Chapter 2

# Key Concepts and Definitions

Climate change, food security, and food systems are each highly technical and interdisciplinary fields of study in their own right, with specialized concepts and lexicons. The purpose of this chapter is to briefly list and summarize a set of key terms and conceptualizations that appear throughout the report.

## 2.1 Food Security

Food security is defined as the state or condition "when all people at all times have physical, social, 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, 2012a). Globally, about 805 million people are food insecure (FAO et al. 2014) and at least 2 billion live with insufficient nutrients (Pinstrup-Andersen 2009, Barrett and Bevis 2015). Paradoxically, about 2.5 billion people are overweight or obese (Ng et al. 2014), though not necessarily obtaining the necessary nutrients for development and health. The FAO (Food and Agriculture Organization of the United Nations) definition above holds "sufficient, safe and nutritious" as the goal; overweight or obesity can themselves lead to damaging health effects (Ng et al. 2014).

Food production is an important prerequisite for food security to be achieved but is alone insufficient to do so. Many other factors determine food security, including economic conditions from the global to the micro levels and the conditions of trade, food safety, land use, demographics, and disease (Ericksen et al. 2009, Misselhorn et al. 2012). Food security is not only a reflection of the aggregate balance between supply and demand but integrally includes individual and community access to food as well as economic, social, political, and environmental factors (Devereux 2012, Headey 2013, Maxwell and Fitzpatrick 2012,

Regmi and Meade 2013, Simelton et al. 2012, World Bank 2012b).

Understanding food security requires recognizing its interdisciplinary, interactive, intersectoral, and multiscale nature; misconceptions are not uncommon. One common source of confusion occurs in the application of the term "food security" to the separate, though related, topic of national-scale or regional-scale agricultural production. While the terms were used interchangeably in the past (UN Human Rights 1974), this is no longer the case; food security is distinct from food production. Food production (not necessarily domestic) is an important element of the food-availability component of food security but alone is insufficient to guarantee food security. For example, the United States produces an annual average of over 3,600 kcal per-capita per day (FAOSTAT 2014b), yet 14.3% of the U.S. population is currently food insecure (Coleman-Jensen et al. 2014). In contrast, Singapore's population remains food secure and is ranked fifth out of 109 nations globally from the Economist's Global Food Security Index (Economist Intelligence Unit 2015), though the country has effectively no cropland under cultivation within its borders (FAOSTAT 2014a). This compares with 0.54 hectare (ha) under cultivation per-capita in the United States (FAOSTAT 2014b), demonstrating that food security may be achieved even in the absence of domestic crop production; trade can effectively substitute for domestic production where there is economic access to international markets.

The four components of food security (Table 2.1) are not mutually exclusive but serve to organize the topic into an analytically meaningful framework and allow for systematic analysis of food and nutritional outcomes (Ericksen 2008, Ingram 2011, Maxwell 1996, Maxwell and Smith 1992).

Food security is determined by each of these components acting and interacting across multiple spatial and temporal scales (Carr 2006, Davis et al. 2001, Kotzé 2003, Maxwell 1996, Maxwell and Smith 1992). Changes in one region may affect food security in other countries at great distances (Dronin and Kirilenko 2008). While some changes may directly diminish food security, they may be compensated for through alternative pathways (e.g., as when supply disruptions are addressed through trade (Parry et al. 2004). A globalized food system can in this way buffer the local effects of weather events but may also increase vulnerability by transmitting price shocks globally (Godfray and Beddington et al. 2010). As a major food importer and exporter (USDA ERS 2013a), the United States can be significantly influenced by climate events and changes in other parts of the world.

Climate change can affect food security in multiple ways (National Research Council 2007, Wheeler and von Braun 2013). Rising temperatures, altered precipitation patterns, and extreme weather events have already affected agricultural yields, the geographical distribution of food- and water-borne diseases, and trade patterns (Schmidhuber and Tubiello 2007). Meeting each component of food security described in Table 2.1 depends upon the functioning of each of the food system elements shown in Figure 2.1, whose climate sensitivities are described throughout this report.

***Table 2.1: The Components of Food Security.*** *For food security to be achieved, all four components must be attained simultaneously. Adapted from FAO 2008d.*

| Component | Definition |
|---|---|
| **Availability** | The existence of food in a particular place at a particular time. Addresses the "supply side" of food security, which is determined by food production, transportation, food stocks, storage, and trade. |
| **Access** | The ability of a person or group to obtain food. Economic access to food (including affordability) and allocation within society (including intranation and intrahousehold distribution) are integral to this component. |
| **Utilization** | The ability to use and obtain nourishment from food. This includes a food's nutritional value and how the body assimilates its nutrients. Sufficient energy and nutrient intake is also the result of biophysical and sociocultural factors related to food safety and food preparation, dietary diversity, cultural norms and religious practices, and the functional role of food in such practices. |
| **Stability** | The absence of significant fluctuation in availability, access, and utilization. When stable, food availability, access, and utilization do not fluctuate to the point of adversely affecting food security status, either on a seasonal or annual basis or as a result of unpredictable events. Weather, political unrest, or a change in economic circumstances may affect food security by introducing instabilities. |

## 2.2 Food Insecurity

Food insecurity is the absence of food security. It exists over different time horizons and affects people through both under- and overconsumption. Much of the scientific literature to date addresses the former issue, though the latter is now receiving more attention (Hawkes et al. 2012, Ng et al. 2014).

When households face long-term deficits in acquiring sufficient food, often a result of long-term poverty and lack of resources, they experience "chronic food insecurity" (Maxwell and Smith 1992). Alternatively, households that face unexpected or short-term food deficits experience "transient food insecurity," often the result of reductions in food production, lack of imports, higher prices, or climatic events (Devereux 2006). Climate change can influence both types of food insecurity. Long-term changes in temperature and precipitation may reduce income and result in higher levels of chronic food insecurity, whereas extreme events such as droughts and floods might increase the frequency of transient food insecurity.

Just as food security is determined through interactions occurring across multiple spatial and temporal scales, the consequences of food insecurity are also observable across those ranges. For an individual, chronic food insecurity may manifest as a reduced capacity to perform physically, diminished mental health and development, and an increased risk of chronic disease (Jyoti et al. 2005, Seligman et al. 2007, Seligman et al. 2009, Slack and Yoo 2005, Whitaker et al. 2006). Undernourishment, including inadequate caloric and/or nutrient intake (WFP 2012), is a consequence of food insecurity and leads to outcomes such as stunting (short for one's age), wasting (thin for one's age), and micronutrient malnutrition.

Collectively, these changes diminish global economic productivity by 2%–3% annually (USD 1.4–2.1 trillion; FAO 2013b), with individual country costs estimated at up to 10% of national GDP (WFP 2013a, Martínez and Fernández 2008).

## 2.3 Food Systems

Food security depends not only on yields and trade but also on changes that affect food processing, storage, transportation, and retailing; the ability of consumers to purchase food; and food-consumption patterns. Food security is therefore an important outcome of a functioning food system (Figure 2.2; Ingram 2011, FAO 2008c), in concert with emergent properties of the food system, such as food prices, and (frequently) external factors, such as income.

- **Producing** food relies on agricultural production, including crops, livestock, and fisheries and their relationships with climate and environmental change (Crane et al. 2011, Ericksen et al. 2011, IPCC 2007c, Schlenker and Lobell 2010, Vermeulen and Aggarwal et al. 2012).

- **Processing** of primary agricultural commodities transforms these commodities into more-easily edible and digestible food (Boughton and Reardon 1997).

- **Packaging** food protects it during transportation, extends its shelf life, and reduces the chance of contamination.

- **Storing** food items keeps them in one location for a period of time and may occur at each step of the food system.

- **Wholesaling** refers to the purchase and resale of agricultural commodities and food in bulk, to be retailed by others.

- **Retailing** describes economic agents, from roadside vendors and open markets to supermarkets and restaurants, selling a range of unprocessed to processed and prepared foods to consumers.

- **Trading** refers to economic exchanges of food or other materials for payments or export revenue; it can occur across all of the food system activities.

- **Transporting** describes the movement of food to and between markets, and from markets to communities and homes.

- **Consuming** is individuals and families eating food to sustain themselves in their day-to-day lives.

- **Disposing** refers to feeding spoiled, inedible, or surplus food to animals, composting food to harvest it for nutrients, or discarding food into a landfill or centralized waste facility.

Food systems vary. Some are characterized by long distances separating production and consumption, greater reliance on technology, and industrial components; these are termed *capital-intensive* food systems in this report. Other food systems are simpler, with farmers eating the food they grow with minimal processing (Brown et al. 2009, Niles and Roff 2008); these are termed *labor-intensive* food systems in this report.

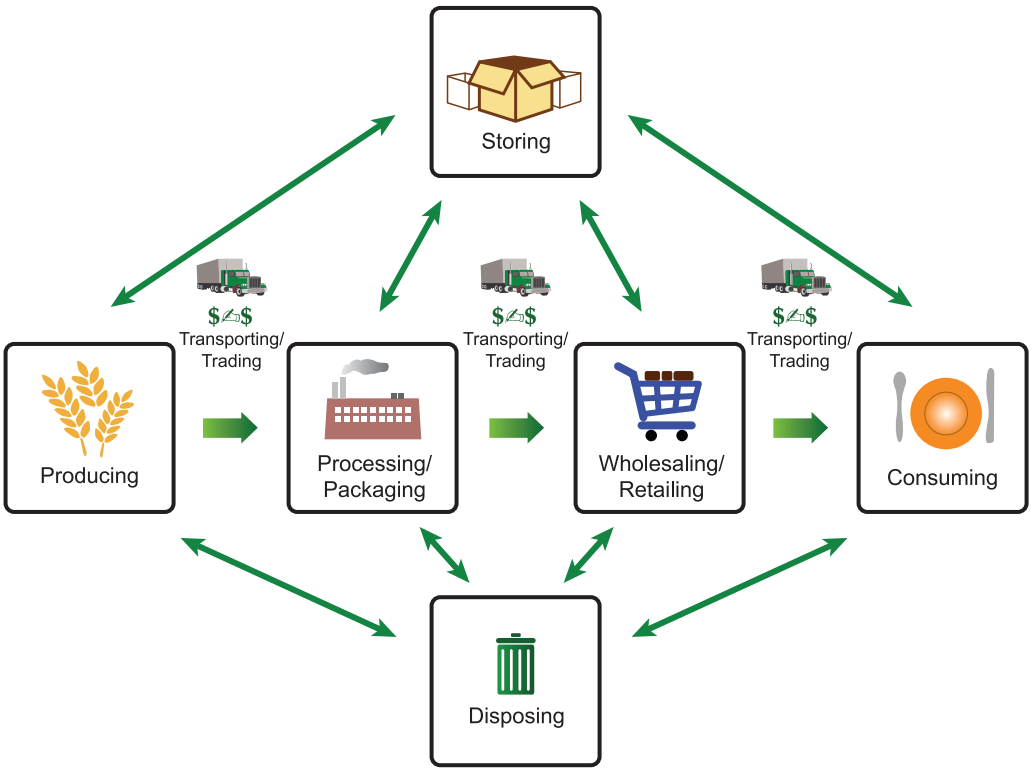



***Figure 2.1. Food-system activities and feedbacks.*** *Food-system activities include the production of raw food materials, transforming the raw material into retail products, marketing those products to buyers and product consumption. Food transportation, storage and waste disposal play a role in each of these activities.*

Changes within any food-system activity have the potential to affect food-security outcomes (Ericksen et al. 2011, Ingram 2011). Effects are often most easily documented following extreme-weather events. Such extreme events are sometimes attributable to changes in climate, and in fact recent studies have been able to apportion the enhanced risk of some specific events to anthropogenic drivers; other times they are not, but either type of event can be used to understand underlying vulnerabilities in the food system. For example, a drought may expose regional susceptibility to supply shortages, whether or not the drought was attributable to climate change. This information can then be used together with projections of changing drought incidence in the future to help to determine future risk.

Climate change is identified by changes over an extended period in the average and/or variability of properties such as temperature and precipitation.

## 2.4 Climate Change

Climate change is identified by changes over an extended period in the average and/or variability of properties such as temperature and precipitation. This report also considers elevated atmospheric carbon dioxide ($CO_2$) concentrations, which are a driver of climate change. Human activities have resulted in large changes in Earth's climate over the last few centuries (Stocker et al. 2013). Much larger changes are projected for the next century if greenhouse-gas emissions (GHG) and concentrations continue to increase (Stocker et al. 2013).

Human activities have changed and will continue to change the Earth's climate (Stocker et al. 2013). Since 1750, atmospheric concentrations of $CO_2$ have increased by about 40%, nitrous oxide by 20%, and methane by about 150%, leading to increasing temperatures and changes in the timing and amount of precipitation in many areas. $CO_2$ concentrations have reached 400 ppm, and global average temperatures increased by 0.85 °C (about 1.6 °F) between 1880 and 2012 (Stocker et al. 2013). Precipitation has observably increased over the mid-latitude terrestrial areas of the Northern Hemisphere (estimates range from 1.44 to 3.82 mm per year per decade), while precipitation trends over other areas have been less significant. Increased ocean temperatures along with the melting of glaciers and ice caps have contributed to an observed rise in global sea level of approximately 0.2 m between 1901 and 2010 (Stocker et al. 2013).

This report investigates how past climate has influenced food-system activities and food security, using those historical relationships as a basis for understanding possible future near-term (~2040–

2060) and longer term (~2080–2100) food security outcomes. This report focuses on two different scenarios of climate change: (1) relatively low emissions and atmospheric concentrations of GHG, and (2) high emissions and concentrations of GHG, both derived from the recent climate assessments of the IPCC (IPCC 2013). The low scenario discussed in this report is Representative Concentration Pathway (RCP) 2.6, in which $CO_2$ concentrations increase to about 421 ppm and then stay at about that level (current concentrations are about 400 ppm). The high scenario is RCP 8.5, in which concentrations increase steadily throughout the 21st century, reaching a level of about 936 ppm by 2100. This report also outlines five broad scenarios, or pathways, of socioeconomic change that could affect the structure of society over time and future capabilities and willingness of society to adapt to and mitigate climate change and its effects.

Effects of changes in climate on agriculture tend to be gradual until a threshold is reached (IPCC 2013). For example, at increasingly high temperatures, plants may continue to grow at a reduced pace until a particular temperature is reached (with the precise temperature specific to the crop type and variety). At the point that the plant ceases to grow, it has reached a threshold temperature (Walthall et al. 2012). Thresholds may influence food security in a number of ways, with consequences for market access or for a community awaiting a shipment. Instances of thresholds are discussed in this report.

## 2.5 Non-climate Drivers of Food Systems and Food Security

Food security and food systems are driven by many factors. Although this report focuses on changes caused by climate change, climate change is only one set of interconnected trends and drivers facing agriculture, food systems, and hence, food security (FAO 2008d). Some of the most relevant technological and socioeconomic factors driving changes in food systems include technological and structural changes in the food system, including food production, processing, distribution, and markets; increasing population; changes in wealth; demographic changes; urbanization; disaster response; and changes in energy availability and use (Figure 2.2).

**Technological and Structural Changes in the Food System:** Technology has been historically important to allowing the food supply to keep pace with increased demands caused by population and income

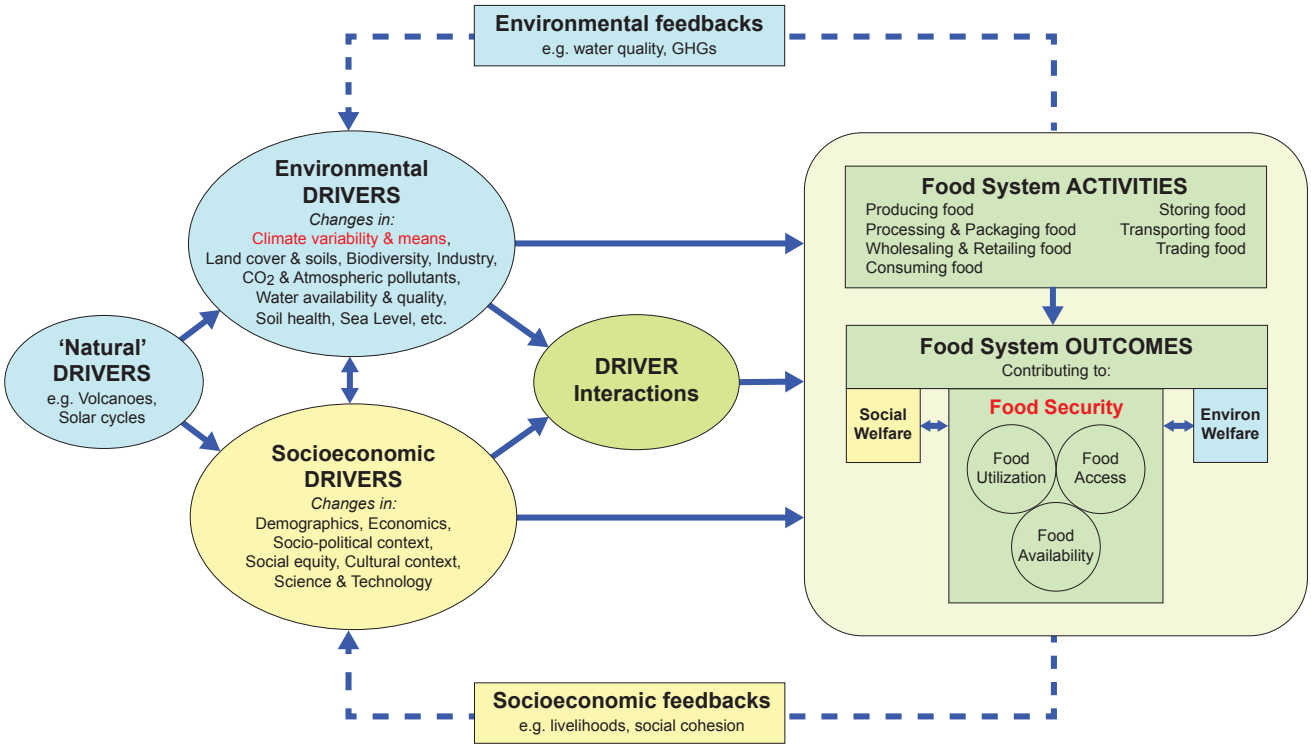



***Figure 2.2 Food system drivers, interactions, and feedbacks.*** *Changes and interactions in environmental and socioeconomic conditions can affect food security outcomes in distant locations. The primary foci of this report are highlighted in red but occur within a broader context, with many feedbacks. Source: Adapted from Ingram 2011.*

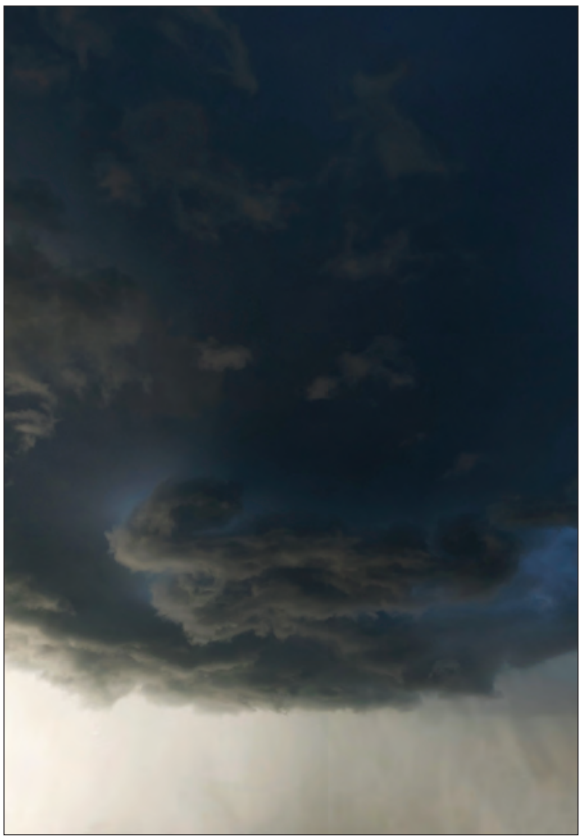
growth in the 20th century (Pingali 2012). Those technological advances included, for example, better fertilization, crop improvements through breeding and hybridization, and improved mechanization, all of which increased individual farm outputs. These technological changes went hand-in-hand with major structural changes in agricultural production, for example, with a continuing concentration of commercial production at larger farms in the United States and some other industrialized countries (MacDonald et al. 2013). Also, the food processing, distribution, and market systems have moved increasingly to larger scale, integrated firms (Ericksen 2008, Ingram 2011, Reardon et al. 2012).

**Economic Growth:** Between 2010 and 2013, GDP growth in developing countries was higher than in developed countries, at between 4% and 7% (International Monetary Fund 2013). As developing economies grow and incomes rise, marginal increases in disposable income have diminishing effects on food purchases, meaning that low-income households devote a larger proportion of their increasing incomes to food than higher-income households (FAO 2012a, Regmi and Meade 2013). Since the mid-20th century, real food prices have fallen as real per-capita incomes have risen, making food more accessible (Fuglie and Wang 2014, Schmidhuber and Tubiello 2007). At the same time, there have been important shifts in demand from cereal sources of calories and protein consumed by low-income people toward animal and fish sources of protein and the more diverse diets preferred by people with higher incomes. This is also important to achieving food security from the perspective of the nutrition aspect of food utilization.

Population expansion over the next century is expected to occur primarily in less-developed, food-insecure nations, placing more pressure on stressed systems with limited adaptive capacity for climate change.

**Population and Demographic Change:** Population is a strong driver of the demand for food. Population expansion over the next century is expected to occur primarily in less-developed, food-insecure nations, placing more pressure on stressed systems with limited adaptive capacity for climate change. By 2050, the world population is projected to be 9.6 billion, rising to 10.9 billion by 2100 (UN 2012). Globally, family size is expected to decline in the latter half of the 21st century due to changing age and educational structures (Lutz and Samir 2010, UN 2012). These changes in overall population size may be expected to lead to overall changes in food demand.

**Urbanization:** As of 2011, half of the global population is classified as urban (UN 2012). This is projected to increase to about 67% by 2100 (UN 2012). The growth in urban populations and reduction in rural populations leads to fewer



agricultural producers overall, shifting dietary demands, larger and more centralized food-distribution structures, and a greater role for transportation and trade (Lee et al. 2012, Neven et al. 2009, Reardon et al. 2012, Satterthwaite et al. 2010).

In coastal cities, in particular, imported food that is affordable and accommodates changing dietary preferences will increasingly compete with food produced by domestic inland producers (Pingali 2007). As urban centers expand to accommodate growing urban populations, neighboring arable land will be removed from production and remaining cultivated lands will be subject to greater pollution (Chen 2007). It is important to note that the overall loss of arable land attributable to urbanization is not large in a global context. Recent estimates of current urban land extent vary depending on methodological and classification decisions, but most range from about 0.2% to 2.4% of global land area circa 2000, excluding Greenland and Antarctica (Seto et al. 2011). This is projected to triple by 2030 (Seto et al. 2012) but would still amount to less than 2% of global arable land.

Urbanization therefore has a direct influence on food systems and food-security outcomes. Urban areas also face threats to food security induced by

climate change, primarily through disruption of the transportation and distribution of food (Satterthwaite et al. 2010).

**Disasters and Disaster Response:** Food systems and their adaptive capacity are affected by changes in socioeconomic, cultural, and environmental conditions that play out over years and decades (Frankenberger et al. 2012). They can also be affected by more-rapid changes, such as conflicts or natural disasters, which disrupt production, transport, and trade.

Communication and food security analyses have improved knowledge of and past response to food-security shocks (Hillbruner and Moloney 2012). Management of environmental disruption often improves in a given location over the long term, though climate-related shocks—that is, abrupt changes that cause a sudden change in food security—tend to have a detrimental effect on the adaptive capacities of affected households, particularly when such shocks are repetitive (USAID 2011).

The actual effects of natural disasters and food-security shocks are mediated by socioeconomic conditions and the effectiveness of disaster response (Coughlan de Perez et al. 2014). A more-sensitive individual, household, or community has lower resilience to a given shock from any source. Chronic vulnerability anywhere in the world may be due to poverty, degraded ecosystems, inadequate physical infrastructure, conflict, and ineffective governance (FAO 2008a, Schreiner 2012), meaning that vulnerable people are at greater risk to weather extremes (Coughlan de Perez et al. 2014) and other stresses. In such settings, a relatively mild stress on chronically vulnerable households can lead to serious consequences due to the households' inability to respond effectively (Frankenberger et al. 2012).

**Energy:** Energy is a major driver of economies, societies, and food production. Agricultural production, food storage, and other elements of the food system are energy intensive. Therefore, energy costs are reflected at multiple stages of the food system (Vermeulen and Campbell et al. 2012), affecting access for income-limited consumers. Higher energy prices can also affect commodity markets, incentivizing biofuel production and land-use conversions away from food production (Diffenbaugh et al. 2012, Hazell 2013).

## 2.6 Conclusions

Food security, food systems, and climate change are multifaceted topics. Their interactions are likewise complex and affected by a wide range of environmental and socioeconomic factors. It is nevertheless clear that there are multiple connections between climate conditions and many different elements of food systems and that climate change can affect food systems in ways that alter food-security outcomes.