Chapter 1
Climate Change and Food Security: a Glance at Principles and a Strategic Road Map

Mostafa Jafari and Vahideh Jafari

Context and Setting

As the world population moves inexorably toward the projected 9 billion by 2025 and as already 2 billion people worldwide suffer from inadequate nutrition, there is an urgency at the local, regional and global levels to combat hunger, under-nutrition and the associated misery. For millions upon millions of people who are already under threat of food insecurity, climate change may make their current food production strategies irrelevant. In this chapter, we examine a number of important issues and set the scene for the chapters that follow.

Definitions and Terminology

What Is Climate Change?

The climate change issue as one of the main challenging phenomena in recent years has been debated at different levels from scientifically based consideration to management discussion and political dimensions over the past thirty years. The Intergovernmental Panel on Climate Change (IPCC) has investigated climate change assessments through three working groups, a task force and a task group, with supporting information derived from monitoring GHG emissions. The activi-

M. Jafari (✉)
Macro National Strategic Plan on Climate Change Research (RIFR-AREEO) and IPCC LA, ar4, ar5, ar6, Tehran, Iran
e-mail: mostafajafari@rifr-ac.ir; mostafajafari@libero.it

V. Jafari
Sapienza University of Rome, Rome, Italy

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ties of each working group and of the task force are coordinated and administrated by a technical support unit (TSU). Working Group I (IPCC-WGI) as can be realized from its topic (The Physical Science Basis) deals with climate change issues on a scientific basis, focusing on the physical science of the climate system and climate change.

Working Group II (IPCC-WGII) has a topic named Impacts, Adaptation and Vulnerability, and concentrates on the assessment of the vulnerability of natural systems and of socio-economic factors with climate change. Options for adapting to negative and positive consequences of climate change are reported by IPCC-WGII, which assesses the impacts of climate change from a worldwide view to continental and regional views. All impacted sectors such as ecosystems and biodiversity, and humans with their diverse societies, cultures and settlements, are assessed in a region and location. The vulnerability and the capacities and limits of these natural and human systems are being considered to adapt to climate change and thereby reduce climate-associated risks, and options are proposed for creating a sustainable future for all through an equitable and integrated approach to mitigation and adaptation efforts at all scales (IPCC 2019a).

Working Group III (IPCC-WGIII: Mitigation of Climate Change) focuses on climate change mitigation, assessing methods for reducing greenhouse gas emissions, and removing greenhouse gases from the atmosphere (IPCC 2019b).

If we concentrate on food production and food security, we can realize that a range of various and different factors affect food security. The principal classification of the affecting factors may briefly be categorized by sectors as follows: climate (location characteristics), land base physical (soil, gradient, etc.), and human-related factors (technology, machinery, social, etc.) (Fig. 1.1).

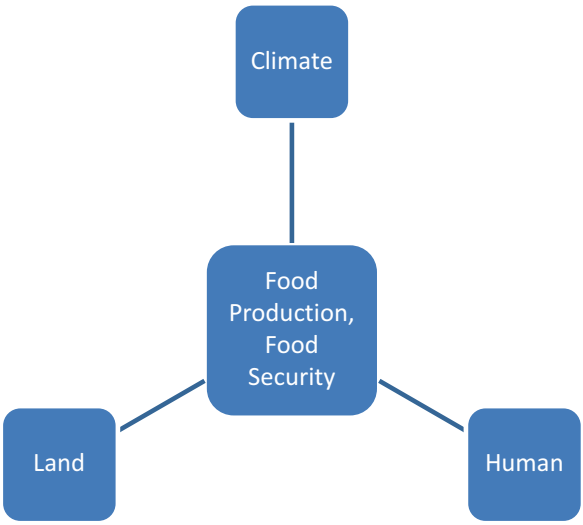

Fig. 1.1 Principal factors affecting food security

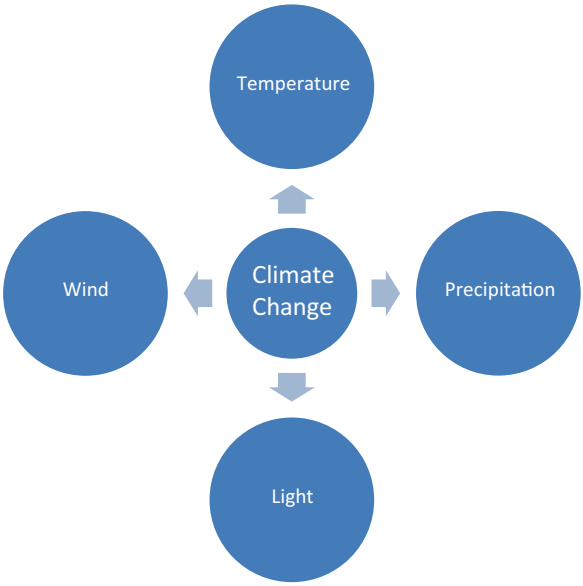

Fig. 1.2 Main climate-related factors affecting food production

In general, climate change may refer to "a change in the pattern of weather, and related changes in oceans, land surfaces and ice sheets, occurring over time scales of decades or longer" (Australian Academy of Science, no date) (Fig. 1.2).

In relation to the role of emissions, climate change is "a change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels" (Webster's Dictionary).

The combination of environmental, socio-economic and geographic factors that may result in greater variability in weather patterns, mainly in terms of temperature fluctuations, is referred to as 'global warming'. Temperatures increase, and rainfall becomes more irregular, with an increase in the frequency of extreme weather events, and less predictability in weather patterns (EC-FAO 2012). Adaptation, mitigation, and reducing emissions are the three main actions responding to climate change (EC-FAO 2012).

Climate Variability

Climate variability may refer to shifts of weather patterns occurring over short time frames such as a 12-month period, or over decades of observation, or even longer. Climate variability is a function of natural forces and patterns and can be distinguished from climate change by being predictable and largely cyclical (EC-FAO 2012).

Main Aspects of a Food System

We need to have an integrated view of the various food systems to allow strategic consideration of food security and provide a road map in relation to the climate change impact. Key components of the food system could generally be categorized as described below (K. State 2019).

Food Production, Processing and Distribution

In the frame of food production, growing crops and other food-producing sources need to be considered carefully and also food harvest, post-harvest transport and storage are important parts of food production and consumption. Generally food, once produced, needs to be processed before consumption. Transformation and packaging of food play very important roles in the food system. Different types of produced or processed food need different methods of storage. Food distribution stages including warehousing, transporting and retailing have to be considered according to the food quality and quantity.

Food Consumption and Food Waste

Food consumption patterns, including diet patterns (which refer to the selected type of food and cooking and eating methods) are to be reviewed in a food system assessment. Post-harvest losses may be a major factor. Diet patterns are changing and there is now a narrowing of the range (number) of species of plants and animals that are eaten (Squires 2019). Wasting of food may take place from the time of its early production, harvesting, storage, transportation, processing and/or cooking, up to when it is eaten. Increasing productivity percentages and reducing wasting rate by using suitable diets and proper methods could help to ensure food security. Food waste may be highly dependent on the food packaging systems (Fig. 1.3).

What Is Food Security?

Food security, as defined by the United Nations Committee on World Food Security, "is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for active and healthy life" (World Food Summit 1996). Food security comprises four components: availability, access, utilization and stability (FAO 2019).

These definitions apply mainly to the developed world and for some on subsistence rations there is the question of survival foods and the luxury of 'safe and nutritious' may take a lower ranking (Squires et al. this volume). Box 1.1 sets out some further explanation of what is meant by food security and its components.

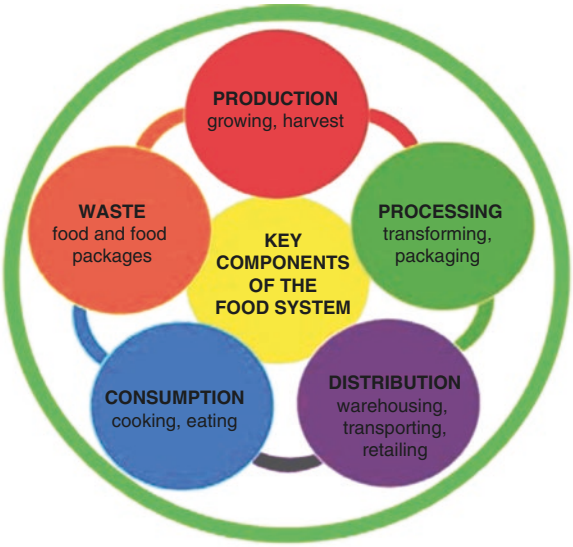

Fig. 1.3 Key components of the food system (K. State 2019)

Box 1.1 Some Definitions of Terminology Around Food Security

Access: The degree to which available food can be sourced through markets, own production, or other means. Households' or individuals' ability to secure adequate resources for acquiring appropriate foods (in terms of macronutrients, micronutrients and cultural acceptability) for a nutritious diet (EC-FAO 2012). The ability of individual households to acquire food, either by producing it themselves, hunting, fishing or gathering from wild sources, or through purchases, exchanges or as gifts. Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources) (FAO 2019). The *food access gap* measures the extent to which a household is able to meet the minimum consumption level required for an adequate diet. The difference between what households can access and the minimum consumption level is referred to as the access gap (EC-FAO 2012). To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security (FAO 2019).

Affordability: Purchasing power is a key determinant of access in most settings. Food access depends on household purchasing power, which varies in relation to market integration, market access, price policies, and local economies (in terms of employment and livelihoods) (EC-FAO 2012).

(continued)

Box 1.1 (continued)

Availability: Adequate quantities of food, supplied through domestic production, stocks, imports and food aid to ensure that the minimum nutritional requirements of the population can be met. Food availability addresses the 'supply side' of food security (EC-FAO 2012). It is usually measured in terms of the total quantity of food that is physically present in the area of concern, through domestic production, commercial imports and food aid. This may be aggregated at the regional, national, district or community levels. Food availability alone is not enough to ensure food security (EC-FAO 2012). The availability of sufficient quantities of food of appropriate *quality*, supplied through domestic production or imports (including food aid) is also important (FAO 2019).

Food insecurity exists when people are at risk of, or actually are, consuming food of inadequate quality or quantity (or both) to meet their nutritional requirements. This may be a result of the physical unavailability of food, a lack of social or economic access to adequate food, inadequate food utilization or a combination thereof. Food insecurity may be chronic, acute, transitory, or cyclical. It may characterize individuals, households, groups, areas or an entire country (EC-FAO 2012). A related but separate problem relates to *food insufficiency*, defined as "the experience of periodically or consistently not having enough food to eat". It pertains to food quantity, not quality, and is not a formal measurement, but is rather a qualitative judgment (EC-FAO 2012).

Food quality refers to the overall safety and hygiene standards of a given food. Foods with high quality standards are those which pose no threat to human health. Food quality may also refer to foods conferred with higher nutritional, cultural or economic value by virtue of how or where they were cultivated or produced. But in nutritional contexts, foods with great nutritional utility to the body are considered higher quality than foods with low nutritional content (EC-FAO 2012).

Food safety encompasses all measures taken during food production, processing, transport and handling, cooking, consumption and disposal which limit the risks of food-borne illness. In food security contexts, food safety and food security are seen as separate and distinct topics, and care should be taken not to use the terms interchangeably (EC-FAO 2012). Food safety is a growing concern (Squires et al. 2015, Squires and Feng, this volume).

Food utilization is important. It is often listed as the third pillar of food security. The term refers to (a) physical utilization of food at the household level (including food storage, food preferences, food preparation, feeding practices, and water requirements), and (b) biological utilization of food at the individual level (health, hygiene, nutrition, sanitation) (EC-FAO 2012), i.e. households' use of the food to which they have access. Utilization includes all food handling, preparation and consumption methods, hygiene and sanitation, and waste disposal. It includes how food

is distributed within a household. An individual's ability to absorb and metabolize nutrients – the conversion efficiency of food by the body – often depends on the health of the individual (EC-FAO 2012). Food quality and safety are key factors. The aim is to have utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-food inputs in food security (FAO 2019).

Stability of food supply is the fourth pillar of food security. Stability refers to the continuity of availability, access and utilization over time. It is emphasized in the World Food Summit definition of food security by the phrase "all people, at all times". Major factors that affect stability include climatic uncertainties, uneven income-earning opportunities, crop disease, etc. (EC-FAO 2012).

Ensuring access to food and achieving food security, as defined here, will need to be considered in relation to the influential factors in the food production system. The main important factors could be summarized in four principal sectors: (1) biodiversity, (2) climate, (3) soil, and (4) water (see Fig. 1.4).

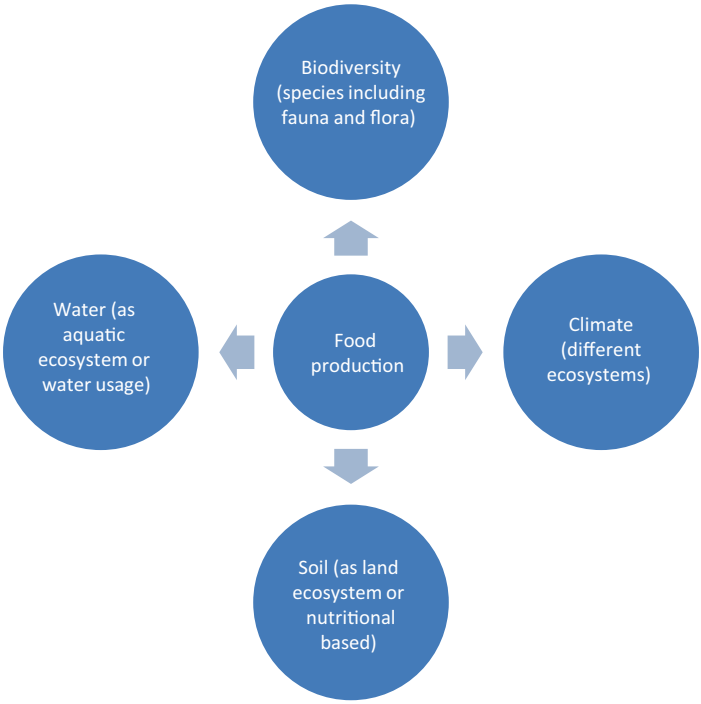

Fig. 1.4 Main factors related to food production

What Is the Global Food Security Index?

The Economist Intelligence Unit's Global Food Security Index (GFSI) is a country-level food-security measurement tool that addresses the issues of affordability, availability, quality and safety in 113 countries around the world (The Economist 2018).

When we deal with food security, we need to have a general and clear understanding of some related terms. Some food security definitions have been provided here. But terms such as food access, affordability, food availability, food insecurity or insufficiency, food quality, food safety, food stability, and food utilization carry meanings that cover a set of required actions. For example, shock leading to food vulnerability is a function of exposure, susceptibility, and resilience to shock, leading to a possibility of negative outcomes (EC-FAO 2012). Generally, the level of vulnerability is determined by the inadequacy of adaptive mechanisms, coping mechanisms or accumulated capital or food stocks to meet daily needs (EC-FAO 2012). So if reduction of vulnerability is among our objectives, we need to enhance individual adaptive mechanisms to cope with vulnerability matters in accordance with daily needs (Van t'Wout et al. this volume). Depending on different scenarios and time frames, various vulnerability maps could be drawn. For example, climate scientists from the Met Office Hadley Centre have worked in collaboration with food security analysts from the World Food Program to better understand the relationship between climate change and food insecurity (https://www.metoffice.gov.uk/food-insecurity-index/). An example is shown here as Fig. 1.5.

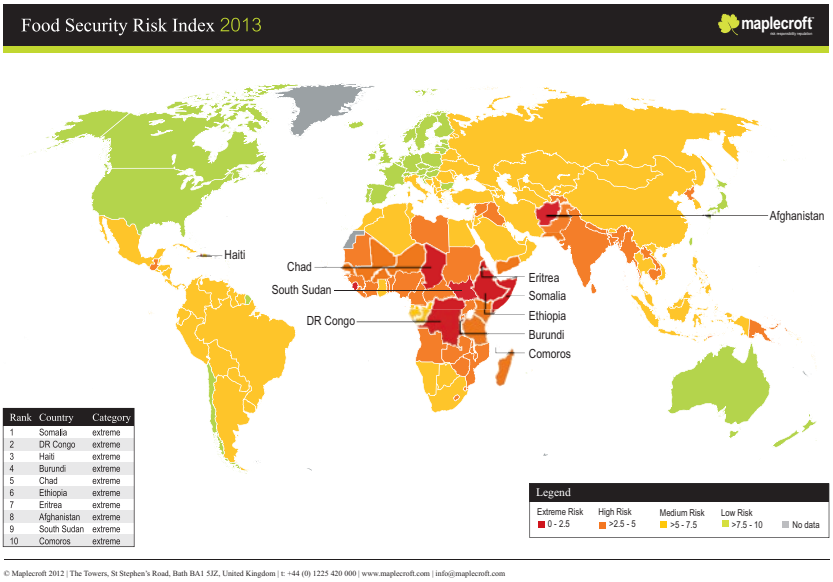

Fig. 1.5 Food insecurity is not uniformly distributed. Areas of extreme risk (red on this map) are mostly in Africa or in war-torn regions such as Afghanistan

Principles of Climate Change

To have a clear and transparent view of climate change in certain areas and understand its effect on a particular sector or ecosystem, we should collect and analyze the necessary information related to the four essential stages.

1. Revealing changes (detection) in climatic factors (1st stage)

As a first step, it is necessary to provide a clear picture of the current climate situation in a study zone and or region by using observed data and also to estimate climate change by producing proxy data for the past using proper methods such as dendrochronology. In this stage, it is also possible and suitable to have some future projections of climate change according to the different scenarios which may exist in a region, e.g. dependency on thermal power stations or on groundwater extraction for irrigated food crop production.

2. Impact and vulnerability (2nd stage), adaptation (3rd stage) and mitigation (4th stage)

When different climatic factors change the effects of climate change on different sectors, it is clear that these impacts could sometimes expose vulnerability. Vulnerability is a function of exposure, susceptibility, and resilience to hazard/shock, leading to the possibility of negative outcomes. In general terms, the level of vulnerability of a household and/or individual is determined by the inadequacy of their adaptive mechanisms, coping mechanisms or accumulated capital or food stocks to meet their daily needs (EC-FAO 2012). Vulnerability of a sector or crops to a changing climatic factor need to be studied and recognized (Van t'Wout et al. this volume, Nagabhatla this volume).

Climate change adaptation refers to the actions taken to lower the adverse effects of climate change and more particularly, any action taken to permanently eliminate or drastically reduce the long term risk and hazards of climate change to biodiversity, human life and property. Even if the emission of greenhouse gases is stabilized through climate change mitigation, the effects of global warming may last many years, and adaptation is necessary to face the changes in climate. Thus, climate change adaptation includes anticipating the negative consequences of climate change and taking appropriate measures to prevent or reduce the damage it can cause.

Adaptation to a changing climate is inevitable and much has been written about the types of adaptations that society and individuals within it may need to follow. Many adaptations and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link mitigation and adaptation. A more pro-active approach is to try to mitigate the impacts by pursuing a raft of policy and 'on-the-ground' measures to retard the rate and severity of climate change. Mitigation – reducing climate change – involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases (for example, the burning of fossil fuels for electricity, heat or transport) or by enhancing the 'sinks' that accumulate and store these

gases (such as the oceans, forests and soil). The goals of mitigation are to avoid significant human interference with the climate system and stabilize greenhouse gas levels.

The role of mitigation in the frame of climate change and its impact on food security could be considered in different dimensions. Some of these issues may generally be categorized as described below.

Food production patterns can change. Examples are changes in types of livestock (in terms of comparing GHG production) or types of crops (in terms of water use efficiency). Reductions in methane (CH_4) will help retard the rate of global warming (Steinfeld et al. 2006) while increased water (and fertilizer) efficiency will lower costs and reduce harmful contaminants entering the environment. Other examples are employment of technology in agricultural systems such as 'drought tolerant crops', micro-irrigation, climate-smart agriculture, etc., and adoption of other new technologies, e.g. drones, for precision crop spraying, etc.

Food consumption patterns are changing as more and more people become urbanized and demand more meat and dairy products in their diets. At the same time there are advocates of a return to diets based on a wider range of components. The case has been made for a shift to mini-livestock (insects, rodents, reptiles, etc) and the Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) have been supportive of such moves (Vietmeyer 1991, van Huis and Oonincx 2017, Hoffman and Cawthorn 2013). Others advocate heavier reliance on 'local' foods including those from natural vegetation (Vinceti et al. 2013, Bharucha and Pretty 2010).

Principles of Food Security

Four pillars have been identified by the FAO, related to food security: 1. *Availability*: Food can be provided by food production or food purchasing. 2. *Access*: This is a contested concept that is not easily defined. 3. *Utilization*: Reference has already been made to processing of foodstuffs to improve palatability, nutritive value or shelf life. The specter of food waste is also a concern and heightened awareness of the need to avoid practices that are wasteful and reclamation or re-use of food are encouraged. 4. *Stability*: Many food crops are vulnerable to climatic variability that can destroy them at critical times, e.g. unseasonal frost, or at flowering time or at fruit ripening, winds can cause grain crops to 'lodge' with considerable loss of grain yields, etc. Continuity of supply of key food items may not be guaranteed.

Interaction Between Food Security and Climate Change

Food security is a multidimensional problem and climate change is not the only trigger but one of the important dimensions. There are also other important issues such as vulnerability, conflict, population dynamics, etc. It is also important to men-

tion that land use, land use change and deterioration of land by different causes will certainly impact on food security in various ways.

At the global level, governments are trying to achieve the agreed United Nations Sustainable Development Goals (SDGs). These goals are closely linked together. SDG13 is highlighting the impact of climate change which directly or indirectly impact on poverty (SDG1), hunger (SDG2) and water (SDG6). All are likely to be severely affected by population increase (Godfray et al. 2010) and by climate change. According to the climate change projections, temperatures will increase as well as the frequency and severity of extreme weather events and precipitation, and the predictability of weather is projected to reduce as set out in Box 1.2 (Lewis et al. 2018).

Box 1.2 The Main Conclusions of Analyses by Panels of Experts

"Increasing the risk of hunger, climate change increases the frequency and intensity of some disasters such as droughts, floods and storms. This has an adverse impact on livelihoods and food security."

"Food availability: Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity."

"Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity."

The Global Food Security Index (GSFI), impacted as it is by climate change, should take into consideration the issues of affordability, availability and quality at global, regional, national and local levels. These indices need to be used for adaptation of plans of action (Figs. 1.6 and 1.7).

The principal livelihood sectors producing food may be listed as follows: fruit, vegetables, cash crops, cereals, legumes, sheep, tree crops, goats, barley, camels, fishing, horticulture, poultry, and off-farm work. The farming systems based upon water usage (Nagabhatla et al. this volume) may be mentioned as follows: irrigated, highland mixed, rain-fed mixed, dry land mixed, pastoral, sparse (arid), coastal artisanal fishing, and or urban-based (Lewis et al. 2018).

To consider the major trends affecting agriculture for small-scale farmers in the Near East North Africa (NENA) region, the FAO has developed Climate Impacted Farming System (CIFS) maps, which, by using temperature and precipitation data, demonstrate what changes will occur for the farming systems of the region in moderate and worst case scenarios by the mid-twenty-first century and allow identification of the potential hot spot areas in the considered region for agriculture under a changing climate (Lewis et al. 2018) (Fig. 1.8).

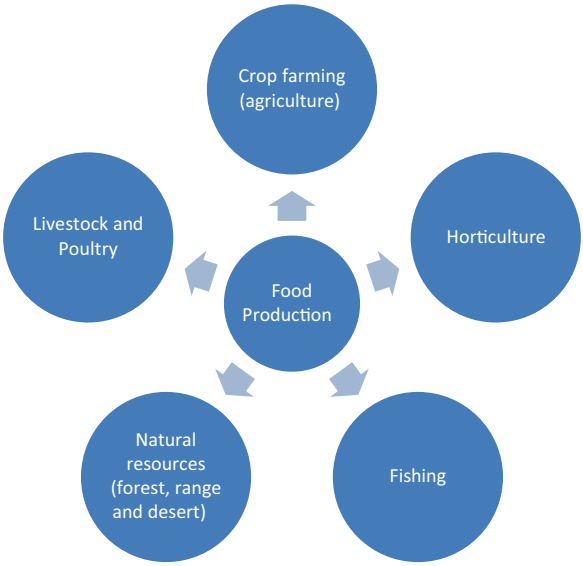

Fig. 1.6 Different sectors of food production

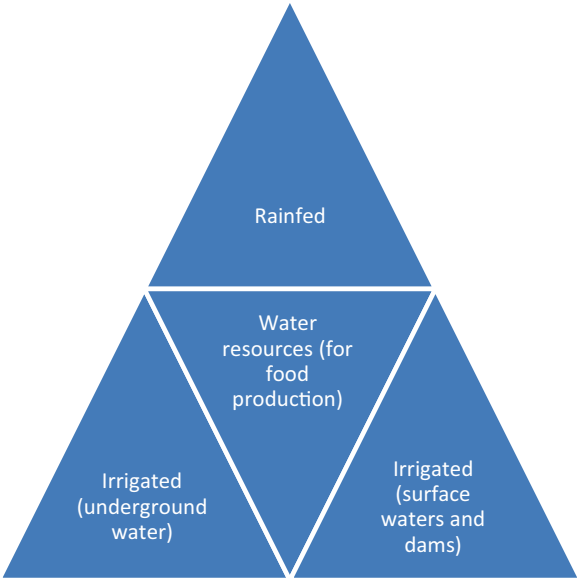

Fig. 1.7 Water resources to be used for food production

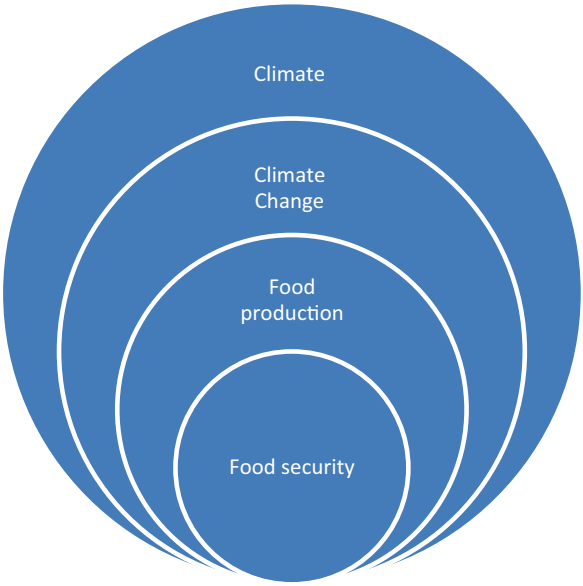

Fig. 1.8 Interaction between climate change and food security

Food security and food production are tightly linked with social and economic conditions of related societies and areas. This factor has a much more critical role when we are faced with climate change, which is due in part to human activities. Social and economic factors impact on technological advances and on the direction of research into resilience and the sustainability of investment in vulnerable and food insecure areas.

According to The Economist Intelligence Unit report on the Global Food Security Index (GFSI), the trend in global food security returned to positive territory in the year 2018, after its slight decline in 2017 (The Economist 2018). According to the report provided by The Economist, when the Natural Resources and Resilience category is applied as an adjustment factor to different income groups, the average food security scores for high-income countries are heavily exposed to the impacts of climate and natural resource risks. Climate and natural resources risks pose a threat for most regions and all governments have to prepare to face this daunting challenge (The Economist 2018).

Strategic Road Map of Climate Change and Food Security

The key features are captured in Figs. 1.9 and 1.10.

If successful there should be significant regional and global mitigation of global warming by limiting GHG emissions and major and widespread uptake and operationalization of adaptation strategies.

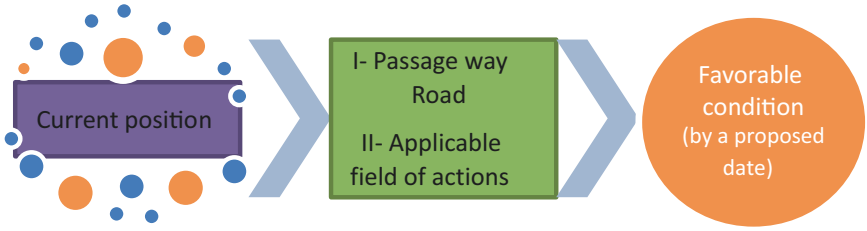

Fig. 1.9 Strategic road map of climate change and food security

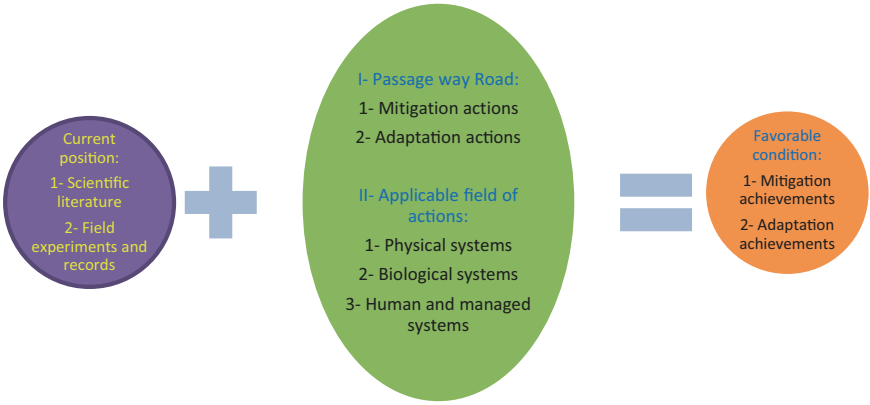

Fig. 1.10 Important advances in resilience policy and strategies

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