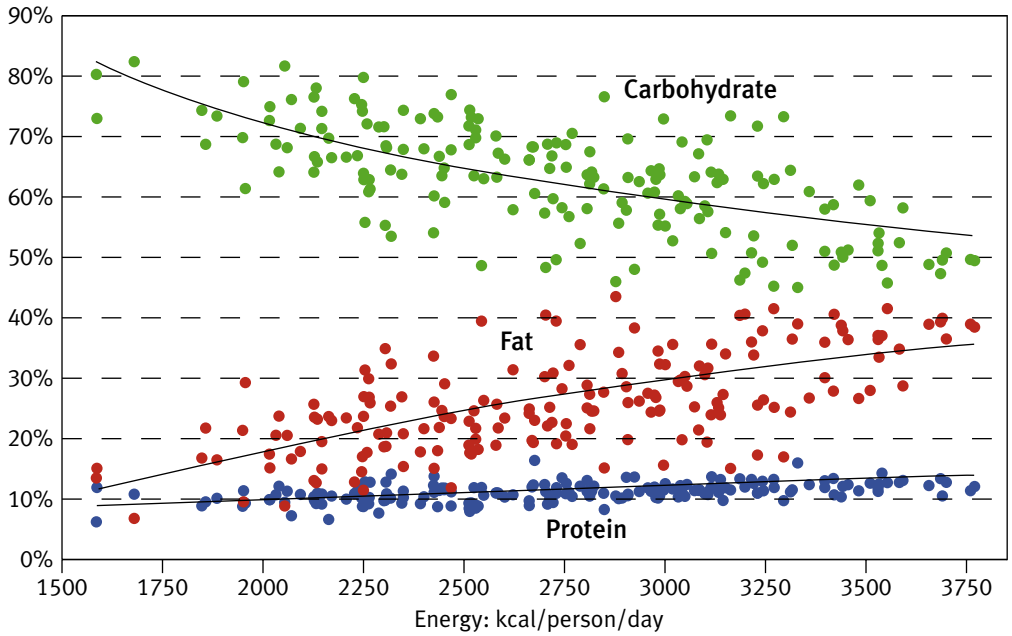


Figure 4. Structure of the world diet, 2005-2007. Diet composition for 178 countries is represented by three data points along a vertical line corresponding to national dietary energy supply (blue = energy share from protein, red = energy share from fat, green = energy share from carbohydrate). As economies develop, improvement in food access leads to increased caloric intake up to a plateau. From there, diet structure changes are observed: consumption of cereals and vegetables decreases while that of sugar, fats and animal products increases. Developed countries have undergone this second transition over a century. A similar but greatly accelerated pattern can be seen in Asia, Central and Latin America, and to a lesser extent in Africa, where these diet transitions are occurring within 20 years in emerging countries and within 40 years in developing countries. Source: Total energy supply and shares of protein, fat and carbohydrate have been computed from the average values for the last three available years in the FAO database (2005, 2006 and 2007) Update to Combris 2006, courtesy of the author.

Progress has been made towards the Millennium Development Goal of reducing the global poverty rate below 23%, yet there is great disparity in income growth both between and within countries.[43] The majority of the world's poor and chronically undernourished live in rural settings and are directly or indirectly dependent on agriculture for their livelihoods.[44] The likelihood of poverty is influenced by household-level conditions such as health, education, harvests, assets and expenses as well as by regional-level conditions such as infrastructure, markets, economic growth, enabling institutions and conflict or disasters.[45] Where capital investment in agriculture is low, value added per worker also tends to be low and rural poverty tends to be higher.[46]

The number of people suffering from chronic hunger increased from under 800 million in 1996 to over 1 billion in 2009.[47] In October 2010, 925 million people were estimated to be undernourished.[48] In 2008, 1.5 billion adults were overweight, including over 200 million men and nearly 300 million women who were obese.[49] In addition, a growing number of low- and middle-income countries are facing a 'double burden' of malnutrition: a persistence of both macronutrient and micronutrient undernutrition, notably among children, along with a fast rise in the number of overweight and obese people, and consequent diet-related chronic diseases.[50]

For households that are chronically undernourished or at risk of food insecurity, food choices are extremely limited and are largely driven by prices relative to incomes. As income increases, households' eating preferences are driven more by the relative prices of different foods (for example, the prices of fats versus carbohydrates) (see Figure 5). These households have greater choice within a context largely determined by retailers, as well as by culture and lifestyles.[51] As freedom of eating choice increases, caloric intake reaches a plateau while the relative consumption of fats continues to increase.[52] Highest-income, maximum-choice households achieve a plateau in terms of both caloric intake and diet composition.

[43] United Nations 2011.
[44] UNCTAD 2011.
[45] IFAD 2011.
[46] IAASTD 2009.
[47] Vermeulen et al. 2012.
[48] FAO 2010.
[49] WHO 2011.
[50] World Bank 2008; WHO 2011.
[51] Guyomard et al. 2012.
[52] Combris 2006; Popkin 2006.

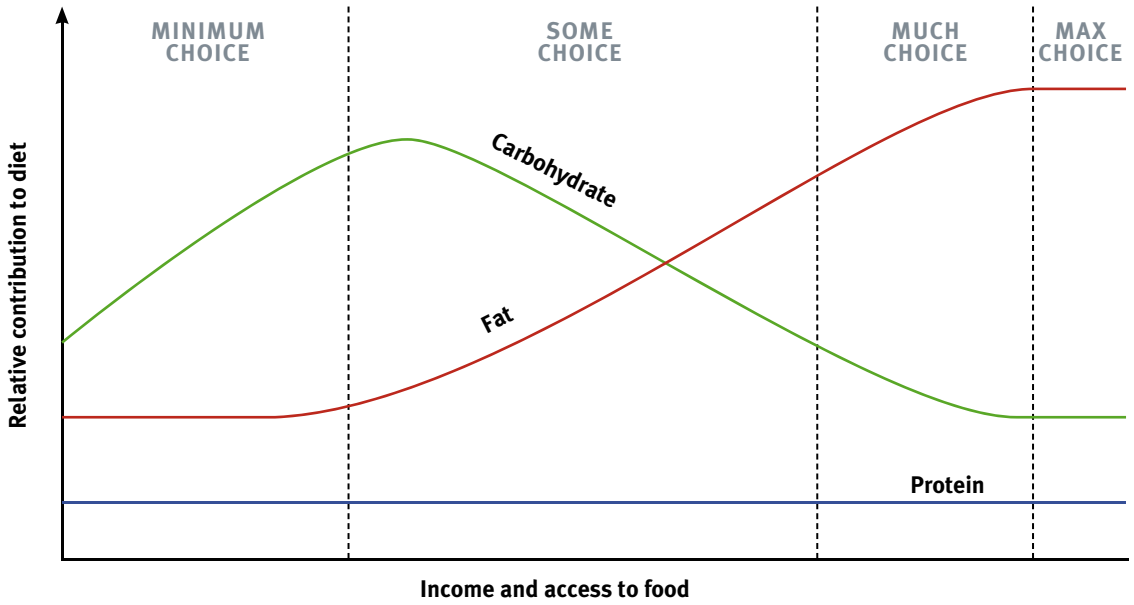


Figure 5. Relationship of human diet to income. Despite great underlying differences in culture and environment, the pattern of average diet change is remarkably similar around the world, as per capita income and access to food improve.[53] This schematic illustrates that, as food access increases, protein intake remains almost constant, but the dominant sources typically shift from vegetables to animal products. (A high proportion of animal products in diets translates into larger land areas required for food production and greater impacts on the climate.) Simultaneously, the predominant source of dietary energy shifts from complex starches to simple sugars and fats (ie, fat intake increases while carbohydrate share declines: simple sugars and fats replace complexes starches). These patterns of change have important consequences for the health of individuals (eg, obesity-related diseases result from excessive intake of energy and diet dominated by sugars and fats). Source: figure derived from analyses first presented in Perisse et al 1969.

Total global food demand, GHG emissions and land competition will increase as more of the world's consumers switch to diets that are richer in meat, dairy products and processed foods.[54] Dietary changes are highly significant for the future food system because, per calorie, some food items require considerably more resources (such as land, water and energy) to produce than others. Methane, nitrous oxide and carbon dioxide emitted by livestock activities (i.e. enteric fermentation and manure management) and land use changes make a substantial contribution to anthropogenic GHG emissions.[55] While patterns of dietary change are strongly dependent on the interaction of economic drivers with cultural, social and religious influences, studies predict significant increases in per capita meat consumption[56] from its current level of 15% of the total global human diet.[57]

Tomato fruits damaged by insect pests. Climate change brings risk of increased crop losses due to pest outbreaks

Photo: IITA

[53] The interdependence of income, food access and diet composition have been recognized for many years (Périssé et al 1969).
[54] Parry et al. 2009.
[55] Steinfeld 2006.
[56] Bruinsma (2009) projects increases from 37 kg/person/year at present to approximately 52 kg/person/year in 2050.
[57] FAO 2006.

Table 1. Status of selected global parameters

People in the world (2011)[58]	**7 billion**
Undernourished people (2010)[59]	**0.9 billion**
Overweight people over age 20 (2008)[60]	**1.5 billion**
People living on less than USD 1.25 per day (2005)[61]	**1.4 billion**
People living in dryland areas (2007)[62]	**2 billion**
People dependent on degrading land[63]	**1.5 billion**
Losses due to climatological events (extreme temperature, drought, forest fire) (2011)[64]	**USD 11.4 billion**
Area of agricultural land (2009)[65]	**4.9 billion hectares**
Area of croplands, pasture and grazing lands devoted to raising animals[66]	**3.7 billion hectares**
Annual growth in world agricultural production (1997–2007)[67]	**2.2%**
Food produced for human consumption lost or wasted annually[68]	**1.3 billion tonnes**

II-B. Climate change impacts on agriculture

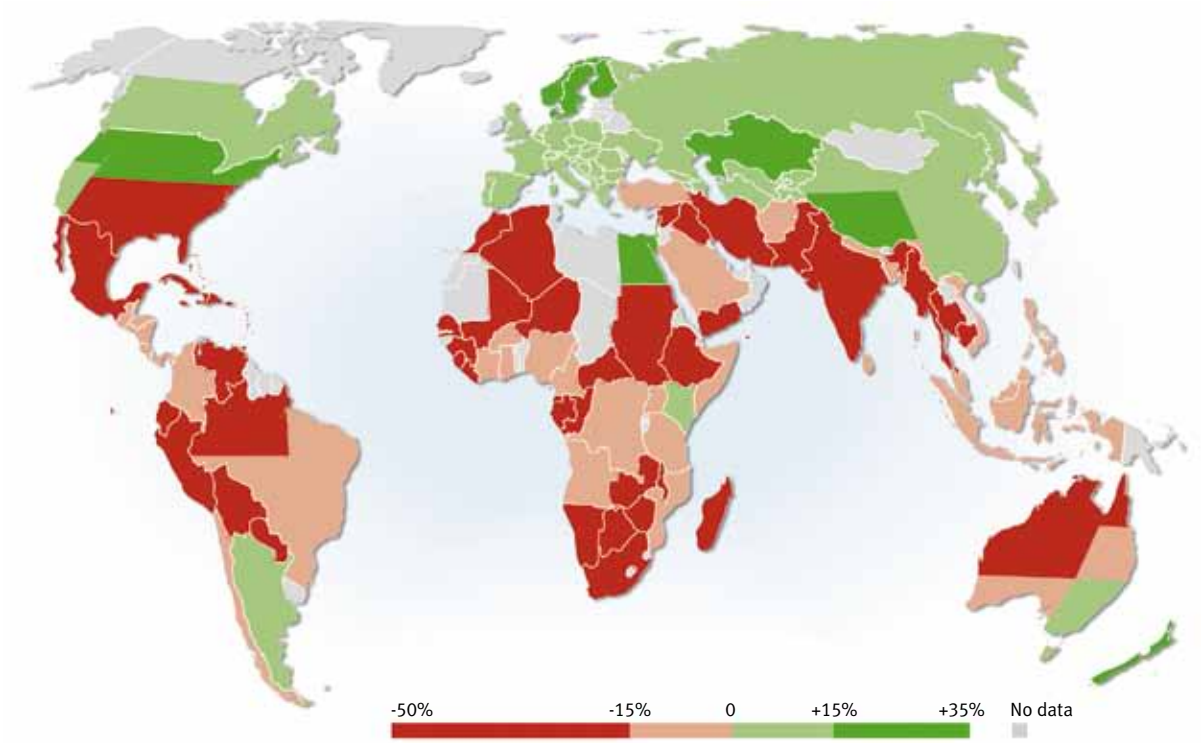
Our climate is changing and, given the levels of GHGs already in our atmosphere, will continue to do so, presenting threats of serious social, economic and ecological consequence. The planet is experiencing more extreme weather (e.g. heavy precipitation events, coastal high water, and geographic shifts in storm and drought patterns) and warmer temperatures.[69] Ever-higher average global temperatures are likely unless there are dramatic and urgent reductions in GHG emissions across a wide range of human activities, including the burning of fossil fuels and land use. In the coming decades, global climate change will have an adverse overall effect on agricultural production (see Figure 6) and will bring us towards, and perhaps over, critical thresholds in many regions. Areas currently suffering from food insecurity are expected to experience disproportionately negative effects. To reduce the effect of climate change on food supplies, livelihoods and economies, incentivizing greatly increased adaptive capacity in agriculture — both to long-term climatic trends and to increasing variability in weather patterns — is an urgent priority.

Climate change refers to a broad array of alterations in climatic and weather conditions characterized by shifts in average conditions and in the frequency and severity of extreme conditions. Agriculture is highly sensitive to climate, both in terms of longer-term trends in the average conditions of rainfall and temperature, which determine the global distribution of food crops, but also in terms of interannual variability and the occurrence of droughts, floods, heat waves, frosts and other extreme events.[70] One of the expected results of climate change is increasing climatic variability; for example, even where mean rainfall is not projected to change, there are likely to be more significant droughts and more significant extreme precipitation events. A changing climate is associated with increased threats to food safety, post-harvest losses and pressure from invasive species, pests and diseases.[71] Already heightened by increased global movement of goods and people, a warming climate is likely to increase the incidence and geographic spread of human, animal and plant diseases.[72]

Extreme weather events and climate change will exacerbate the fragility of food production systems and the natural resource base — particularly in environments prone to degradation and desertification, in areas of widespread or intense water stress, and wherever poverty undermines the capacity of rural people to take the needed preventive steps.[73] Farmers can no longer rely on historical averages of temperature and rainfall, making it harder for them to plan and manage production when planting seasons and weather patterns are shifting. Rainfed agriculture and agropastoral systems are particularly vulnerable to climatic variability. In some situations, global warming may make water more available, but for others, the effect will be to make water scarcity even more acute.[74]

Modest climate change (at the levels that now seem near-inevitable, indexed by a global mean temperature rise of around 2°C[75]) will lead to decreases in agricultural production in some places (notably places already hot and dry) and increases in others (these are likely to be local areas within mid- to high-latitude regions).[76] Even a 2°C increase is not risk free. Climate change is likely to change rainfall patterns, resulting in shorter growing seasons in the future, particularly for subsistence farmers in Africa and parts of South Asia who rely on rainfed agriculture.[77] Global food production will still

[58] www.un.org/en/development/desa/news/population/world-to-welcome-seven-billionth-citizen.html
[59] FAO 2010.
[60] World Health Organization 2011.
[61] World Bank: Poverty and Equity Data. http://povertydata.worldbank.org/poverty/home/
[62] UNCCD 2011.
[63] Ibid.
[64] Munich RE Geo Risks Research NatCatSERVICE. Natural catastrophes worldwide 2011. Climatological events represent 3% of natural catastrophes. Meteorological (storm) events represent 19% (USD 72.2 billion) and hydrological (flood, mass movement) events represent 17% (USD 64.6 billion).
[65] Foley et al. 2011. Croplands cover 1.53 billion hectares. Pastures and grazing lands cover another 3.38 billion hectares. In combination, agriculture uses approximately 38% of the earth's ice-free land.
[66] Ibid. Croplands devoted to animal feed cover about 350 million hectares. Combined with 3.38 billion hectares of pasture and grazing lands, land use for raising animals totals approximately 3.73 billion hectares (75% of the world's agricultural land).
[67] Bruinsma 2009.
[68] Gustavsson et al. 2011. This estimate is equivalent to roughly one-third of the edible parts of food produced globally for human consumption.
[69] IPCC 2012.
[70] IPCC 2012.
[71] Costello et al. 2009; IAASTD 2009; Vermeulen et al. 2012.
[72] Foresight 2011; IAASTD 2009; Royal Society 2009.
[73] IPCC 2012.
[74] Ibid.
[75] Moss et al. 2008.
[76] IAASTD 2009; Parry et al. 2009; Vermeulen et al. 2012.
[77] World Bank 2008.



Hugo Ahlenius, UNEP/GRID-Arendal

Figure 6. Projected changes in agricultural production in 2080 due to climate change. Source: Cline. 2007. Projections assume a uniform 15% increase in yields due to the fertilization effect of rising carbon dioxide in the atmosphere on some plant species. (Note that this coarse-grain analysis does not project local-scale impacts which require geographically-specific analysis.)

be possible at levels similar to or above current production levels, but new farming practices to adapt to climate change will be needed, and these may increase production costs. Issues of inequitable burden sharing are more likely, as are potential increases in the already-existing problems of local food insecurity. Climate change above 3°C risks overall decreases in the global food production capacity that would be profoundly destabilizing even in places where food production remains adequate locally. However, there is still much that is not known, and there are many uncertainties in future climate trajectories, generated by complicated feedback loops and by potential tipping points in the climate system.

II-C. Food production, supply chains and the environment

Inefficiencies in food supply chains have a negative impact on the environment, lower productivity and waste food. Current farming practices, including land clearing and inefficient use of fertilizers and organic residues, make agriculture a significant contributor to GHG emissions.[78] From the farm gate to consumers, processing, refrigeration and other supply chain activities are an additional source of GHG emissions. As global demand for food, fodder and bioenergy crops grows, many agricultural systems are depleting soil fertility, biodiversity and water resources. In many regions there are large gaps between potential and actual crop yields (see Figure 7). Every year, an estimated 12 million hectares of agricultural land, which could potentially produce 20 million tonnes of grain, are lost to land degradation, adding to the billions of hectares that are already degraded.[79] It is estimated that a third of food produced for human consumption is lost or wasted across the global food system.[80] It is clear that our collective choices relating to agriculture and food systems must be revisited to eliminate avoidable waste and losses.

Globally, agriculture is both part of the problem and part of the solution to climate change. Activities relating to the production of food currently contribute between a quarter and a third of the GHG emissions that cause global climate change. Agriculture continues to expand into forested and other lands in a number of regions. Land use change, primarily deforestation, is responsible for as much as 18% of global GHG emissions and another 12–14% are associated with direct agricultural GHG emissions, including from fertilisers and livestock.[81] Agriculture's contribution to global GHG emissions will remain high in the foreseeable future and may even grow relative to emissions from other sectors.[82] There is

[78] IPCC 2007; The Hague Conference 2010.

[79] United Nations Convention to Combat Desertification. 2011; Bai et al. 2008.
[80] Gustavsson et al. 2011.
[81] Royal Society 2009; Foresight 2011.
[82] Smith et al. 2007.

technical potential to reduce the contribution of the food system to climate change, but not eliminate it, given the growing need for food and the fundamental nature of the processes that result in the emissions.

GHGs are emitted across the food supply chain. The largest sources of emissions are related to agricultural production through clearing of new land for cultivation, use of nitrogen fertiliser and methane from ruminant livestock. Drivers for many production systems occur throughout the supply chain, and are influenced through global and national policies.[83] Emissions resulting from land use change, specifically tropical deforestation, are likely to remain significant over the next three decades, but their location and cause are likely to shift.[84] Livestock production is the world's largest user of land resources for grazing and feed production and an important driver of deforestation.[85]

There is a large potential for reducing net food system emissions, per unit of food consumed as well as in absolute terms, through efficiency measures in production and also through demand management, for example reduction of loss and waste in supply chains and changing food preferences.[86] There is meaningful potential for carbon sinks associated with a number of agricultural practices. Some of these, such as improved land management, have co-benefits for both the reliability of food production and the quality of the environment. However, the contribution of such sinks may be small in comparison with the scale of the global climate change problem and their benefits are realizable in only the short to medium term (i.e. there is sink saturation).[88] The biophysical potential of agricultural mitigation has been estimated based on highly aggregated data and implementation has been limited due to financial and policy constraints[89].

Farming systems around the world range between large-scale, highly specialized, capital-intensive operations (e.g. in Europe and North America) and small-scale, labour-intensive production systems with diverse livelihood strategies both on and off farm.[90] Some types of food production system destabilize the natural resource base, drive the loss of biodiversity, and contribute to GHG emissions, with the potential to damage the environment irreparably and to compromize the world's capacity to produce food in the future. Market demand for organic and eco-certified products, consumer expectations for social and environmental corporate responsibility and longer-term concerns about sources of supply have contributed to greater attention being paid to sustainability by some agribusinesses.[91]

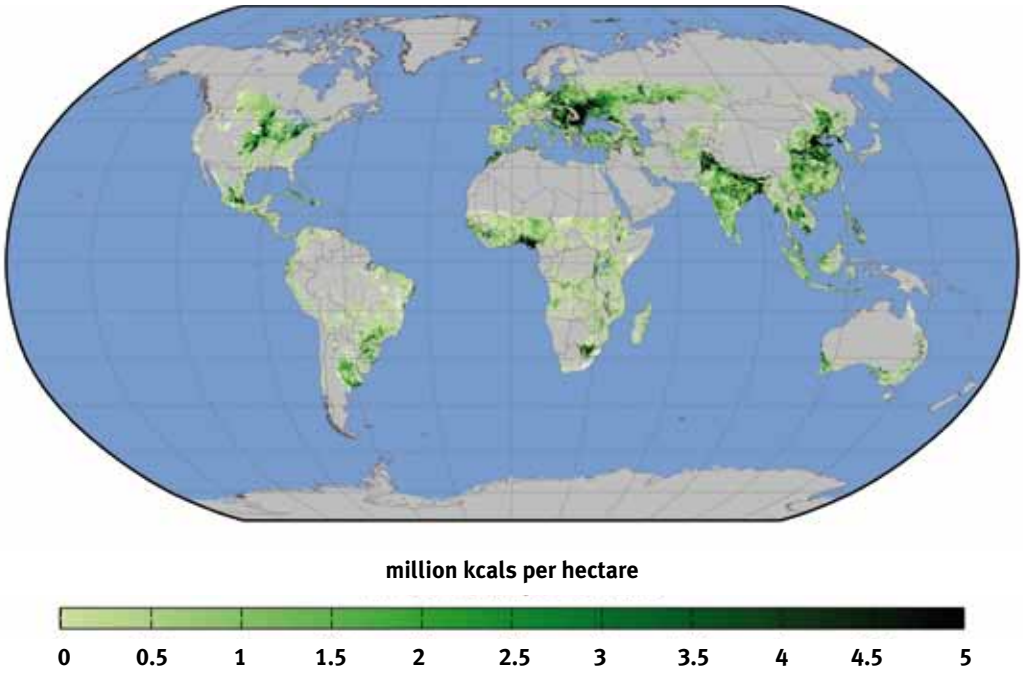


Figure 7. Closing yield gaps for major crops. Crop production in many parts of the world does not meet its full yield potential. Improved nutrient and water supplies and other production strategies can lead to significant improvements in crop yield. A recent analysis of 16 major staple food and feed crops[87] estimated that increasing yields to within 95% of their potential would add 2.3 billion tonnes of crop production (5 x 10^15 kilocalories), which is a 58% increase over current production. *Source*: Foley et al, 2011. Data provided by University of Minnesota's Institute on the Environment.

[83] Foresight 2011.
[84] Lambin and Meyfroidt 2011.
[85] Lipper et al. 2010.
[86] Foresight 2011; INRA/CIRAD 2011.
[87] Barley, cassava, groundnut, maize, millet, potato, oil palm, rapeseed, rice, rye, sorghum, soybean, sugarbeet, sugarcane, sunflower and wheat.
[88] Smith et al. 2007.
[89] Vermeulen et al. 2012.
[90] World Bank 2010a.
[91] Worldwatch 2011.

Going beyond the major cereal crops

There is a wide variety of edible plant species in use around the world, yet research and development has been directed to only a very few of the possible crop species suitable for agriculture, most of them cereals. Many understudied edible species compare very favourably with major grains on a production per growing time basis for protein and calories and have more favourable nutritional properties and cooking requirements. Some of these advantages may be offset by post-harvest losses, although estimated loss rates are difficult to determine, especially where the crops are used for subsistence. Many of these species can be left to be harvested as needed, or can slot into very short cropping windows, further highlighting the role they can play in agricultural systems that are more resilient and better manage the risks of climate change and extreme weather. Some species, such as cassava and amaranth, have been shown to thrive under hot and dry growing conditions. Varieties of beans and millet are already important sources of nutrition in many places around the world. Given strong trends towards the urbanization of food-insecure populations, peri-urban and urban agriculture, which typically include minor crop species, are likely to become even more significant with respect to subsistence and in some cases may lead to the development of new markets.

Many edible species may be resilient to climate changes, but they are currently understudied. Genebanks and traditional breeds may contain varieties that offer multiple benefits for food, forage and climate adaptation

Photo: N. Palmer (CIAT)

Agricultural production systems are associated with a series of interconnected natural resource management challenges. Agriculture consumes 70% of total global 'blue water' withdrawals from available rivers and aquifers, and will increasingly compete for water with pressures from industry, domestic use and the need to maintain environmental flows.[92] One-fifth of the world's freshwater renewable resources are shared between countries,[93] creating tensions over resource sharing. Some modern agricultural practices adversely affect soil quality through erosion, compaction, acidification and salinization, and reduce biological activity as a result of pesticide and herbicide applications, excessive fertilisation, and loss of organic matter.[94] Climate change is likely to exacerbate land degradation and desertification. Excessive use of fertilizers and pesticides in water catchment areas can pollute waterways and aquifers, often causing eutrophication in water bodies and damage to aquatic ecosystems. A lack of available access to basic fertilizer and pesticide inputs, leads to extreme gaps between potential and actual yields. Rising energy and agricultural input prices and the loss of crop biodiversity also threaten production systems.

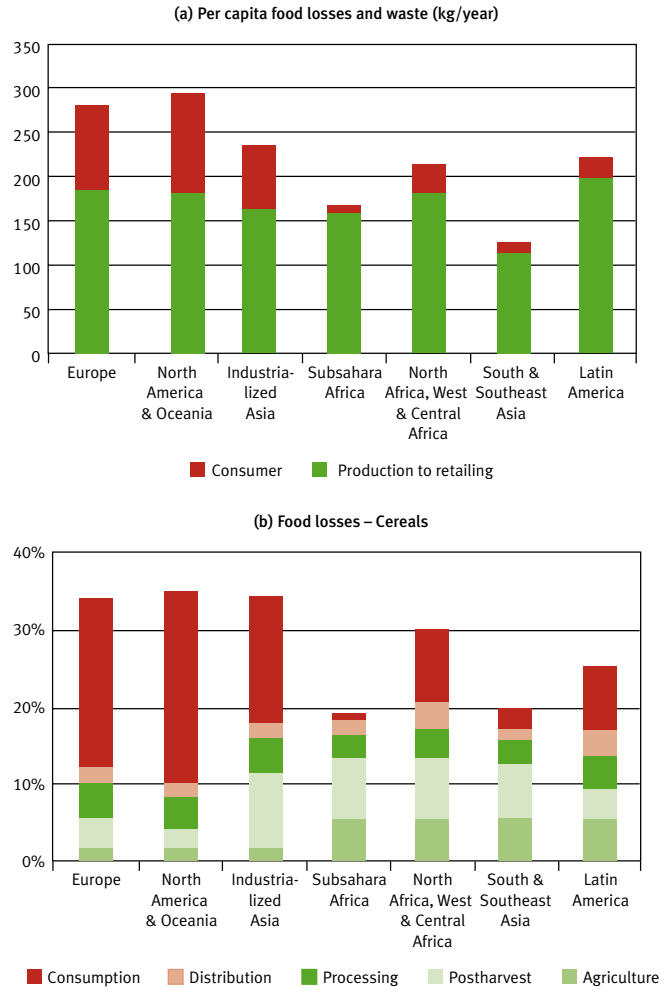


Figure 8. Food loss and waste within the food system.
(a) Per capita food losses and waste (all agricultural products), at consumption and pre-consumption stages, in different regions. (b) Part of initial cereal production lost or wasted at different stages of food supply chains, in different regions. Please note these figures do not highlight losses due to animal feed (gap between the amount of plant calories consumed in animal feed and the amount of animal calories recovered). For further information, see Lundqvist et al. (2008).
Source: Gustavsson, 2011.

[92] Foresight 2011; The Hague Conference 2010.
[93] World Bank 2010b.
[94] NAS 2010.

Food waste and loss vary by region and by point in the food supply chain (see Figure 8). Overall, food loss in low-income countries occurs in the production, storage and distribution stages of supply chains, whereas there is significant waste at the consumption stage in medium- and high-income countries. Climatic fluctuations affect post-harvest losses and food safety during storage (e.g. by causing changes in populations of toxin-producing fungi). More frequent extreme weather events caused by climate change will damage infrastructure (such as warehouses and roads), resulting in detrimental impacts on food storage and distribution, to which the poor will be most vulnerable. Food loss will be greater where links between producers and consumers are slow. In retail settings, over-ordering of stock, cosmetic imperfections and other issues contribute to food waste.[95] In households, food waste results when consumers buy too much or at the wrong time or have a careless attitude.[96]

Producers face a growing set of risks relating to natural disasters, environmental changes, health threats, resource constraints and the volatility of food prices.[97] Multiple risks limit the ability of poor rural farmers to take up new agricultural practices.[98] Access to land and marine resources for food production is affected by insecure property rights, changes in sea level and river flows (with new land in high latitude countries becoming suitable for cultivation), increases in large-scale land acquisition, pressure on common property resources and emerging land uses such as urbanization and biofuel production.[99]

II-D. Investment, trade and food price volatility

Agriculture continues to be the economic mainstay of most low-income countries, employing the majority of the population in those countries. Investments made by farm households are critical to overall improvements in agricultural productivity. The importance of agricultural research and development (R&D) has been recognized,[100] yet investment has been declining from both donor partners and low-income country governments over recent decades.[101] This has constrained improvements in food security and reductions in poverty and has created a knowledge divide between low- and high-income countries, interspersed with a few high-investment, high-performance emerging economies.[102] The capacity of most low-income countries to fill the investment gap is limited. In low-income countries with agriculture-based economies, domestic public support to agriculture is, on average, about 4% of gross domestic product (GDP) and official development assistance (ODA) provides the balance (ODA commitments for agriculture in 2008 were USD

A farmer in Ghana's Upper West Region, which has suffered failed rains and rising temperatures. Areas currently experiencing food insecurity will be hit worst by climate change

Photo: N. Palmer (CIAT)

4 billion).[103] At the beginning of the 21st century, only 6% of total spending in low-income countries came from private companies.[104] Commercial bank lending to agriculture in low-income countries is also small — less than 10% in sub-Saharan Africa.[105] Private investment funds targeting agriculture in these countries are an interesting recent development, but such investments are currently still small.

Most food system investments are focused on boosting global food supply, expanding the role of agribusiness and increasing trade rather than on reinvigorating local markets and smallholder producers.[106] Large institutional gaps remain in supporting the competitiveness of smallholders (e.g. by securing access to land, inputs, financing, markets and insurance). Producer organizations are only just beginning to represent the interests of poor smallholders. The rapid growth of retail chains and higher product and process standards by global retailers tend to inhibit the participation of small-scale producers in world food markets.[107]

From 1961 to 2003, world food trade increased from 1500 Gkcal/day to over 7000 Gkcal/day.[108] Latin American and Organisation for Economic Co-operation and Development (OECD) countries are net exporters of food calories, while Asia, Africa and the Middle East are net importing regions.[109] Increasingly, raw materials are standardized, food is more highly processed and the role of large-scale distribution systems is expanding. Important new features of the global trade in food include the growing integration of global supply

[95] Worldwatch 2011.
[96] Gustavsson et al. 2011.
[97] IAASTD 2009; The Hague Conference 2010.
[98] IFAD 2011.
[99] Foresight 2011; Parry et al. 2009; Royal Society 2009.
[100] The Maputo declaration by African governments committed 10% of national budgets to agriculture.
[101] IAASTD 2009; World Bank 2008.
[102] World Bank 2008.
[103] Lipper et al. 2010. World Bank 2008.
[104] IAASTD 2009.
[105] Mhlanga 2010.
[106] The Hague Conference 2010; Worldwatch 2011.
[107] IFAD 2011.
[108] INRA/CIRAD 2011.
[109] Ibid.

chains and the emergence of large economies such as Brazil, China and India as major sources of both demand and supply of agricultural products. Although, in many low-income countries, rural and urban areas are ever more interconnected,[110] the imperfect connectivity between global and domestic markets means price transmission across global, national and local markets are inhibited.[111]

Global agricultural markets have a high level of public sector intervention, including production subsidies, export restrictions and trade barriers. Agricultural subsidies in OECD countries are around USD 260 billion per year.[112] Commodity support payments and risk management policies can incentivize monocropping, extensive hydrologic modification of landscapes and increased input use.[113] In low-income countries, fertilizer subsidies implemented in the absence of infrastructure investments (e.g. improved food storage or transportation infrastructure) can lead to oversupply, market dumping and low prices.[114]

Global food prices have risen dramatically in the last few years and are forecast to rise further and become more volatile.

In 2007/2008, food price rises shocked many policy makers from the belief that stable or declining food prices and assured supplies could be taken for granted. Before the price spike, poverty meant that 800 million people were hungry. Following the price spike, this number increased to a little over 1 billion people[115] (a rise that significantly set back progress towards the UN Millennium Development Goal to halve the proportion of people suffering hunger between 1990 and 2015[116]). It is estimated that an additional 44 million people have since fallen into extreme poverty due to the rise in food prices since June 2010.[117] These events have drawn increased attention to the fact that a significant proportion of humanity remains chronically undernourished, even during periods of relatively normal prices and low volatility.

Over the past 50 years, a long-term downward trend in the real price of food has been interspersed with short periods of price volatility. In the past decade, global food prices trended gradually upwards and then doubled from 2006 to 2008. Rising food prices signal an excess of demand over supply (factors include growing resource scarcity, increasing population and incomes and reduced productivity due to climate change). Future price projections indicate a continued upward trend.[118] The transfer of a shock (supply impacts such as extreme weather, pest infestations or trade-related issues, among other things) can quickly translate to higher global food prices, while supply response can be relatively slow (e.g. at least one planting season). Much of the increased production response to higher prices has come from high-income countries.[119]

Food price surges can be positive for some agricultural producers when higher prices increase profits and boost farm income. Price surges can trigger increased investment in agricultural production, leading to greater output, but they can also discourage agricultural investment through uncertainty about returns. Price volatility is associated with hunger and malnutrition among the world's poorest people.

Export and import restrictions, currency depreciation and increases in oil prices and the related costs of production are generally seen as important contributors to food price volatility, while low food stocks and speculative trading in spot and futures markets are recognized as having an amplifying effect.[120] Low-income country markets often lack capacity to absorb shocks such as adverse weather, and thus can be subject to high domestic price volatility even under calmer global market conditions.[121] Climate change is expected to be an increasing driver of food price volatility due to the increasing frequency and intensity of extreme climatic events, such as heat stress, droughts and flooding, as well as increasing risks of fires and pest and pathogen outbreaks.[122]

Photo: P. Casier

[110] IFAD 2011.
[111] FAO/OECD 2011.
[112] World Bank 2010a.
[113] NAS 2010.
[114] INRA/CIRAD 2011.
[115] FAO 2009b.
[116] HMG 2010.
[117] World Bank 2011b.
[118] IAASTD 2009; Nelson et al. 2011.
[119] IFAD 2011.
[120] Hajkowicz et al. 2012.
[121] FAO/OECD 2011.
[122] OECD 2011.

Photo: N. Palmer (CIAT)

Chapter III: Investing in an alternative future food system

Food systems must shift to better meet human needs, and, in the long term, reach a balance with the planet's resources. This will demand major interventions, at local to global scales, to transform current patterns of food production, distribution and consumption.[123] Investment, innovation and a deliberate effort to empower the world's most vulnerable populations will be required to construct a global food system that adapts to climate change and ensures food security while minimizing GHG emissions and sustaining our natural resource base. Greatly expanded investments in sustainable agriculture, including improvements to the supporting infrastructure and the restoration of degraded ecosystems, are an essential component of long-term economic development. The sooner these investments are made, the greater the benefits will be.

As climate change amplifies the environmental and socioeconomic drivers of food insecurity, it is imperative to prioritize where, how and when to act. The threats posed by climate change to food supplies and livelihoods are likely to vary geographically; therefore global hotspots where the threats are greatest will need to be identified, and specific, practical interventions developed to boost resilience in these areas. For example, some of the world's major food-producing regions lie in mega-deltas that are threatened by accelerating rates of saltwater intrusion. In Africa, the pronounced gaps between actual and potential crop yields and the shrinking per capita land base[124] inhibit food security. In Europe, North America and elsewhere, a combination of intensive agriculture systems, food storage and sourcing practices aimed at the elimination of seasonal variations in availability, retail systems and eating habits generates high per capita GHG emissions and food waste. Thus the environmental and human diversity of the planet forbids the imposition of one-size-fits-all solutions.

Humanitarian, environmental and global security concerns demand a global commitment to improve the lot of the large proportion of the human population that is currently food insecure or vulnerable to food insecurity. This requires building resilience to climate shocks and food price volatility, halting land degradation and boosting productive assets and infrastructure. There are many entry points for action. Many policies and programmes provide ample evidence of multiple benefits for livelihoods and the environment, with meaningful participation at local and regional scales.

Many millions of people around the world depend on agriculture for basic subsistence. Efforts to reduce net GHG emissions from agriculture must not have perverse effects on the food security and livelihoods of these people. Techniques for restoring degraded areas and sequestering soil carbon to enhance future productivity should increase or stabilize food production. Where the path to long-term sustainability means reducing productivity in the short term, economic incentives and transitional programmes will be required. Specific actions must be taken to assist those most vulnerable to long- and short-term increases in the price of food rather than relying on trickle-down economic effects. Appropriate targeting of a portfolio of interventions at key points of vulnerability, such as meeting the food and nutritional needs of mothers and young children, will have disproportionately positive pay-offs in future productivity and development.

[123] The Hague Conference 2010.
[124] United Nations Population Division 2010.

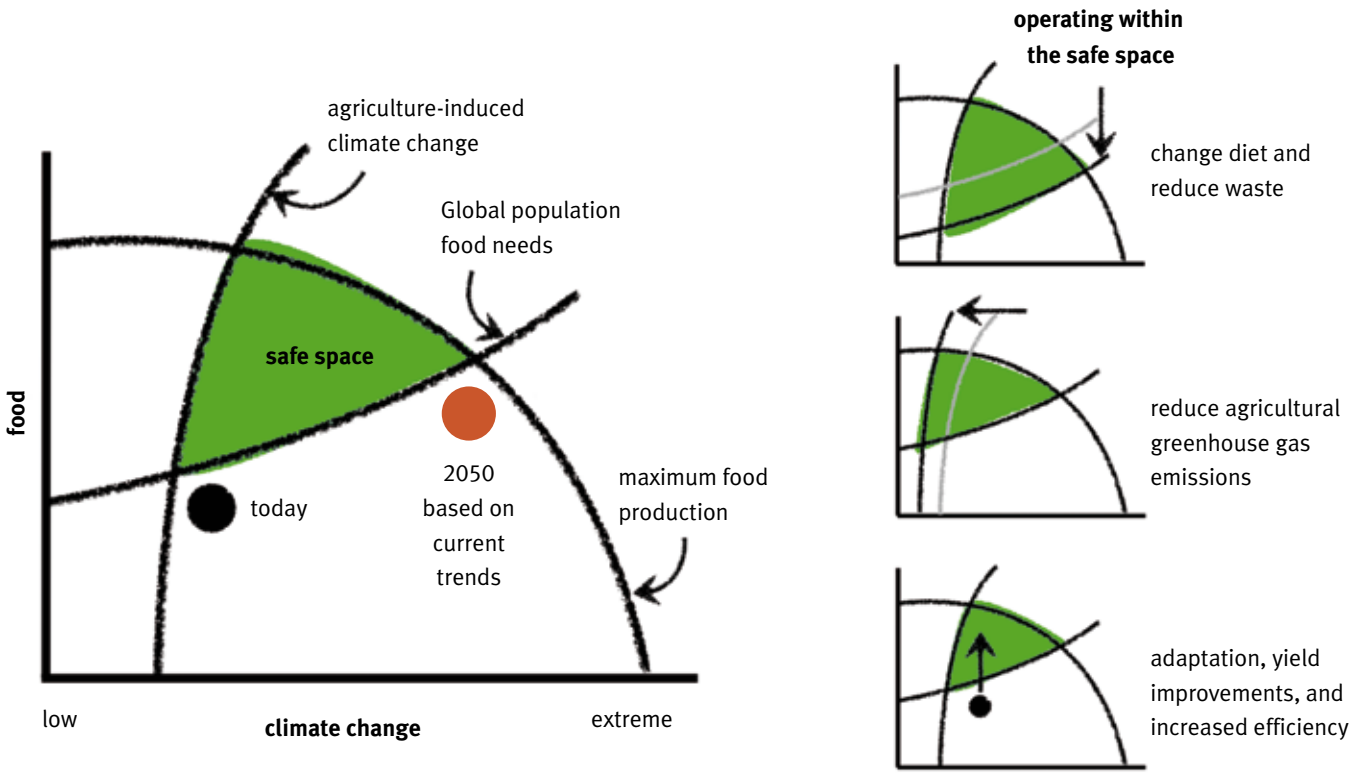


Figure 9. Safe operating space for interconnected food and climate systems. The global community must operate within three limits: the quantity of food that can be produced under a given climate; the quantity needed by a growing and changing population; and the effect of food production on the climate. At present the planet operates outside that safe space, as witnessed by the enormous number of people who are undernourished. If current trends in population growth, diets, crop yields and climate change continue, the world will still be outside this 'safe operating space' in 2050. The situation then will be unsustainable and there will be very little room to manoeuvre. Various changes can be made to either enlarge the safe space or move ourselves into the safe space. For instance, the global demand for food will increase with population growth, but the amount of food per person that needs to be produced can be brought down by eliminating waste in supply chains, ensuring more equitable access to food and moving to more resource-efficient (and healthier) vegetable-rich diets. Agricultural innovation, including better water management and careful matching of crops to environments, can help adapt food systems to climate change, but not if the world warms excessively. In a much warmer world it will be impossible to even produce current levels of food. Mitigating emissions of greenhouse gases from activities related to agriculture will allow people to meet their food needs while helping keep the global climate within a tolerable range. Developed in collaboration with University of Minnesota, Global Landscapes Initiative. An animated version of this diagram can be accessed at http://bit.ly/SafeSpaceClimateFood

The multiple emergent challenges — food insecurity and undernutrition, climate change, increasing competition for energy and water, degradation of land and biodiversity — are connected in complex ways and demand an integrated management approach. Adaptive management and governance to improve nutritional security, economic prosperity and environmental outcomes will require a much better global system for integrating spatially explicit information about agriculture, ecosystem services, markets and human populations in real time. Existing and future investments in information and knowledge must be structured to identify limits, inform trade-offs and deliver practical guidance for a sustainable future, not simply to maximize single components of the food system. Such an information system will provide a richer understanding of the dynamic systems on which humanity depends and will enable renewed and broadened efforts to secure a more sustainable and healthy food system for current and future generations.

The global community must navigate towards a 'safe operating space' that provides adequate food and nutrition for everyone without crossing critical environmental thresholds. Plotting a course towards this space will require innovative technologies, institutions and policies and will severely test our social, technological and agricultural ingenuity. Whatever the specific circumstances, governance will be needed at multiple levels and will need to accommodate participation, learning and the ability to correct course. Success requires a robust, widely shared appreciation of agriculture as a multifunctional enterprise that delivers nutritious food, rural development, environmental services and cultural heritage, through and beyond the 21st century.

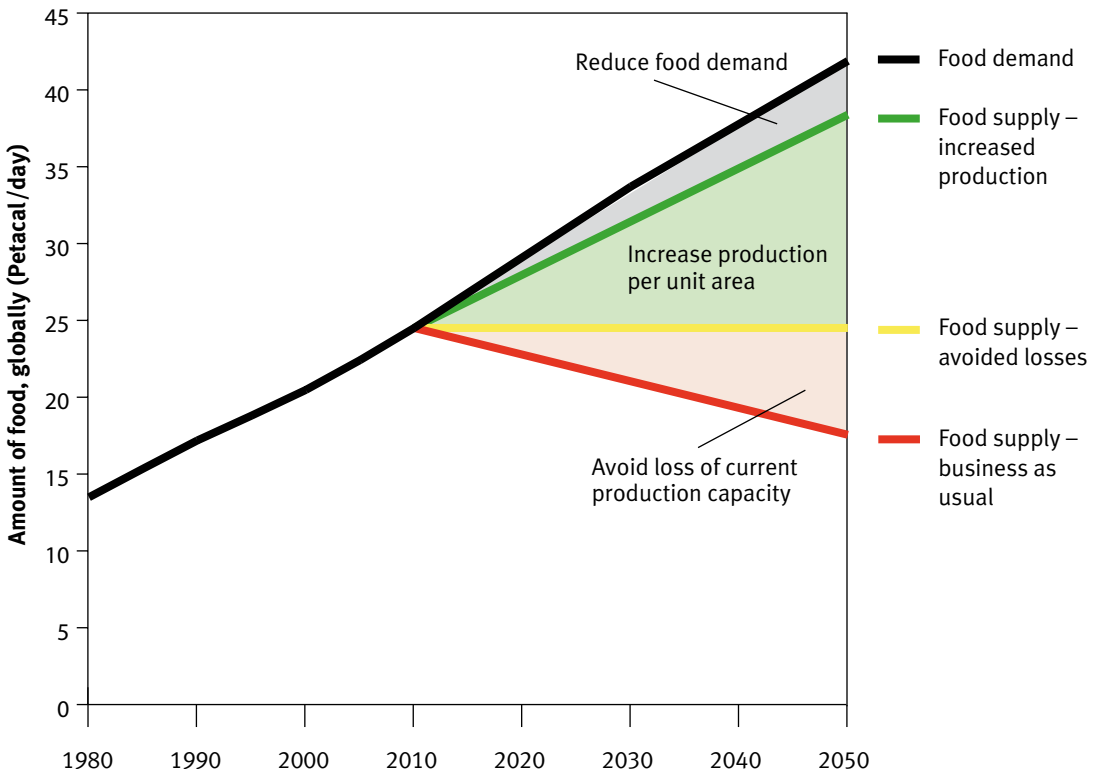


Figure 10. Balancing food supply and demand. Globally, food demand will grow in the future due to population growth and changing diets (*upper line*) and food supply must somewhat exceed food demand if everyone's needs are to be met and food prices are to remain affordable. Under a 'business as usual' approach, food production will decrease over time due to land degradation, climate change and the emergence of new pests (*lower line post 2010*). The large resulting gap between food supply and demand can be bridged by simultaneously applying three general approaches. (1) Avoiding losses in current productive capacity can include actions to adapt to or mitigate climate change, to reduce land and water degradation and to protect against emerging pests and disease. (2) Increasing agricultural production per unit land area can be achieved through use of improved technologies, practices and policies, more efficient use of existing agricultural land and targeted expansion of agricultural land and water use (where negative environmental impacts are minimal). (3) Reducing food demand can be accomplished through efforts to promote healthier and more sustainable food choices and to reduce food waste across supply chains. None of these three approaches alone are sufficient and all three require substantial innovation in the food system. *Source*: B Keating, CSIRO Sustainable Agriculture, based on Keating and Carberry (2010).

Without a global commitment to reducing GHG emissions from all sectors, including agriculture, no amount of agricultural adaptation will be sufficient under the destabilized climate of the future. While change will have significant costs, the cost of remaining on the current path is already enormous and growing. Given the already intolerable conditions of many livelihoods and ecosystems, and the time lag between R&D and widespread application, urgent action must be taken now.

Photo: Dave Mills, The WorldFish Center

Chapter IV: Essential actions for food security and climate stabilization

The transition to a global food system that satisfies human needs, reduces its GHG footprint, adapts to climate change and is in balance with the planet's resources requires concrete and coordinated actions, implemented at scale, simultaneously and with urgency. Public and private sector leaders around the world have recognized the consequences of inaction and are already taking steps to overcome technical, social, financial and political barriers to achieving food security in the context of climate change.

Based on robust scientific evidence, the Commission on Sustainable Agriculture and Climate Change has identified critical leverage points and proposes the following evidence-based actions to deliver long-term benefits to communities in all countries.

Photo: N. Palmer (CIAT)

Recommendation 1: Integrate food security and sustainable agriculture into global and national policies

Fragmentation of issues across multiple policy platforms and narrowly bounded institutional mandates encourages unilateral, single-sector responses, discourages innovative leadership and inhibits development of policy actions informed by the full complexity of food security, sustainable agriculture and climate change challenges. Global food systems are highly diverse in their governance. Strong international supply chain coordination and consolidation is the norm for products such as coffee, but for many of the world's staples such as rice and maize, most of the harvest is supplied and consumed locally through small-scale markets, with only a minor proportion being traded across international borders.[125] This means that transformation of global food systems needs both global and local action.[126]

Global governance relevant to climate change, sustainable agriculture and food security has evolved rather than been established through explicit design. Despite the intertwined nature of these challenges, they have developed as separate strands with varying degrees of global dialogue and action. The lack of coherence across these three domains is a barrier to achieving outcomes in all three areas. The issues are complex and span global, regional and national scales. Ultimately, actions have local application and consequences. Dialogue around these issues is increasing in various national and international forums, but more coordinated and concrete actions are needed.

The spectrum of governance structures includes national governments, United Nations bodies (e.g. UN High-Level Taskforce on the Global Food Security Crisis), global agreements and conventions (e.g. UNFCCC, World Trade Organization trade treaties, L'Aquila Food Security Initiative, Convention on Biological Diversity, treaties on plant genetic resources), multilateral programs (e.g. Global Partnership for Agriculture, Food Security and Nutrition), regional economic communities (e.g. European Union, African Union), political forums (e.g. G8, G20) and standard-setting bodies (e.g. International Organization for Standardization, ISO). Cutting across these structures are systems of market and industry governance and of civil society influence and agenda setting.

Establish a work programme on mitigation and adaptation in agriculture in accordance with the principles and provisions of the United Nations Framework Convention on Climate Change (UNFCCC), based on Article 2, as a first step to inclusion of agriculture in the mainstream of international climate change policy.

The mandate of the UNFCCC is to broker agreement among parties that will lead to stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous changes in the climate and food production systems.[127] Adaptation to climate change has become an increasingly important focus. As a major contributor and potential solution to climate change, agriculture should be given robust attention within the UNFCCC. A credible commitment by high-income countries to drastically reduce their emissions would stimulate R&D in sustainable technologies for agriculture.[128]

The political foundation for establishing a work programme on agricultural adaptation and mitigation within the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA) at the 17th Conference of the Parties (COP17) in late 2011 was supported by a number of official statements by political and scientific leaders[129] (for example, a common position by African ministers,[130] the scientific Wageningen Statement,[131] a joint letter from the UN and other agencies,[132] and public statements by South African President Jacob Zuma and former UN Secretary-General Kofi Annan). The outcome of COP17, the *Durban Platform for Enhanced Action*,[133] did not commit to an agriculture work programme; however, there was agreement to consider adopting a framework for sectoral actions, which could include agriculture, and for the SBSTA to "exchange views on agriculture".[134] This exchange is under way and SBSTA is looking into the development and implementation of a work programme. How different views on agriculture will be taken into account in the intended work programme has not yet been made explicit, but some elements of the content of such a work programme have been discussed, including both adaptation and mitigation.

[125] IFAD 2011.
[126] This report specifically addresses the areas where global governance can make a difference, such as in transferable technologies and policy approaches, knowledge systems, international trade, subsidies, etc.
[127] UNFCCC Article 2. http: //unfccc.int/essential_background/convention/background/items/1353.php
[128] World Bank 2010b.
[129] Beddington et al. 2012.
[130] The Johannesburg Communiqué, 2011.
[131] Global Science Conference on Climate-Smart Agriculture, 2011.
[132] *Agriculture: A Call to Action for COP17 Climate Change Negotiators*, 2011.
[133] Durban Climate Change Conference, November/December 2011. http: //unfccc.int/meetings/items/6240.php
[134] Ibid.

Tanzanian farmer with drought-tolerant maize. Researchers can help breed crops that are adapted to future climate conditions
Photo: A. Wangalachi (CIMMYT)

This relatively modest progress can be attributed to several challenges that must be addressed in order for agriculture to be given higher priority within global climate change policy debates.[135] The agriculture sector's vulnerability to climate change impacts and potential to increase productivity and mitigate GHG emissions vary considerably across different countries, and this will shape national positions on the inclusion of agriculture under the UNFCCC (for example, the acceptability of potential restrictions on land clearing for agriculture).[136] Agriculture has the potential to deliver benefits for both adaptation and mitigation, but these topics are handled through separate UNFCCC negotiating tracks. This structure inhibits a 'multiple benefits' approach to agriculture and amplifies the perception that agricultural adaptation will be given inadequate priority (although it is anticipated that both adaptation and mitigation will be taken up by the SBSTA). The COP17 agreements came under the mitigation track, triggering concerns about mandatory commitments, market-based approaches and trade restrictions in the agriculture sector.

The research community has a critical role in supporting policy progress, including:[137]

- clearly describing adaptation and mitigation strategies that span agriculture and forestry and improve food security and livelihoods to inform development of the REDD+ mechanism;[138]
- at the national level, quantifying the vulnerability of agriculture to climate change, options for adaptation in agriculture and food systems, GHG emissions from agriculture, and opportunities to reduce emissions from changes in agricultural practice;
- forecasting outcomes (e.g. 'winners' and 'losers') under a broad range of potential mechanisms for agricultural adaptation and mitigation, with emphasis on both countries (e.g. economies, impacts of climate change and GHG footprints) and farmer groups (e.g. smallholders and export-focused producers); and
- clarifying current capacity to meet technical challenges (e.g. GHG monitoring in agricultural landscapes, and breeding climate-adapted crop and livestock varieties).

Make sustainable, climate-friendly agriculture central to Green Growth[139] and the Rio+20 Earth Summit.[140]

At the Rio+20 Earth Summit, governments should agree to financial commitments for regional programmes that support and facilitate research, implementation, capacity building and monitoring to improve agriculture and food systems. This should include commodity-specific, pilot-scale research on alternative agricultural practices, implementation of alternative practices and enhanced institutional capacity to accelerate transitions between the pilot research, upscaling and establishment phases. High-quality time series data on land use change, food production, human health and well-being and environmental conditions, in the public domain, is required to demonstrate improved agro-ecological and socioeconomic outcomes.

Governments can call for a harmonization or restructuring of the architecture for planning, programme design and implementation support across institutions with mandates relating to food security, sustainable development and climate change. These institutions include UN agencies (i.e. the World Bank, UNEP, IFAD, FAO, etc.) and regional development banks. The intended outcome would be to ensure an integrated interface for national governments and to maximize coherence and efficient use of global donor funds. While politically challenging, governments can begin to discuss a framework for tackling land tenure issues that inhibit sustainable investments (e.g. the level of land rights essential to create a reasonable expectation of a return on any investment in sustainable land management).

The multilateral agencies, sectoral groups and non-governmental organizations (NGOs) that are contributing to the design of the Rio+20 Earth Summit can play a key role in articulating the practical meaning of agriculture within the Green Growth agenda. Such efforts should reframe small-scale farming as a critical source of income, food and resilient landscapes rather than characterizing smallholder farming as an arena for poverty relief. Outcomes from the Rio+20 meeting should elevate the importance of multisectoral approaches to landscape management (including sustainable agriculture and use of natural resources) and food security (including addressing the 'double burden' of undernutrition and overconsumption).

[135] Beddington et al. 2012.
[136] The Hague Conference 2010.
[137] Beddington et al. 2012.
[138] There is a rich foundation in the work of the FAO, CGIAR, IFAD, Global Research Alliance and other multilateral groups.
[139] Green Growth is a policy focus that emphasizes environmentally sustainable economic progress to foster low-carbon, socially inclusive development. www.greengrowth.org
[140] Rio+20, United Nations Conference on Sustainable Development, Rio de Janeiro, Brazil, 4–6 June 2012.

The scientific community has mobilized to ensure that a robust evidence base will facilitate global action at Rio+20 to bridge development gaps and reduce poverty within the context of the planet's boundaries. Through events such as Planet Under Pressure (March 2012 in London), a climate-smart agriculture conference (in Hanoi) and the Forum on Science, Technology and Innovation for Sustainable Development (June in Rio de Janeiro), a wide range of scientific groups, government agencies and other stakeholders are collaborating to present integrated knowledge relating to human well-being and environmental sustainability. In addition to effectively integrating and communicating current knowledge to policy audiences, researchers must work across disciplinary boundaries to develop a pragmatic understanding of what it means to navigate towards a 'safe operating space' for humanity's future (see Figure 10).

Finance 'early action' to drive change in agricultural production systems towards increasing resilience to weather variability and shocks, while contributing significantly to mitigating climate change. This includes supporting national climate risk assessments, developing mitigation and adaptation strategies, and programme implementation.

Many technologies and practices can deliver both resilience to climate change and a lower GHG emission per unit production. Countries can make progress on agriculture that meets climate objectives ahead of global agreement. There are clear opportunities for investments that can improve food security now while also providing for longer-term adaptation and delivering mitigation benefits.

Researchers can help to mobilize increased investment by detailing ways in which farmers, industry, consumers and government can achieve multiple benefits from sustainable farming practices and by clarifying geographic and sectoral potential for GHG mitigation.[141] This includes evaluating potential mechanisms for directing climate finance to agricultural producers to support the upscaling of pilot-tested economically and ecologically sustainable practices (with emphasis on resilience and reduced GHG footprint) and the development of critical supporting infrastructure.

Investments in agriculture are already being made through major programmes such as the Adaptation Fund of the Kyoto Protocol (see Annex I for further examples) and new initiatives such as the Euro 5.3 million climate-smart agriculture project in Malawi, Vietnam and Zambia funded jointly by the FAO and the European Commission.[142] The Green Climate Fund is to invest USD 100 billion per year for mitigation and adaption to climate change in developing countries. This will need processes that allow investments in integrated agricultural adaptation and mitigation.[143]

[141] Beddington et al. 2012.
[142] www.fao.org/news/story/en/item/119835/icode/
[143] Beddington et al. 2012.

A key role for global donors will be identifying finance mechanisms to support interventions and systems that build on the large potential synergies between agriculture and climate change.[144] Emphasis should be given to integrated, locally relevant, end-user-driven approaches to increasing productive assets in smallholder communities. A tiered approach should be used that accommodates multiple sources of innovation and looks 'upstream' for solutions.[145]

Governments can better integrate targets for agriculture in national plans for adaptation and mitigation.[146] Efficient, sustainable agricultural practices can be encouraged in higher-income countries by redirecting public and private investments and through changes in incentives and markets, and in lower-income countries by increasing overall investment in agricultural development, emphasizing food security.[147]

Positive directions include the partnership on climate-smart agriculture and the UN High-Level Taskforce on the Global Food Security Crisis' engagement on climate change issues. The current G20 focus on agriculture and the Rio+20 meeting represent an opportunity to enhance the coherence of global governance. The Government of Mexico and subsequent G20 leaders should prioritize food security as a recurring item to increase public and private investments in sustainable agriculture.

Develop common platforms at global, regional and national levels for coherent dialogue and policy action related to climate change, agriculture, crisis response and food security, at global, regional and national levels. These include fostering country-level coalitions for food security and building resilience, particularly in countries most vulnerable to climate shocks.

A clear framework for collective action (such as a higher-level institution or an overarching set of rules) would help stakeholders at all levels avoid taking 'narrowly rational' actions that result in poor collective outcomes and discontinuities across policy mandates. Many governments, companies and regional groupings are contributing to the international dialogue and taking action on climate change ahead of global agreement. There have been public and private investments in climate mitigation and in enhanced productivity, sustainability of agriculture and food security. These have been less effective than they could have been due to a lack of overarching architecture, which has led to low coherence or, at worst, conflict between programmes. Globally, there is an ongoing challenge to institutional capacity to participate in action-oriented dialogues and decision making, to successfully implement programmes,

[144] The Hague Conference 2010.
[145] Keynote by Rachel Kyte, World Bank Vice President of Sustainable Development, at Agriculture and Rural Development Day in Durban, South Africa, Dec 3, 2011.
[146] The Hague Conference 2010.
[147] Beddington et al. 2012.

A clear framework is needed for making collective decisions and actions
Photo: IRRI

and to respond to rapidly changing markets and global political conditions.

Funders of multilateral activities can incentivize increased coordination and outcome-focused programming within and among institutions. They can mandate, fund and implement multigovernment initiatives while leveraging national and private sector investments (for example, the climate-smart agriculture partnership, the Global Research Alliance on Agricultural Greenhouse Gases and regional programmes such as the Comprehensive Africa Agriculture Development Programme (CAADP)).

Governments can develop and implement internationally agreed frameworks (such as the Global Plan of Action for Plant Genetic Resources for Food and Agriculture). Integration across multiple policy and financing mechanisms (e.g. REDD+, nationally appropriate mitigation actions (NAMAs), the Green Fund, public and private development aid) is important to accelerate uptake of sustainable practices. In the reform of national and regional policies on agriculture (such as the European Common Agricultural Policy (CAP)[148] and the CAADP[149]), member governments should include objectives on achieving sustainable agriculture and pay explicit attention to impacts on global food security.

Research partnerships that span a broad range of disciplinary expertise and multiple levels of activity (e.g. data collection, modelling, pilots and evaluation) can produce dramatic improvements in natural resource management. Information sharing and cooperation among stakeholders, researchers, institutions and the media can facilitate convergence on policy directions.

Case study 1: Brazil's integrated approach to land use policy

National governments can stimulate sustainable food production by coordinating policies. In addition to successes in inclusive economic growth — a reduction in poverty from 20% of the population in 2004 to 7% in 2010 — Brazil has a set of complementary policies and programmes to reduce the environmental impact of agriculture. As the fifth highest GHG-emitting country in the world, 80% of Brazil's pledge under the Copenhagen Accord will be fulfilled by the agriculture and forestry sectors. These two sectors generate more than 70% of domestic emissions. To meet its target of reducing the rate of deforestation in the Amazon by 80% by 2015, Brazil has established ecological and economic zoning plans, as well as a satellite monitoring system to facilitate prompt action against illegal logging.[150] Introduced in 2008, Brazil's National Climate Change Plan is credited with successfully reducing deforestation and making the shift to low-emission agriculture. Agro-ecological zoning laws for sugar cane and palm oil balance competing land uses and address multiple objectives in the agriculture, forest, water and energy sectors.[151] Key policy documents, such as the National Plan, Sustainable Amazon Plan and National Water Resources Plan, prohibit cultivation of sugar cane in protected areas (the Amazon and Pantanal, for example).[152] The Forest Code provides for maintaining forest cover on private property in rural areas. The Brazil Development Bank has also restructured its guidelines to make lending conditional on environmental protection measures that avoid deforestation, and land and water pollution.

In Brazil, sugarcane cultivation is prohibited in protected areas.
Photo: Rom Srinivasan

[148] Reform of the European Union's Common Agricultural Policy (CAP), which includes direct subsidies, price supports, import tariffs and quotas on non-EU goods, may include a phased transition of subsidies from specific crops to land stewardship.
[149] www.nepad-caadp.net/

[150] World Bank 2011a.
[151] Meridian 2011.
[152] World Bank 2011a.

Recommendation 2: Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade

The range of sustainable agricultural practices that can improve adaptation, mitigation and livelihoods is highly diverse, and varies by region and by farming system. Many such practices are already well known but others are yet to be invented or lack general awareness. The process by which sustainable agricultural practices are taken up in specific farm regions and commodity sectors will be idiosyncratic, controlled by factors such as type and level of investment, availability of relevant knowledge and infrastructure, and the institutional and policy context. The type and amount of public and private sector investment vary from country to country, although, in general, investment in agriculture is low in low-income countries and higher in wealthier countries (where the selection of agricultural practices is driven by a complex mixture of policy and market signals). The role of farmers' organizations and agribusinesses is also highly variable by country and by region. Global investment in sustainable agriculture and food security needs to increase across local, national, regional and international organizations.

Implement and strengthen the existing G8 L'Aquila programmes and commitments to sustainable agriculture and food security, including long-term commitments for financial and technical assistance in food production and to empower smallholder farmers.

The risks (e.g. food price volatility, food insecurity and civil unrest[153]) and benefits (e.g. the stability of the global food system) of a commitment on a global scale to sustainable agriculture make a clear case for following through on the G8 L'Aquila food security initiative. Announced in 2009, this was a commitment to provide USD 20 billion over three years for agricultural development in impoverished countries. The initiative has resulted in strong but underfunded programmes such as the multilateral Global Agriculture and Food Security Program, designed to reduce hunger and poverty through more consistent investments in agriculture and food security; this has received 55% of total pledges, equivalent to USD 1.1 billion.[154] Rather than creating new systems, L'Aquila could be a cornerstone in increasing investment for agriculture.

Greatly increased investment in the agricultural sector offers significant potential for economic growth and livelihood improvements. For example, economic growth of 1% in agriculture generates a 6% increase in overall expenditure by the poorest 10% of populations.[155] To boost sustainable agriculture practices, increased coordination and financing should be organized around nationally owned action frameworks (see below).

Enable UNFCCC Fast Start[156] funding, major development banks and other global finance mechanisms to prioritize sustainable agriculture programmes that deliver food security, improved livelihoods, resilience to climate change and environmental co-benefits. Such programmes should emphasize improving infrastructure and land rehabilitation.

The Fast Start funds agreed at the UNFCCC meeting in 2009 in Copenhagen represent an important window of opportunity to accelerate implementation of climate-smart agriculture. To date, Fast Start has not had a strong focus on food security and sustainable agriculture. The requirement to demonstrate additionality (i.e. to document a net reduction in GHG emissions from a projected baseline scenario) is a barrier to their inclusion, as accomplishing sustainable agricultural development is not a sufficient condition to access funds. Despite its high vulnerability to climate change, agriculture risks becoming an even more underinvested sector if climate funds are not explicitly designed to include sustainable farming practices. This is especially worrisome if development funds are redirected to climate funds.

Major development banks should be encouraged to prioritize sustainable agriculture programmes that have food security and environmental co-benefits, where investments can be linked clearly to sustainable long-term growth in regional agriculture markets. Multilateral agencies should collaborate to create an integrated interface or portal through which national governments can access all relevant UN agencies. Through this portal, agencies could cross-reference plans and implement integrated global accounting to ensure coherence

Photo: R. Willock

[153] Guillou and Matheron 2012.
[154] www.gafspfund.org/gafsp/content/funding
[155] World Bank 2008.
[156] The Copenhagen Accord notes developed countries' commitment to providing developing countries with fast start finance for enhanced action on mitigation (including reducing emissions from deforestation and forest degradation, REDD), adaptation, technology development and transfer and capacity building. www.faststartfinance.org/home

among global donors and thereby increase effectiveness and reduce redundancy and gaps. Multilateral agencies should also convene support teams for countries building national climate-smart agriculture business plans, drawing on experts from the UN, CGIAR and leading countries.

There is a range of investment types (including basic and applied R&D, infrastructure, education, financing programmes, etc.) with potential for growing national and regional agriculture sectors. (Annex I outlines the major sources of climate finance and agricultural development funding currently available.) To identify highest-priority needs for development and adaptation in agriculture, researchers should work to improve knowledge systems on agricultural practices that deliver multiple benefits in different regions, farming systems and landscapes, especially in the most vulnerable socioecological systems.

Adjust national research development budgets, and build integrated scientific capacity, to reflect the significance of sustainable agriculture in economic growth, poverty reduction and long-term environmental sustainability, and focus on key food security issues (for example, developing nutritious non-grain crops and reducing postharvest losses).

National investments in agricultural production systems should be directed towards:

- improving market connectivity through the development of infrastructure such as roads, telecommunications, post-harvest storage facilities, rural value-added food processing, decentralised and renewable-based energy systems, coordinated systems for fertilizer and seed supply, land restoration and water supply;[157]
- expanding the number and scope of regional pilot programmes that demonstrate effective interventions such as the appropriate use of fertilizer subsidies, pragmatic adjustments in land tenure systems, balanced focus on short-term yield and long-term resource base, agricultural intensification strategies to increase input use efficiency, and comprehensive land use policies and payments for environmental services; and
- revitalizing agriculture (including livestock, agroforestry and fisheries) in both irrigated as well as rainfed areas, balancing the emphasis on agricultural productivity, economic development and environmental conservation.

Parallel investment in multiple points in food supply chains and through multiple policy and finance strategies has been demonstrated in Brazil (see Case Study 1). The Global Research Alliance on Agricultural Greenhouse Gases[158] demonstrates that there are exciting opportunities for bottom-up collaboration in the move towards global consistency and multilateral cooperation.

[157] IAASTD 2009; IFAD 2011; Lipper et al. 2010.
[158] www.globalresearchalliance.org/

Case study 2: China's research, policies and pilot programmes promote agricultural adaptation and mitigation

In China, recent advances in agricultural productivity and poverty reduction have been built on a significant domestic agricultural R&D base. With annual increases of roughly 10% since 2001, agricultural R&D spending equalled USD 1.8 billion in 2007 and shifted an estimated seven people out of poverty for every USD 1500 of investment.[159] National policies and pilot programmes also catalyse agricultural adaptation and mitigation.[160] The Plan for the Construction of Protective Cultivation Projects will cover 2.7 million hectares in 2009–2015. In addition to enhancing soil resilience to drought, 1.7–2.5 billion cubic meters of irrigation water have been saved. By the end of 2009, 25.6% of Chinese grasslands had been closed to grazing, or had been fallowed or zoned for rotational grazing, while 1.6 million severely degraded hectares of grassland were reseeded.[161] Strategies to improve rice yields while reducing GHG emissions have been promoted. These include encouraging farmers to grow low-emission and high-yield rice breeds, use intermittent irrigation methods and convert straw to a biomass feedstock for the production of fuel, products and power. Subsidies for water-saving irrigation technologies, machinery and equipment, as well as for improving crop varieties and industrial systems, have been established. Under the Special Climate Change Fund, pilot projects to develop alternative water sources, adopt water-saving technology and adaptively manage irrigation and drainage have been launched in the Yellow, Huaihe and Haihe river basins, as well as in the Ningxia Hui region. Successful strategies will be integrated into future national plans. National climate change targets for 2010 (such as 15% non-fossil fuel sources for Chinese energy consumption and forest coverage of 40 million hectares) were encouraged by subsidies, labelling and tax incentives.

In China, low-emission and high-yield rice breeds have been promoted.
Photo: IRRI

[159] Chen KZ, Zhang T. 2011.
[160] National Development and Reform Commission. 2009.
[161] Ibid.

Investment in national research systems can help revitalize sustainable agriculture
Photo: N. Palmer (CIAT)

Increase knowledge of best practices and access to innovation by supporting revitalized extension services, technology transfer and communities of practice (for example, North-South, South-South, cross-commodity and farmer-to-farmer exchanges), with emphasis on low- to high-income countries and on women farmers.

Public sector funds may be limited, the lag time between R&D investment and potential use or commercialization too long, and market returns on investment too low to attract R&D expenditure from the private sector alone. While the economic rates of return on investment in agricultural R&D are high (around 40% in both high-income and low-income countries[162]), the timescales from research to impact vary from the (almost) immediate to the long term (decades), depending on the area of work funded and the complexity of the issue being addressed. The uptake of both biological and mechanical innovations in agriculture may take many years, with a long lag of perhaps 15–25 years between research expenditures and widespread implementation at farm level. Once benefits have been demonstrated in trials, farmers need to be able to find and use these innovations effectively.

It is vital to take a long-term, strategic view and to conduct research now to meet future challenges, particularly long-term climate change, as well as developing approaches to facilitate the timely transfer of new knowledge and technologies into practical application. For example, the Belmont Challenge calls for the international scientific community "to develop and deliver knowledge in support of national and international government action to mitigate and adapt to global and regional environmental change with an emphasis on regional hazards".[163] Increased demand for food can be met in a number of ways, which have different implications for equity and sustainability. It is critical to better link public and private R&D systems to ensure that high-priority science and technology gaps are filled (e.g. climate-resilient crops and livestock, integrated farm management strategies, and efficient water, energy and nutrient use). It is also imperative to develop the governance structure for private sector participation, innovation and delivery, with an emphasis on the effective use of public–private partnerships characterized by shared risk and return on investment as well as clarity on open access. Effective use of technology transfer should emphasize researchers working directly with smallholder farm communities to adapt holistic farming techniques to local assets.

Further actions include:

- developing local and community capacity (farmer organizations/associations, community-based organizations, public–private partnerships, etc.);[164]
- building the case for increased productivity resulting from farmer-to-farmer empowerment and education;
- clarifying the conditions under which local agricultural production systems integrate innovative technologies or approaches; and
- facilitating communication linkages among farmer innovators who have produced useful adaptations.

[162] CGIAR 2009.

[163] ICSU 2010.
[164] The Hague Conference 2010.

Case study 3: Bangladesh is investing in smallholders and food security

Despite tripling rice production over the past 40 years, food security in Bangladesh is challenged by population growth, climate change, scarce natural resources, vulnerability to price shocks, persistent poverty and malnutrition. Based on broad consultation, the five-year Bangladesh Country Investment Plan (BCIP) sets out 12 priority investment programmes that, when implemented together, will improve food security and nutrition. The total cost will be USD 7.8 billion.[165]
Key elements include:

- improving access to and tenure of land and water resources;
- improving access to credit and other financial resources;
- enabling private sector involvement; and
- recognizing the key role of women in household food production.

To measure progress against baselines, a set of target indicators were agreed, which included reducing the prevalence of chronic energy deficiency among women from 32% in 2005 to 20% by 2015. With its focus on replication and scaling up successful innovations, the BCIP addresses the need for extension services, such as farmer field schools, to promote agricultural adaptation to climate change, as well as to build awareness of tools such as the land and soil guide Upazila Nirdeshika. The BCIP aims to more effectively target social safety net programmes that currently absorb 15% of the Bangladesh Government's annual budget (2.4% of GDP), and particularly to ensure that benefits reach women. The BCIP recognizes the need to improve farmers' access to markets, reduce pre- and post-harvest losses, and to add value across whole food chains, including by working with the private sector in public–private partnerships.

An irrigation channel in Bangladesh is an example of an infrastructure investment that helps improve access to water resources
Photo: IRRI

[165] Government of the People's Republic of Bangladesh. 2011.

Recommendation 3: Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture

Sustainable intensification is potentially the most promising means of simultaneously increasing food production while achieving land-based mitigation, as long as non-crop land uses such as forestry, grasslands or wetlands are able to sequester more carbon or emit lower levels of GHGs than cultivated land. When implemented appropriately, sustainable intensification uses suitable technologies to increase production per hectare, without negative environmental consequences on site or off site, and while maintaining other ecosystem services. Policy instruments for sustainable intensification need to be given special care based on solid understanding of the drivers of land use change and agricultural GHG emissions. For example, GHG footprint in agriculture varies greatly with specific practices (e.g. the timing of fertilizer application) and conditions (e.g. soil type), and mitigation benefits decline as the use of fertilizers, pesticides or fossil fuel energy increases.[166]

The Intergovernmental Panel on Climate Change (IPCC) provided broad estimates of mitigation opportunities in 2007, but they are not at an operational level of detail. Also, these guidelines do not attempt to offer advice on the GHG benefits of specific changes in farming practices, nor to advise on the production and economic implications of those changes. Terms such as 'climate-smart agriculture' and 'sustainable intensification' are widely used; however, a common understanding of how these terms address adaptation and mitigation is needed.[167]

Commonly, farmers struggle to balance pressures for short-term income and the longer-term benefits associated with shifts to more sustainable practices. In addition, social acceptance of innovation and new technology can encounter barriers based on the social norms and values of different producer communities. Small-scale producers often have difficulty entering export markets and benefitting from expanded income opportunities. Newer risks and costs relating to climate change adaptation can compound this challenge.

Develop, facilitate and reward multi-benefit farming systems that enable more productive and resilient livelihoods and ecosystems, with emphasis on closing yield gaps and improving nutrition.

There are diverse opportunities throughout the global food system for minimizing its environmental footprint while satisfying the food needs of the world through increased agricultural productivity, stronger social protection, more efficient and effective markets and better governance. Sustainable agricultural practices include diversified rotations (including crop varieties and species with different temperature requirements), improved nutrient and water use efficiency, resistance to pests and disease, and lower yield variability.[168] Other practices include farm forestry, agroforestry or evergreen agriculture, and minimum tillage to reduce soil erosion and increase the soil's capacity to hold water and sequester CO_2.[169]

Important potential advances in diverse fields, including crop management, agro-ecology and agronomy, organic and inorganic chemistry, engineering and biotechnology, have different contributions to make to raising productivity in different regions and in diverse social and agricultural localities. A number of areas of science promise to contribute to sustainable intensification including:

- the development of new varieties or breeds of crops, livestock and aquatic organisms;
- advances in nutrition for livestock and aquaculture using feed additives or formulated feeds to increase productivity gains and reduce methane emissions in ruminants;
- improved soil management that preserves ecosystem functions and sequesters carbon;
- agro-ecological approaches that complement the biological and ecosystem services that inherently support agriculture and that better manage risks; and
- the promotion of engineering technologies that increase water use efficiency.

Scientific advancement will require international, regional and local collaboration. The benefits and dangers of new developments need to be articulated in an open and transparent way so that public trust is promoted and informed debate on new advances can be supported.

An enabling environment will incentivize regionally relevant, multibenefit farming practices, redirect income to poor producers (linked to the adoption of sustainable practices) and realign the financial signals that influence management practices used by higher-income producers (e.g. sustainability standards for food products). It will also meet the essential knowledge needs of a broad range of actors across supply chains and policy venues with a core emphasis on increasing transparency and predictive capacity. A good example has been the building of agricultural research capacity in Africa under the governance of the CAADP.

[166] Tilman et al. 2002.
[167] Beddington et al. 2012.
[168] Lipper et al. 2010; The Hague Conference 2010; World Bank 2010b.
[169] Parry et al. 2009.

Case study 4: Upscaling techniques to deliver higher yields and climate benefits in Vietnam

Agricultural sustainability hinges on the development and uptake of farming techniques that simultaneously deliver robust yields and incomes, climate resilience and GHG mitigation. With a projected 12–14% decline in global rice production by 2050 due to climate change,[170] integrated crop management (ICM) helps farmers to boost production while adapting to climatic changes and resource scarcity. Developed to benefit smallholder farmers, ICM reduces requirements for inputs and labour. In the ICM method, alternate wetting and drying and balanced fertilisation on paddy fields lower methane and nitrous dioxide levels compared with continuous flooding.[171] There is less need for fertilizers and other inputs and so indirect GHG emissions are minimized. Yield increases are attributed, in part, to more vigorous root systems, and better resilience to biotic and abiotic stresses. In Vietnam, the ICM programme began in 2002, and by 2004 already engaged 103,000 farmers in 13 provinces (i.e. 15% of the Mekong delta area, with two rice crops per year). Compared with control sites, these farms saw higher rice yields and significantly reduced use of nitrogen fertilizer, seeds, water and pesticides, leading to considerably lower production costs and higher profits. A recent survey shows that Vietnamese farmers are implementing ICM on more than 1 million hectares. The system of rice intensification (SRI) has shown positive results in Vietnam as an ICM alternative method. Oxfam-funded field trials, demonstrations and dissemination have mobilized farmers to act as local extension agents, and helped to bring SRI to 21 provinces. A 2008 review found 11% higher average SRI yields, 16% lower urea fertilizer use, 45% less frequent pesticide application, 35% reduction in average irrigation expenses, and 50% increases in income.[172]

Techniques for growing rice such as alternate wetting and drying and balanced fertilisation can help to lower GHG emissions, reduce the needs for fertilizers, and increase yields

Photo: N. Palmer (CIAT)

[170] Nelson et al. 2009.
[171] Nguyen et al. 2007.
[172] Africare, Oxfam America, WWF-ICRISAT Project. 2010.

Agro-ecological approaches, such as this silvo-pastoral system in Colombia, can be beneficial for local ecosystems and biodiversity, while helping to close yield gaps and improve nutrition

Photo: N. Palmer (CIAT)

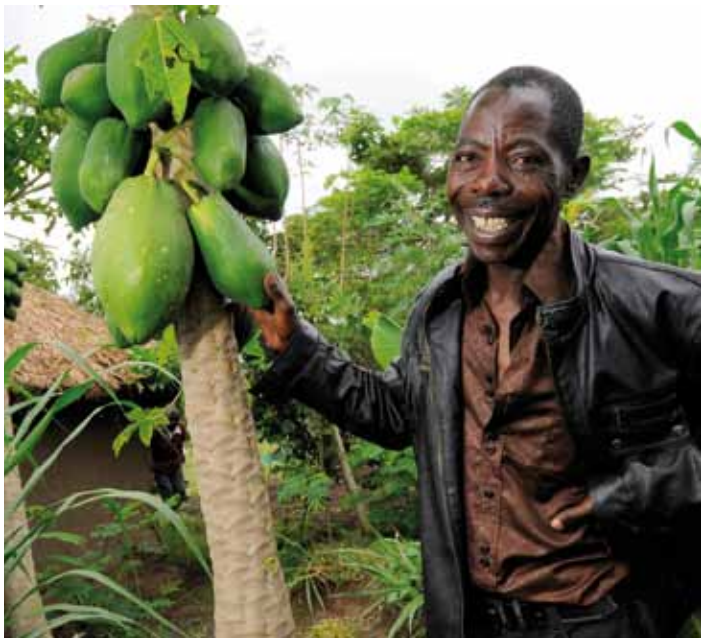
Introduce strategies for minimizing ecosystem degradation and rehabilitating degraded environments, with emphasis on community-designed programmes.

Given the massive land area under agricultural use, strategic mainstreaming of low GHG agriculture could deliver a major contribution to the mitigation of GHG emissions while supporting long-term productivity and resilience (i.e. decoupling increase in yield from emissions). Soil carbon sequestration is estimated to have the highest economic mitigation potential, although incentives for its adoption as well as its permanence, variability and monitoring need to be addressed.[173] There is limited scope for land expansion to cope with the demand for food in the decades ahead, and sustainable intensification will be an important strategy to increase food production.

Empower marginalized food producers (particularly women) to increase productivity of a range of appropriate crops by strengthening land and water rights, increasing access to markets, finance and insurance, and enhancing local capacity (for example through farmer and community-based organizations).

Producers need to be empowered to benefit fairly from the management of soils, water, biological resources, pests, disease vectors and genetic diversity, and to conserve natural resources in a culturally appropriate manner.[174] To enable food-insecure smallholder households to achieve food self-sufficiency and emerge from poverty, coping strategies

[173] Vermeulen et al. 2012.
[174] IAASTD 2009; The Hague Conference 2010.



Smallholder agroforestry in Kenya is an example of sustainable intensification
Photo: N. Palmer (CIAT)

should emphasize engagement in productive community asset-building activities with clear economic and environmental benefits. A range of financial services to poor rural people should be expanded along with supporting social protection programmes.

The integration of different agricultural enterprises could help to contribute to improvements in production and quality, as well as in the efficient use of natural resources. Many poor people in low- and middle-income countries have complex, diverse and risk-prone livelihoods, often integrating different aspects of cropping, livestock production, forestry and fisheries with off-farm earning.

Gender inequalities can be reduced through increased awareness of the central role of women in the food system via education and training. A wide range of policy and legal measures should be implemented to empower women through stronger rights of inheritance and equal access to credit, land and water. Women's ability to be involved in the design and use of technology, extension services and farmer cooperatives should be strengthened.[175]

Empowerment through collective action has the potential to equalize relationships on the local as well as the national and global scale and is a joint responsibility of producers, civil society and governments. Community-level organizations can be strengthened and assisted in identifying new mechanisms of social solidarity. This includes urban agriculture — 70% of urban households in developing countries are estimated to participate in agricultural activities.[176] It can provide up to 60% of a family's food requirements, with resulting benefits for nutrition and income.

Designers of development programmes should invest in institutional capacity building (stable funds, systems and skills development) with key low-income country partners. Efficient and rapid delivery of technology packages to underserved farmers should provide new mechanisms for ensuring public access to improved agricultural technologies developed in the private sector (especially by small farmers for staple foods) and build on the best available knowledge of the social dimensions of technology uptake. Governments and other donors should invest in targeted training and in educating producers, as well as in a mix of traditional and innovative knowledge transfer structures (e.g. peer-to-peer training and farmers' field schools).

Case study 5: Land tenure reform in southern Africa empowers women farmers

Although women in low-income countries play a significant role in food production, they often do not have clear rights to land. This can inhibit their ability to access credit, improve their yields and economic status, or take up sustainable agricultural methods. Since 2009, the Women and Land Rights Project has been implemented by Action Aid in the five southern African countries of Malawi, Mozambique, South Africa, Zambia and Zimbabwe.[177] In South Africa, post-apartheid land reform policies and land-related programmes, such as the Settlement/Land Acquisition Grant and the Land Acquisition and Redistribution Programme, present an opportunity for women farmers to establish their rights to own, reside on and cultivate land. However, women encounter obstacles. For example, they may be barred from participating in local decision-making systems affecting land or there may be gender inequities concerning the rights to land after the death of the head of the household. Several NGOs, such as the Legal Resources Centre and the Association for Rural Advancement, provide legal assistance to advance women's land rights and challenge laws that disadvantage women. In Eastern Cape and KwaZulu-Natal, NGOs have been specifically addressing land issues affecting women through education and leadership development.

A woman's rights to land can empower her to plan for the future.
Photo: S. Mann (ILRI)

[175] Foresight 2011.
[176] Lipper et al. 2010.
[177] Kachika 2009.

Identify and modify subsidies (such as for water and electricity) that provide incentives for farmers to continue agricultural practices that deplete water supplies or destroy native ecosystems. Introduce compensation schemes that target the poor.

High-income countries are generally dominated by highly managed, intensive agricultural systems delivering high yields through production maximization strategies that also generate negative environmental impacts. Subsidies and other incentives, as well as public expectations of low food prices and standards imposed by processors, retailers and consumers, create inertia for changing existing production practices (although experience in New Zealand shows that the farm sector can maintain economic activity when public support is significantly reduced[178]). Agricultural subsidies are not restricted to high-income countries, and, in some cases, they support inefficient use of natural resources (e.g. in India and Mexico, subsidies for electricity result in excess groundwater use) or land clearing for agriculture. Public subsidies should promote farming practices that have the potential to increase resilience and reduce poverty, and that are anchored in a pragmatic financial model (such as commitments with a defined time horizon, such as capital costs for infrastructure improvements).

The use of market and other mechanisms to regulate and generate rewards for sustainable agricultural practices can include payments for ecosystem services to farmers and local communities or higher prices for agricultural products that meet certification standards.[179] Especially for poor farmers, these mechanisms can produce more stable incomes that facilitate the continuation of sustainable practices.

Couple economic incentives for sustainable intensification of agriculture with strengthening governance of land tenure and land zoning to prevent further loss of forests, wetlands and grasslands.

It is generally believed that more stable global and national governance will improve the conditions for farmers to reinvest in sustainable agriculture as they face increasing risks due to climate change. Poorly targeted incentives for agricultural intensification can encourage agricultural expansion (e.g. higher profits provide capital for land clearing; increased supply lowers domestic prices and land costs for extensive agriculture).[180] Intensification incentives should be targeted to crops and production systems that are not easily adapted to forested and wetland areas or to areas that do not contain these vulnerable systems.[181] Strong, well-enforced land tenure and land zoning laws and norms can be important deterrents to agricultural expansion. However, careful attention needs to be paid to potential perverse outcomes in land users' decision making.[182]

[178] Gouin 2006.
[179] IAASTD 2009.
[180] Angelsen 2010.
[181] Ibid.
[182] Ibid.

Recommendation 4: Develop specific programmes and policies to assist populations and sectors that are most vulnerable to climate changes and food insecurity

Much of the governance of the food system resides in the private sector, with actors ranging from multinational companies that control a large proportion of the global food trade to the many individual small-scale farmers who produce the majority of the world's food. Barriers to sustainability vary among countries at the production end of supply chains. Smallholder farmers are frequently locked into unsustainable production systems as a result of limited access to knowledge resources, assets and markets, as well as through low recognition of the value of traditional knowledge. Gender inequalities, established power relationships and insecure tenure rights also reinforce unsustainable production systems.

Small-scale producers and landless labourers in developing countries and underdeveloped markets are weakened by changes in global and regional trade, poor market infrastructure, inadequate bargaining capacity and lack of skills to comply with new market demands, and they will face reduced access to food and livelihoods.[183] Infrastructure can increase producers' access to local and regional markets in low-income countries and increase consumer access to diversified food products.

Smallholder producers are already structurally marginalized in supply chains and policy development and this situation will worsen due to growing pressures (e.g. land and resource scarcity, market and environmental volatility). Given the very large representation of smallholders in global food production, sustainable food systems require reshaped supply chains that can deliver economic well-being to all food suppliers to ensure that they continue and improve their food production capacities. For example, lands cultivated by smallholders will lose their capacity to provide food under increasingly severe pressures, given those smallholders' extremely low financial capacity for adaptation.

Develop funds that respond to climate shocks, such as 'index-linked funds' that provide rapid relief when extreme weather events affect communities, through public-private partnerships, based on agreed principles.

Large-scale pilot schemes for index-linked funds have been implemented in countries such as India and Mexico. Together with the World Bank, the G20 will explore innovative insurance and risk management instruments designed to protect very poor populations from rising prices or events affecting harvests. Under the UNFCCC, parties have discussed the creation of an international fund that would deliver funds to any participating country that experiences a major disaster. In the short term, researchers and possible proponents (e.g. international NGOs) can continue to investigate the concept of index-linked funds and clarify how such funds can best reduce the duration of lost productivity and increased hunger and poverty for climate-affected populations.

At the recent G20 summit in Cannes, attention was directed to a broad set of risk management concerns which included integrating risk analysis and management in agricultural and food security policies. The multilateral development banks have reviewed the existing risk management instruments (hedging strategies for humanitarian agencies, advance purchase, countercyclical mechanisms, weather insurance, contract farming and crop insurance, etc.) and the International Finance Corporation is developing a risk management instrument pilot project (Agricultural Price Risk Management or APRM) in Latin America, with extensions in Africa, the Middle East and Eastern Europe. The G20 has put in place a risk management advice mechanism for the clients of developing countries through multilateral and regional banks and bilateral development agencies, in order to network the different actors and their experiences. This platform, which initially comprises the World Bank, the Inter-American Development Bank, IFAD and the French Development Agency (AFD), should also contribute to building risk management capacities in developing countries.

Rushing to buy bread as wheat runs short and food prices rise in Mozambique
Photo: S. Mann (ILRI)

[183] IAASTD 2009.

Case study 6: Index-based insurance in Mexico spurs investment in sustainable agriculture

Extreme weather (for example, droughts, floods and heat waves) can not only trigger crises and cause hardship in farming families, but can also inhibit investment in agriculture. Farmers are reluctant to invest in their enterprises in the face of uncertainty and risk. Index-based insurance automatically pays out to farmers when the weather exceeds an established level. There is no need for insurers to make site visits.[184] Making sure farmers receive insurance payments quickly can minimize distress sales of assets. Index-based insurance also boosts risk tolerance among farmers, banks, microfinance lenders and agricultural industries. In Mexico, risk insurance products are well developed, especially those targeting smaller-scale farmers. In 2010, the public insurance agency Aseguradora Nacional de la Agricultura y Ganadería (ANAGSA) provided traditional and index-based insurance covering more than 8 million hectares–half of the area sown with annual crops and mostly rainfed maize.[185] Farmers who borrow land from the government, known as *ejidatarios*, pay much lower premiums than other farmers. Only non-irrigated major crops are eligible.[186] Index-based insurance to safeguard the livelihoods and assets of poor producers, such as that provided by ANAGSA, usually needs to be subsidised and requires special delivery channels. Schemes to help viable farm businesses manage risk are usually provided by the private sector.[187]

Index-based insurance can help farmers endure climate-induced crop losses
Photo: N. Palmer (CIAT)

Moderate excessive food price fluctuations by sharing country information on production forecasts and stocks, strengthening market databases, promoting open and responsive trade systems, establishing early warning systems and allowing tax-free export and import for humanitarian assistance. This includes embedding safeguards related to import surges and trade distortions in trade agreements.

Agricultural trade represents an important pathway for poverty reduction and increased viability in the agricultural sector. However, current market practices and trade requirements have major distributional impacts that tend not to favour small-scale farmers or improved rural livelihoods. In the absence of basic institutions and infrastructure, a wider opening of national agricultural markets to international competition can undermine the agricultural sector.[188]

Global trade agreements should provide room for protection of the lowest-income countries that represent a very small share of agricultural trade and have only a very limited impact on world agricultural trade and prices. Protection mechanisms for these domestic markets should encompass imports (tariff and non-tariff barriers) and domestic policies including price supports, subsidies coupled to production and input subsidies. Improved access to futures trading and realignment of regional and preferential trade agreements and trading blocs can contribute to improved access or protection for low-income farmers. Developing countries would benefit from the removal of barriers on products in which they have a comparative advantage (e.g. preferential market and credit access, or a reduction in the escalating tariffs for processed commodities).[189]

While interventions to buffer food price volatility are crucial for food security, caution is warranted given the possibility of unintended consequences and the imperfect ability to forecast how markets will respond to policy interventions. Global trade policy should work towards a reduction in unilateral trade actions (export bans in exporting countries and import subsidies in importing countries in price peak situations). A critical precursor is the development of robust mechanisms for effective multilateral action to reduce excessive price volatility. Transparent information on physical markets, including stocks as well as financial markets, is seen as a 'no regrets' step in this direction (see the discussion of the G20's Agriculture Market Information System, AMIS, under Recommendation 7). Together, provision of food stocks in urgent situations (to prevent suffering and depletion of productive assets) and promotion of liberalised international

[184] Barrett et al. 2007.
[185] Hazell et al. 1986.
[186] Fuchs and Wolff 2011.
[187] Hess and Hazell 2009.
[188] IAASTD 2009.
[189] Ibid.

trade (to compensate for production shock in one region by output and trade adjustments in others) should be part of the global response to food price volatility. Provisions should be made under the WTO for actions to moderate the negative consequences of excess food price volatility, for both producers and consumers.[190]

World Trade Organization (WTO)

Current multilateral WTO rules are not well adapted for addressing the issues of global food security, agricultural price volatility, climate change and biodiversity protection. Baseline sustainability standards and policy shifts are needed to achieve a fair and secure global trade regulation system that ensures that food-producing economies obtain adequate benefits and incentives for the sustainable intensification of agriculture, while protecting the environment and vulnerable sectors.[191] Short-term investments are needed to strengthen the capacity of low-income countries to undertake trade analysis and negotiation; these will include the provision of better tools for assessing trade-offs in proposed trade agreements and of incentives for producing environmental services.[192]

To reduce distortions in the global trade of agricultural products, work under the WTO should address export subsidies, tariff and non-tariff barriers, distorting domestic measures and country categories.[193] Improved links across international policy bodies charged with managing trade, climate change and biodiversity are essential, with the aim of building a common framework. Maintenance of the principles of special and differential treatment for 'developing' and 'least-developed' countries (using WTO terminology) and safeguard mechanisms, as well as continuous improvements in world trade negotiations, are essential for stabilizing food prices and reducting hunger and poverty.[194] The central purpose of improved harmonization is to create mechanisms for approving market-distorting interventions where these are needed for critical environmental protection (e.g. reductions in GHG emissions and biodiversity conservation).

Create and support safety nets and other programmes to help vulnerable populations in all countries become food secure (for example, cash and in-kind transfers, employment guarantee schemes, programmes to build resilience, health and nutrition, delivery of education and seeds of quick growing foods in times of famine).

Safety nets, infrastructure and education can all help smallholder farmers who are vulnerable to food insecurity to diversify farm enterprises, providing multiple income streams.[195] Market access and increased incomes for poor agricultural producers are important to enhance their capacity to take up sustainable practices that promote ecological intensification and to escape the poverty trap.

Global donors and national governments can design large-scale programmes to increase incomes and market access for poor agricultural producers (e.g. through provision of safety nets, infrastructure and education), thereby increasing their capacity to move out of poverty and take up sustainable practices (e.g. diversification of farm production). Local participatory programmes should be designed to respond to the needs of poor rural people based on their local knowledge, customs and priorities. Programme evaluation can demonstrate the wide variety of interventions that respond to local assets and barriers.

Safety nets are important for vulnerable people in both poor and wealthy countries. These may include cash and in-kind transfers, seed and tool distribution, employment guarantee schemes, mother-and-child health and nutrition and school feeding programmes and social pensions.[196]

Establish robust emergency food reserves and financing capacity that can deliver rapid humanitarian responses to vulnerable populations threatened by food crises.

Small, international food reserves, strategically positioned, can act as a buffer against price volatility. They must be targeted at vulnerable, typically low-income, countries during times of crisis.[197] The G20 has launched a Rapid Response Forum to prevent and manage market crises in a coordinated manner and has also decided to exempt World Food Programme (WFP) humanitarian aid from all export restrictions. To assist vulnerable populations, the G20 has begun to implement a system of prepositioned emergency humanitarian food reserves in the Economic Community of West African States (ECOWAS) countries.

[190] Foresight 2011.
[191] Foresight 2011; INRA/CIRAD 2011.
[192] IAASTD 2009.
[193] Ibid.
[194] Foresight 2011.
[195] Royal Society 2009.
[196] Parry et al. 2009.
[197] Foresight 2011.

Further work is needed to articulate the key criteria and optimal design for implementation of effective food reserves. A better understanding of the drivers of food crises will help to improve targeting of fiscal responses including mechanisms for aid to poorer countries that are counter-cyclical to food price movements.

Case study 7: National guaranteed employment in India bestows multiple benefits

Poverty alleviation programmes can also address environmental sustainability objectives, particularly when they involve locally appropriate, bottom-up planning. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), launched in 2006, now operates in every district in India. In 2010–2011, MGNREGA provided jobs for over 50 million rural households at a cost of USD 9.1 billion. MGNREGA entitles every adult to 100 days a year of minimum wage, unskilled manual employment on public works, such as water management, drought proofing, tree planting, land development and rural connectivity. Village-level governments (*gram panchayats*) propose projects based on the needs felt by local communities and MGNREGA priorities. Over 80% of the projects have contributed to rejuvenating the natural resource base in some way. MGNREGA jobs deliver local environmental services, such as recharging groundwater, enhancing soil fertility and increasing biomass, which, in turn, contribute to climate change resilience and mitigation, as well as conserving biodiversity. The right to employment and flexible access to the scheme help small-scale farmers and landless rural households to manage risk. MGNREGA specifies that at least one-third of workers should be women. Flexible working hours that accommodate women's unpaid work and the mandatory presence of women in *gram panchayat* committees mean that women provide more than 50% of the MGNREGA workforce.[198]

Rural women in India benefit from guaranteed national employment
Photo: UNDP

[198] Mahapatra 2010.

Create and support platforms for harmonizing and coordinating global donor programmes, policies and activities, paying particular attention to systematically integrating climate change risk management, adaptation and mitigation co-benefits, and improved local nutritional outcomes.

Informal information sharing as well as more structured coordination can reduce duplication and fill key gaps and increase links between climate and development communities.[199] Formal consortia activities are already under way through entities such as the GDPRD and the CGIAR Fund Council, which are working to integrate concerns regarding food security, mitigation and adaptation. A core emphasis should be to facilitate knowledge-intensive agriculture that takes account of a diverse range of simple techniques (e.g. IFAD's Adaptation for Smallholder Agriculture Programme (ASAP), which focuses on assisting smallholders and includes research).

Explicit engagement among global donors should work to ensure that climate finance and agricultural development funds are accessed by smallholders and not just by large-scale producers.[200] This is particularly true of global 'public interest' institutions whose mandates hold them accountable to their publics.

[199] Negra and Wollenberg 2011.
[200] Havemann and Muccione 2012.

Case study 8: Complementary, predictable long-term response to food insecurity in Ethiopia

A community in Ethiopia helps restore a watershed by planting trees
Photo: Trees for the Future

Support to chronically food insecure populations can be designed to protect and create assets at the household and community level, as an alternative to annual emergency food appeals. In Ethiopia, the Productive Safety Net Programme (PSNP) takes a development-oriented approach to food aid that creates an assured governmental safety net and greater predictability for smallholders.[201] By combining international donor funding (over USD 1.27 billion over the last six years) with government-supplied infrastructure, labour and inputs (USD 500 000 annually), the PSNP ensures food access, stimulates markets and rehabilitates natural resources.[202] Chronically food insecure households with able-bodied adults receive transfers of cash and food for their participation in labour-intensive public works, while other households receive unconditional transfers. The public works initiatives improve soil quality, water supply, ecological condition, infrastructure and social services, as prioritized through a participatory watershed planning approach. Now in its third phase and operational in 317 *woredas* (administrative districts), the PSNP is reaching 7.7 million beneficiaries. The PSNP is associated with a range of successes including graduation of approximately 1.3 million individuals from food insecurity, rehabilitation of 9 million hectares of land, growth in livestock holdings, better access to clean water and increase in school attendance, as well as enhancing the impact of other food security programmes.[203] Complementary programmes address household asset building, community infrastructure development and resettlement. The WFP and other partners have developed a unified stream of technical advice and a stakeholder platform provides oversight.

[201] World Bank. 2010c.
[202] Gilligan et al. 2008.
[203] Ibid.

Recommendation 5: Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating patterns worldwide

In recent decades, global food production has increased, but undernutrition is still responsible for 15% of the global disease burden.[204] Among those with sufficient caloric intake, micronutrient deficiency resulting from poor diet quality and a lack of diversity is prevalent in many countries.[205] While some countries have made good progress towards the Millennium Development Goal for reducing undernourishment, many countries in Africa and South Asia are struggling to meet the target of 8% by 2015.[206]

In emerging and urbanizing economies, dietary patterns are shifting away from cereals, roots, tubers and pulses to livestock products, vegetable oils, fruits and vegetables, and, at the same time, tightening quality and safety standards are increasing the vertical integration of food systems.[207] In the coming decades, 'westernization' of eating patterns and associated increases in chronic disease (e.g. obesity, diabetes and heart disease) will become a major stress to food security and public health.[208] To develop dietary guidelines to prevent overconsumption, a more sophisticated understanding is needed of the wide variety of food combinations that can deliver a nutritionally appropriate and environmentally low-impact diet.[209] Similarly, greater knowledge is needed about the relationships between agricultural and food prices and diet composition.[210]

Address chronic undernutrition and hunger by harmonizing development policy and coordinating regional programmes to improve livelihoods and access to services among food-insecure rural and urban communities.

There are three fundamental pillars of food security:

1. availability, which is a function of food production;
2. access to food, which is a function of income and purchasing power; and
3. absorption of food, which is a function of health.

While future global food security will require increased overall food production, access and health are critical areas for improvement.[211] Effective initiatives will coordinate interventions at national to household levels.

More people are switching to diets that are richer in meat, dairy products and processed foods
Photo: F. Jachim

Model-based scenarios indicate that significant increases in agricultural productivity can achieve dramatic reductions in undernutrition.[212] Agricultural production and food gathering (e.g. hunting, fishing and foraging) to meet food needs rely on appropriate technologies, infrastructure, institutions and incentives.[213] Conventional approaches to enhancing productivity have emphasized high-yielding seed varieties, large-scale irrigation and fertilizer application on degraded soils.[214] Effective deployment of existing technologies for producing, processing and distributing food, as well as targeted development of new technologies, is critical to achieving food security.[215]

The vulnerability of smallholder farmers to food insecurity can be lowered through improvements in agricultural productivity and resilience to climate change and other threats.[216] This includes urban agriculture (for example, in community gardens, in private backyards, on rooftops and on vacant public land), which provides the majority of food for 800 million people in Asia and parts of Africa[217] and accounts for up to 15% of the world's food.[218] Increasing the efficiency and diversity of urban agriculture requires public and private initiatives to increase access to growing spaces with suitable soils.[219]

[204] IAASTD 2009.
[205] IAASTD 2009; World Bank 2008.
[206] Foresight 2011; MEA 2005.
[207] World Bank 2008.
[208] INRA/CIRAD 2011.
[209] Guillou and Matheron 2012.
[210] Guyomard et al. 2012.
[211] INRA/CIRAD 2011; Royal Society 2009.
[212] Nelson et al. 2011.
[213] Foresight 2011.
[214] Worldwatch 2011.
[215] IAASTD 2009; The Hague Conference 2010.
[216] Foresight 2011; INRA/CIRAD 2011.
[217] Worldwatch 2011.
[218] Lipper et al. 2010.
[219] IAASTD 2009; Worldwatch 2011.

Achieving food security requires ensuring adequate nutrition and encouraging healthy eating choices.
Photo: IRRI

Countries with low agricultural production are highly dependent on global food trade and are particularly vulnerable to spikes in hunger rates when food prices rise.[220] With large rural populations, widespread poverty, degraded natural resources, low agricultural productivity, high climatic risks and weak markets, South Asia and sub-Saharan Africa are home to most of the world's hungry.[221] Sustainable agriculture can be an important pathway for poor people, including women and other vulnerable groups, to secure access to food and increase their incomes.[222] Where economic and social constraints inhibit secure food access, mechanisms for social protection (see Recommendation 4) are essential.

Improvements in nutrition can be achieved through a variety of approaches. Diversification of small-scale production, improved crop varieties and biofortification of staple food crops hold promise for addressing micronutrient deficiencies.[223] Other health threats, such as biological hazards and chemical exposures (e.g. to pesticides, heavy metals, hormones or antibiotics), that can compound undernutrition can be addressed through government and civil society programmes to monitor and control public health and veterinary risks along the entire food chain.[224]

Policies and interventions designed to reduce undernourishment and undernutrition are hampered by weaknesses in measurement capacity and data systems as well as narrowly bounded mandates for national agencies (for example, where agriculture, hunger and poverty reduction are handled separately).[225] Robust knowledge systems and multisectoral approaches are critical given our increasingly globalized food system.[226]

Promote positive changes in the variety and quantity of diets through innovative education campaigns, which target young consumers especially, and through economic incentives that align the marketing practices of retailers and processors with public health and environmental goals.

The 'toolbox' for promoting sustainable diets includes economic interventions (e.g. taxation of specific food types), retailers' purchasing guidelines (e.g. to restrict consumer choices), public education campaigns (e.g. advertising and programmes in schools and workplaces) and labelling.[227] Agricultural and food policies (such as production subsidies, trade barriers, consumption taxes and food labelling requirements) are generally inconsistent in terms of promoting healthy, sustainable diets.[228] Policy objectives are more commonly focused on food quantity or price rather than dietary quality.[229] Research is needed to understand the impact and cost-effectiveness of a range of interventions on dietary behaviour among different socioeconomic groups.[230]

Lifestyle regulations are highly contested by consumers, producers and agribusinesses, therefore policy action is most likely to be directed towards improving food literacy and social marketing and information campaigns, as well as voluntary agreements with the private sector.[231] In lieu of regulatory approaches to change consumer behaviour, innovative education campaigns that are supported by appropriate incentives and champions may be effective in encouraging new social norms, especially those that target young consumers. In some countries, the potential of local councils, municipalities or states to educate the consumer can be tapped. Public sector incentives to distributors to provide food products that help consumers achieve their nutritional requirements represent another potential tool. In medium- and high-income countries, researchers should identify and describe successful examples of interventions resulting in healthier eating choices (e.g. school-based programming). By themselves, public information campaigns have frequently proven to be insufficient to induce diet shifts (for example, evaluations of the '5-a-day' fruit and vegetable campaigns in Europe and the USA show that guidelines are generally not followed due to a range of limitations including cost, time, cooking skills and family reluctance[232]), and new approaches must be developed that integrate private sector marketing and social networks more usefully.

[220] Worldwatch 2011.
[221] Vermeulen et al. 2012.
[222] Foresight 2011; World Bank 2008.
[223] Foresight 2011; IAASTD 2009; World Bank 2008.
[224] IAASTD 2009.
[225] Foresight 2011.
[226] IAASTD 2009.
[227] Foresight 2011.
[228] Guyomard et al. 2012.
[229] IAASTD 2009.
[230] Etiévant et al. 2010.
[231] Foresight 2011.
[232] Etiévant et al. 2010.

Case study 9: Public health messages promote healthy eating habits in France

Public policy can be used to change unhealthy eating habits. In France, concern about rising levels of childhood obesity and the influence of the fast food industry on consumption habits led the government to target food advertising. In 2004, France passed public health legislation requiring advertisements for processed food and drink containing added sugar, salt or artificial sweeteners to include health information.[233] Companies that did not include a public health message in advertisements were required to pay a levy of 1.5% of their advertising budget. The levies were channelled to the National Institute for Health Prevention and Education. A 2007 study confirmed the link between advertisements and children's eating habits, noting that 89% of all commercials during children's programmes were for products rich in sugar, fat or salt.[234] The study also found that 57% of children did not notice the health messages — usually flashed as a thin band on the screen or as a notice displayed after the advertisement — in advertisements on television and in the cinema. In 2007, the legislation was amended to require health messages to emphasize eating fruit and vegetables and avoiding snacking and eating too many foods high in fat, sugar or salt.

Food labelling can help promote healthy diets.
Photo: IJ Clark

The structure and dynamics of the current food system are significantly influenced by consumers' preferences and choices, both of which are constrained by cultural preferences and shaped by food industry marketing strategies. Social norms, values and behaviours often drive decisions and choice around investments, policy making and governance of the food system. Increased globalization of the trade in agricultural commodities has broadened exposure to different social behaviours, knowledge, practices, norms and values.

Individual consumption decisions are anchored in the food environment and the family and community context.[235] However, supermarkets' share of the retail sector is increasing in many countries and they are powerful drivers of the food system, influencing both consumers' eating patterns and the supply requirements that they pass on to wholesalers and producers.[236]

Promote and support a coherent set of evidence-based sustainability metrics and standards to monitor and evaluate food security, nutrition and health, practices and technologies across supply chains, agricultural productivity and efficiency, resource use and environmental impacts, and food system costs and benefits. This should include providing consumers with clear labelling.

Consumers and civil society organizations concerned about and supportive of sustainable development have triggered private sector action on sustainability initiatives, voluntary standards and long-term supply chain security. Within the global market place there are various sets of standards relating to food safety and quality, sustainable production practices (such as organic) and social equity (e.g. Fairtrade). The proliferation of standards provides a rich base of knowledge and experience from which to work towards more holistic coverage of all environmental, social and governance issues in criteria and indicators. Rather than multiple private standards, there is a need for coherent global standards that apply across the private and public spheres.

Challenges in the development of sustainability metrics include achieving transparency and broad agreement (given variations in ethical values), identifying metrics with relevance for multiple scales of decision making in a globalized food system, defining metrics that accommodate less easily quantified values such as biodiversity, and producing aggregate indices despite enormous complexity. Improved, comprehensive metrics for GHG emissions in the global food system are particularly needed. These and other metrics must push towards standardization while relying on a diverse suite of existing databases.[237]

[233] Jolly R. 2011.
[234] Que Choisir. 2007.
[235] Guyomard et al. 2012.
[236] Reardon et al. 2008.
[237] Foresight 2011.

Case study 10: Standard certification informs consumer choices in the United States

National governments play a key role in certifying and enforcing food standards and labelling to ensure that consumers receive accurate information about the way in which agricultural products are grown and processed, their nutritional value and their environmental impact. From 1990 to 2010, sales of organic products in the United States grew from USD 1 billion to nearly USD 27 billion.[238] This made certification to verify the claims of organic producers essential. Organic labelling rules introduced by the United States Department of Agriculture (USDA) require that organic products, whether produced in the US or abroad, meet established standards. These standards include assurance that organic products are produced without antibiotics, pesticides, hormones or bioengineering, and that they adhere to criteria for soil and water conservation as well as animal welfare. Products must be certified as 95% or more organic to display the voluntary USDA organic sticker or 70% or more organic to be labelled 'made with organic ingredients'.[239] Individuals or companies that sell products with organic labels but do not meet USDA standards can be fined up to USD 10 000 for each violation. Cumbersome certification processes can exclude small-scale organic farmers, so USDA certification exempts producers with less than USD 5000 in organic sales (for example, farmers selling limited quantities at farmers' markets).

A small-scale farmer harvests organic greens, Virginia, USA
Photo: L Cheung (USDA)

A new public–private partnership, involving diverse actors in the global food system, should develop global standards based on the substantiation of sustainability and equity in food value chains. To ensure that sustainability metrics are relevant for policy and investment decision making, they will ideally account for both positive (e.g. livelihoods of smallholders) and negative (e.g. environmental degradation) measures associated with different forms of food production.[240]

[238] Organic Trade Association 2011. www.ota.com
[239] USDA 2011.
[240] Ibid.

Recommendation 6: Reduce loss and waste in food systems, targeting infrastructure, farming practices, processing, distribution and household habits

Overcoming the financial, managerial and technical limitations that drive food loss and waste in low-income countries has the potential to improve the livelihoods of many smallholder farmers who live on the margins of food insecurity. Efforts to lower food loss may increase the overall efficiency of food supply chains and thereby reduce unnecessary use of energy, water, fertilizer and land.[241] Raising awareness of food waste and promoting the use of efficiency strategies among food businesses, retailers and consumers will probably need to be targeted at specific economic and cultural characteristics.[242]

Reduction of post-harvest losses will require the necessary investments to support the development of: a) infrastructures for storage and cooling facilities in difficult climatic conditions; b) packaging, transportation and marketing; and c) efficient disease control and harvesting techniques. [243] Loss and waste at distribution and final consumption levels are driven by many factors, such as consumer behaviour, supply chain management, packaging and storage, climatic conditions and safety rules, as well as opportunities for recycling wasted food. For example, quality standards commonly result in the withdrawal of fruit and vegetables that are cosmetically imperfect. Reductions in these types of loss and waste may require more profound changes in food consumption patterns and more nuanced food safety regulations.[244] Major strategies include increasing the percentage used for human food, and redirecting waste food towards animal feed and energy production. The Rio+20 Earth Summit provides an opportunity to consider mechanisms for this.

In all sustainable agriculture development programmes, include research and investment components focusing on reducing waste, from production to consumption, by improving harvest and postharvest management and food storage and transport.

Although waste reduction captures only a small fraction of agricultural research investments,[245] there has been progress in identifying the causes of loss for key crops as well as the development of many practical post-harvest technologies for reducing loss. Priorities for technical research include:

- integrated crop management systems that maximize yield without sacrificing quality;
- cultivars with good flavour, nutritional quality and long post-harvest life, with special emphasis on the physiology and handling of 'minor' and indigenous crops;
- optimal post-harvest handling for quality and safety (i.e. avoiding chemical and microbial contamination); and
- documentation of costs and financial benefits of post-harvest technologies.[246]

Most effective technological advancements in production, harvesting, and post-harvest handling systems will be made through interdisciplinary teams composed of producers, researchers and extension personnel with expertise across plant biology, engineering, agricultural economics, food processing, nutrition, food safety and environmental conservation.[247]

Public and donor financing should be directed towards locally relevant infrastructure improvements within a well-conceived model for reducing food loss and waste. These improvements may include the development of roads, energy sources, markets and infrastructure for storage, packing and transport (e.g. cold chain facilities), which can provide the foundation for subsequent private sector investments.[248] The most promising investments for food loss and waste reduction will address improved packaging to extend transport, storage and shelf life and low-technology and low-fuel innovations (e.g. low-cost sensor technology to detect spoilage in perishable foods).[249]

Better processing and storage can help reduce food waste.
Photo: IRRI

[241] Gustavsson et al. 2011.
[242] Ibid.
[243] Guyomard et al. 2012.
[244] Ibid.
[245] Foresight 2011.
[246] Kitinoja et al. 2011.
[247] Ibid.
[248] Foresight 2011; Gustavsson et al. 2011.
[249] Foresight 2011.

Case study 11: Kenyan smallholders have improved market access and production efficiency

Poverty among smallholder dairy producers results, in part, from poor access to markets and degradation of grasslands. More efficient production and more opportunities to market their produce can boost smallholders' resilience and create sustainable livelihoods while helping to meet growing demand for food. The East Africa Dairy Development Project is a regional industry development programme implemented in Kenya, Uganda and Rwanda by Heifer International and a consortium of partners that includes the International Livestock Research Institute, the World Agroforestry Centre, TechnoServe and Nestlé.[250] Funded by the Bill and Melinda Gates Foundation, the project enhances services and training to boost farm yields and the incomes of millions of smallholders in East Africa. The project, modelled on the 'hub' concept, increases access to markets and reduces post-harvest losses. Twenty-seven collection hubs that will store and chill milk are being developed. These will be managed by new business associations. Smallholders will receive training in business and production, such as improved breeding technologies and animal nutrition practices, to improve the quality of their milk.

Better systems for collecting and storing milk can help smallholder dairy farmers access markets and boost income
Photo: Gates Foundation

[250] www.eadairy.wordpress.com

Investments in capacity building can address a broad array of needs for reducing food loss and waste including technical knowledge on handling practices, access to tools and supplies, and information about costs and benefits. Formal training and extension programmes for post-harvest loss reduction should include appropriate follow-up to ensure that equipment, local support and other requirements are in place.[251] Extension activities would benefit from central sites within each country for conducting adaptive, locally relevant post-harvest research and extension programmes (e.g. demonstrations and hands-on training) as well as for engaging marginalized agricultural producers, especially women.[252] Scientific and technical training programmes should be designed to increase the number and calibre of people supporting post-harvest and food supply chain technologies in rural and urban areas in low-income countries.[253] This includes the capacity to produce, handle and store food, using good agricultural and hygienic practices, in compliance with food safety standards.[254]

There is a range of opportunities for reducing consumer and food service sector waste in middle- and high-income countries using public campaigns, advertising, taxes, regulation, purchasing guidelines and improved labelling.[255] However, a more robust knowledge base is needed urgently, including better monitoring of the amount, quality and causes of food waste and losses across supply chains.[256] Improved understanding of the sociological dimensions of food consumption in different cultural and economic settings, including home food management (e.g. food waste and energy consumption in culinary processes), is important for designing effective education campaigns.[257] Policy development and private sector innovation will benefit from greater clarity about the sources of commercial or market advantages for food companies that implement waste reduction strategies and the role of public pressure in catalysing change within those companies and commodity supply chains.[258]

Develop integrated policies and programmes that reduce waste in food supply chains, such as economic innovation to enable low-income producers to store food during periods of excess supply and obligations for distributors to separate and reduce food waste.

Improved connectivity of agricultural producers to each other and to markets and consumers can facilitate a reduction in food loss by optimizing production and distribution. Market cooperatives can reduce loss by increasing the efficiency of

[251] Kitinoja et al. 2011.
[252] Ibid.
[253] Foresight 2011.
[254] Gustavsson et al. 2011.
[255] Foresight 2011; IAASTD 2009.
[256] Gustavsson et al. 2011.
[257] Guyomard et al. 2012.
[258] Ibid.

Traditional maize storage in Yunnan, China. Reduction of post-harvest losses will require investments to support climate-resilient food storage facilities
Photo: Eloise Phipps (CIMMYT)

assembling and transporting food products from smallholders' farms and can also foster crop diversification and improved market facilities.[259] Cooperation and sharing of surplus crops across farms can reduce the incentive for farmers to overproduce as a risk management strategy — and therefore lower the resulting food waste.

Enhanced links between smallholders and regional and international food chains can improve consistency and quality of food supply and provide better returns on investment, with farmers better able to meet market requirements and reduce seasonal overproduction and wastage. This can be facilitated by using communication technologies such as mobile phones to access information about market prices as well as information critical to efficient production (e.g. weather forecasts and details of locally appropriate crop varieties and agricultural practices).[260]

Public sector initiatives to facilitate private sector investment should encourage agribusinesses to also invest in capacity building among agricultural producers in order to achieve efficient long-term supply.[261] Where agricultural producers have reliable access to domestic and international markets and an enabling local environment, food loss reduction strategies may allow those producers to enhance their incomes by selling their products under certification standards or other supply chain incentives.[262] Innovative approaches to increase farmers' access to credit (e.g. using crop inventory as collateral, or the pooling of cash crops or animals among smallholders) may be needed to cover associated capital costs.[263]

[259] Gustavsson et al. 2011.
[260] Foresight 2011.
[261] Gustavsson et al. 2011.

Promote dialogue and convene working partnerships across food supply chains to ensure that interventions to reduce waste are effective and efficient (for example, redirecting food waste to other purposes), and do not create perverse incentives.

Food system activities encompass the production, processing, distribution and consumption of food. Poor coordination among actors in increasingly globalized food supply chains encourages food loss and waste. Many food items are produced, transformed and consumed in very different parts of the world, and, across supply chains, the level of connectivity between producers and consumers varies enormously. Importantly, the relationship between globalization of the food system and food loss and waste is not well understood.[264]

Platforms are needed that allow producers, processors, retailers, consumers, regulators and governments to discuss the causes of food loss and waste and support experimentation with reduction strategies. For example, country-level working groups could collaborate domestically and regionally on strategies to reduce food loss and waste.[265] Partnerships among NGOs and food businesses could organize the collection and sale of waste food for use as animal feed or bioenergy feedstock. Farmers' markets and other direct marketing of farm products may reduce the levels of rejected crops, as farmers can safely bypass the strict quality standards applied to supermarkets and other retail settings.[266]

The food industry has significant potential to alter the food environment (e.g. advertising, labelling, marketing and packaging) to increase efficiency and reduce waste through innovative partnerships with government, researchers and consumer groups.[267] Consumer and retailer expectations and regulatory standards for food quality should be realigned to encompass food waste concerns. This could be achieved by using a combination of surveys and public health research, pilot programmes, public education campaigns and regulatory reviews.[268]

[262] Foresight 2011.
[263] Gustavsson et al. 2011; Worldwatch 2011.
[264] Gustavsson et al. 2011.
[265] Kitinoja et al. 2011.
[266] Gustavsson et al. 2011.
[267] Guyomard et al. 2012.
[268] Gustavsson et al. 2011.

Case study 12: The United Kingdom is reducing emissions and waste in food chains

Efforts to improve the environmental footprint of food systems can mobilize public–private partnerships. The Climate Change Act of 2008 commits the United Kingdom to an 80% economy-wide reduction in GHG emissions from 1990 levels by 2050. The agriculture industry's ambitious Greenhouse Gas Action Plan (GHGAP) aims to reduce annual emissions by 3 million tonnes CO_2-equivalent by 2018–2022 through the strategic delivery of messages, technical advice and information to agricultural producers in all farming sectors.[269] GHGAP builds on existing initiatives (for example, the Dairy Roadmap) and brings together whole supply chains to encourage the adoption of farm practices that are more efficient and reduce GHG emissions while enabling cost savings per unit of production and enhancing landscapes and biodiversity. Another UK initiative, the Waste and Resources Action Programme (WRAP) works with businesses, individuals and communities to reduce food waste. Household food and drink waste represents £12 billion in lost value and 20 million tonnes of CO_2-equivalent in emissions each year.[270] Research by WRAP focuses on ways to cut down the amount of food thrown away by consumers and covers consumer habits, attitudes and behaviours, appropriate ways of communicating to priority audiences and retail innovation. In partnership with WRAP, the grocery sector has made changes to make it easier for consumers to buy the right amount of food and to optimize freshness and value, as well as implementing large-scale consumer-facing campaigns (for example, Love Food Hate Waste). As a result, 670,000 tonnes of food waste have been diverted from landfills, saving £600 million a year.[271]

Efforts in the UK to reduce household food waste have made it easier for consumers to buy the right amount of food.
Photo: V. Meadu

[269] GHG emissions – agriculture's action plan. www.nfuonline.com/ghgap/
[270] Chapagain and James. 2011.
[271] www.wrap.org.uk.

Recommendation 7: Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions

Too often, policy, investment and management decisions are inadequately supported by appropriate evidence and analysis. There is generally a weak understanding among national policy makers of current and future agricultural constraints (i.e. the challenges of both climate and food security) and among global donors of the business case for better-directed investments. Underdevelopment of decision support tools that can evaluate the return on investment in resource allocation decisions fosters inaction or unintended outcomes.

Navigating towards a 'safe operating space' requires a place-specific understanding of potential benefits, trade-offs and limits, anchored in both human and ecological dimensions. Integrated information that covers all the critical issues requires observations to be compatible in time and space and to be measured and expressed in ways that are meaningful in many contexts. Many impacts, drivers and trade-offs occur on a regional or global scale, which means that information must be shared across sectors and nations.

The need for shared information in order to address global problems was recognized at the World Summit for Sustainable Development, leading to the formation of the Group on Earth Observations and the development of the Global Earth Observation System of Systems.[272] These and similar existing mechanisms pave the way to achieve an integrated system, but as yet do not adequately integrate biophysical and socioeconomic data. At the same time, sensor information and communication technologies are rapidly making the creation of such systems technically achievable. What is needed is a renewed commitment to this goal and sufficient resourcing to make it a worldwide reality.

Researchers measure the greenhouse gas emissions of rice production
Photo: N. Palmer (CIAT)

Sustain and increase investment in regular monitoring, on the ground and by public domain remote sensing networks, to track changes in land use, food production, climate, the environment, human health and well-being worldwide.

Regularly repeated and consistent remote sensing observations of land characteristics are vital to the management and improved understanding of the dynamics of agricultural land. This can be achieved by streamlining data from existing and planned earth-orbiting satellites to user communities. In addition, agriculturally relevant sensors should be included on upcoming satellite platforms. For example, advances are being made in the use of fine-scale satellite data for predicting the timing of pest population expansion; this can inform scouting efforts and pesticide applications.[273] The use of unmanned aerial vehicles should be expanded for targeted data acquisition.[274]

Limited availability of plot- and landscape-level data for long-term monitoring disadvantages decision making on local and farm scales as well as national policy making. This can be addressed through investment, development and introduction of new monitoring technologies to aid in the planning, management and maintenance of the world's food-, fibre-, feed- and fuel-producing land. For example, the efficiency of irrigation in agriculture can be increased through the use of sensors, models and wireless technology to integrate the spatial variability of soil water with crop sensitivity.[275]

Research institutions, with support from public and private sector partners, should renew their efforts to develop a global system of repeated observations of ecological and human systems at scales that are relevant to land management (e.g. smallholder agriculture).[276] Technical capabilities should be advanced (for example, the application of remote sensing methods to soil mapping and spatially explicit health and poverty observatories) and communicated through scientific meetings.

[272] Group on Earth Observations 2005. www.earthobservations.org

[273] Lensky and Dayan 2011.
[274] Xiang and Tian 2011.
[275] Greenwood et al. 2010.
[276] Beddington et al. 2012.

Taking carbon measurements in the tropical forest area in Colombia
Photo: N. Palmer (CIAT)

Support improved transparency and access to information in global food markets and invest in interlinked information systems with common protocols that build on existing institutions.

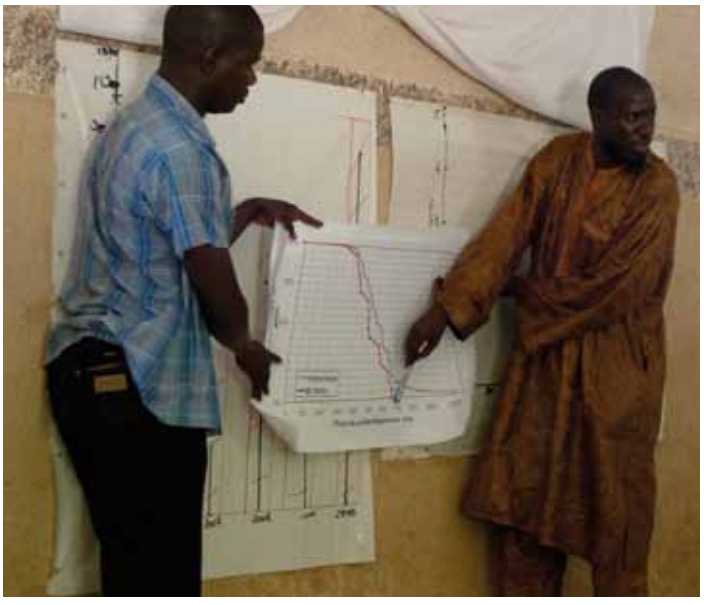
A more robust understanding of the interactive drivers of food price spikes will better enable effective interventions by those agencies responsible for national statistics, early warning and crisis response.[277] Excessive food price fluctuations can be addressed, in part, by sharing country information on production forecast and stocks, strengthening market databases, establishing early warning systems and allowing export for humanitarian assistance.

As part of their commitment to greater transparency for the physical agricultural and energy markets, the G20 created the Agriculture Market Information System (AMIS) database in September 2011. Housed at the FAO, AMIS is designed to coordinate data collection and analysis, improve the quantity and quality of information available on agricultural markets, especially stock levels and harvest forecasts, and help developing countries build their market analysis capacities. It will cover wheat, maize, rice and soya, which form the main agricultural output worldwide.

[277] Guillou and Matheron 2012.

Develop, validate and implement spatially explicit data and decision-support systems that integrate biophysical and socioeconomic information and that enable policy makers to navigate trade-offs among agricultural intensification, nutritional security and environmental consequences.

Integration of existing (and future) biophysical and social data to assist land managers and policy makers in decision making is critical to sustainable agriculture and food systems. Many existing data, information and knowledge assets exist, but they are underutilised. Novel frameworks are needed to assimilate these resources and incorporate them into decision-making pathways. Satellite and in situ sensors can be combined to provide real-time geospatial information (for example on vegetation productivity) through web-based delivery platforms.[278] Locally grounded input from stakeholders is critical in the design of these systems. Improved mechanisms to alert decision makers (e.g. 'situational awareness' for managing crises such as floods[279]) can incorporate geo-referenced information from both expert and citizen sources.[280] New farm management approaches are under development in which decision making relies on the integration of databases, recommended guidelines and documentation (e.g. the EU-funded Farm Information Management System).[281] Methods such as differential zone management can integrate farmer knowledge and spatial data to improve yields through more targeted, evidence-based management interventions.[282]



Farmers in Mali are benefiting from seasonal climate forecasts. Good climate information can help farmers prepare for the season ahead
Photo: J. Hansen (CCAFS)

[278] Kooistra et al. 2009.
[279] Lienert et al. 2011.
[280] De Longueville et al. 2010.
[281] Sørensen et al. 2010.
[282] Oliver et al. 2010.

Case study 13: Australian initiatives and information services support adaptive agriculture

Real-time information and forecasting for rainfall, temperature, humidity and drought are critical to successful climate change adaptation and mitigation in agriculture. In Australia, these challenges need to be undertaken in the most variable climate of any inhabited continent. For example, the El Niño Southern Oscillation drives cycles of drought and flood that significantly affect the rural sector. Australian agriculture, including land clearing, accounts for at least 25% of the country's GHG emissions (similar to the global average), creating the combined imperative of reducing GHG emissions by 50–80% by 2050 while increasing food production by 30–80%. Australia's Carbon Farming Initiative is the world's first national legislation for land-based mitigation and rural income enhancement. To support adaptive agriculture and 'carbon farming' by Australian producers, the Bureau of Meteorology (BoM) provides seasonal climate outlooks with detailed forecasts and risk assessments, including a three-month prediction based on the Troup Southern Oscillation Index and a six-month El Niño Southern Oscillation prediction . In addition, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the BoM provide longer-term climate projections to help farmers prepare for future changes. In some areas, such as southwest Australia, climate projections are already an important tool for farmers forced to change their farming practices in response to changing climatic conditions. The initiatives are supported by Australia's Farming Future programme, which provides information, funding, training and support to help farmers adapt to climate change, including grants targeted at women farmers and 'next generation' farmers.

Carbon-rich agricultural landscape, Tasmania, Australia
Photo: M Castley, Private Forests Tasmania

Biophysical knowledge (on agriculture, forestry, fisheries and climate change) should be harmonized with socioeconomic and policy contexts to provide regionally differentiated and prioritized adaptation and mitigation options that address associated trade-offs. Multilateral agencies (such as the FAO, CGIAR and Earth System Science Partnership (ESSP)) can take the lead in harmonizing rules for national accounting of land sector GHG emissions.

Investments in increasing data access and integrated analysis, with input from actors across the supply chain, can help to clarify the types and magnitude of risk over the short and long term (e.g. national climate change risk assessments to understand risks for the agriculture sector). It will be important to document the return on investment of creating platforms for integrating existing data streams to better understand their value and direct future developments.

Photo: N. Palmer (CIAT)

Chapter V: Conclusion

Over the course of the 21st century, the world will need to produce significantly more food in order to deliver a basic, but adequate, diet to everyone. The amount of food required will be even greater if current trends in diets and the existing management regimes of food systems continue. Concurrent efforts are needed to establish a sustainable global food system with climate-resilient agricultural production systems, efficient use of resources, improved marketing and distribution infrastructure, low-waste supply chains, and more consumer choice for healthy diets. Intensification of agricultural production must be accompanied by concerted action to reduce greenhouse gas emissions from agriculture to avoid further acceleration of climate change and avert threats to the long-term viability of global agriculture. Making these changes, although technically feasible, requires urgent, collective and substantially increased action internationally, nationally, locally and individually.

Based on robust scientific evidence from the recent assessment reports on global food security, the Commission on Sustainable Agriculture and Climate Change has identified critical leverage points and proposes the following evidence-based actions to deliver long-term benefits to communities in all countries.

1. Integrate food security and sustainable agriculture into global and national policies

- Establish a work programme on mitigation and adaptation in agriculture in accordance with the principles and provisions of the United Nations Framework Convention on Climate Change (UNFCCC), based on Article 2, as a first step to inclusion of agriculture in the mainstream of international climate change policy.
- Make sustainable, climate-friendly agriculture central to Green Growth and the Rio+20 Earth Summit.
- Finance 'early action' to drive change in agricultural production systems towards increasing resilience to weather variability and shocks, while contributing significantly to mitigating climate change. This includes supporting national climate risk assessments, developing mitigation and adaptation strategies, and programme implementation.
- Develop common platforms at global, regional and national levels for coherent dialogue and policy action related to climate change, agriculture, crisis response and food security, at global, regional and national levels. These include fostering country-level coalitions for food security and building resilience, particularly in countries most vulnerable to climate shocks.

2. Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade

- Implement and strengthen the existing G8 L'Aquila programmes and commitments to sustainable agriculture and food security, including long-term commitments for financial and technical assistance in food production and to empower smallholder farmers.
- Enable UNFCCC Fast Start funding, major development banks and other global finance mechanisms to prioritize sustainable agriculture programmes that deliver food security, improved livelihoods, resilience to climate change and environmental co-benefits. Such programmes should emphasize improving infrastructure and land rehabilitation.
- Adjust national research and development budgets, and build integrated scientific capacity, to reflect the significance of sustainable agriculture in economic growth, poverty reduction and long-term environmental sustainability, and focus on key food security issues (for example, developing nutritious non-grain crops and reducing postharvest losses).
- Increase knowledge of best practices and access to innovation by supporting revitalized extension services, technology transfer and communities of practice (for example, North-South, South-South, cross-commodity and farmer-to-farmer exchanges), with emphasis on low- to high-income countries and on women farmers.

3. Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture

- Develop, facilitate and reward multi-benefit farming systems that enable more productive and resilient livelihoods and ecosystems, with emphasis on closing yield gaps and improving nutrition.
- Introduce strategies for minimizing ecosystem degradation and rehabilitating degraded environments, with emphasis on community-designed programmes.
- Empower marginalized food producers (particularly women) to increase productivity of a range of appropriate crops by strengthening land and water rights, increasing access to markets, finance and insurance, and enhancing local capacity (for example through farmer and community-based organizations).
- Identify and modify subsidies (such as for water and electricity) that provide incentives for farmers to continue agricultural practices that deplete water supplies or destroy native ecosystems. Introduce compensation schemes that target the poor.
- Couple economic incentives for sustainable intensification of agriculture with strengthening governance of land tenure and land zoning to prevent further loss of forests, wetlands and grasslands.

4. Develop specific programmes and policies to assist populations and sectors that are most vulnerable to climate changes and food insecurity

- Develop funds that respond to climate shocks, such as 'index-linked funds' that provide rapid relief when extreme weather events affect communities, through public-private partnerships, based on agreed principles.
- Moderate excessive food price fluctuations by sharing country information on production forecasts and stocks, strengthening market databases, promoting open and responsive trade systems, establishing early warning systems and allowing tax-free export and import for humanitarian assistance. This includes embedding safeguards related to import surges and trade distortions in trade agreements.
- Create and support safety nets and other programmes to help vulnerable populations in all countries become food secure (for example, cash and in-kind transfers, employment guarantee schemes, programmes to build resilience, health and nutrition, delivery of education and seeds of quick growing foods in times of famine).
- Establish robust emergency food reserves and financing capacity that can deliver rapid humanitarian responses to vulnerable populations threatened by food crises.
- Create and support platforms for harmonizing and coordinating global donor programmes, policies and activities, paying particular attention to systematically integrating climate change risk management, adaptation and mitigation co-benefits, and improved local nutritional outcomes.

5. Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating patterns worldwide

- Address chronic undernutrition and hunger by harmonizing development policy and coordinating regional programmes to improve livelihoods and access to services among food-insecure rural and urban communities.
- Promote positive changes in the variety and quantity of diets through innovative education campaigns, which target young consumers especially, and through economic incentives that align the marketing practices of retailers and processors with public health and environmental goals.
- Promote and support a coherent set of evidence-based sustainability metrics and standards to monitor and evaluate food security, nutrition and health, practices and technologies across supply chains, agricultural productivity and efficiency, resource use and environmental impacts, and food system costs and benefits. This should include providing consumers with clear labelling.

6. Reduce loss and waste in food systems, targeting infrastructure, farming practices, processing, distribution and household habits

- In all sustainable agriculture development programmes, include research and investment components focusing on reducing waste, from production to consumption, by improving harvest and postharvest management and food storage and transport.
- Develop integrated policies and programmes that reduce waste in food supply chains, such as economic innovation to enable low-income producers to store food during periods of excess supply and obligations for distributors to separate and reduce food waste.
- Promote dialogue and convene working partnerships across food supply chains to ensure that interventions to reduce waste are effective and efficient (for example, redirecting food waste to other purposes), and do not create perverse incentives.

Photo: S. Mann (ILRI)

7. Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions

- Sustain and increase investment in regular monitoring, on the ground and by public domain remote sensing networks, to track changes in land use, food production, climate, the environment, human health and well-being worldwide.
- Support improved transparency and access to information in global food markets and invest in interlinked information systems with common protocols that build on existing institutions.
- Develop, validate and implement spatially explicit data and decision-support systems that integrate biophysical and socioeconomic information and that enable policy makers to navigate trade-offs among agricultural intensification, nutritional security and environmental consequences.

There is no room for delay on integrated, strategic policy action that confronts the difficult trade-offs facing the global food system and sets a new course toward long-term sustainability. Only by implementing these real changes across the global food system will food security for the world's most vulnerable populations and a stable climate for the long term be achievable. This will require a break from business as usual and a significant shared commitment by policy makers, investors, agricultural producers, consumers, food companies and researchers. These recommendations point the way forward for such investment and innovation in support of an adaptive, efficient and secure global food system.

References

Agriculture: A call to action for COP17 climate change negotiators. Open letter from Agriculture and Rural Development Day, 3 December 2011. www.agricultureday.org/openletter.

Africare, Oxfam America, WWF-ICRISAT Project. 2010. *More rice for people: more water for the planet, system of rice intensification (SRI)*. Hyderabad, India: WWF-ICRISAT Project.

Angelsen A. 2010. Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academies of Science* 107(46): 19639–19644.

Bai ZG, Dent DL, Olsson L, Schaepman ME. 2008. *Global assessment of land degradation and improvement identification by remote sensing*. Wageningen: International Soil Reference and Information Centre (ISRIC).

Barrett CB, Barnett BJ, Carter MR, Chantarat S, Hansen JW, Mude AG, Osgood D, Skees JR, Turvey CG, Ward MN. 2007. *Poverty traps and climate risk: limitations and opportunities of index-based risk financing*. IRI Technical Report No. 07-02. Columbia University: International Research Institute for Climate and Society (IRI).

Beddington JR, Asaduzzaman M, Clark ME, Fernández Bremauntz A, Guillou MD, Howlett DJB, Jahn MM, Lin E, Mamo T, Negra C, Nobre CA, Scholes RJ, Van Bo N, Wakhungu J. 2012. What next for agriculture after Durban? *Science* 335: 289–290.

Bellarby J, Foereid B, Hastings A, Smith P. 2008. *Cool farming: climate impacts of agriculture and mitigation potential*. Amsterdam: Greenpeace International. www.greenpeace.org/international/en/publications/reports/cool-farming-full-report/

Bruinsma J. 2009. *The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050?* Expert Meeting on How to Feed the World in 2050. Rome: Food and Agriculture Organization of the United Nations.

Cabinet Office. 2008. *Food matters: a strategy for the 21st century*. London: Cabinet Office.

Chapagain A, James K. 2011. *The Water and Carbon Footprint of Household Food Waste in the UK. Banbury, UK: Waste & Resources Action Programme*.

Chen J. 2007. Rapid urbanization in China: A real challenge to soil protection and food security. *Catena* 69(1): 1–15.

Chen KZ, Zhang T. 2011. *Foresight Project on Global Food and Farming Futures. Regional case study R2: agricultural R&D as an engine of productivity growth: China*. London: Foresight, Government Office for Science. www.bis.gov.uk/assets/bispartners/foresight/docs/food-and-farming/regional/11-591-r2-agricultural-r-and-d-productivity-growth-china.pdf. Conversion at interbank rates of 15 June 2007 at www.oanda.com.

Choudhury ML. 2006. Recent developments in reducing post-harvest losses in the Asia-Pacific region. In: Rolle RS, ed. *Reports of the APO Seminar on Reduction of Postharvest Losses of Fruit and Vegetables, October 2004*. Tokyo: FAO, Asian Productivity Organization (APO). pp 5–11.

Cline WR. 2007. *Global warming and agriculture: impact estimates by country*. Washington, DC: Peterson Institute. http://maps.grida.no/go/graphic/projected-agriculture-in-2080-due-to-climate-change

Combris P. 2006. Le poids des contraintes économiques dans les choix alimentaires. *Cahiers de Nutrition et de Diététique* 41(5): 279–284.

De Longueville B, Annoni A, Schade S, Ostlaender N, Whitmore C. 2010. Digital earth's nervous system for crisis events: real-time sensor web enablement of volunteered geographic information. *International Journal of Digital Earth* 3(3): 242–259.

Etilé F. 2010. Food consumption and health. In: Lusk J, Roosen J, Shogren J, eds. *Oxford handbook of the economics of food and agricultural policy*. Oxford: Oxford University Press.

Etiévant P, Bellisle F, Dallongeville J, Etilé F, Guichard E, Padilla M, Romon-Rousseaux M. 2010. Dietary behaviours. What factors come into play? What action, for what result? Collective scientific expertise, INRA (Paris). www.international.inra.fr/the_institute/scientific_expertise/expert_reports/dietary_behaviours

FAO Country Profiles. China: food safety and security. www.fao.org/countryprofiles/index.asp?lang=en&iso3=CHN&paia=2

FAO Country Profiles. France: food safety and security. www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/country_profiles/eng/France_E.pdf

FAO Country Profiles. South Africa: food safety and security. www.fao.org/countryprofiles/index.asp?lang=en&iso3=ZAF&paia=2

FAO. 2006. *World agriculture: towards 2030/2050. Prospects for food, nutrition, agriculture and major commodity groups*. Interim Report. Rome: Global Perspective Studies Unit, Food and Agriculture Organization of the United Nations.

FAO. 2009a. *How to feed the world in 2050*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2009b. *The state of agricultural commodity markets. High food prices and the food crisis—experiences and lessons learned*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2010. *The state of food insecurity in the world: addressing food insecurity in protracted crises*. Rome: Food and Agriculture Organization of the United Nations. www.fao.org/docrep/013/i1683e/i1683e.pdf

FAO. 2011a. *The state of the food insecurity in the world: how does international price volatility affect domestic economies and food security?* Rome: Food and Agriculture Organization of the United Nations.

FAO. 2011b. *State of the world's forests*. Rome: Food and Agriculture Organization of the United Nations.

FAO/OECD. 2011. *Price volatility in food and agricultural markets: policy responses*. Policy report coordinated by FAO and OECD including contributions by IFAD, International Monetary Fund, UNCTAD, WFP, the World Bank, the WTO, International Food Policy Research Institute and the UN High-Level Task Force. Rome: Food and Agriculture Organization of the United Nations.

FAOSTAT. Mexico. http://faostat.fao.org/site/666/default.aspx

Foley JA et al. 2011. Solutions for a cultivated planet. *Nature* 478: 337–342.

Foresight. 2007. *Tackling obesities: future choices*. 2007. Project report. London: Government Office for Science.

Foresight. 2011. *Migration and global environmental change: future challenges and opportunities*. Final project report. Futures. London: Government Office for Science.

Foresight. 2011. *The future of food and farming*. Final project report. Futures. London: Government Office for Science.

Fuchs A, Wolff H. 2011. Concept and unintended consequences of weather index insurance: the case of Mexico. *American Journal of Agricultural Economics* 93(2): 505–511.

GHG emissions—agriculture's action plan. www.nfuonline.com/ghgap/

Gilligan DO, Hoddinott J, Kumar NR, Taffesse AS. 2008. *An impact evaluation of Ethiopia's productive safety nets program*. Washington, DC: International Food Policy Research Institute (IFPRI).

Global Science Conference on Climate-Smart Agriculture. 2011. *The Wageningen Statement: Climate-Smart Agriculture—Science for Action*. Ede/Wageningen, The Netherlands, 24–26 October 2011. www.gscsa2011.org/LinkClick.aspx?fileticket=eDIto5l7EoE%3d&tabid=2871

Gouin D. 2006. *Agricultural sector adjustment following removal of government subsidies in New Zealand*. Lincoln, New Zealand: Agribusiness and Economics Research Unit, Lincoln University. www.lincoln.ac.nz/Documents/2332_Report284_s6505.pdf

Government of the People's Republic of Bangladesh. 2011. *Bangladesh Country Investment Plan: a road map towards investment in agriculture, food security and nutrition*. Updated version June 2011. www.nfpcsp.org/agridrupal/sites/default/files/Bangladesh%20Food%20security%20CIP%202011%20Final.pdf

Greenwood DJ, Zhang K, Hilton W, Thompson AJ. 2010. Opportunities for improving irrigation efficiency with quantitative models, soil water sensors and wireless technology. *Journal of Agricultural Science* 148: 1–16.

Group on Earth Observations. 2005. *Global Earth Observation System of Systems (GEOSS): 10-year implementation plan reference document*. Noordwijk, The Netherlands: European Space Agency Publications Division.

Guillou M, Matheron G. 2012. *The world's challenge: feeding 9 billion people*. Versailles: Editions Quae.

Gustavsson et al. 2011. *Global food losses and food waste*. Rome: Food and Agriculture Organization of the United Nations. www.fao.org/fileadmin/user_upload/ags/publications/GFL_web.pdf

Guyomard H, Darcy-Vrillon B, Esnouf C, Marin M, Momot A, Russel M, Guillou M. 2012. *Eating patterns and food systems: critical knowledge requirements for policy design and implementation*. Paris: INRA. In preparation for *Agriculture and Food Security*.

Hajkowicz S, Negra C, Barnett P, Clark M, Harch B, Keating B. 2012. *Food price volatility and hunger alleviation: Knowledge requirements for policy design*. Canberra: CSIRO. In preparation for *Agriculture and Food Security*.

Havemann T, Muccione V. 2011. *Mechanisms for agricultural climate change mitigation incentives for smallholders*. CCAFS Report No. 6. Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). www.ccafs.cgiar.org

Hazell PBR, Pomerada C, Valdes A, eds. 1986. *Crop insurance for agricultural development: issues and experience*. Washington, DC: International Food Policy Research Institute.

Hess U, Hazell P. 2009. *Innovations in insuring the poor. Sustainability and scalability of index-based insurance for agriculture and rural livelihoods*. 2020 Vision. Focus 17; Brief 5. Washington, DC: International Food Policy Research Institute.

HMG. 2010. *The 2007/2008 agricultural price spikes: causes and policy implications*. London: HM Government.

ICSU. 2010. *Regional environmental change: human action and adaptation*. Paris: International Council for Science (ICSU).

IFAD. 2011. *Rural poverty report: new realities, new challenges: new opportunities for tomorrow's generation*. Rome: International Fund for Agricultural Development.

IPCC. 2011. *Summary for policy makers: special report on managing the risks of extreme events and disasters to advance climate change adaptation*. Cambridge: Cambridge University Press.

IPCC. 2012. Summary for policy makers. In: Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK, Tignor M, Midgley PM, eds. *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. Pp 1–19.

INRA/CIRAD. 2011. *Agrimonde: scenarios and challenges for feeding the world in 2050*. Versailles: Editions Quae.

International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). McIntyre BD, Herren HR, Wakhungu J, Watson RT, eds. 2009. *Agriculture at a crossroads: a synthesis of the global and sub-global IAASTD reports*. Washington, DC: Island Press.

Jolly R. 2011. *Junk food, advertising and kids*. Research Paper No. 9 2010–2011. Canberra: Parliament of Australia Parliamentary Library. www.aph.gov.au/library/pubs/rp/2010-11/11rp09.htm#_Toc282609530

Kachika T. 2009. *Women's land rights in Southern Africa*. South Africa: Niza, ActionAid International. www.niza.nl/documenten/100129_womens_land_rights.pdf

Keating BA, Carberry PS. 2010. Sustainable production, food security and supply chain implications. *Aspects of Applied Biology* 102: 7–20.

Kitinoja L, Saran S, Roy SK, Kader AA. 2011. Postharvest technology for developing countries: challenges and opportunities in research, outreach and advocacy. *Journal of the Science of Food and Agriculture* 91: 597–603.

Kooistra L, Bergsma A, Chuma B, de Bruin S. 2009. Development of a dynamic web mapping service for vegetation productivity using earth observation and in situ sensors in a sensor web based approach. *Sensors* 9: 2371–2388.

Laborte AG, de Bie K, Smaling EMA, Moya PF, Boling AA, Van Ittersum MK. 2011. Rice yields and yield gaps in Southeast Asia: past trends and future outlook. *European Journal of Agronomy* 36: 9.

Lambin EF, Meyfroidt P. 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academies of Science* 108(9): 3465–3472.

Lensky IM, Dayan U. 2011. Detection of fine-scale climatic features from satellites and implications for agricultural planning. *Bulletin of the American Meteorological Society*: 1131–1136.

Lienert C, Weingartner R, Hurni L. 2011. An interactive, web-based, real-time hydrological map information system. *Hydrological Sciences Journal – Journal des Sciences Hydrologiques* 56(1): 1–16.

Lipper L, Mann W, Meybeck A, Sessa R. 2010. *'Climate-smart' agriculture: policies, practices and financing for food security, adaptation and mitigation*. Rome: Food and Agriculture Organization of the United Nations.

Lobell DB et al. 2011. Climate Trends and Global Crop Production Since 1980. *Science* 333: 616-620.

Lundqvist J, de Fraiture C, Molden D. 2008. *Saving water: from field to fork—curbing losses and wastage in the food chain*. SIWI Policy Brief. Stockholm, Sweden: Stockholm International Water Institute.

Mahapatra R. 2010. *MGNREGA: making way for women's empowerment*. http://southasia.oneworld.net/fromthegrassroots/mgnrega-paving-way-for-women-empowerment

Meridian. 2011. *Addressing agriculture in climate change negotiations: a scoping report*. Dillon, Colorado: Meridian Institute.

Mhlanga N. 2010. *Private sector agribusiness investment in sub-Saharan Africa*. Rome: Food and Agriculture Organization of the United Nations.

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being. Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: synthesis*. Washington, DC: Island Press.

Mittal S. 2007. Strengthening backward and forward linkages in horticulture: some successful initiatives. *Agricultural Economics Research Review* 20: 457–469.

Moss R, Babiker M, Brinkman S, Calvo E, Carter T, Edmonds J, Elgizouli I, Emori S, Erda L, Hibbard K, Jones R, Kainuma M, Kelleher J, Lamarque J-F, Manning M, Matthews B, Meehl J, Meyer L, Mitchell J, Nakicenovic N, O'Neill B, Pichs R, Riahi K, Rose S, Runci P, Stouffer R, van Vuuren D, Weyant J, Wilbanks T, van Ypersele J-P, Zurek M. 2008. *Towards new scenarios for analysis of emissions, climate change, impacts, and response strategies. Technical summary*. Geneva: Intergovernmental Panel on Climate Change.

Munich Re Foundation. 2012. Geo Risks Research NatCatSERVICE. Natural catastrophes worldwide 2011. www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/annual_statistics.aspx

National Academy of Sciences. 2010. *Toward sustainable agricultural systems in the 21st century*. Washington, DC: The National Academies Press.

National Development and Reform Commission. 2009. *China's policies and actions for addressing climate change—The progress report 2009*. Beijing: National Development and Reform Commission. www.ccchina.gov.cn/WebSite/CCChina/UpFile/File571.pdf

Negra C, Wollenberg E. 2011. Lessons learned from REDD for agriculture. In: Wollenberg E et al, eds. *Climate change mitigation and agriculture*. London, UK: Earthscan.

Nelson GC, Rosegrant MW, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, Magalhaes M, Valmonte-Santos R, Ewing M, Lee D. 2009. *Climate change: impact on agriculture and costs of adaptation*. Washington, DC: International Food Policy Research Institute.

Nelson, GC, Rosegrant MW, Palazzo A, Gray I, Ingersoll C, Robertson R, Tokgoz S, Zhu T, Sulser TB, Ringler C, Msangi S, You L. 2011. *Climate change: impact on agriculture and costs of adaptation and food security, farming, and climate change to 2050*. Washington, DC: International Food Policy Research Institute.

Nguyen VT, Nguyen QT, Nguyen VA. 2007. *Influence of on farm water management to the methane emissions in the Red River Delta Area—Vietnam*. Vietnam National Commission on Large Dams.

OECD/FAO. 2011. *Agricultural outlook 2011–2020*. Paris: OECD Publishing.

Oliver YM, Robertson MJ, Wong MTF. 2010. Integrating farmer knowledge, precision agriculture tools, and crop simulation modelling to evaluate management options for poor-performing patches in cropping fields. *European Journal of Agronomy* 32: 40–50.

Paarlberg RL. 2002. *Governance and food security in an age of globalization*. Washington, DC: International Food Policy Research Institute.

Parry M, Evans A, Rosegrant MW, Wheeler T. 2009. *Climate change and hunger: responding to the challenge*. Rome: World Food Programme.

Périssé J, Sizaret F, François P. 1969. Effet du revenu sur la structure de la ration alimentaire. *Bulletin de Nutrition FAO* 7(3): 1–10.

Popkin BM. 2006. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with non-communicable diseases. *American Journal of Clinical Nutrition* 84(2): 289–298.

Pretty J, Sutherland WJ, Ashby A, Auburn J, Baulcombe D, Bell M, Bentley J, Bickersteth S, Brown K, Burke J, Campbell H, Chen K, Crowley E, Crute I, Dobbelaere D, Edwards-Jones G, Funes-Monzote FH, Godfray CJ, Griffon M, Gypmantisiri P, Haddad L, Halavatau S, Herren H, Holderness M, Izac A, Jones M, Koohafkan P, Lal R, Lang L, McNeely J, Mueller A, Nisbett N, Noble A, Pingali P, Pinto Y, Rabbinge R, Ravindranath NH, Rola A, Roling N, Sage C, Settle W, Sha JM, Shiming L, Simons T, Smith P, Strzepeck K, Swaine H, Terry E, Tomich TP, Toulmin C, Trigo E, Twomlow S, Kees Vis J, Wilson J and Pilgrim S. (eds). 2011. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability* 9(1): 5-24.

Prosser IP, ed. 2011. *Water: science and solutions for Australia*. Collingwood, Australia: CSIRO Publishing.

Que Choisir. 2007. *Obésité et publicités télévisées, quelles mesures de protection pour les enfants?* Dossier. Paris: UFC-Que Choisir. www.quechoisir.org/alimentation/nutrition/etude-obesite-et-publicites-televisees-quelles-mesures-de-protection-pour-les-enfants

Reardon T, Timmer CP, Barrett CB, Berdegué J. 2003. The rise in supermarkets in Africa, Asia, and Latin America. *American Journal of Agricultural Economics* 85: 1140–1146.

Rockstrom J, Steffen W, Noone K, Persson Å, Chapin III FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley JA. 2009. A safe operating space for humanity. *Nature* 461: 472–475.

Royal Society. 2009. *Reaping the benefits: science and the sustainable intensification of global agriculture*. London: The Royal Society.

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B, Irotenko O. 2007. Agriculture. In: Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA, eds. *Climate change 2007: mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Sørensen CG, Fountas S, Nash E, Pesonen L, Bochtis D, Pedersen SM, Bassoc B, Blackmore SB. 2010. Conceptual model of a future farm management information system. *Computers and Electronics in Agriculture* 72: 37–47.

Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C. 2006. *Livestock's long shadow. Environmental issues and options*. Rome: Food and Agriculture Organization of the United Nations.

The Hague Conference on Agriculture, Food Security and Climate Change. 2010. Chair's summary.

The Johannesburg Communiqué. 2011. *Africa: a call to action*. African Ministerial Conference on Climate-Smart Agriculture, Johannesburg, South Africa, 13–14 September 2011. http://climatechange.worldbank.org/sites/default/files/documents/CSACommunique14.09.11.pdf

Turral H, Burke J, Faurès J-M. 2011. *Climate change, water and food security*. FAO Water Report 36. Rome: Food and Agriculture Organization of the United Nations.

United Nations Convention to Combat Desertification. 2011. *Desertification: a visual synthesis*. Bonn: UNCCD Secretariat. www.unccd.int/knowledge/docs/Desertification-EN.pdf

United Nations. 2009. *World urbanization prospects*. New York: United Nations Department of Economic and Social Affairs.

United Nations Population Division. 2010. *World population prospects: the 2010 revision*. New York: United Nations Department of Economic and Social Affairs, United Nations Population Division. http://esa.un.org/wpp/unpp/panel_population.htm

United Nations. 2011. The Millennium Development Goals Report 2011. New York: United Nations.

UNCTAD. 2011. *Report of the Secretary-General of UNCTAD to UNCTAD XIII. Development-led globalization: towards sustainable and inclusive development paths*. New York and Geneva: United Nations.

USDA. 2011. *What does the 'organic' label really mean?* Brooklyn: US Department of Agriculture, Food and Drug Administration. http://usda-fda.com/articles/organic.htm

Vermeulen SJ, Aggarwal PK, Ainslie A, Angelone C, Campbell BM, Challinor AJ, Hansen JW, Ingram JSI, Jarvis A, Kristjanson P, Lau C, Nelson GC, Thornton PK, Wollenberg E. 2012. Options for support to agriculture and food security under climate change. *Environmental Science and Policy* 15: 136–144.

World Bank. 2008. World Development Report, 2008: Development and Agriculture. Washington, DC: The World Bank.

World Bank. 2010a. *The Hague Conference on Agriculture, Food Security and Climate Change Opportunities and Challenges for a Converging Agenda: country examples*. Conference edition. Washington, DC: The World Bank.

World Bank. 2010b. *World development report, 2010: development and climate change*. Washington, DC: The World Bank.

World Bank. 2010c. *Designing and implementing a rural safety net in a low income setting: lessons learned from Ethiopia's Productive Safety Net Program 2005–2009*. Independent Evaluation Group of the World Bank's assistance to social safety net. Washington, DC: The World Bank.

World Bank. 2011a. *Climate-smart agriculture: increased productivity and food security, enhancing resilience and reduced carbon emissions for sustainable development, opportunities and challenges for a converging agenda: country examples*. Washington, DC: The World Bank.

World Bank. 2011b. Food Price Watch. http://siteresources.worldbank.org/INTPOVERTY/Resources/335642-1210859591030/FPW_April2011.pdf

World Health Organization. 2011. *Obesity and overweight*. Factsheet No. 311. Geneva: World Health Organization. www.who.int/mediacentre/factsheets/fs311/en/

Worldwatch Institute. 2011. *State of the world: innovations that nourish the planet*. New York: WW Norton & Company.

WRAP. 2008. *The food we waste*. Banbury: Waste and Resources Action Programme.

Xiang H, Tian L. 2011. Development of a low-cost agricultural remote sensing system based on an autonomous unmanned aerial vehicle (UAV). *Biosystems Engineering* 108: 174–190.

Annex I: Sources of climate and agriculture finance

Adapted from Shames S; Scherr S. 2011. Blending climate and agriculture finance to support climate-smart landscapes. *EcoAgriculture Policy Focus No. 8. Washington, DC: EcoAgriculture Partners.*

Source	Description/funding level	Details
Climate finance		
Green Climate Fund (GCF)—financial mechanism of the UNFCCC	Pledges for the GCF and the associated 'fast start' financing have been made for USD 30 billion by 2012 and USD 100 billion a year by 2020, to be balanced between adaptation and mitigation.	Little clarity on distribution criteria, funding sources (e.g. public vs private) and level (i.e. only 8% of the promised USD 30 billion has been disbursed, in many cases drawing from development aid funds).
Climate Investment Funds (CIF)—administered by multilateral development banks	Manages USD 6.4 billion to support mitigation and adaptation in developing countries, but USD 4.1 billion of this is pledged to the Clean Technology Fund, which generally does not include land use. CIF has a Pilot Program for Climate Resilience (PPCR) and a Forest Investment Fund (FIP).	Many of the submitted projects to PPCR include agricultural and rural resilience components.
Reducing emissions from deforestation and forest degradation (REDD)	Potential for agriculture to be integrated into REDD projects supported by forest-related funds such as the Forest Carbon Partnership Facility (FCPF) and the UN-REDD Programme.	Little clarity on how FCPF or UN-REDD will address agriculture.
Global Environment Facility (GEF)	The GEF is expected to provide about USD 1.1 billion for mitigation projects from 2010 to 2014, and agriculture and sustainable land use is in one of the six objectives of the funding strategy.	Little clarity on funds committed to agriculture and sustainable land use.
Least Developed Country Fund (LDCF) and Adaptation Fund (AF)—linked to UNFCCC	LDCF and AF have distributed USD 220.5 million, representing the majority of financial support for the development of national adaptation programmes of action (NAPAs) and implementation of some adaptation projects.	18 of 25 projects for LDCF and 6 of 10 for AF focused on agriculture and food security, which will probably continue to be a primary focus.
Nationally appropriate mitigation actions (NAMAs)—linked to UNFCCC	These refer to voluntary actions pledged by developing countries to reduce their emissions, contingent on support from developed countries. Flexible design and implementation of NAMAs may make them more amenable to agriculture than the current carbon markets.	No formal definition for NAMAs. Most governments have not fully scoped their targets so it is difficult to estimate the size of the required funding (which will probably be too high for public sector funding alone).
Regulated carbon markets—clean development mechanism (CDM); European Union's Emissions Trading Scheme (EU-ETS)	In 2010, regulated markets had a total value of USD 124 billion, principally for energy projects. Land use sequestration projects are difficult to develop under the CDM and are banned from the EU-ETS. Most of the CDM 'agriculture' projects are renewable energy projects. New regulated markets (e.g. the US–Canada Western Climate Initiative and Australia) could potentially include land use carbon credits.	Weak demand is projected for agriculture projects in carbon emission offset markets in the short term (pre-2015). Little clarity on whether new markets will support international offsets in the short term.

Source	Description/funding level	Details
Voluntary carbon markets	In 2010, voluntary carbon markets had a total value of USD 424 million (0.2% of all carbon offset markets). About USD 208 million worldwide was used for land use carbon projects (49% of the total): USD 13 million for agricultural soil management; USD 8.5 million for livestock projects; USD 25 million for afforestation and reforestation projects; and USD 123 million attributed to REDD (including agroforestry).	Several standards have quantification methodologies for various types of land use; some include livelihood benefits as an explicit project objective.
Company supply chain standards on climate and climate certification	Global market demand for eco-certified agricultural products totalled approximately USD 56 billion in 2010. Sustainable commodity roundtables and the development of climate certifications (e.g. the Rainforest Alliance's climate module) are playing a growing role.	Some certification criteria have indirect climate benefits (e.g. improved soil management, use of shade trees) but very few are linked explicitly to climate.
Philanthropic funding by private foundations and international NGOs	Diverse investments in climate-smart agriculture are being made through partnerships between among foundations, national and international NGOs and farmer organisations.	
Mainstream agricultural finance		
Official development assistance (ODA)	In 1997–2007, an average of USD 33 billion per year was invested in developing country agriculture. From 2007/2008, USD 7.2 billion in ODA was directed to agriculture, with the majority going to sub-Saharan African and South and Central Asia.	To double agricultural production from 2005 to 2050, USD 9.2 trillion will be needed to maintain and expand capital stock across the agricultural supply chain (an average of USD 204 billion annually).
Foreign direct investment (FDI) and private domestic sources, including banks, microfinance, and companies in the agricultural supply chain	Total private financial sector investment in farmland and agricultural infrastructure ranges from USD 10 to 25 billion a year. FDI in agricultural production had reached USD 3 billion annually by 2007, and FDI for the entire agriculture value chain is over USD 40 billion per year.	Since 2001, as many as 227 million hectares of land in developing countries have been sold or leased to foreign investors.

Acronyms and abbreviations

ACTS	African Center for Technology Studies
AF	Adaptation Fund
AFD	Agence Française de Développement (French Development Agency)
AMIS	Agriculture Market Information System
ANAGSA	Aseguradora Nacional de la Agricultura y Ganadería
APRM	Agricultural Price Risk Management
ASAP	Adaptation for Smallholder Agriculture Programme
BCIP	Bangladesh Country Investment Plan
BoM	Bureau of Meteorology
CAADP	Comprehensive Africa Agriculture Development Programme
CAP	Common Agricultural Policy
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CDM	clean development mechanism
CGIAR	CGIAR is a global research partnership for a food secure future
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIF	Climate Investment Funds
COP17	17th Conference of the Parties to the United Nations Framework Convention on Climate Change
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ECOWAS	Economic Community of West African States
ESSP	Earth System Science Partnership
EU-ETS	European Union's Emissions Trading Scheme
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FDI	foreign direct investment
FIP	Forest Investment Fund
G20	Group of 20 Nations
GCF	Green Climate Fund
GDP	gross domestic product
GDPRD	Global Donor Platform for Rural Development
GEF	Global Environment Facility
GHG	greenhouse gas
GHGAP	Greenhouse Gas Action Plan
ICM	integrated crop management
IFAD	International Fund for Agricultural Development
INRA	Institut Scientifique de la Recherche Agronomique (French National Institute for Agricultural Research)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LDCF	Least Developed Country Fund
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NAMA	nationally appropriate mitigation action
NAPA	national adaptation programme of action
NGO	non-governmental organisation
NOGAMU	National Organic Agricultural Movement of Uganda
Norad	Norwegian Agency for Development Cooperation
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PPCR	Pilot Program for Climate Resilience
PSNP	Productive Safety Net Programme
R&D	research and development
REDD+	reducing emissions from deforestation and forest degradation (includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks)
SBSTA	Subsidiary Body for Scientific and Technical Advice of the United Nations Framework Convention on Climate Change
SRI	system of rice intensification
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WFP	World Food Programme
WRAP	Waste and Resources Action Programme
WTO	World Trade Organization

Achieving food security in the face of climate change

Final report

The Commission on Sustainable Agriculture and Climate Change was established by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) with support from the Global Donor Platform for Rural Development (GDPRD) to produce a clear and authoritative set of policy recommendations. The Commission brings together senior natural and social scientists working in agriculture, climate, food and nutrition, economics and natural resources in governmental, academic and civil society institutions in Australia, Brazil, Bangladesh, China, Ethiopia, France, Kenya, India, Mexico, South Africa, the United Kingdom, the United States and Vietnam. During 2011, the Commissioners undertook a synthesis of major assessment reports to clearly articulate scientific findings on the potential impact of climate change on agriculture and food security globally and regionally and to identify the most appropriate actions and pathways to achieve food security in the context of climate change. These include:

1. Integrate food security and sustainable agriculture into global and national policies
2. Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade
3. Sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture
4. Target populations and sectors that are most vulnerable to climate change and food insecurity
5. Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating habits worldwide
6. Reduce loss and waste in food systems, particularly from infrastructure, farming practices, processing, distribution and household habits
7. Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions

A Summary for Policy Makers and more information is available at
www.ccafs.cgiar.org/commission