Chapter 1
Managing Food Systems, Climate Change and Related Challenges to Ensure Sustainable Food Security: The Urgent Need of a Paradigm and Policy Shift

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Abstract Addressing the challenge of global food security in our era is strongly linked with other global issues, most notably climate change, population growth and the need to sustainably manage the world's rapidly growing demand for energy, land, and water. Our progress in ensuring a sustainable and equitable food supply chain will be determined by how coherently these long-term challenges are tackled. This will also determine our progress in reducing global poverty and achieving the Millennium Development Goals. The challenge is to deliver nutritious, safe and affordable food to a global population of over nine billion in the coming decades, using less land, fewer inputs, with less waste and a lower environmental impact. All this has to be done in ways that are socially and economically sustainable. In this paper, we try to analyze the different challenges affecting the global capacity to build a food system with the potential to enhance a sustainable food security. Actions needed to make such a paradigm and policy shift, in both developed and developing countries, have been demonstrated.

Keywords Food security • Climate change • Eating patterns • Adaptation • Natural resources • Food losses and waste

1.1 Introduction

Food is the most basic of all human needs and collective food security governance has been with us since the dawn of human society. Failure to perform it effectively has inevitably engendered social unrest. The riots in capital cities around the world

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in late 2007 are reminiscent of the hungry crowds that threatened the life of Roman Emperor Claudius in AD 51 and the bread riots that helped to spark off the French Revolution in 1789. History and common sense tell us that a functioning food system is an indispensable pillar of a stable economy and a society capable of reproducing itself. However, achieving a permanent food security has become increasingly complex. For most of the twentieth century, it was mainly focused on issues of agricultural production. Today access and ecological concerns are understood to be equally relevant. Food system needs to consider not only how food is produced but also how it is processed, distributed, and consumed. Food system and governance have become a complex web of processes and often overlapping or contradictory formal policies and regulations, complicated by unwritten rules and practices that are not subject to political oversight (McKeon 2011).

Thus, addressing the challenge of global food security in our era is strongly linked with other global issues, most notably climate change, population growth and the need to sustainably manage the world's rapidly growing demand for energy, land, and water. Our progress in ensuring a sustainable and equitable food supply chain will be determined by how coherently these long-term challenges are tackled. This will also determine our progress in reducing global poverty and achieving the Millennium Development Goals. The challenge is to deliver nutritious, safe and affordable food to a global population of over nine billion in the coming decades, using less land, fewer inputs, with less waste and a lower environmental impact. All this has to be done in ways that are socially and economically sustainable.

Within this perspective, the present chapter aims at analyzing the different challenges affecting the global capacity to build a food system with the potential to enhance a sustainable food security. Actions need to be taken to ensure food security, in both developed and developing countries, have been highlighted.

1.2 Food Systems, Climate Change and Other Challenges: The Unachieved Food Security

The European Commission President has stated on 2010, "*a world where one billion people are hungry is not just a deep stain on our collective conscience. It is a growing threat to global security. If the financial crisis has taught us anything, it is that, if we ignore risks building up in the system, it is much harder to manage them.... Like the fight against climate change, the fight against hunger cannot wait* . . .".

According to the 1996 World Food Summit "*food security at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO 1996). For Guyomard et al. (2011), this definition broadens the initial focus of the 1974 World Food Summit on the volume and stability of food supplies, by

including secured access for all people, especially the most vulnerable, to available supplies, and by incorporating food safety and nutritional balance. The 1996 definition also reflects concerns about food composition and nutrients requirements for an active and healthy life.

Food may be the staff of life, but affordable access to food and good nutrition is still a huge challenge in many parts of the world. Guyomard et al. (2011) indicates that global food is clearly – and increasingly – insecure. According to FAO figures (2010), 925 million people were undernourished and many people were affected by vitamin and mineral deficiencies – one out of three in developing countries according to Beddington et al. (2011). At the same time, 1.5 billion adults were overweight in 2008, including over 200 million obese men and nearly 300 million obese women (Beddington et al. 2011). In addition, a growing number of low and middle-income countries are facing a double burden of malnutrition, i.e., the persistence of under-nutrition, notably among children, along with a rapid rise in overweight and obesity, and diet-related chronic diseases.

On a planet with sufficient food for all, a billion people go hungry (FAO 2010) while another billion over-consume, increasing risks from chronic diseases (Foresight 2007). A number of causes contributed to the jump in the cost of food: low levels of world cereal stocks; crop failures in some major exporting countries and export restrictions in others; increased demand for meat in East Asia; rapidly growing demand for agricultural commodities for biofuels; and rising energy and agro-chemical prices. Although such dramatic price hikes have now relatively eased, prices still remain high in many developing countries despite record production. Worse, global food prices appear to be on the rise once again according to the latest FAO Food Price Indexes.

Global Food Security Challenges and Drivers

Some of the main drivers underlying the challenge of ensuring food security are summarized in brief in the following points.

- Global population growth, coupled with demographic change, increasing affluence and urbanization, will lead to growth in demand for food and changing patterns of demand – rising affluence is associated with increases in food consumption, especially of meat and dairy products. Much, but not all, of the expansion in population will occur in developing countries: improving food security (especially affordability, access and availability) is closely linked with the need to reduce poverty.
- Global climate and other environmental changes that will have direct or indirect impacts on food production and supplies include rising carbon dioxide and other GHGs, leading to rising temperatures, changing rainfall patterns and increasing incidence of extreme weather events (such as storms, floods, heat waves and droughts), rising sea level and ocean acidification. Changing climate may also lead to changes in the

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distribution and/or severity of pests and diseases (in crops and animals, including zoonotic infections where disease organisms transfer from vertebrate animals to humans) and has the potential for severe impacts on food production and animal welfare. As well as threats, changes in climate may offer new opportunities for food production in some parts of the world.

- Environmental impacts of farming and food: negative impacts can include increasing water and land use, soil erosion and degradation, loss of biodiversity, as well as GHG emissions and water pollution.
- Key resources for agriculture are limited, notably land, fresh water and energy, but also sources of other inputs such as mineral phosphate (an essential plant nutrient). Shortages of resources may be exacerbated by increasing competition, for example from urban and industrial development.
- Social drivers include urbanization, demographic change, issues of land tenure, governance and international security, changing patterns of consumer needs, preferences, choices, tastes, habits and practices affecting the demand for and consumption of different foods and patterns of waste.
- Economic drivers include issues of trade, land tenure, food markets and their volatility, supply and distribution, regulation, affordability and accessibility (particularly in the developing world) with associated globalization.
- There is a need to ensure adequate nutrition, including not only calories but all necessary macro- and micro-nutrients for healthy and balanced diets for populations throughout the world. At the same time as increasing numbers of people globally are inadequately fed, the over-consumption of high-calorie diets adds to the rising demand for food, with all the associated economic, social and environmental impacts.

Business as usual in our globally interconnected food system will not bring us food security and environmental sustainability. Several converging threats – from climate change, regional conflicts, population growth and unsustainable use of resources – are steadily intensifying pressure on humanity and world governments to transform the way food is produced, distributed and consumed (Beddington et al. 2011).

The food system faces additional pressure as the global population grows, to around nine billion by 2050 (United Nations Population Division 2010), and as diets shift towards higher consumption of calories, fats and animal products. 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,

Table 1.1 Status of selected global parameters

People in the world (updated on Dec. 2012)	7.06 billion
Undernourished people (2010)	0.9 billion
Overweight people over age 20 (2008)	1.5 billion
People living on less than USD 1.25 per day (2005)	1.4 billion
People living in dryland areas (2007)	2 billion
People dependent on degrading land	1.5 billion
Losses due to climatological events (extreme temperature, drought, forest fire) (2010)	USD 7.5 billion
Area of agricultural land (2009)	4.9 billion hectares
Area of croplands, pasture and grazing lands devoted to raising animals	3.7 billion hectares
Annual growth in world agricultural production (1997–2007)	2.2 %
Food produced for human consumption lost or wasted annually	1.3 billion tonnes

Source: Beddington et al. (2011)

migration to urban areas and across borders, and political and economic instability (Table 1.1).

Our climate is also changing and, given the levels of greenhouse gases (GHGs) already in our atmosphere, will continue to do so. In the coming decades, global climate change will have an adverse overall effect on agricultural production and will bring us toward, 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, it's believed that nations must greatly increase their adaptive capacity in agriculture – both to long-term climatic trends and to increasing variability – as an urgent political priority.

Within this global context, many scientists have endeavoured to identify pathways to achieving food security in the context of climate change. Many believe that food systems must shift to better meet human needs and, in the long term, balance with planetary resources. This will demand major interventions, from local to global scales, to transform current patterns of food production, distribution and consumption. Investment, innovation, and 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 greenhouse gas emissions and sustaining our natural resource base. Greatly expanded investments in sustainable agriculture, including improving supporting infrastructure and restoring degraded ecosystems, are an essential component of long-term economic development. The sooner they are made, the greater the benefits will be (Beddington et al. 2011).

Over the course of the twenty first 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 management of food systems continue. However, food security is not just about supply matching demand. The development of agricultural and food systems must be viewed in the context of sustainability. It must take into account the progressive

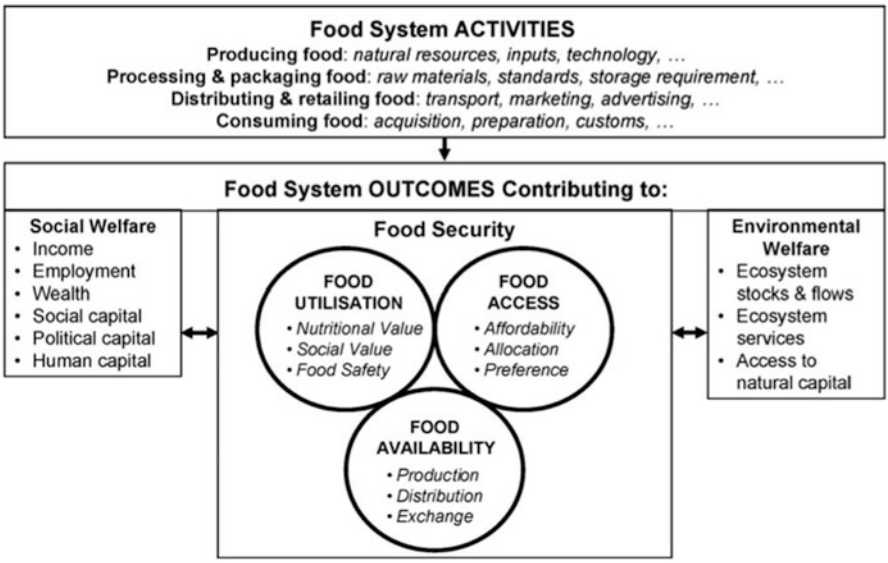

Fig. 1.1 Food system concept (Source: Editorial 2009)

depletion of fossil energy, the protection of soil and water resources, the preservation of biodiversity and the issue of climate change. If they are to feed more than nine billion by 2050, farmers around the world will have to produce crops using less fossil fuel in an environmentally friendly way. They will also have to provide energy and industrial commodities in place of petrochemical products, as well as environmental and rural services like water management, biodiversity protection, carbon sequestration, or diversified and open landscapes. In addition, food consumption habits will need to adapt. The Foresight Study Agrimonde (Paillard et al. 2010) clearly shows that by 2050 eating patterns will be a major issue of world food security. It shows in particular that Western dietary pattern cannot be generalized throughout the world (Fig. 1.1).

In this broad perspective, we need to make concurrent efforts to establish climate-resilient agricultural production systems, make efficient use of resources, develop low-waste supply chains, ensure adequate nutrition and encourage healthy eating choices. Together, these processes will found a sustainable food system. Intensification of food production must be accompanied by concerted action to reduce GHGs 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 and locally (Beddington et al. 2011).

As climate change amplifies the environmental and socioeconomic drivers of food insecurity, it is imperative that we prioritize where, how and when to act. The threats posed by climate change to food supplies and livelihoods are likely to be spatially variable. We will need to identify global hotspots where the threats

are greatest and to develop specific, practical interventions to boost resilience in these areas while benefitting from the positive opportunities.

In Europe, North America and elsewhere, a combination of intensive agriculture, food storage practices, retail systems and eating habits generates high per capita GHG emissions and food waste. The environmental and human diversity of the planet prevents the imposition of one-size-fits- all solutions.

Humanitarian, environmental and global security concerns demand a global commitment to improve the situation of a large proportion of the human population that is currently food insecure or vulnerable to food insecurity. This requires the reinforcement of resilience to climate shocks and food price volatility, halt land degradation, and boost productive assets and infrastructure. There are countless entry points for action. Many policies and programs provide ample evidence of multiple benefits for livelihoods and the environment, with meaningful participation at local and regional scales (Beddington et al. 2011).

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 give us a richer understanding of the dynamic systems we depend on and enable us to renew and broaden our efforts to secure a more sustainable and healthy food system for our own and future generations.

As a global community, we need to navigate toward 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. In all circumstances, we will need a governance system at multiple levels that accommodates participation, learning and the ability to adjust existing processes for more efficiency. To be successful, we will need 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 twenty-first century.

1.3 Ensuring Global Food Security: Some Recommended Actions

Without a global commitment to reducing GHGs from all sectors, including agriculture, no amount of agricultural adaptation will be sufficient under a destabilized climate in the future. While change will have significant costs, the costs of keeping unchanged the current path are already enormous and growing. Given the already intolerable conditions for many livelihoods and ecosystems, and the time lag between research and development and widespread application, we need to take urgent actions. Some selected actions are presented in the below analysis.

1.3.1 Changing Eating Pattern

Acting on eating patterns is a key condition for ensuring global food security in the future. The reason behind this assumption is that there is a strong correlation between food production and consumption. According to the Foresight Study Agrimonde (Paillard et al. 2010), if daily food consumption per person keeps steadily increasing, it will reach 3,600 kcal in 2050 and the world will have to produce no less than 62 G kilocalories for feeding nine billion people at that date (Scenario "Agrimonde GO"); but if daily food consumption per person remains limited to 3,000 kcal in 2050, only 42 G kilocalories will need to be produced to achieve this goal – that is 32 % less (Scenario "Agrimonde 1").

Ensuring global food security does not mean setting up a common eating pattern for every part of mankind: although undoubtedly have tended to coverage over the past decades, eating patterns remain diverse throughout the world, determined by a complex set of physiological, economic, historical, cultural and sociological factors. From that perspective, the Westernization of eating patterns is not suitable for every part of the world because of its numerous shortcomings and drawbacks, especially in terms of health and environmental implications.

A holistic approach is needed to make eating patterns more suitable and healthy. This involves first reducing losses and waste along the whole chain (production, distribution, and consumption). Such a reduction strategy should result in significant savings of fossil energy and other natural resources, and those savings are a key condition to increasing the sustainability of both eating patterns and food systems. In fact, eating patterns and food systems can be sustainable if they rely on a thrifty use of fossil energy and other resources, such as land and water. Setting up such systems must be a priority on the worldwide research agenda. Lastly, food security can be ensured thanks to healthier and more sustainable food diets. This objective requires assessing the impacts of food diets, both nutritionally and environmentally. Far from being imposed, more sustainable diets must be based on changes recognized by everyone. This means a better understanding of food consumption values and behaviours and of their various determinants, so as to favour desirable

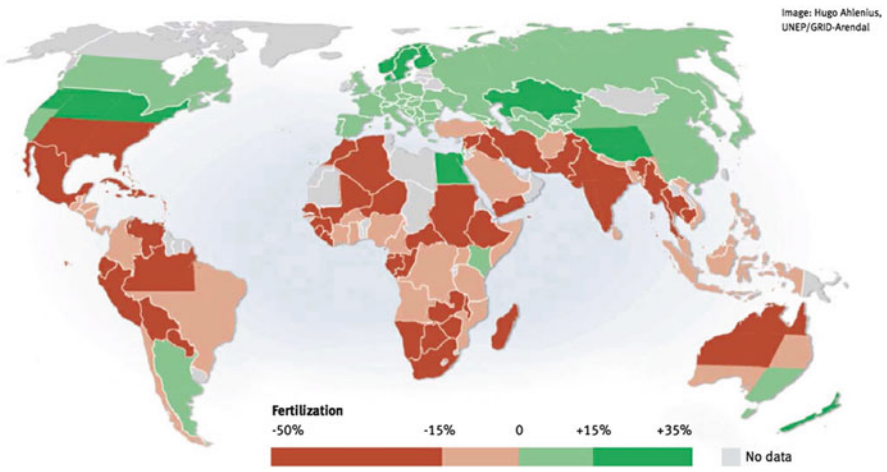

Fig. 1.2 Projected changes in agricultural production in 2080, due to climate change (Source: Cline 2007)

changes through actions on demand and supply factors, and also on the relative prices of foodstuffs. These actions, of course, will have to take the specificities of individuals, social groups and countries into consideration.

Many actions need to be taken to ensure food security throughout the world. And many of these actions have something to do with eating patterns. In other words, when it comes to food security, nothing can be carried out if eating patterns are not taken into consideration.

1.3.2 Reducing Significant Food Losses and Waste at Distribution and Consumption Levels

At global level, less than half of the calories produced by farmers ever make it onto the dinner table, as illustrated by Fig. 1.2. In the early 2000s, farmers globally produced an average of 4,600 kcal per capita per day, including nearly 600 kcal lost at the time of harvesting or just after. At that stage, the percentages in losses were strikingly higher in developing countries compared to developed nations. The remaining 4,000 kcal used were divided between animal feed (43 %) and human food (57 %). The 1,700 kcal used for animal feed produced in return 500 kcal in the form of eggs, dairy product or meat. Over the 2,800 kcal available for human consumption, another 800 kcal were lost through distribution and final consumption. At this stage, the percentages of losses were much higher in countries where the diet transition was achieved or occurring, than in the developing world. Finally, on average, the 4,600 kcal produced from plant products for each inhabitant of the world, only 2,000 ended up for actual human consumption (Smil 2000).

These figures show that reducing losses and waste, from field to plate, is a potentially powerful lever that can be used to increase world food availability and define more sustainable food systems and diets. These losses and waste correspond to both market (pecuniary) and non-market (environmental) costs. It is relatively easy to reduce post-harvesting losses, through efficient disease control and the development of infrastructure for storage, transport, and marketing. At this level, it is essentially a matter of investment and thus of budget resources. It is much more difficult to reduce losses and waste at distribution and final consumption levels since this requires profound changes in food consumption patterns and possibly an easing of regulations (as long as food safety requirements are met). There is notably a data shortage on the amount, quality and causes of food waste and losses at the household level.

1.3.3 Balancing Food Security and Climate Change: The Strategic Role of Climate-Smart Agriculture

According to FAO estimates, food production must increase by at least 70 % to meet the growing demands of a world population expected to surpass nine billion by 2050. Meeting that demand is further complicated by the world's changing climate, which poses severe risks to food security and the agriculture sector. Changing weather patterns can be expected to lead to increased temperatures and rainfall, severe droughts and flooding, shorter growing seasons, changes in ocean temperatures and fish stocks, heat stress on crops and animals, changes in disease patterns, and reduced crop yields. In addition, some poor developing countries could suffer disproportionately from climate change impacts because temperatures and precipitations are often already close to the tipping points beyond which crops fail or animals die, despite having contributed the least to GHG emissions. For example, Africa is responsible for a mere 4 % of global GHG emissions, but the potential impact of climate change on the African continent could be devastating. Here, an equitable share of long-term funding to help poorer nations deal with global warming (especially in terms of adaptation) is imperative.

Within this perspective, many studies and successful experiences have recently catalyzed thinking about the ways in which agriculture – which has a vital role in global food security, development and natural resources use – can and must be fully integrated into national strategies and a consensus-based multilateral framework to address the challenges of climate change (Elbehri et al. 2011). Consequently, it's increasingly believed that agriculture must become central to future climate-change and food security debate and governance. This is on account of at least three important interrelated reasons:

- *Firstly*, agriculture is the sector most vulnerable to climate change and many threats, including the reduction of agricultural productivity, production stability and incomes in many areas of the world already characterized by high levels of food insecurity and limited means of coping with adverse climate impacts.

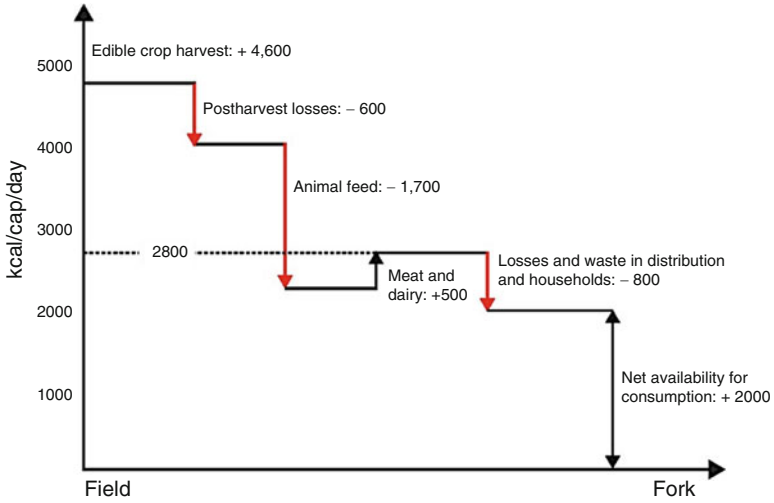

Fig. 1.3 From field to fork: estimation of food losses, conversion and wastage in global food chain (Source: Lundqvist et al. 2008) from Smil (2000)

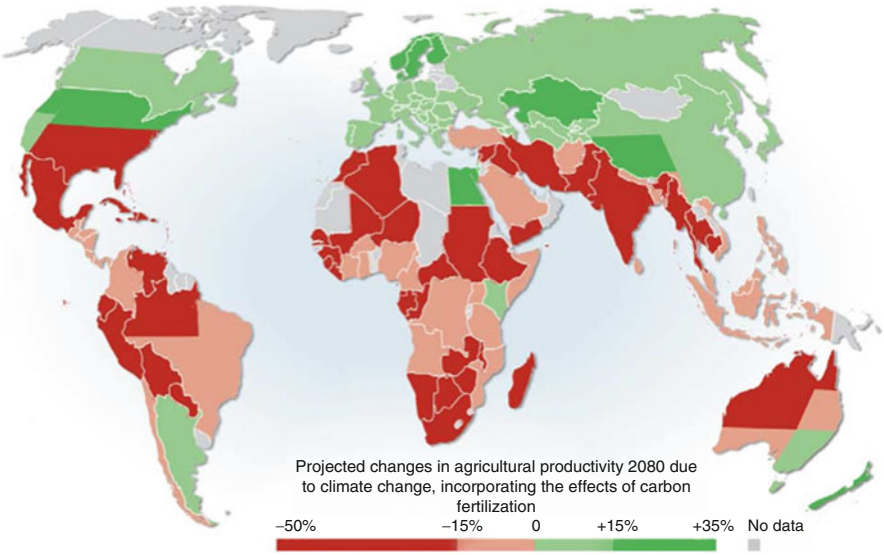

Fig. 1.4 Long-term projected changes in agricultural productivity, from 2007 to 2080 (Cline 2007)

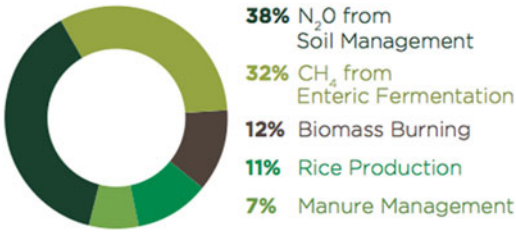

Fig. 1.5 Emissions in the agriculture sector (Source: IPCC 2007; Smith et al. 2008)

Moreover, climate change will affect agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts. Many impact assessment studies point to severe crop yield reductions in the next decades without strong adaptation measures, especially in areas where rural households are highly dependent on agriculture and farming systems are highly sensitive to inclement climate. The impacts of climate change on our ability to feed a growing world population are being robustly documented. Climate models indicate that rising temperatures may have a beneficial effect on crops in the temperate areas. Tropical and subtropical areas, however, may experience significant reductions in crop productivity in a long-term perspective, i.e., towards 2080 (Figs. 1.3 and 1.4).

- *Secondly*, agriculture is not only affected by climate change, but also contributes about 20 % of the GHGs which cause climate change (including land clearing). The two most harmful GHGs from agriculture are nitrous oxide from soils and methane from cattle, but carbon dioxide emission due to conversion of forests to cropland, is also important.
- *Thirdly*, agriculture can be a major part of the solution: enhancing food security while mitigating impacts of climate change (agriculture has the potential to capture a significant part of the excess atmospheric carbon in the soil in the form of organic matter). This mitigation potential can be largely achieved in developing countries. In addition, many potential adaptation measures are drawn from existing good practices that promote sustainable agricultural development: shifting crop rotation to optimize the use of available water; adjusting sowing dates according to temperature and rainfall patterns; planting crop varieties better suited to new weather conditions; and creating wind-breaks on arable land to reduce water and soil run-off (Fig. 1.5).

Based on the above reasons, it's needless to demonstrate the urgency of implementing measures which favour actions and policies that simultaneously address climate change mitigation and adaptation in agriculture while supporting development objectives and ensuring food security. In terms of mitigation, it is fundamental to rethink the ways agriculture is practiced in industrial economies. In developing countries, mitigation practices include conservation agriculture, organic agriculture

and greater reliance on renewable energy for domestic use in rural households . Finding ways to reduce reliance on chemicals and synthetic fertilizers and creating incentives to promote the use of renewable energy throughout the modern agricultural systems is of the utmost urgency and requires concerted policy action.

In terms of adaptation to climate change, potential strategies should be multi-dimensional, ecological and socio-economic. Much agricultural adaptation occurs autonomously at the local level as farmers adjust their planting systems to climatic change. Planned adaptation occurs at the sectoral and national levels and includes policies such as addressing changes in food insecurity, identifying vulnerabilities, re- assessing agricultural research priorities, and strengthening agriculture extension and communication systems. Planned action on climate change adaptation should build on, coordinate with, and remove impediments to autonomous local adaptation, while pursuing sector-level and long-term adjustment (Elbehri et al. 2011).

In addition, adaptation of the food system will require complex social, economic and biophysical adjustments to food production, processing and consumption. Such changes will be most difficult for the poorest and most vulnerable regions and populations. Moreover, climate change models suggest that severe effects are likely to be felt in tropical regions, especially the expected further drying of the arid tropics. Many of the poorest countries are found in these regions and hence the nations least able to adapt may be the most affected. Any hope of making substantial progress on the poverty and hunger Millennium Development Goals thus requires successful adaptation in least-developed countries. But all countries will eventually be challenged by climate change (HLPE 2012).

1.3.4 Collect Information Locally, Share Knowledge Globally, and Refocus Research to Address a More Complex Set of Objectives

The information base available to facilitate policy and program developments to reduce the food security effects of climate change is awfully inadequate. National governments need to improve their efforts. But there is also a need for international data gathering on climate change and its effects to improve information on vulnerable communities, populations and regions.

Local lessons learned can be made much more valuable when shared. The knowledge already gained by farmers about practices that work in their conditions today could prove invaluable to farmers elsewhere in the future. But some consequences of climate change are outside the realm of recent human experience and focused, systematic data generation efforts are needed to develop effective response efforts. Because the benefits cross national borders, knowledge gathering and sharing requires global coordination as well as national programs.

A major increase in the quality and quantity of the biophysical, economic and social data available to policy makers is required. Particular challenges include:

- linking existing and future data sources using global metadata standards;
- making use of modern technology (ICT, remote sensing) to harvest real time data;
- enabling disaggregated data collection, including at the intra-household level, to identify drivers of social vulnerability to food security and challenges to mitigation and adaptation; and
- improving the pipeline from data gathering, analysis and feeding into policy making (HLPE 2012).

1.4 Conclusions

Plausible climate and socio-ecological change scenarios can be invaluable tools in developing appropriate response options for ensuring food security and human wellbeing in the future. Climate change effects on the vulnerable are significant but are by no means the only threats to sustainable food security. Sustainable development efforts that lead to broad-based economic growth are essential to addressing the needs of vulnerable people and regions. Given the uncertainties in local and regional outcomes of climate change, policies and programs that are based on specific climate scenarios could potentially be counterproductive. Rather, efforts should be based on activities that provide both sustainable economic growth and increase resilience to a wide range of potential climate change threats.

Humans have had to adapt the way they produce, process and consume food to changing circumstances since agriculture came into existence after the last ice age. The challenges – and opportunities – posed by climate change thus need to be seen in the context of the ever changing biophysical and socioeconomic environment within which the now globalized food system exists. However, the need for the food system to adapt to climate change has several unique features. First, climate change will affect the whole globe so all food production systems will need to make changes. Second, adaptation will need to occur at a time when the food system is suffering many other pressures: for example increased demand from a larger and wealthier global population, increasing competition for water, land and other inputs, and almost certainly higher – and more volatile – energy prices.

Adaptation of the food system will require complex social, economic and biophysical adjustments to food production, processing and consumption. Such changes will be most difficult for the poorest and most vulnerable regions and populations. Moreover, climate change models suggest that particularly severe effects are likely to be felt in tropical regions, especially the expected further drying of the arid tropics. Many of the poorest countries are found in these regions and hence the nations least able to adapt may be the most affected. Any hope of making substantial progress on the poverty and hunger Millennium Development Goals thus requires successful adaptation in least-developed countries. But all countries will eventually be challenged by climate change (HLPE 2012).

Climate-change adaptation starts from an assessment of risks and vulnerabilities of a specific system, of how climate change will modify them and what impact it will have on food security. There is seldom a single best way to adapt. And adaptation does not necessarily require new technologies, but is often mobilizing existing practices and resources in a different orientation. Adaptation can require substantial changes in the food system and therefore will need to build on comprehensive approaches.

Climate-change adaptation will certainly require new practices and changes in the livelihood strategies of most if not all food producers as well as other actors throughout the food chain. But the changes required are more systemic and must involve farmers, retailers and intermediaries in the food chain, agri-business, the financial sector and civil society. It will require action and oversight by governments, international organizations, and civil society organizations concerned with food security and sovereignty,[1] hunger and sustainable development (HLPE 2012).

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[1] Food sovereignty is defined as "the right of peoples and sovereign states to democratically determine their own agricultural and food policies" (IAASTD 2008).

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